Successful Silage

TOPFODDER

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Contents

The main body of the manual contains 15 chapters, divided by numbered tabs, each covering a specific aspect of silage production or use:

Foreword

Ian Macdonald, MLC, NSW Minister for Primary Industries

Silage has an important and expanding role in Australia's dairy, beef and sheep industries, and provides producers with a valuable tool for growing the farm business. Apart from providing an opportunity to improve productivity and profitability, silage can also be used as a long-term feed reserve to cope with drought, floods and bushfires.

Until now, the adoption of silage technology in Australia has been held back by the lack of a comprehensive extension package specifically designed for our conditions and industries. Many of the recent developments in silage are recorded in research papers and locked in the heads of a few, very experienced people.

To address this gap, NSW Department of Primary Industries and Dairy Australia with support from Meat and Livestock Australia, initiated a project to develop an extension package on silage.

Over the past three years, a team led by NSW Department of Primary Industries and including representatives from the Department of Primary Industries Victoria, Queensland Department of Primary Industries, and Department of Primary Industries, Water and Environment Tasmania, have written this manual. Dr Alan Kaiser and his silage team at NSW Department of Primary Industries, Wagga Wagga Agricultural Institute have taken the lead role in this project.

This manual draws together information from around the world on all aspects of silage relevant to the Australian grazing industries. It has been written for a broad audience – farmers, silage contractors, advisers and consultants, agribusiness and students – with a specific interest in silage. It is intended as a reference manual when information is needed on some specific issue concerning the production or feeding of silage.

This manual has been a major undertaking and has required a considerable commitment from the writing and editing team. It is a valuable contribution that will be of lasting benefit to Australia's grazing industries.

I am delighted to introduce the first of our TopFodder products – *Successful Silage* – the definitive technical manual on all things silage for the Australian dairy industry.

Silage is an important strategy used by dairy farmers to fill seasonal feed gaps, to manage pastures, and to provide high quality, low cost forage for cows. Even though this has been common practice, market research shows that only a minority of Australian dairy farmers produce silage to acceptable levels of quality with minimal losses, and that there is large scope for improved returns on most farmers' silage making investment. There have also been a number of recent innovations in areas such as silage additives, plastics and machinery.

The TopFodder Silage program has been developed, with core funding from Dairy Australia and NSW Department of Primary Industries, as well as from the dairy Regional Development Programs and Meat and Livestock Australia, to take knowledge on modern silage practices out to motivated dairy farmers, and their advisers.

This will be done in a number of ways, including a farmer workshop series to be rolled out in all States. At the outset of this program, two meetings of stakeholders identified that a comprehensive reference manual was an essential prerequisite to underpin the delivery of silage technology to industry.

The authors and editorial team, led by Dr Alan Kaiser at the Wagga Wagga Agricultural Institute, are to be congratulated on the high standard of this reference manual, and on the comprehensive coverage of subjects and user-friendly indexing.

The following quote from a Gippsland dairy farmer who 'test-read' this manual, says it all – "I have been making large tonnages of silage for 20 years, and learnt much from this. An *excellent* manual, well done."

I commend *Successful Silage* to all thinking dairy farmers and providers of silage services to the dairy industry. In my opinion, this authoritative reference manual will become an essential tool of trade to develop profitable silage systems on Australian dairy farms in the future.

Pat Rowley
HON D.PHIL, CMG
Chair, Dairy Australia

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Supporting organisations

The development of this manual has been supported by a range of organisations. These include:

Dairy Regional Development Programs

- Dairy SA
- DairyTas
- DIDCO – Dairy Industry Development Company (NSW)
- Subtropical Dairy Program
- Western Dairy
- WestVic Dairy

Rural research and development corporations

- Dairy Australia
- Meat and Livestock Australia

State agriculture departments

- New South Wales Department of Primary Industries
- Primary Industries and Resources South Australia
- Queensland Department of Primary Industries
- Tasmanian Department of Primary Industries, Water and Environment
- Victorian Department of Primary Industries
- Western Australian Department of Agriculture

How to use this manual

This manual is aimed at a very broad audience – farmers/producers, contractors, advisers, consultants and agribusinesses with a specific interest in silage. Our aim has been to cover “everything you ever needed to know about silage” – from the practical to the scientific. Not all the information is relevant to all readers, and not everyone will want the level of detail on a given subject.

There are a number of ways in which you can go about finding information. If you are looking for information on a specific topic, it can be found by checking the:

- Chapter topics (see Contents, page 3).
- The Quick Find Index (see pages 7-22) will direct you to the chapters and sections that relate to a particular topic.

How the information is organised

- Each chapter has been written as a separate entity, containing a Table of Contents for easy referencing. Following the Table of Contents is a Key Issues section and an Introduction, which summarise the main points of that chapter. A quick glance through these will give readers an overview of each chapter.
- The hierarchy of headings used allows the reader to go into as much detail as required. For example, Section 11.2 of Chapter 11 covers the various costs of forage conservation in several sub-sections, including 11.2.3 ‘Contracting costs’. These sub-sections may also be divided under further sub-headings, e.g. Section 11.2.3 is divided into sections discussing the pros and cons of contracting, contract rates and what to include in the contract agreement.
- Although each chapter is written as a separate entity, there is considerable cross-referencing between them so that readers interested in more detail on a particular topic can follow the cross-referencing directions to the relevant chapter and section. To make it easier to locate specific sections, the section numbers appear in the corner of the colour band at the top of the right-hand pages.
- In the interest of readability, references have not been cited in the text. However, when actual data is presented in tables or figures, the source has been acknowledged. Details can be found in the reference list (see pages 25-30).
- The Glossary in this section (see pages 31-32, immediately before the Chapter 1 divider), contains definitions of terms that may not be familiar to you.

Quick Find Index

Subject

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Glossary

< – Less than.

≤ – Less than or equal to.

> – Greater than.

≥ – Greater than or equal to.

ADF – Acid Detergent Fibre consists of cellulose, which is partially digested by ruminants, and lignin, which is virtually indigestible.

ADIN – Acid Detergent Insoluble Nitrogen is the small proportion of nitrogen that is bound (either naturally or due to heat damage) in the ADF fraction and is unavailable to the animal.

accessibility to silage – How easily the silage can be reached or approached, and removed and eaten by the animal.

additives – Include a range of chemical, feed and biological products that are added to forages at the time of ensiling. Additives have a range of uses: to increase silage fermentation quality, reduce losses and/or improve aerobic stability.

aerobic – With air, specifically oxygen.

aerobic spoilage – The loss of DM and nutrients that occurs during prolonged exposure to air during feedout and also during storage if the silage is inadequately sealed or the seal is damaged. Heating is the first sign of aerobic spoilage.

aerobic stability – The time taken for the silage to begin heating after opening and exposure to air.

anaerobic – Without air, specifically oxygen.

ash – Part of a sample remaining after heating for several hours in a muffle furnace at extremely high temperatures (usually 550-600°C); is the inorganic matter or minerals present in the sample.

bacterial growth – The increase in the number of bacteria or the size of the population.

bacteriophages – Viruses that attack bacteria.

buffering capacity (BC) –The ability of a forage to resist changes in pH.

bypass protein – Dietary protein that remains undegraded by micro-organisms after passing through the rumen. Also known as undegraded dietary protein (UDP).

chop length – *Theoretical* length of chop (TLC) or nominal chop length is the chop length nominated for a particular machinery setting.
The *actual* chop length produced by the machine can be 2-3 times longer due to factors such as blade sharpness and speed, and equipment power.

closure, period of – The time between when stock are excluded from a pasture or crop and when the forage is cut or the stock re-introduced.

conditioning – An operation performed, usually at mowing, by specifically designed machines to damage the cut forage so that the rate of moisture loss during wilting is increased.

colony forming units (cfu) – A unit of measure relating to population size of micro-organisms.

crude protein (CP) content – Calculated as N x 6.25; is a measure of total protein.

digestibility – The proportion of a feed that is digested by an animal. The undigested portion is excreted in the faeces. A forage's digestibility is directly related to its ME level.

DM (dry matter) content – The proportion remaining after all moisture (water) has been removed, e.g. 30% DM comprises 30% DM and 70% moisture.

DM loss – The quantity of forage lost (on a DM basis), not a change in DM content.

DMD –Dry matter digestibility.

DOMD – Digestible organic matter in the DM (known as 'D value' in the UK/European literature).

DSE (Dry Sheep Equivalent) – One DSE is the maintenance energy requirement for a Merino wether with a standard weight of 50 kg; DSE/ha is an estimate of the stock carrying capacity for a paddock or whole farm.

effective fibre – That component of the forage fibre that is of sufficient particle size to stimulate rumination and saliva production. It is an important consideration in dairy cow diets for maintaining milk fat synthesis.

effluent (silage) – Surplus moisture released by low DM silages. It contains valuable nutrients including WSCs, silage fermentation products and minerals.

ensilability – Likelihood of achieving a good silage fermentation without wilting or a silage additive.

epiphytic population – Natural population of bacteria present on the forage.

FCM – Fat-corrected milk (usually 4%).

feed efficiency (or feed conversion efficiency – FCE) – The efficiency with which an animal can convert feed to animal product. Often expressed as, e.g. kg feed/kg liveweight gain or liveweight gain/t of feed.

feedout rate – The speed at which silage is removed from the feeding face. For example, removing 15-40 cm/day from the silage face, or the number of days to remove one layer of bales from a bale stack.

fodder – A general term describing feeds (fresh, dried and processed) fed to ruminant livestock.

forage – Edible parts of plants, other than separated grain, that can provide feed for grazing animals or that can be harvested for feeding.

free amino acids – Those amino acids that have been released during the degradation of forage protein, e.g. during silage fermentation or in the rumen; can be further degraded to other compounds, e.g. ammonia-N.

GR site – Measurement of tissue depth over the 12th rib, 110 mm from the midline in sheep; is an estimate of carcase fat cover.

harvest window – The period in which the crop/pasture is at the desired growth stage for harvest.

harvesting forage – The picking up and processing of the mown or unmown (direct cut) material for delivery to the storage site.

heat damage – The result of excessive heating caused by aerobic respiration at the time of ensiling or at feedout; heat damage at ensiling reduces digestibility and increases the proportion of bound protein N (which is unavailable to the animal); heat damage at feedout reduces palatability, silage DM intake and silage ME.

intake – Unless otherwise specified refers to the amount of DM consumed, expressed as kg/day or g/day and meaning kg/head/day or g/head/day.

in vitro – When biological processes are simulated in the laboratory (test tube).

inoculation factor (IF) – The ratio of the number of LAB applied in an inoculant, compared to the natural population already present in the crop.

LAB – Lactic acid bacteria.

ME – Metabolisable energy (MJ/kg DM); that component of the feed energy available to the animal for heat production, maintenance and production. The ME levels of a forage are usually calculated from the forage digestibility, which is more easily measured in animals or by laboratory tests. Digestibility and ME are essentially interchangeable when assessing the energy status of a feed.

milk production – Expressed as both kg/cow and litres/cow. Litres of milk x 1.03 will give an approximation of kg/cow. The exact conversion factor will vary with the solids-not-fat (SNF) and milk fat levels of each milk sample.

MJ – Megajoule, a measure of energy, expressed as MJ/kg DM.

moisture content – The water content of any substance (including forage or silage). All substances are composed of moisture (water) and DM, e.g. a silage with a moisture level of 60% will contain 40% DM.

NDF – Neutral Detergent Fibre is an estimate of the total cell wall content of the forage; it is the hemicellulose + fibre remaining in the ADF fraction.

non-protein nitrogen (NPN) – N compounds in a feed that are not true protein; urea and anhydrous ammonia are commonly used NPN supplements or additives.

OMD – Organic matter digestibility.

P8 site – Used to estimate carcase fat cover in cattle; is the point of intersection of a line drawn from the centre of where the ligament forming the channel rim joins the pin bone, parallel with the sawn chine, and a line centred on the crest of the third sacral vertebrae at 90^o to the sawn chine.

parent forage – The fresh forage from which the silage is made.

pH – Measure of acidity or alkalinity of a solution, with a pH level of 7.0 being neutral. Levels <7.0 are in the acidic range while levels >7.0 are in the alkaline range.

protein nitrogen – The proportion of forage or feed nitrogen present as protein. Lupins and cottonseed meal are examples of commonly used supplements.

proteolysis – Breakdown of proteins and products of that degradation process.

quality, silage quality – Used as a generic term that encompasses all the attributes of a silage that influence its nutritive value for animals.

quality loss – The loss of individual nutrients present in the initial forage. Most commonly applied to changes in digestibility, energy or the nitrogen fraction during the ensiling process, and the loss of WSCs during wilting.

respiration – The breakdown of WSCs by plant enzymes to produce carbon dioxide, water and energy (as heat).

rumen degradable protein (RDP) – The component of dietary protein degraded in the rumen.

secondary fermentation – Takes place after the initial fermentation, when growth of clostridial bacteria occurs in the silage.

silage – The fermented product resulting from the anaerobic fermentation of sugars (WSCs) in forage.

silage fermentation – The fermentation of plant sugars and other compounds by micro-organisms in the silage.

silage fermentation quality – A qualitative term describing the extent to which the silage has been preserved by the desired lactic acid fermentation. Where this has been achieved, lactic acid is the dominant fermentation product and there has been minimal breakdown/degradation of protein.

silo – Structure in which silage is stored, including pits, bunkers and stacks.

substrate – The initial compound used in a chemical reaction.

swath – The mown material left behind by a mower or mower-conditioner.

tedded swath – Mown forage that has been spread by a tedder or material being respread.

tedding – Describes the spreading of mown material after mowing.

TLC – Theoretical length of chop.

TMR (total mixed ration) – A formulated feed mix that supplies all the nutrients an animal requires.

undegraded dietary protein (UDP) – See bypass protein.

volatile fatty acids (VFAs) – Produced during the ensiling process; include acetic acid, propionic, and butyric acid. Their relative levels can be used to assess the silage fermentation quality.

WSCs – Water soluble carbohydrates are plant sugars, mainly glucose, fructose, sucrose and fructans, which are soluble in cold water.

wilting – The process where moisture evaporates from the mown forage to increase DM content to the desired level for harvesting.

windrow – The mown material that has been raked in preparation for harvest.

Chapter 1

Silage in the farming system

Chapter 1

Silage in the farming system

In this chapter

The authors

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The Key Issues

- Focus on increasing profitability, targeting high-quality silages and reducing wastage.
- Silage can be used to increase productivity, improve pasture management and provide greater management and marketing flexibility. Key benefits for most grazing industries are:
  - increased production/ha through an increase in stocking rate;
  - increased production/head;
  - improved product quality; and
  - increased capacity to supply markets with specified products at designated times.
- When incorporating silage into a production system, take a whole farm perspective. Key questions are:
  - Why silage? What is the production or management goal?
  - Is surplus feed available for silage production, or can it be grown or purchased?
  - Is silage the most cost-effective way to meet the production/management goal?
  - How will silage influence other activities on the farm?
- At an operational level, integrating silage into the production system is basically a feed budgeting exercise.
- The main economic issues are economies of scale, justification of capital investment and the potential for saving labour.

Section 1.0

Introduction

Successful livestock management involves matching the supply of feed with the animals' requirements as efficiently and profitably as possible. The aim is a product that meets market specifications when the market wants it.

Although grazing is the lowest-cost animal production system in Australia, it may not necessarily be the most profitable. In most regions, seasonal shortages in the quantity and/or quality of feed available for grazing limits production.

Most dairy, lamb and beef production systems are based around grazing, but feed supplements are often required to meet production targets. Forage conservation can fill feed gaps by transferring high-quality feed from periods of surplus to times of deficit. Silage is an ideal forage conservation method for this purpose.

For each producer considering the silage option or changes to their silage system, the issues can be condensed into questions in four key areas:

1. Why silage? What is your production or management goal? How are you going to change your production system to pay for, or make a profit from, your silage operation?
2. Do you have surplus feed or can you grow (or buy) additional forage for silage production?
3. Is silage the most cost-effective strategy for meeting your goal?
4. How will silage influence, either positively or negatively, other activities on your farm?

Evaluating the potential role for silage within a farming enterprise involves a number of issues that will influence farm management and planning. These can be both strategic and operational:

Strategic: Silage's role in improving farm business profitability in the longer term.

Operational: Incorporating silage into the farming system, on a daily basis, to manage feed gaps and feed surpluses.

Some of the key strategic issues that need to be considered are:

- the impact on the growth and profitability of the farming business;
- the ability to supply a product when it is required and that meets market specifications;
- the implications of seasonal variations in pasture availability and quality;
- planning for variations in feed availability between years, e.g. guarding against exceptional circumstances, such as drought or flood;
- improving the utilisation of available forage when it is at a high-quality stage of growth;
- the role of silage as a pasture management tool; and
- integrating silage with other activities or enterprises on the farm.

The principles associated with integrating a successful silage program into the farming system are similar between farms and grazing enterprises. Some industry-specific issues are covered in more detail later in this chapter.

Plate 1.1

This pasture is under-utilised. Conserving surplus growth and better grazing management would improve utilisation.

Photograph: Department of Agriculture, WA

Section 1.1

Trends in forage conservation in Australia

Production of hay and silage has increased significantly during the past century (see Figure 1.1).

Assuming a market value of $100/tonne for hay and $45/tonne for silage, on an ‘as fed’ basis, the average value of the hay produced each year between 1996 and 2000 was $542 million. The figure for silage was $108 million a year.

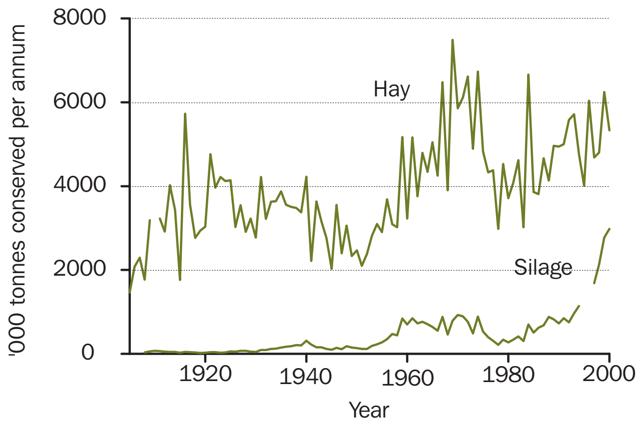
Most of the hay and silage is used on the farm on which it was produced. However, there is significant trading of hay and, in recent years, there has been some trading of silage and crops for silage production, particularly in the beef feedlot sector and the dairy industry.

Hay and silage production has varied considerably between years. Hay is clearly the dominant form of forage conservation, with production peaking in 1969. From 1970 to 2000, annual hay production has been between 3.7 and 6.7 million tonnes a year. Silage production grew rapidly during the 1990s; annual production reached about 3.0 million tonnes in 2000.

There has been significant growth in silage production in each of the grazing industries during the past decade, although detailed statistics are only available for the dairy industry (from a recent ABARE study). Average silage production per dairy farm increased from 64 tonnes in 1991/92 to 142 tonnes in 1999/2000; over the same period, hay production rose from 97 to 114 tonnes.

Figure 1.1

Annual hay and silage production in Australia.



Source: Australian Bureau of Statistics

Factors driving the increased adoption of silage

- A need to improve pasture utilisation and increase productivity.
- Capacity to cut earlier in the season, produce a higher-quality product and spread the harvesting time over a longer period than with hay.
- Valuable role of silage as a pasture management tool.
- Improved silage-making technology (e.g. wilting, plastics, additives) that make the process more reliable.
- Improved harvest mechanisation and availability of a diverse range of harvesting and storage systems.
- Improved mechanisation of silage feeding systems, reducing labour requirements and wastage.
- Increased focus on consistency of product supply and quality, and the need to supplement animals for ‘out-of-season’ production.
- Reduced susceptibility to adverse weather (rain) compared to hay, particularly early in the season.
- Reduced conservation losses compared to hay.
- The possibility of silage production with a much wider range of crops, that in some enterprises can lift productivity to levels higher than that possible with pasture alone.
- The suitability for long-term storage for a drought or flood.

Section 1.2

Hay and silage compared

There is clear evidence from a number of studies that the digestibility and crude protein of silages made on farms are higher than for hays. This is borne out in the results from feed testing laboratories (see Chapter 12, Appendix 12.A1). (The advantages of silage are highlighted in the text box on the previous page.)

A beef production study in WA showed an advantage in favour of a silage system compared with the conventional hay system, at three levels of grain feeding (see Table 1.1). Adjacent annual ryegrass/subterranean clover pastures were cut for silage on 10-11 October or for hay on 6 November. (Cutting hay earlier in this environment is not practical due to the high risk of rain damage.)

The advantages of the silage system were:

- higher forage quality – DM digestibility (68.5 versus 60.9%), estimated ME content (9.7 versus 8.6 MJ/kg DM), and crude protein content (15.1 versus 8.1% DM) were all higher for the silage;
- steer liveweight gains and feed efficiency (kg gain/t feed DM) were better on the silage diets (see Table 1.1).

The silage's higher ME and crude protein content, and shorter particle length, would have contributed to the improved liveweight gain:

- Higher ME content, and perhaps an improved efficiency in the use of available energy, are likely to be the main advantages in favour of silage in this study.
- The low crude protein content of the hay-based diet (due to the hay's low crude protein content) would have inhibited growth at low levels of concentrate feeding, but not at the high level of concentrate feeding, where cattle gained at 1.20 and 0.88 kg/day on the silage and hay respectively.
- The silage was chopped (using a forage wagon) and this may be an advantage in terms of higher intake compared to longer particle length of hay (see Chapter 14, Section 14.2.5).

A four-year study of perennial grass dominant pastures (perennial ryegrass and cocksfoot) in a dairy production enterprise in Gippsland, Victoria, found superior milk production was obtained from a silage compared to a hay system (see Table 1.2).

Table 1.1

Growth of steers (initially 277 kg) on hay and silage produced from an annual ryegrass/subclover pasture in WA, and given various levels of concentrate.

	Hay (5.6 t DM/ha)			Silage* (5.0 t DM/ha)		
Concentrate in diet (% liveweight)**	0.5	1.0	1.5	0.5	1.0	1.5
DM intake (kg/day):						
Forage	4.36	3.86	2.82	4.99	4.26	3.58
Concentrate	1.39	2.90	4.47	1.45	2.94	4.39
Total	5.75	6.76	7.29	6.44	7.20	7.97
Liveweight gain#:						
kg/day	0.33	0.63	0.88	0.81	1.09	1.20
kg/t feed DM	57	93	121	126	151	151

** Silages were made with and without an enzyme additive. There was no effect of enzyme additive on animal production.*
*** Concentrate comprised 67% barley, 30% lupins and 3% minerals.*
 # Liveweight gain from the mixed diets.

Source: Adapted from Jacobs and Zorilla-Rios (1994)

Table 1.2

A comparison of milk production from silage and hay systems on perennial grass-based pastures in Gippsland, Victoria.

	Silage farmlet	Hay farmlet
Average cutting date	28 October	7 December
Quantity of forage cut each year (t DM)*	11.4	10.4
DM digestibility of the conserved forages (%)	69.8	61.4
Milk production – commencement of feeding to end of lactation:		
Milk (L/cow**)	1,178	925
Milk fat (kg/cow)	54.5	41.9
Milk production – whole lactation:		
Milk (L/cow)	4,380	4,049
Milk fat (kg/cow)	190.8	170.5

* *Additional surplus forage was conserved as hay in Year 4 on the silage farmlet and is included here, but is not included in the means for cutting date or digestibility.*

** *To convert milk production from L/cow to kg/cow, use the equation in the 'Milk production' entry in the Glossary.*

Source: Adapted from Thomas and Mathews (1991). Mean results for four years

The silage system allowed an earlier cutting and produced conserved forage of higher digestibility than the hay system.

If the silage system had not suffered a high level of loss, the advantage of the silage system would have potentially been greater. Losses of 26% were reported for the small experimental stacks, compared to typical losses of only 7% in well-sealed commercial silage stacks in the district. The losses in the experimental stacks included the storage component and losses from the exposed face during feedout (aerobic spoilage). Aerobic spoilage can occur in small experimental stacks where there is a slow rate of feedout, and leads to high DM losses and reduced silage quality (see Chapters 2 and 9).

There is also evidence of a milk production advantage for silage when hay and silage are cut from the same crop on the same day. In a number of American studies with lucerne cut at various stages of growth, milk production was consistently higher for cows fed a mixed silage/concentrate diet (see Table 1.3). This reflects the higher DM and quality losses in the field and during harvesting with hay compared to silage. The hay and silages in these studies were produced under good drying conditions – a greater advantage in favour of silage would be expected under adverse weather conditions. The milk production differences would probably have been even greater if lower levels of concentrate were fed.

Table 1.3

Milk production (kg/day) from cows given hay or silage made from the same lucerne crop.

Study	Conservation method	Concentrate in diet (%)	Stage of maturity at harvest			
			Early bud	Mid-bud	Early flower	Full-late flower
1	Hay	45	26.6		25.5	25.5
	Silage	45	27.2		27.0	27.7
2	Hay	40		30.7	32.1	
	Silage	40		33.6	33.4	
3	Hay	40	35.0		36.0	
	Silage	40	38.1		37.0	

Source: Nelson and Satter (1990,1992)

Section 1.3

Impact of silage on the farming system

There are a number of long-term implications for whole farm management when silage is first incorporated into the production system or significantly expanded. These can be thought of in terms of increasing land productivity, efficiency of resource use and management control over production.

Increased land productivity may occur through pasture or replacement of some pasture with forage crops. Efficiency gains may occur in the use of land, water, nutrients and capital. Greater management control enables the desired product to be sold on time.

Greater flexibility and new marketing opportunities

Silage production may provide new options, such as:

- potential for new or supplementary animal enterprises on the farm;
- sale of surplus crop/pasture/silage;
- finishing or opportunity feedlotting cattle and sheep for slaughter (including purchase of additional animals);
- ability to change calving or lambing time to improve reproductive performance and produce 'out-of-season' product for high-value markets;
- ability to target new markets; and
- better integration of existing enterprises, such as animal production and cropping.

Possible management changes for the current animal production enterprise

The decision to produce silage, or expand the use of silage in livestock enterprises may lead to other changes on the farm, such as:

- changing the cropping rotation to grow specialist silage crops;
- increasing fertiliser use to maximise yield and replace nutrients removed by silage cuts;
- changing irrigation strategies to meet grazing and silage-making demands;
- increasing stocking rates to utilise conserved forage;
- reducing reliance on irrigation for forage production for grazing and on supplementary feeds such as grain or hay;
- potential to improve water use efficiency on irrigation farms; and
- modifying the drought or flood risk strategy.

The Key Principles for a successful silage program

On any farm where silage is made, there are three key principles that should be the focus of a successful silage program. These are emphasised throughout this publication.

1. **Improved economic decision making:** There is increasing pressure for management decisions to be economically justified. Decisions concerning silage use should not be made in isolation of other activities on the farm – a 'whole farm' approach is essential. Farmers need to be aware of the costs and potential returns for silage, and a strong emphasis is needed on improving economic performance. Chapter 11 looks at the economic decision-making process.
2. **Improving quality:** It is almost always better to have a lower yield of a higher-quality silage than to compromise silage quality in order to maximise the quantity of forage harvested per hectare.
3. **Reducing losses:** One of the key factors affecting the cost of silage are the losses that can occur at each stage of the production process – in the field, during storage, and during feeding out. There can be losses in both quality and quantity. Losses must be minimised to improve the economic performance of silage systems.

Pasture management

Most silage produced on farms is from surplus pasture or specifically grown crops. Silage production can be integrated with grazing management to:

- manage pasture surpluses and so improve pasture utilisation;
- provide higher quality forage by cutting early for silage and utilising regrowth after silage making, and by allowing more grazing pressure on the rest of the farm;
- increase pasture production by maintaining pastures at a more active growth stage longer through increased grazing pressure;
- improve weed management through strategic cutting to reduce the production of viable weed seeds;
- reduce the need for slashing (or mulching) on some farms to maintain pasture quality; and
- close paddocks or reduce the grazing pressure on pastures at critical time(s) of the year by strategic feeding with silage to improve the survival and productivity of desirable pasture species.

The last point is particularly relevant in southern Australian where late autumn 'breaks' often result in poor pasture growth during winter. Reducing grazing pressure allows the pasture to more quickly increase leaf area, thereby increasing growth rates and production over winter. Depending on the pasture species, growth rate is optimised at pasture heights of 5-10 cm.

Chapter 3 covers the integration of silage production with grazing as a pasture management tool in greater detail.

The planning process

When these whole farm implications have been considered at the individual farm level, technical and operational issues need to be taken into account, including:

- the cost of silage compared to alternative feeds;
- land, machinery, buildings and labour requirements associated with silage use;
- planning and logistical issues such as the efficiency of feeding systems, and the siting of silage storage and feedout facilities;
- the quantity of silage required – number of animals to be fed, duration of feeding and proportion of silage in the diet;
- silage quality targets – the level of animal production required;
- the choice and cost of the silage production and feeding systems;
- management required to optimise silage quality;
- management required to minimise harvest, storage and feedout losses; and
- a plan for ongoing monitoring (quality assurance) of the silage operation.

When farmers are confident that the use of silage is technically feasible, and that all the implications of incorporating or expanding the use of silage in the farming system have been considered, they then need to investigate the economic viability of this strategy (see Chapter 11).

Plate 1.2

Rapid growth of tropical grasses in summer often results in poor utilisation. Integrating silage production with grazing management, although not widely practised, may improve the utilisation of these pastures (see Chapter 4, Section 4.9). *Photograph: M Martin*

Section 1.4

Integrating silage into the farming system

1.4.1

Developing a feed budget

Developing a feed budget for the farm will identify pasture surpluses and feed deficits, and allow an assessment of the potential role for silage. A feed budget is often used to outline the feed supply and demand at monthly intervals over 12 months – a feed year plan. Historical records can be used to budget for year-to-year variations, to cover the risk of poor seasons, drought, extremely wet conditions and flood.

The simplest feed budget will compare daily pasture growth rate with daily animal requirements (see Figure 1.2). This approach does not account for carryover standing pasture or variations in pasture quality.

There are substantial differences between regions and pasture types in the seasonality of pasture production in Australia. In addition, differences between animal production enterprises and market requirements can mean that pasture supply and animal requirements are 'relatively' well matched, as in Figure 1.2, or very poorly matched when peak demand coincides with a period of poor pasture growth or quality. In many cases, it is usually pasture quality rather than quantity that limits animal production.

On most farms, there is marked seasonal variability in both pasture quality and growth rate (quantity). As plants mature and progress from a vegetative through to a reproductive phase, growth rate slows and quality declines (see Figure 1.3).

Feed budgeting must account for pasture quality as well as quantity. This can then be matched to estimated animal requirements, which are based on the number and class of livestock to be fed and the production targets. The resulting budget will indicate when the pasture can adequately meet animal requirements.

Using information from the feed budget, farmers can determine when supplementation is required to meet production targets or prevent dramatic loss of body condition. In some cases, loss of production or condition is acceptable; supplementation is not required to maintain overall productivity. This can occur at various stages in the production cycle in beef and sheep enterprises, e.g. some loss of condition in breeding stock, provided it is not severe and animals calve or lamb in good condition, may have little effect on animal production.

Figure 1.2

Annual feed budget for a temperate perennial pasture-based dairy farm in Tasmania, stocked at two cows per hectare, and with a seasonal calving.

Note: This example is for a high stocking rate dairy enterprise in Tasmania. Some cows would be off-farm when they are dried off, hence the low demand in June-July. Intakes in other dairying regions would generally be higher than indicated here.

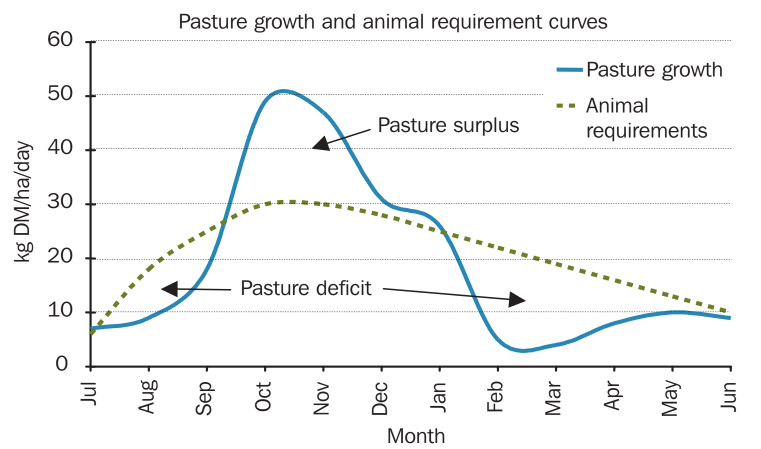
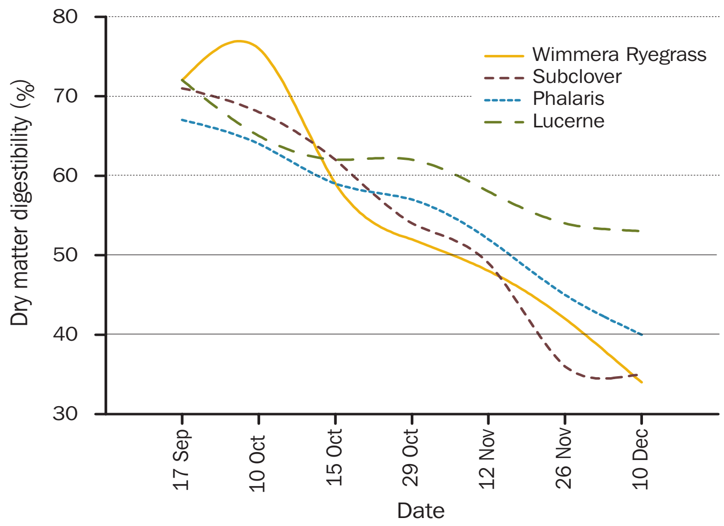


Figure 1.3



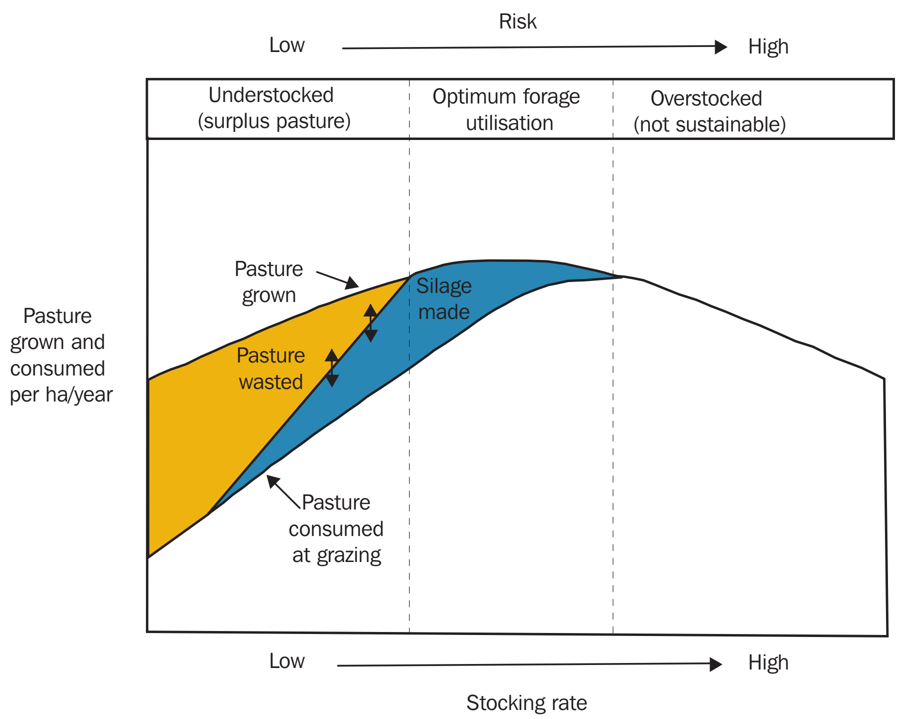
Decline in digestibility with advancing maturity over spring for a number of pasture species grown in South Australia.

Source: Ratcliffe and Cochrane (1970)

Feed budgets can also be used to assess the adequacy of various management or intervention strategies to improve the balance between animal requirements and pasture supply – varying stocking rate, calving/lambing dates, stock trading, increasing pasture growth (fertiliser, irrigation) and supplementary feeding strategies (including silage). An example of this use of feed budgeting is provided in Section 1.5.1 (see Figure 1.6). This same approach is used to evaluate silage management issues, such as closure date, duration of closure period, mowing date and their subsequent effect on pasture production and quality (see Chapter 3).

Various feed budgeting tools are available for the grazing industries in each State. Advisers from the various State agriculture departments have access to many of the computer-based programs. The Tasmanian Department of Primary Industries Water and Environment (DPIWE) created the feed budgets in Figures 1.2 and 1.6 from a simple feed budgeting program (DPIWE Feedbudgeting Program).

Figure 1.4



Influence of stocking rate and silage production on the annual utilisation of forage.

See page 10 for details.

Notes:

1. The extent to which stocking rate can be increased in the optimum forage utilisation zone, will depend on the seasonality of pasture production and the type of animal production enterprise. Some additional supplementary feeding may be required if insufficient silage is available.

2. Pasture grown in Figure 1.4 is the net growth (or 'utilisable growth') after subtracting the losses due to senescence.

3. Pasture wasted is pasture not utilised. It could be argued that this unutilised pasture has some sustainability benefit by reducing wind and/or water erosion, and recycling nutrients and organic matter.

1.4.2

Factors influencing the amount of silage produced on a farm

Stocking rate and the seasonality of pasture production and quality are the two main factors affecting the amount of forage that can be conserved on a farm. Increasing the stocking rate reduces the quantity of surplus feed, and therefore the amount of forage available for conservation as silage (see Figure 1.4), increasing the need for feeds from outside the farm to complement pasture. Any feed deficit that existed before stocking rate was increased is likely to increase as well.

The relative size of periods of pasture surplus and deficit (the seasonality of forage availability) will affect the level of silage produced on farm. For example, annual temperate pastures in southern Australia have a marked seasonality of the pasture growth, with a very large surplus in spring and significant deficits in pasture quantity and/or quality during late summer, autumn and winter. There is a high potential to increase animal production by transferring surplus spring pasture, at a high-quality stage of growth, to other times of the year.

Many farming systems use very conservative stocking rates as a risk management strategy to cope with periods of lowest feed availability. As a result, pasture is often considerably under-utilised during periods of high growth. Increasing stocking rate for short periods, when there is surplus pasture available, is often not practical or economically feasible. This can create large deficits at other times of the year, which must be addressed by the purchase of additional supplements or by de-stocking. Both options have the potential to decrease farm profit if not properly evaluated and managed.

Producers can use a combination of silage production and an increase in stocking rate to optimise the utilisation of forage during the 12-month production cycle indicated in Figure 1.4. This also allows grazing intensity (effective stocking rate) to be increased during periods of rapid pasture growth, maintaining the forage at a higher quality, vegetative stage of growth for longer.

At low stocking rates, where some of the surplus pasture is conserved as silage, producers can increase stocking rate with a low risk of a feed shortfall, secure in the knowledge that silage is available as a buffer.

When all available pasture is utilised by a combination of grazing and silage production, producers are entering the high risk zone. Any further increases in stocking rate can only occur at the expense of the quantity cut for silage. As stocking rate increases and the opportunity for silage production decreases, there is a greater risk of a feed shortage due to adverse seasonal conditions. This risk can be lowered by the use of other supplements. An alternative is to choose the lower stocking rate end of the optimum forage utilisation zone in Figure 1.4. This is a lower-risk strategy that achieves optimum utilisation of the forage grown each year; stocking rate is reduced marginally and more silage is cut.

As can be seen from Figure 1.4, there is a relatively narrow range of stocking rates at which pasture conservation will give a substantial benefit to production. The type of animal production system, the desired level of animal production per head, and economics are all important considerations.

1.4.3

Time of cut – management implications

High-quality silage is produced from pastures and crops cut early, in the late vegetative to early reproductive growth stages, before forage quality deteriorates with advancing plant maturity (see Chapter 4, particularly Figure 4.3, and Chapter 5). This will ensure high levels of animal production from silage (see Chapters 13, 14 and 15).

The potential pasture management benefits of silage production are discussed in detail in Chapter 3. Benefits will vary with the pasture type, but the growth stage of the pasture at harvest is critical in determining the extent to which pasture productivity is improved. An early harvest usually produces the best total production response from the pasture (silage yield plus regrowth). However, if optimum weed control is the goal, a delayed harvest may be necessary.

Achieving a particular pasture management goal, such as weed control, may result in a lower quality silage. In these situations, the pasture management benefits need to be weighed against the animal production lost due to the reduction in silage quality. An additional consideration is the reduced flexibility in feeding, with the use of lower-quality silages being limited to those parts of the production cycle when the animal's nutrient requirements are lower, e.g. dry stock in early pregnancy.

1.4.4

Purchasing silage

It may be necessary to import fodder to increase animal production on farms where stocking rates are already high and all available forage is being effectively utilised.

Buying silage, or crop for silage, can provide producers with greater management flexibility. However, the profitability of this strategy needs to be thoroughly assessed, taking account of the forage's nutritive value and DM content, and transport and handling costs (see Chapters 11 and 12). Farmers should also ensure that any bought feed is free of chemical residues and weed seeds.

1.4.5

Other considerations

A number of economic factors need to be considered when integrating silage into the production system. These are covered more fully in Chapter 11.

- ➤ Introduction of a silage system can affect the farm's capital structure. Although a new system may improve the gross margin, the farm profit may not improve if the production increase is eroded by increased overhead costs.
- ➤ The capital cost of machinery ownership can have a significant impact on silage-making costs. Producers need to consider whether they should buy mowing and harvesting equipment, share ownership (syndicate) or use a contractor.
- ➤ In many cases, expenditure on facilities to reduce storage and feedout losses, and an efficient feedout system, may be the best initial investment of capital set aside for forage conservation.

Section 1.5

Silage in dairy, beef and sheep enterprises

It is critically important that the silage operation be integrated into whole farm management and not viewed in isolation. Silage is a means to an end, not an end in itself.

There are many potential roles for silage in grazing systems. These are summarised in Table 1.4. Their relative importance will vary from enterprise to enterprise, and from region to region.

Table 1.4

The role for silage in various livestock enterprises.

Silage use	Dairy	Beef	Lamb	Wool
Improve animal product quality or market compliance through the use of silage supplements	✓	✓✓✓	✓✓✓	✓✓
Improve capacity to supply animal product when required ('out-of-season')	✓✓✓	✓✓✓	✓✓✓	
Provide opportunity to access new markets or develop complementary enterprises	✓	✓✓✓	✓✓✓	✓
Increase stocking rate	✓✓✓	✓✓✓	✓✓✓	✓✓
Supplement to increase production/head	✓✓✓	✓✓✓	✓✓✓	✓
Change calving or lambing time (and calving or lambing %)	✓✓	✓✓	✓✓	✓✓
Improve weaner survival or growth of replacement animals	✓	✓✓	✓	✓✓
Drought, flood or bushfire reserve	✓✓	✓✓	✓✓	✓✓
Improve pasture management and utilisation	✓✓✓	✓✓✓	✓✓✓	✓✓
Weed management/control	✓	✓✓	✓✓	✓✓
Reduce dependence on irrigation	✓✓✓	✓	✓	✓
Reduce dependence on purchased feed	✓✓✓	✓✓	✓	✓

✓✓✓ Very important ✓✓ Moderately important ✓ Relevant on some farms

Note: Silage is not likely to be important in the more extensive beef enterprises in northern Australia, or in the more extensive wool enterprises in the low rainfall rangeland areas.

1.5.1

Dairy

Conservation of surplus pasture and specialty crops as silage can play an integral role in matching feed supply with requirements, improving pasture utilisation and management, and profitability on dairy farms. Chapter 13 covers the utilisation of silage in dairy feeding systems in greater detail.

Production benefits

- An increase in the yield, quality and utilisation of pasture grown (see Chapter 3). This will improve milk production per cow, increase stocking rate and increase 'whole farm' productivity.
- Transferring forage from times of surplus to times of deficit reduces the need to buy other supplementary feeds to sustain milk production. For example, on a typical Queensland dairy farm conserved forage is used to overcome feed deficits in the March to August period (see Figure 1.5). As production systems intensify, the current trend is for the silage component of the diet to increase at the expense of grazed pasture. In southern Australia, silage is used to fill quantity or quality feed gaps in late summer, autumn and winter.
- A portion of the farm can be set aside to grow high-yielding, high-quality specialist crops for silage, increasing the total amount of forage produced on farm. This can lead to a further increase in stocking rate.
- Purchasing pasture or crop for ensiling on farm is becoming a useful strategy for dairy farmers who are already fully utilising their forage resources, enabling them to expand their business without having to outlay capital to buy additional land.
- Silage can be the key feed resource that allows dairy farmers to expand and intensify their production system. Better economies of scale can be achieved by using silage to increase milk production on the farm, reducing overhead and labour costs per litre of milk produced.

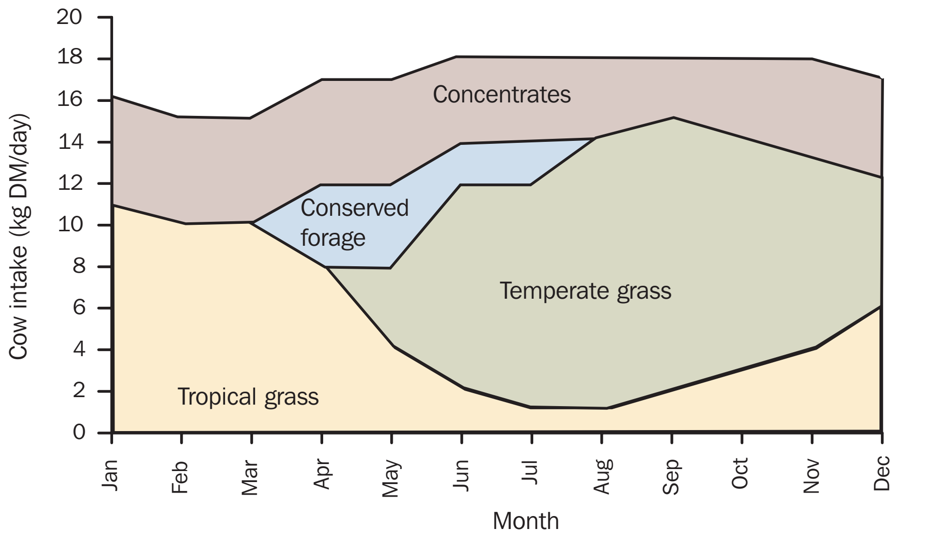


Figure 1.5

Seasonal change in feed intake for a dairy cow producing 5,200 litres of milk annually in a typical feeding system in northern Australia.

Source: Cowan (2000)

Additional benefits

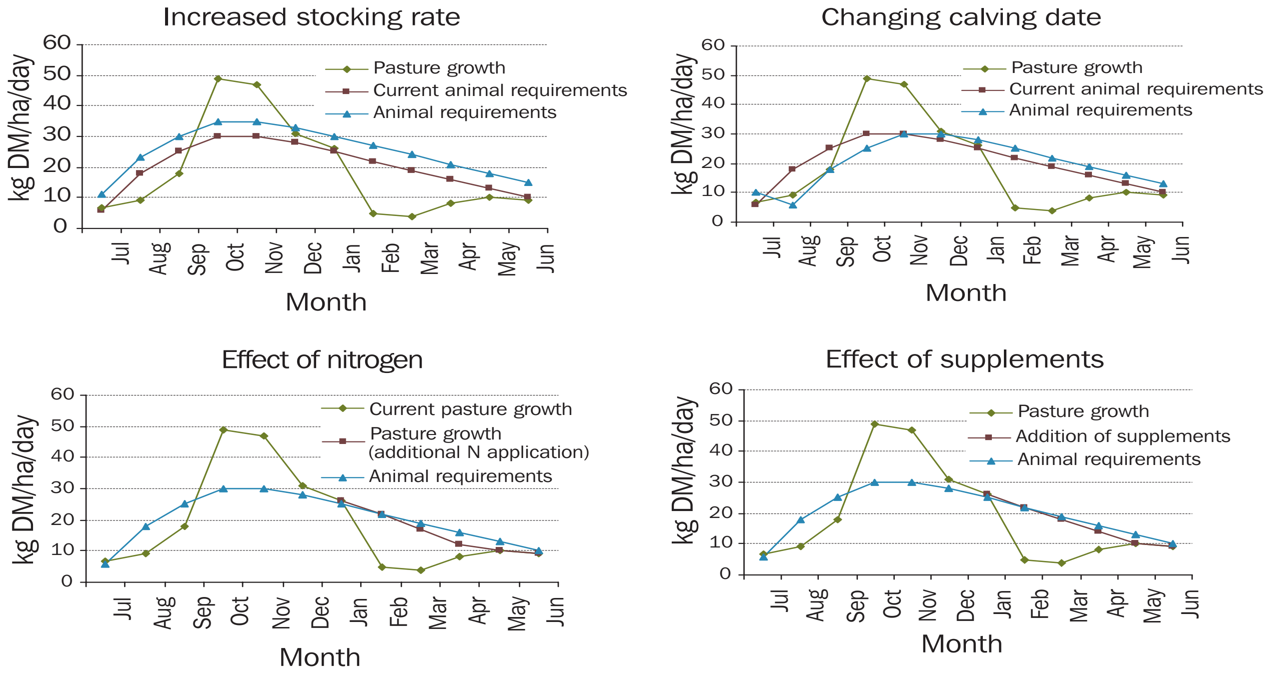
- ➤ Silage can be used as a supplement for replacement heifers when pasture supply and quality is insufficient to ensure adequate growth rates before joining.
- ➤ In many situations, it is more efficient to use available water to produce crops than pasture. Producing silage during favourable times of the year can reduce reliance on irrigation to produce pasture for grazing. This water is then available to higher-value crops such as maize.
- ➤ Irrigation water may be more effectively used by irrigating during spring or autumn when evaporative losses are lower, rather than during a hot, dry summer. In many areas, surplus forage can be produced more cheaply during these periods, and conserved as silage for later use.
- ➤ Silage can be used to balance the dietary intakes of dairy cows by supplying fibre to cows grazing lush pastures or receiving concentrates. Legume silages can be used to supply additional protein to cows consuming low-protein feeds, such as maize or sorghum silage.
- ➤ Where there are price incentives to produce 'out-of season-milk', silage can provide the feed needed for the required change in calving time.
- ➤ Silage can be a valuable drought, flood or bushfire reserve.
- ➤ Silage can be used as a replacement or 'buffer feed' to allow grazing management objectives to be achieved without a significant penalty in milk production.

How much silage to conserve

The optimum level of conservation on a dairy farm will depend on the balance between animal requirements and pasture growth, with any surplus being available for silage production. Management changes on the farm, such as increased

Figure 1.6

The effect of different management strategies on pasture supply and animal demand.



Example

At a stocking rate of two cows per hectare and an average predicted pasture growth rate through the silage period of 45 or 100 kg DM/ha/day what proportion of the farm should be cut for silage?

	Example 1*	Example 2**
Predicted pasture growth rate	45 kg DM/ha/day	100 kg DM/ha/day
2 cows/ha consuming 15 kg DM/cow/day	30 kg DM/ha/day	–
2 cows/ha consuming 20 kg DM/cow/day	–	40 kg DM/ha/day
Pasture available for silage production	15 kg DM/ha/day	60 kg DM/ha/day
Amount required for grazing	(30/45) = 66%	(40/100) = 40%
Amount available for silage	(100%-66%) = 34%	(100%-40%) = 60%

* *Example 1 relates to the feed budget presented in Figure 1.2.*

** *Example 2 represents the situation likely to occur in a high-production situation.*

stocking rate, changing calving time, applying N fertiliser, and feeding supplements, can influence the availability of a surplus (see Figure 1.6).

Methods to determine the appropriate level of conservation on a farm are covered in greater detail in Chapter 3.

A balance is needed between under-harvesting and suffering reduced pasture quality and utilisation, and over-harvesting and restricting cow intake. The most appropriate way to decide the proportion of the farm that should be cut for silage is to estimate average animal requirements and pasture growth rate over the period of surplus pasture growth. Pasture growth in excess of animal requirements can be targeted for silage (see examples above) – in this case an increase in stocking rate should be considered (see Figure 1.4).

As paddocks are dropped from the grazing rotation, monitoring should continue to adjust animal requirements and actual pasture growth rates for seasonal conditions.

Conclusion

Silage can be used to increase dairy farm profit if it is integrated into the dairy system, if silage production is properly managed to guarantee a high-quality product and silage losses are minimised. Where pasture is the cheapest source of forage, only genuine surpluses should be harvested. A predictive tool such as a feed budget should be used to estimate the area of the farm that can be cut for silage.

Dairy: determining the role for silage

The following series of questions need to be addressed:

1. What is the business goal? How much milk does the farmer want to produce?
2. What is the current feed supply?
3. What is the deficit in feed supply?
4. How much of this feed deficit can be covered by home-produced silage? Note that silage is only a means to an end (more feed) and there are other feed options, which may be cheaper.
5. If there is still a feed deficit can silage or forage (to make silage) be purchased nearby?
6. What is the cost of production for the new system? Taking account of all variables, labour and overhead expenses, what is the total cost/litre milk?
7. Compared to the milk price, is it profitable?

This same approach should be used to assess any proposed change to the production system.

1.5.2

Beef

The challenge is to consistently meet selected market specifications, on time, and with a high proportion of cattle falling within the specifications for carcase weight, fat cover and meat quality.

Silage is one of the supplementary feeds that can be used to achieve production goals. It is suitable for all classes of cattle, including calves from three months old.

Chapter 14 provides a more detailed coverage of feeding silage to beef cattle.

Roles for silage in beef enterprises

Full production feeding

Silage can be fed as the sole diet or with concentrates. It is suitable for use in large-scale or small, on-farm opportunity feedlots. Temporary feedlotting may occur in paddocks where pasture availability is severely limited and represents only a small proportion, probably <10%, of total intake.

Supplementary feeding

There are a number of situations where silage can be used as a supplement to pasture, filling gaps in the quantity and/or quality of pasture available:

- ensure adequate nutrition for cows prior to calving;
- meet cow requirements during early lactation when nutritional demands are high (this can be critical in ensuring fertility and maintenance of the calving pattern, particularly in more marginal grazing areas);
- maintain growth rates of weaners and young, growing cattle to meet market specifications for slaughter or feedlot entry; and
- maintain heifer growth rates to ensure fertility, particularly in more marginal areas where poor growth rate may mean that heifers do not conceive until they are more than two years old.

Drought feeding

Producers should always aim for high quality when conserving silage as a drought reserve. High-quality silage is cheaper to produce, on an energy basis (see Chapter 11, Section 11.3.5), and allows increased management flexibility (see Chapter 14, Section 14.5).

Depending on the available reserves, silage can be used to maintain breeding stock and finish growing cattle for sale. A feed budget should be prepared to determine the numbers of cattle that can be fed for maintenance or for production, and those which need to be sold because they cannot be adequately fed.

Silage made on-farm is a valuable source of high-quality roughage and is usually much cheaper than hay purchased during a drought.

Having sufficient reserves of silage allows cattle to be fed in small 'sacrifice' paddocks, protecting the rest of the farm from overgrazing.

Other strategic supplementary feeding

There are a number of other situations where full or supplementary feeding with silage can improve cattle management, production and health:

- Calves can be fed in holding yards at weaning. This is most effective when the calves have been fed silage while still with the cows.
- Silage can be fed to cattle as part of a pre-conditioning program, prior to feedlot entry.
- Silage supplementation will reduce the risk of bloat in cattle grazing lucerne or legume-dominant pastures.
- Silage supplementation will reduce the incidence of grass tetany in cattle grazing young, lush pastures.

Production benefits

Most beef enterprises have marked seasonal variation in pasture production and quality. Much of the surplus DM produced during the period of peak pasture growth is not utilised because stocking rates usually reflect the number of stock that can be carried over the whole year. Utilisation of the total annual production from a pasture can be as low as 30-40% of the potential.

Beef production per hectare may be increased if surplus, high-quality pasture is cut for silage, although this will depend on stocking rate (see Figure 1.4) and beef prices. Estimates of the potential beef production per tonne of forage and per hectare are provided for a range of pastures and crops in Table 1.5.

Integrating silage into a beef enterprise has a number of potential benefits:

- One of the main options for silage use is to increase stocking rate – and production per hectare – without changing the production per head or the market specifications for the animals being sold. Producers can either increase the size of their breeding herd or increase the number of animals turned off from a steer-growing enterprise.
- The other main option for silage use is to increase production per head, thereby increasing production per hectare. A higher proportion of the current turn-off can be finished for sale or slaughter, or turned off earlier and/or at higher weights, independent of prevailing pasture conditions. This will improve the producer's capacity to supply the target market. If the objective is to turn off animals at a younger age, this resulting reduction in the effective stocking rate will provide an opportunity to run more stock.

Some producers will choose a combination of the two options above.

Table 1.5

*Estimated beef production from silages produced from various pastures and crops harvested at a high quality stage of growth.**

Pasture or crop	Silage yield (t DM/ha)	Potential liveweight gain (kg) per t DM	Potential liveweight gain (kg) per hectare
Phalaris/subclover pasture (single cut in spring)	4	115	(460)**
Oat/vetch crop	12	110	1,320
Perennial ryegrass pasture (single cut in spring)	4	120	(480)
Lucerne (from each cut)	3.2	120	(384)
Forage legume crop	6	125	750
Grain sorghum crop (dryland)	5.5	115	633
Maize crop (irrigated)	20	130	2,600

* *Estimates based on a range of agronomic and animal production data from the literature.*

** *Values in brackets are from a single silage cut only. Total production per hectare needs to take account of the beef production generated by grazing the regrowth from these pastures.*

Additional benefits

Within a beef enterprise, silage can also:

- act as a pasture management tool, improving pasture productivity and composition, and reducing weed content (see Chapter 3);
- reduce the reliance on purchased supplementary feeds (purchased hay can be low in quality and is often more expensive per unit of energy or protein fed than silage produced on-farm);
- provide the supplementary feed that may be required to change calving time, allowing producers to target higher-value markets at alternative times of the year or improve reproduction rates (calving percentage); and
- provide producers with the flexibility to target cattle for alternative markets (e.g. heavy grass-fed steers for the Korean market, which is not feasible in many pasture-based enterprises in Australia).

Conclusion

Incorporating silage into a beef enterprise has the potential to increase farm profitability if the silage is of high quality and losses are kept to a minimum.

A target ME content of 9.5-10 MJ/kg DM or higher is essential if high levels of beef production per tonne of silage, and per hectare, are to be achieved.

The two key areas where silage will have the most impact will be an improvement in production per head (improved compliance with market specification, achieved earlier) and an increase in stocking rate.

Beef: determining the role for silage

1. Set clear production goals for the physical and financial components of the beef enterprise. Identify the areas that need change.
2. Assess the forage (pasture, crop, conserved forage) resources available on the farm:
   - When will surplus forage be available for silage production?
   - What silage quality can be achieved from the available forage?
   - Will the quality/quantity match that required for the new production system?
3. Is silage the best strategy for providing the additional feed required for the changed production system?
4. Will silage use change turn-off times, allow access to higher prices, or incur extra costs? Will these need to be budgeted for in a cash flow assessment?
5. How will the new system influence overheads and labour requirements?
6. What is the impact on the cost per kg beef produced from the farm, and how does this compare with beef prices – is it profitable?

1.5.3

Sheep

The challenge for sheepmeat producers is to ensure than market specifications are met. Chapter 15 provides a more detailed coverage of feeding silage to sheep.

Roles for silage in sheep enterprises

Silage produced from surplus pasture, or specialty crops, can be used to increase stocking rates, supplement growing lambs, feed pregnant and lactating ewes, and to finish older surplus sheep. However, silage use is not restricted to prime lamb producers. Wool producers, particularly those in more favourable environments, where forage conservation is more widely practised, can use silage to increase stocking rate, provide improved nutrition to lambing ewes to improve weaner survival and growth rates during periods of pasture deficit, finish prime Merino lambs, sheep for live export and cast-for-age stock.

Some producers are now retaining lambs for 2-3 months longer to meet preferences for heavier weights, which often requires the use of supplementary feeding. It is also possible to finish older, cull sheep through the use of supplements. The sale of cull sheep can contribute 15 to 25% of gross income from sheep and wool enterprises.

Matching feed and animal needs

The majority of lambs are produced in southern Australia, which has a winter rainfall pattern and an often unreliable autumn break. Pasture growth is slow in winter, but surplus feed is usually available in spring, which is followed by a dry summer. Although this pasture growth pattern complements an autumn joining, in about 25% of years heavy lambs cannot be produced unless supplementary feed is used. Later lambing usually necessitates carryover of lambs through summer, for marketing in autumn.

Producers have the option of summer pastures/crops, such as lucerne and/or irrigation, or they may accept slow growth rates on lower quality pastures. In many cases, supplementary feeding or feedlotting will be necessary to meet minimum growth rates and production goals. The use of conserved silage, either alone or with grain, provides a source of supplementary feed to achieve these goals.

Lambs produced in summer rainfall areas will also have feed deficit periods at other times of the year that must be managed.

Because grazing is the cheapest form of feeding, it is important to match the high ewe requirements with the pasture production cycle. A fodder budget can be used to compare animal requirements with pasture production and quality.

The following example is for a higher rainfall (900 mm) grazing property of mixed native and sown pastures and specialty pastures such as lucerne or chicory. Ewes are joined in autumn and stocked at 5/ha (8.5 DSE/ha). The GrazFeed® model (see Figure 1.7) predicts two periods when feed is not sufficient for animal production – ewes in late pregnancy (August) and lambs post weaning (January/February). Silage can be made from the spring surplus for later supplementation. In this example, lambs and ewes are fed a mixed silage and grain supplement.

Silage can be used in ‘normal’ seasons, often in conjunction with grain, when insufficient high-quality pasture is available. Table 1.6 shows situations when silage might be used.

There are obvious management alternatives to forage conservation, such as reducing animal demand by selling lambs at lighter weights or growing specialty

Table 1.6

Probable timing of silage supplementation of lamb production enterprise in temperate zones of Australia, at two times of joining.

Class of sheep requiring silage supplement	Autumn lambing flock	Winter/spring lambing flock
Ewes	March-May	May-July
Ewes with lambs	May-August (drought)	Usually not required
Lambs only	November-December	November-December & February-March

crops. An economic assessment is required to determine the most profitable option (see Chapter 11).

For example:

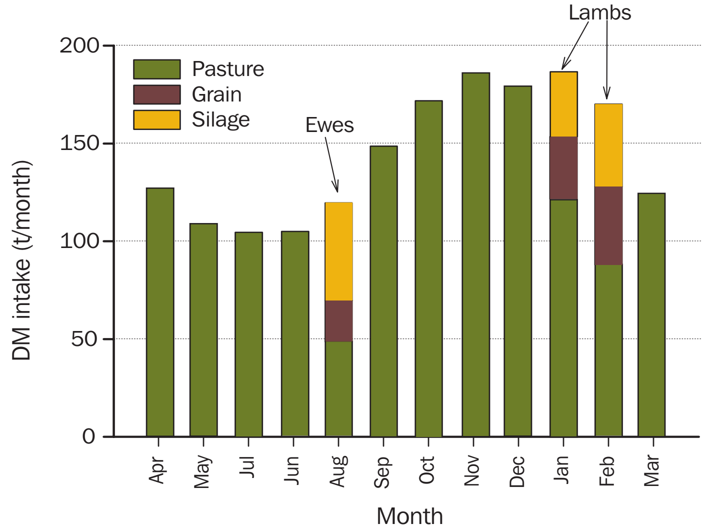
- By marketing the male lambs on the domestic market at 40 kg rather than 48 kg liveweight, the feed deficit for January and February is halved. The decision will depend on carcase and skin values, and feed costs – are feeding costs more than the increase in carcase and skin value?
- The feed deficit may also be reduced by marketing all lambs as stores once they reach a minimum of 32 kg (below this they have low commercial value). While this action would remove the need for summer feed of spring lambs, in most cases it would not be economically viable, unless the store lambs are sold to a specialist finisher within an alliance structure where some ownership could be retained.

Production benefits

- Silage production allows improved utilisation and production of pastures, with the additional feed being used to increase the carrying capacity (number of ewes).
- Silage can be used to fill feed gaps. Silage produced on-farm has the potential to be cheaper than alternatives, such as grain.
- Cutting silage enables grazing pressure to be increased over the whole farm during periods of peak pasture growth. This allows pastures to be maintained at a higher quality, vegetative stage of growth, for longer (see Chapter 3).
- Silage can be used for all classes of sheep as the sole diet, either as a maintenance feed (drought) or for production feeding, particularly when finishing lambs. Growth rates are adequate from good-quality silage when fed alone, but improved animal production can be achieved by adding grain (see Chapter 15, Section 15.1.1).

Figure 1.7

Monthly feed requirements, predicted from the GrazFeed® model, for a prime lamb enterprise in a high rainfall environment, on the central tablelands of NSW. Silage (150 t) is produced from surplus pasture in October.



- Wool quality can be improved by better grazing management and strategic supplementation to avoid sudden feed changes and subsequent problems with staple strength.
- The high-quality regrowth that usually follows a silage cut, provides high-quality grazing for lambs late in the season when other pastures are maturing. This 'clean' regrowth can be used as part of a management strategy to reduce internal parasite burdens and grass seed problems.

Additional benefits

- Silage provides a stable price alternative to grain, which is usually more expensive in dry seasons.
- Silage reduces the impact of drought, particularly at higher stocking rates. The availability of a silage reserve can reduce damage caused by over-grazing of pastures and the environmental consequences of drought and other natural disasters, such as bushfires and floods.
- Silage is a safer feeding option compared to high-grain diets, with reduced risk of animal health problems, such as acidosis.
- Improvements in pasture productivity and composition, and management of weeds will contribute significantly to the economic benefits from silage in grazing and cropping enterprise.
- Risk is reduced, with silage providing an option to finish lambs profitably when conditions are dry and unfinished lambs are discounted. It is also easier to fulfil market contracts.
- The availability of silage provides producers with the option to opportunistically purchase and finish feeder lambs.

Conclusions

Profitable use of silage within a sheep enterprise will depend on the production of high-quality, well-preserved silage.

The main benefits are the ability to increase stocking rate and produce more lambs, to finish lambs to specification more quickly and reliably, and to target the preferred heavy lamb market.

The additional benefits of improved pasture management and wool quality help to economically justify silage production.

Sheep: determining the role for silage

1. Clearly identify production goals for the farm business in terms of numbers of lambs and specifications to be targeted.
2. Identify the forage (pasture, crop and conserved forage) resources available on the farm.
   - How much surplus forage is available for silage production?
   - What silage quality will be produced from the available forage?
   - Will the quantity/quality match that required to meet production targets?
3. What additional feed is required to meet the new production goal(s)?
4. Is silage alone (or in combination with grain) the best strategy for providing the additional feed? What are the alternatives and how do they compare economically?
5. What are the benefits (direct and indirect) and costs of the proposed silage system?
6. How will the new system influence overheads and labour requirements on the farm? Economies of scale can be important here.
7. What is the impact on the cost of production (per lamb or per kg) on the farm, and how does this compare with the price received – is it profitable?

Section 1.6

Longer-term implications of forage conservation

In the mixed grain/animal production farming belt, silage is not only of value to the animal enterprise as a supplementary feed and a pasture management tool, but can also provide significant benefits to the grain enterprise. These benefits include weed control during the pasture phase, and weed control and nitrogen fixation when annual forage legume break crops are used for silage production.

1.6.1

Weed control

Weed control can be a significant cost in the pastoral and cropping regions. Although the development of herbicide resistance in grass weeds, such as annual ryegrass and wild oats, is not a major problem for the grazing industries, it is becoming a serious problem in cropping regions.

Broadleaf weeds can often be expensive to control in pastures if selective herbicides are needed to avoid damage to the legume component. In the cropping areas of southern Australia, wild radish (*Rhaphanus raphanistrum*) is a major problem and farmers are looking to control measures being applied during the pasture phase on farms with crop and animal enterprises.

Strategic silage cutting, either alone or in combination with grazing, provides farmers with another weed control option, reducing the requirement for herbicides. Cutting pastures or annual forage legume crops in spring in southern Australia can significantly reduce seed production in annual weeds (see Chapter 3, Section 3.3). It is generally accepted that most viable seeds present in the cut forage will be sterilised during the ensiling process. However, most weed seeds will survive the hay-making process and can be spread around the farm wherever hay is fed.

Timing of the silage cut in spring is critical to significantly reduce weed seed production. The optimum time of cut will vary with the target weed and should be related to the stage of weed development (see Chapter 3, Section 3.3). A strategic crash grazing of the regrowth may be required if there is any regrowth of the target weed.

Some annual forage legume crops suitable for silage production have the added bonus of competing effectively with weeds and suppressing their establishment and growth through autumn and winter. For example, peas and vetch sown at high rates, preferably with a low cereal sowing rate (see Chapter 5, Section 5.4), have been found to suppress annual ryegrass in studies at Wagga Wagga, NSW.

1.6.2

Soil acidification

All producers should be aware of the possible long-term effects of the removal of agricultural products from a farm, whether it be grain, forage, meat, milk or wool, on soil acidity. Acidification rates vary between soil types and production systems, with greatest concern for declining pH being on naturally acid (low pH) soils under high production systems.

Soil tests should be used to monitor soil pH. Lime application may be required to counteract a decline in soil pH. If soil pH is allowed to fall below critical levels, production will suffer.

Table 1.7 shows indicative lime requirements for a number of silage parent crops. Note that acidification rates will be higher when the forage has a high legume component.

The majority of silage is fed back onto the farm (perhaps not on the same paddock), so the question arises as to whether this system is any more exploitative than one which removes the same quantity of forage by grazing. For example, the acidifying effects of a silage cut may be less if the silage is fed back on that paddock. Long-term studies are required to investigate these issues of nutrient cycling, removal and transfer.

1.6.3

Nutrient cycling, removal and transfer

Large quantities of nutrients are removed when crops and pastures are harvested for silage (see Chapter 4, Table 4.2, and Chapter 5, Table 5.1).

To achieve a sustainable farming system, redistribution of nutrients must be taken into account when silage is fed to animals – the portion that is recycled via excreta and that which is exported off-farm in animals and animal products.

Most nutrients, including phosphorus and potassium, are available to plants through fertiliser inputs or the soil's natural fertility. Nitrogen fixation by legumes makes nitrogen unique.

The cycling of nitrogen is highlighted in the following exercise, where high-quality legume silage is fed for beef or lamb production on a mixed livestock/crop farm. In both systems, approximately 70% of the silage nitrogen is excreted by the animals in dung or urine, while the remaining 30% is retained in the animal and is exported off-farm when the animals are sold.

In the grazing situation the nitrogen is returned directly to the paddock, but the nitrogen in silage is transferred to the paddock where the silage is fed. By controlling the site of feeding, producers can decide where the nitrogen is returned. The transferred nitrogen may be used to

Table 1.7

The equivalent rate of lime required to balance the acidifying effect of product removal.

Product removed	Lime rate (kg lime/t product removed)
Lucerne hay	60
Mixed pasture hay*	30
Subclover	41
Maize**	24

** Predominantly grass species, <20% clover.*

*Sources: Slattery et al. (1991); ** Kaiser and Piltz (1998a)* boost the fertility of pasture paddocks or those to be cropped. Nutrient redistribution by livestock complicates the issue and should be taken into account.

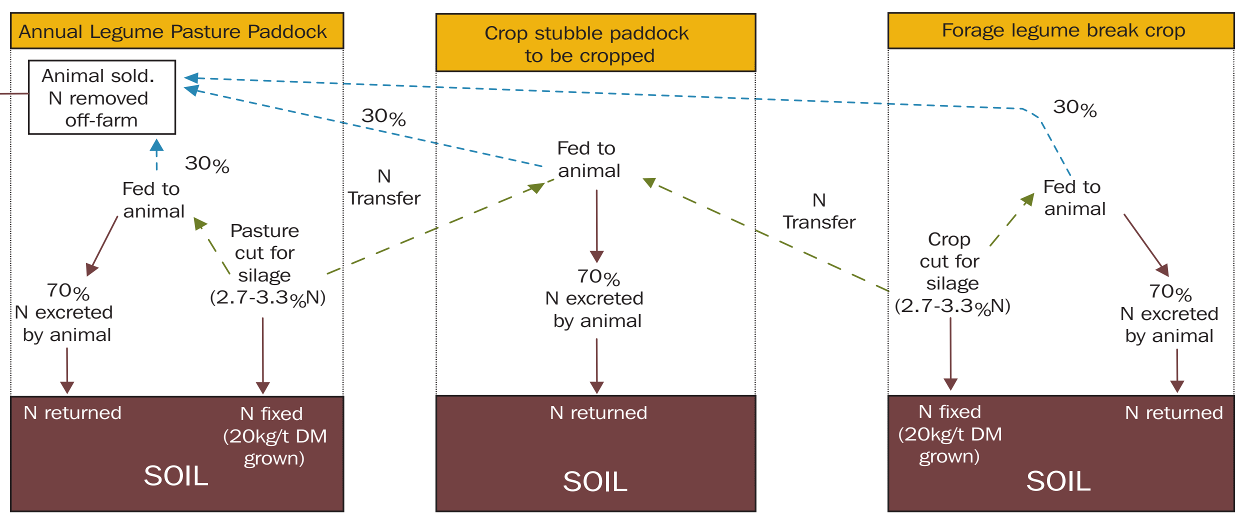
The simplified version of the nitrogen cycle in Figure 1.8 illustrates the effect of the options outlined on the previous page, using a mixed farming system as the example. Losses of nitrogen from the system, due to volatile losses or leaching down the soil profile, although important, are not included.

The main features of the cycling, transfer and loss of nitrogen from this mixed farming system are:

- The quantity of nitrogen fixed by legume pastures and forage crops (and remaining in soil) is generally considered to be approximately 20 kg of nitrogen for each tonne of total legume forage DM produced (grazed and ensiled).
- The nitrogen content of the legume cut for silage is approximately 3% of the DM (or 30 kg N/t silage DM). Therefore, for legume pastures or forage legume crops yielding silage cuts of 4.5 t and 7.5 t DM/ha, the quantity of nitrogen in the silage for each hectare cut would be about 135 and 225 kg, respectively.
- If 30% of the silage nitrogen is exported off-farm in animal product, the nitrogen remaining on-farm, either recycled or transferred, would be approximately 95 and 158 kg nitrogen for each hectare of legume pasture or forage crop cut for silage, respectively.
- Feeding the high-quality silage on a stubble paddock to be cropped next season would not only provide the animals grazing poor-quality stubble with a high-quality, high-nitrogen supplement, but also transfer a significant quantity of nitrogen that could be utilised by the subsequent crop.

Figure 1.8

Simplified description of nitrogen (N) cycling, transfer and removal when legume silage is integrated into a mixed grain/animal farming system.



Chapter 2

Principles of silage preservation

Chapter 2

Principles of silage preservation

In this chapter

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The Key Issues

- The key to producing a well-preserved silage is an anaerobic fermentation dominated by lactic acid bacteria (LAB).
- A good fermentation requires sufficient water soluble carbohydrate (WSC) content to produce enough lactic acid to overcome the buffering capacity of the forage and reduce pH to an adequate level for preservation.
- Shorter chop length increases rate of release of fermentation substrates and improves compaction.
- Effective wilting will improve the fermentation, by concentrating available WSC and restricting activity of undesirable bacteria, and reduce effluent losses.
- Wilt as rapidly as possible to avoid excessive respiration losses in the field and in the early stages of storage.
- Compact well and seal effectively to create an anaerobic (air-free) environment. This will minimise losses during storage.
- Once the silo is opened and the silage is exposed to air, aerobic spoilage will commence. Management during feedout will influence the extent of aerobic spoilage.

Section 2.0

Introduction

An acid fermentation occurs when forages of sufficiently high moisture content are stored under anaerobic conditions. During fermentation, bacteria convert plant sugars, water soluble carbohydrates (WSCs), to fermentation acids and other compounds. Ideally, this fermentation produces mainly lactic acid and in sufficient quantity to quickly reduce pH. At low pH, acid conditions prevent further microbial activity and spoilage.

The final pH achieved in a well-preserved silage depends on the WSC and dry matter (DM) content of the forage at time of ensiling. The final pH may be as low as 3.8-4.2, but could exceed 5.0 in heavily wilted silages, particularly those produced from legumes (see Chapter 12, Table 12.3).

The silage will not deteriorate as long as anaerobic conditions are maintained. In other words, the nutrients in the silage are preserved while the silo or bale remains sealed.

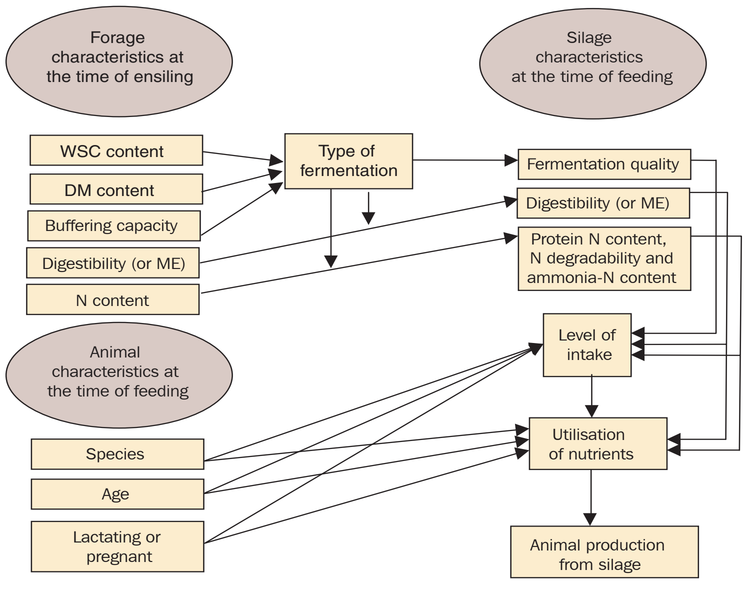
silage – the fermented product resulting from the anaerobic fermentation of sugars in forage

aerobic – in the presence of air (specifically oxygen)

anaerobic – without air (specifically oxygen)

Figure 2.1

Effect of forage characteristics and quality on silage quality and animal production.



The rate and efficiency of the fermentation process, the products of fermentation, and the fermentation quality of the resultant silage depend on several factors, the most important being the composition of the parent material at the time of ensiling and the species of bacteria that dominate the fermentation.

The quality of the silage produced depends on its nutritive value – digestibility, ME, protein and mineral content – combined with its fermentation quality (see Figure 2.1). Poorly fermented silage may result in inferior animal production due to unpalatability and poor utilisation of dietary nitrogen (crude protein).

Losses in quality can occur throughout the silage-making process. The level of loss will depend on:

- the physical and chemical properties of the forage at the time of harvest and ensiling;
- wilting conditions and the extent of wilting;
- the harvesting process;
- the efficiency of the fermentation process;
- maintenance of anaerobic conditions during storage; and
- management during feedout.

Section 2.1

Parent forage composition

The composition of the parent forage at ensiling has a major influence on the silage fermentation. The most important components are DM content, WSC content and buffering capacity (BC).

2.1.1

Dry matter content

The DM content of the parent forage at ensiling can affect the quantity of effluent lost from the silage during storage, the growth of bacteria in the silage and the ease of compaction which, in turn, affects the exclusion of air from the silo or bale.

Effluent

During the early stages of the ensiling process, as the cell structure breaks down due to compaction and the action of plant enzymes and microbial activity, fluids are released from within the cells. If the forage is stored at low DM content – in particular unwilted, direct-cut pastures or forages containing 'free' water from rainfall or dew – surplus moisture (including soluble compounds) will flow out of the silo as silage effluent.

The quantity of effluent produced is directly related to the DM content of the forage ensiled and the extent of compaction of the silage. Effluent flow falls as DM content increases (see Figure 2.2), and stops when the DM content reaches about 30%. As a result, wilting is an effective management strategy for reducing effluent losses.

Effluent flow is slightly greater for finer chopped compared to long chop forage.

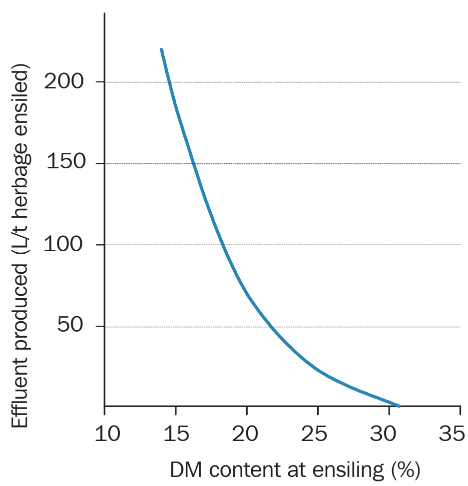
Silage effluent contains WSCs, protein, minerals and fermentation products, so it represents a significant loss of nutrients. The loss of WSCs will reduce the quantity available for the silage fermentation.

Silage effluent is also a serious environmental pollutant if it enters waterways. It has a very high biological oxygen demand (BOD), in the order of 12,000 to 83,000 mg/L. In the UK, silage BOD levels have been estimated to be about 200 times higher than those of untreated domestic sewerage.

Effluent (from various sources) contaminating water systems is receiving increasing attention from the various State environmental protection authorities. In many European countries, landowners face prosecution if silage effluent enters water systems.

Although some silage additives can be used to reduce the amount of silage effluent produced (see Chapter 7), wilting is the most effective way to prevent effluent production.

Figure 2.2



Effect of forage DM content at ensiling on effluent losses from silage.

Source: Adapted from Bastiman (1976)

Growth of silage micro-organisms

The DM content of the forage directly affects bacterial activity during the fermentation phase. The activity of all silage bacteria slows as forage DM content increases and as silage pH decreases. Bacterial activity stops at a higher pH as forage DM content increases.
Therefore, wilted silages have a higher final silage pH.

When fermentation is restricted by falling pH, some of the WSC may be left unfermented. Residual WSCs can cause the silage to be more aerobically unstable, resulting in greater losses during feedout (see Chapter 10, Section 10.2.1).

Bacteria vary in their preferred conditions for optimum growth, especially moisture content (or water activity). Clostridia, one of the main bacteria responsible for silage spoilage, are particularly sensitive and require low DM conditions to flourish. Wilting to a DM content >30% usually restricts clostridial growth and favours the preferred lactic acid bacteria (LAB).

When forages are wilted, the concentration of WSCs on a fresh crop basis increases (see Section 2.1.2). This also favours the growth of LAB and improved silage fermentation quality.

The micro-organisms important to silage production are discussed in detail in Section 2.3.

Compaction and silage density

If forage DM content is too high at ensiling, it is more difficult to achieve adequate compaction. When silage density is low, more oxygen remains in the silo at ensiling and there is increased air infiltration when the silage is opened for feeding. Increased exposure to oxygen in the early stages of the ensiling process leads to increased respiration and loss of DM and energy.

Additional information on storage and feedout losses is provided in Section 2.5, Section 9.8 of Chapter 9 and Chapter 10.

Information on optimum DM content of various forages at ensiling is provided in Chapter 4, Table 4.1; Chapter 5, Table 5.2; and Chapter 6, Section 6.4.1.

2.1.2

Water soluble carbohydrate (WSC) content

Effective ensiling relies on the fermentation of WSCs to lactic acid by LAB. WSC content in the parent forage should be >2.5%, on a fresh forage basis, for good silage fermentation. If WSCs are <2.5%, the forage should be wilted (see Appendix 2.A1, Figure 2A.1) or a silage additive used to reduce the risk of a poor fermentation (see Chapter 7, Section 7.4).

The main non-structural carbohydrates in temperate grasses are glucose, fructose, sucrose and fructans. Fructans are the most important storage carbohydrates. These and other sugars, present in small quantities in plants, are soluble in cold water and are collectively referred to as WSCs.

The WSC contents of temperate legumes, tropical grasses and tropical legumes are lower than that of temperate grasses. The main sugars in temperate legumes are fructose, glucose and sucrose.

The principal storage carbohydrate in temperate legume forages is starch, rather than fructans – starch is insoluble in cold water. In cereal crops WSC contents are high at the vegetative stage of growth, but as grain filling progresses WSC content falls and starch content increases.

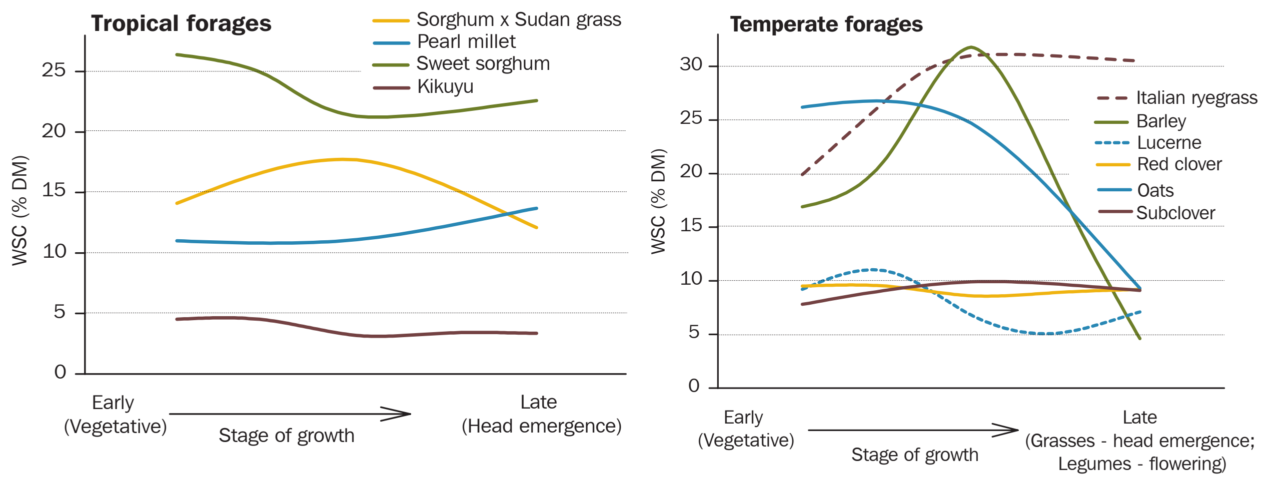
Most naturally occurring LAB are unable to ferment starch. Therefore, starch is not a satisfactory substrate for LAB growth, unless there is some breakdown (hydrolysis) by plant enzymes (amylase) or acid hydrolysis during the fermentation to convert starch to WSCs. In addition, most LAB cannot ferment hemicellulose (a component of the plant fibre fraction), but some hydrolysis of hemicellulose occurs (due to the action of plant enzymes and silage acids) releasing sugars for fermentation.

Although a number of other factors influence the WSCs of forages, species differences (Appendix 2.A1, Table 2A.1) and stage of growth have the greatest effect. The trends for changes in WSC content at different stages of growth are illustrated in Figure 2.3. (More details for crops and pasture species can be found in Chapters 4 and 5.)

The effects of growth stage tend to be greatest with temperate grasses and cereal crops.

Figure 2.3

Influence of stage of growth at harvest on the WSC content of different forages.



Sources: McDonald et al. (1991); Kaiser (various studies, unpublished data)

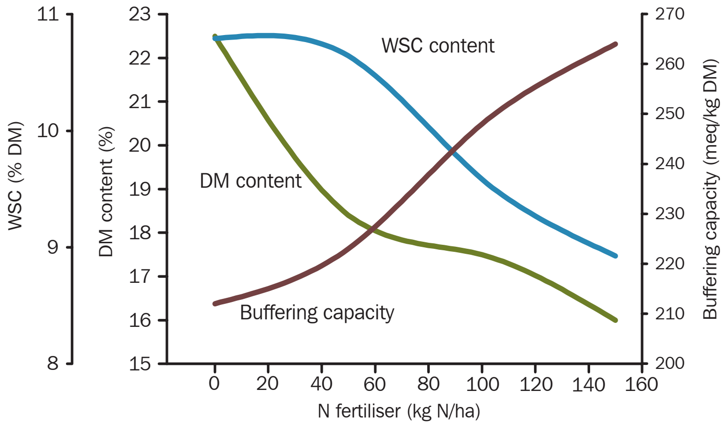
Other factors influencing WSC content include:

Cultivar: There is evidence of significant variation in WSC between cultivars in some grass species. Some plant breeders are selecting for higher WSC content.

Weather conditions: Low light intensity, cloudy weather and high rainfall during crop growth can reduce WSC content.

Figure 2.4

Effect of N fertiliser on WSC and DM content, and buffering capacity of ryegrass.



Source: Adapted from OKiely et al. (1997)

Time of day: On sunny days, WSC content usually increases during the day, until mid afternoon. For this reason some advisers have recommended mowing of crops and pastures mid afternoon. However, the variation in WSC content during the day is considerably less than that due to species and stage of growth. Furthermore, any advantage in WSC content could be lost by slower wilting and higher respiration when forage is cut later in the day (see Chapter 6, Section 6.2).

N fertiliser application: Application of nitrogen fertiliser can reduce WSC and DM content, and increase buffering capacity (see Section 2.1.3). This is highlighted in a study with perennial ryegrass (see Figure 2.4). Consequently, nitrogen fertiliser application is not recommended within four weeks of harvest for most crops, in most situations. The exception is short regrowth crops, such as kikuyu and other tropical grasses during their peak growth periods.

Crops receiving high rates of nitrogen fertiliser must be adequately wilted (see Chapter 4, Section 4.3.2).

2.1.3

Buffering capacity (BC)

All forages contain chemical compounds, called buffers, which resist changes in pH. Most of the BC of forage depends upon the content of organic acids and their salts, with proteins contributing to about 10-20% of BC. In silage production, these buffers neutralise some of the silage acids as they are produced, restricting and delaying the decline in pH, and providing an opportunity for the growth of undesirable bacteria. Therefore, there is an increased risk of a poor fermentation when ensiling forages with a high BC.

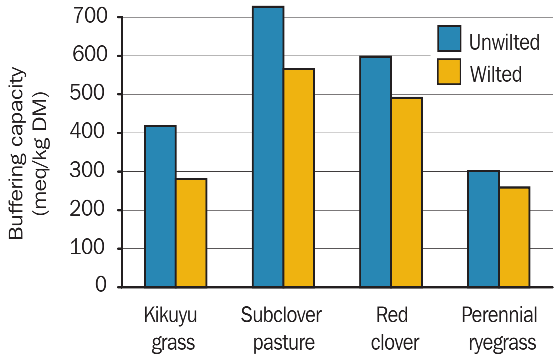
The main factors influencing the BC of forages are:

Species: The BC of forages varies between species (see Table 2A.2, in Appendix 2.A2), with legumes having higher BCs than grasses. Some summer forage crops, in particular maize, have a very low BC, while some broadleaf weeds can have a very high BC.

Stage of growth: There is evidence with a number of pasture and forage crop species that BC declines with advancing crop maturity.

Figure 2.5

Influence of wilting on the buffering capacity of various forages under favourable weather conditions.



Source: Playne and McDonald (1966); Dawson et al. (1999); Kaiser (various studies, unpublished data)

N fertiliser application: The application of nitrogen fertiliser can increase BC (see Figure 2.4).

Wilting: BC is sometimes reduced when forage is wilted (see Figure 2.5), although this may not occur where wilting conditions are unfavourable and there is an ineffective wilt. The reduced BC has been attributed to a reduction in the organic acid content of the forage.

2.1.4

Assessing the ensilability of forages

The ensilability of a forage, or the likelihood of producing a silage with a good lactic acid fermentation, can be assessed by taking account of its DM content, WSC content and BC. Forages with a high WSC content and low BC are relatively easy to ensile successfully. On the other hand, forages with a low WSC content and high BC are more difficult to ensile, particularly if the DM content is also low. In these circumstances, the crop needs to be wilted to DM targets to achieve minimum WSC in the fresh crop (see Section 2.1.2 and Figure 2A.1 in Appendix 2.A1).

Table 2.1 shows the ensilability of a number of common crops, pastures and weeds.

To take account of the three factors influencing the ensilability of forages – DM, WSC and BC – European researchers have developed a *fermentability coefficient,* which can be calculated for each forage. They have identified a minimum score, above which there is a high probability of a good lactic fermentation under European conditions. At this stage, critical scores have not been developed for forages under Australian conditions.

Even if the ensilability of a forage is poor, there are strategies that can be used to increase the probability of a good fermentation. Wilting (see Section 2.2.1 and Chapter 6) and silage additives (see Chapter 7) are effective 'tools' for improving the ensilability of difficult forages.

Table 2.1

*The ensilability of various crops and pasture species.**

Buffering capacity	**WSC content (% DM basis)**		
(meq. NaOH/kg DM)	High (>20%)	Medium (12-20%)	Low (<12%)
Low (<350)	Sweet sorghum	Maize, grain sorghum, winter cereals (heading), perennial ryegrass, lupins	Cocksfoot
Medium (350-550)		Italian ryegrass, peas, sunflowers	Medics, arrowleaf clover, lucerne, white clover, sainfoin, kikuyu grass, other tropical grasses, millets, forage sorghum
High (>550)		Capeweed, variegated thistle	Immature oats, subclover, balansa clover, red clover, berseem clover, vetch, tropical legumes, Paterson's curse

Key (colour shading): Very easily ensiled; Easily ensiled; Moderately easy to ensile; Difficult to ensile successfully without wilting or silage additives

** Some species with a wide range in WSC or BC may appear in more than one category – see Appendices 2.A1 and 2.A2 for mean values and ranges.*

WSC content and BC of a species is modified by the stage of growth, N fertiliser application and weather conditions.

Section 2.2

The silage preservation process

2.2.1

Aerobic phase

The aerobic phase commences when the forage is cut. It includes the wilting period and the time between sealing and when anaerobic conditions are achieved within the silo (see Figure 2.7). Changes in forage composition are mainly due to the action of plant enzymes. Early in this phase enzymes break down more complex carbohydrates (fructans, starch and hemicellulose), releasing simple sugars (WSCs). Plant enzymes continue to use WSCs for the process of respiration until either all the substrate (WSCs) or available oxygen has been used. Plant enzymes will also continue to break down (degrade) protein to various non-protein N compounds – peptides, amino acids, amides and ammonia – the process of proteolysis.

Respiration

Respiration is undesirable because it results in a loss of DM, energy (ME) and available WSCs required by LAB for fermentation. Although some respiration is unavoidable, good silage-making practice will minimise these losses (see Sections 2.5.1 and 2.5.2, and Chapter 6).

During respiration, WSCs are converted to carbon dioxide and water, with energy released in the form of heat. Heat production is the first sign of respiration.

WSC + oxygen → carbon dioxide + water
+ heat (16MJ/kg WSC)

Because the process is oxygen-dependent, respiration ceases once anaerobic conditions are established in the silo or bale.

The extent of aerobic respiration will depend on a number of factors, including characteristics of the forage, the length of wilt, wilting conditions, the time between harvest and compaction and sealing, and the degree of compaction achieved. Two of the most important factors affecting the rate of respiration are forage DM content and temperature (see Figure 2.6). Respiration rate is quite low once forage DM reaches 50-60%, but at all DM levels respiration increases with temperature.

Management factors that affect the time taken to achieve anaerobic conditions – the time taken to fill and seal the bunker or bale, and the degree of compaction – are also important (see Chapter 9, Section 9.4). However, even in a well-sealed silo, the temperature rise increases as silage density falls, especially when DM content is high (see Figure 2.8).

If the aerobic phase continues for a prolonged period after sealing, the sealing is inadequate or a hole develops in the plastic, allowing air into the silo, aerobic micro-organisms (yeasts and moulds) will grow. This results in increased DM and energy losses due to spoilage in the silo and also during the feedout phase (see Section 2.5.3 and Chapter 10).

During the aerobic phase plant enzymes:

Break down WSCs to carbon dioxide and water, and release of heat = respiration.

Break down proteins to various forms of soluble non-protein nitrogen (NPN) = proteolysis.

Respiration rate:

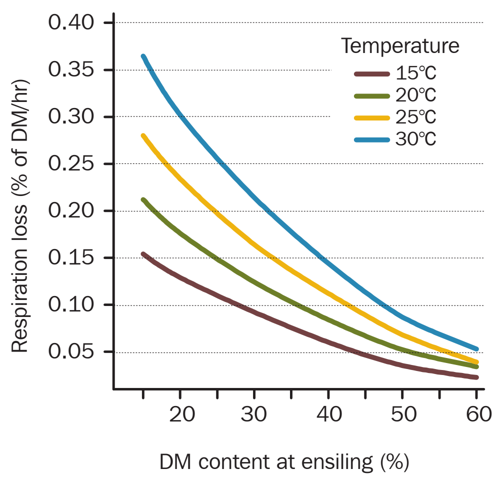
- is highest in leafy forages;
- is greater for legumes than grasses;
- decreases with increasing forage DM content; and
- is greater at higher ambient temperatures.

Respiration depends on the availability of oxygen, so is greater:

- with poorly compacted silages;
- when filling is slow; and
- when sealing is delayed.

Figure 2.6

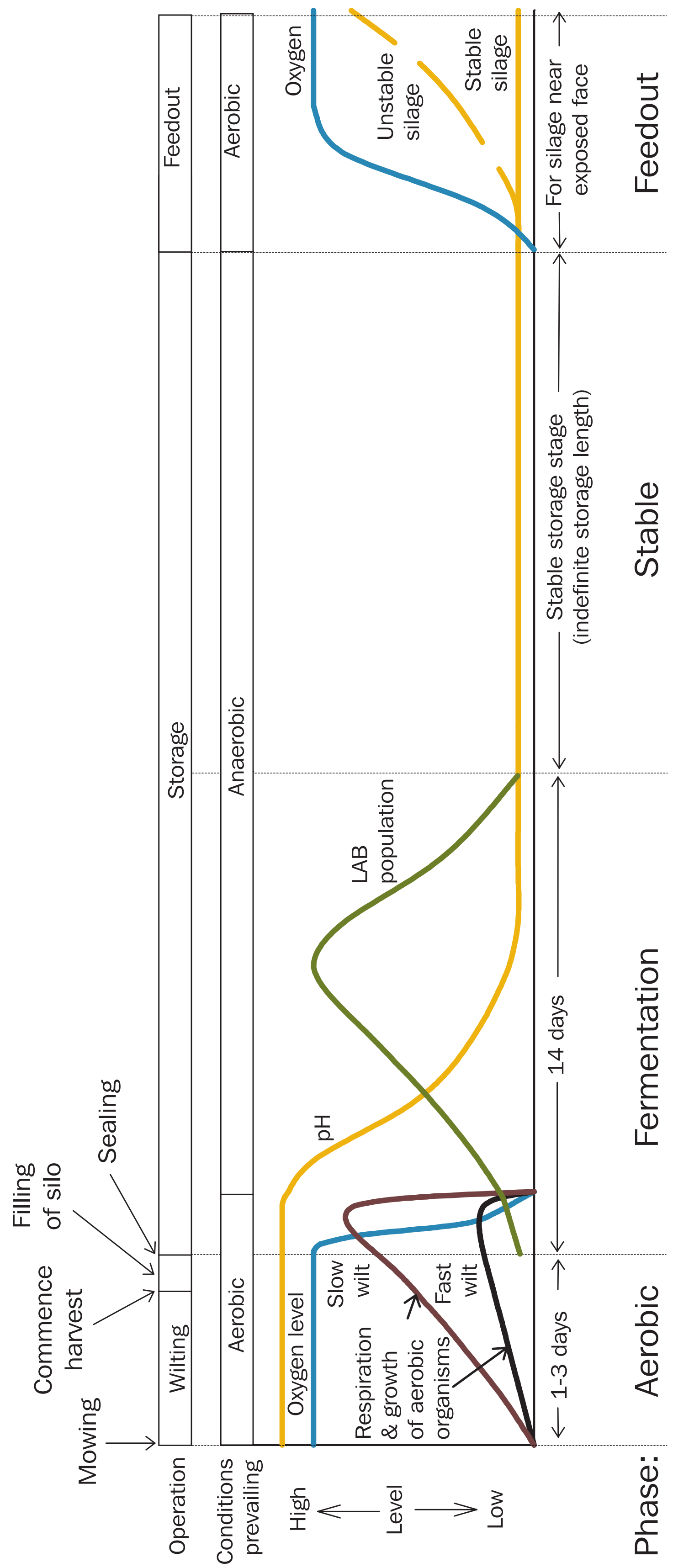
Respiration losses from cut grass in the field.



Source: Adapted from Honig (1980)

Figure 2.7

Changes occurring during the various phases for a well-preserved silage.



Source: Adapted from Pitt (1990)

If the respiration is allowed to continue for a prolonged period, a large amount of heat will be produced. The temperature within the silo or bale can become quite high, resulting in heat damage of the protein and a reduction in digestibility due to a browning reaction (also known as Maillard reaction or caramelisation).

Heat-damaged silages have a pleasant, sweet, burnt sugar aroma and are quite palatable to livestock, provided moulds are not present. However, the digestibility of heat-damaged silage is very low and it is usually only suitable for maintenance feeding. There is a significant drop in quality because the excessive heat binds the protein and amino acids to the hemicellulose fraction, increasing the indigestible fibre and acid detergent insoluble nitrogen (ADIN) content (see latter section of Chapter 12, Section 12.4.4).

Silages with a DM content ≥50% are most susceptible to heat damage. Digestibility will be reduced if the temperature in the silo rises above 50°C.

Proteolysis

Proteolysis is undesirable because ruminant livestock are not able to use degraded protein as efficiently in the rumen (see Chapter 12, Section 12.4.4).

The extent to which proteolysis occurs during wilting varies considerably, and does not appear to be related to either plant species or nitrogen content.

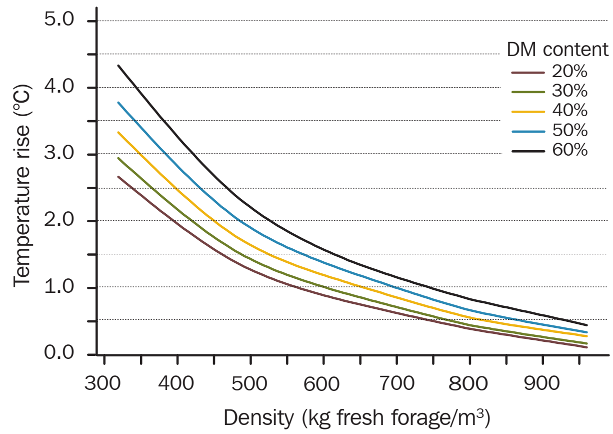
If wilting is achieved quickly there appears to be very little increase in the amount of degraded protein within the forage. However, slow, extended wilts have been shown to increase protein breakdown (see Table 2.2).

Although respiration and proteolysis occur more rapidly at higher temperatures the rate of wilting also increases, with a more rapid wilting usually resulting in less proteolysis and loss of WSCs. Greatest losses will occur when temperatures are high, but rain and humid conditions cause wilting rate to be slow.

Enzymic proteolysis can continue in the ensiled material for several days. Production of fermentation acids will eventually stop the action of the enzymes. For this reason, proteolysis occurs more rapidly in freshly ensiled forage and declines as pH declines. Achieving a rapid lactic acid fermentation will result in less degraded protein in the silage.

Figure 2.8

Effect of forage density and DM content on temperature rise in a well-sealed bun.



Source: Adapted from Pitt (1983)

Increased wilting rate leads to:

- reduced respiration of WSC;
- reduced loss of energy and DM;
- increased WSC available for fermentation;
- better fermentation;
- reduced proteolysis during wilting; and
- reduced proteolysis in the silo due to more rapid decline in pH.

Table 2.2

The effect of wilting on the major nitrogen components of ryegrass/clover forage.

Rate of wilt	Length of wilt (hours)	DM content (%)	Protein-N (% total N)	Ammonia-N (% total N)
Unwilted	0	17.3	92.5	0.12
Rapid	6	34.9	87.7	0.11
Rapid	48	46.2	83.2	0.21
Slow	48	19.9	75.2	0.26
Slow	144	37.5	68.9	2.61

Source: Carpintero et al. (1979)

Types of silage

The composition of the ensiled forage and the subsequent fermentation will determine the type of silage produced. Silages produced under Australian conditions can be broadly classified into five main types:

Lactate silages

- fermentation is dominated by LAB;
- WSCs are primarily converted to lactic acid;
- have a pleasant, acidic and sometimes sweet smell;
- pH values are generally low (3.8-4.2), except in heavily wilted silages where the fermentation is restricted; and
- contain high lactic acid levels relative to other organic acids.

Acetate silages

- fermentation may be dominated by enterobacteria;
- more likely to occur when unwilted, or lightly wilted, low DM forage is ensiled;
- WSCs are primarily converted to acetic acid;
- typified by a sour, vinegar smell;
- pH values are higher than those of lactate silages at the same DM content; and
- DM and energy losses can be significant.

Clostridial silages

- fermentation is dominated by clostridia;
- more likely to occur when unwilted, or lightly wilted, low DM forage is ensiled;
- WSCs and lactic acid are converted to butyric and acetic acid;
- characterised by low lactic acid levels and high pH;
- proteins and amino acids are extensively degraded;
- ammonia-N levels are high as a proportion of total N;
- DM and energy losses can be significant (silages are unpalatable to livestock and the utilisation of the N in these silages is poor); and
- clostridial silages are not common in Australia.

Wilted silages

- fermentation is dominated by LAB;
- fermentation is restricted because of the high DM content (>30%). Less WSC are converted to lactic acid. pH values are higher than those of lactate silages;
- residual, unfermented WSC levels can be high, but vary due to length and extent of wilting;
- very dry forages are harder to compact, especially if chop length is long; there is a greater risk of yeast and mould growth because oxygen levels in the pit or bale are high in poorly compacted silages; and
- higher residual WSC, poor compaction and carry-over yeast and mould spores can make these silages more aerobically unstable.

Silages with additives

- the characteristics and type of fermentation observed varies with additive type. Chapter 7 gives further information on the types of additives available and their use.

A more detailed description of the appearance and aroma of various silages is contained in Chapter 12, Section 12.3.

2.2.2

Fermentation phase

The anaerobic fermentation phase commences once anaerobic conditions are achieved within the silo (see Figure 2.7). During this phase, acids are produced, lowering the silage pH and preventing further microbial activity, and so preserving the silage. The silage will not deteriorate until exposed to oxygen. A slow fermentation increases DM and energy losses, and reduces the palatability of the silage.

The silage quality and fermentation products are determined by the forage characteristics and which micro-organisms dominate.

After the fermentation phase commences there is a short period, about one day, when breakdown of cell walls and the release of fermentation substrates by plant enzymes continue. Bacteria then begin to multiply rapidly, increasing to a population of about 1 billion (10^9) per gram of fresh forage. These silage bacteria ferment WSCs, converting them to acids and other products. Ideally, LAB dominate the fermentation, but enterobacteria and clostridia may be dominant in some silages. Aerobic yeasts can also be present.

This phase may be dominated, in the early stages, by enterobacteria. These bacteria ferment WSCs, producing mainly acetic acid, with lesser quantities of lactic acid. Ethanol, 2,3-butanediol and carbon dioxide are also produced and DM and energy is lost.

In well-fermented silages, as lactic acid is produced the pH drops, enterobacteria cease growing, and LAB quickly begin to dominate the fermentation. If the decline in pH is slow, enterobacteria may continue to dominate the fermentation, and produce an acetate silage.

LAB ferment WSCs to lactic acid, with only very small quantities of other compounds being produced (see Appendix 2.A3). Fermentation dominated by LAB is preferred because lactic acid production is the most efficient chemical pathway. The decline in pH is rapid and there are only very small fermentation losses of DM and energy.

The proportion of lactic acid to other compounds produced will depend on the relative activity of homofermentative and heterofermentative LAB (see Section 2.3.1). Providing sufficient WSC are available, fermentation will continue until a pH of about 4 is achieved. Lower pH values have been observed in silages produced in Australia from forages with high levels of WSC and low buffering capacity, such as maize and forage sorghums. In drier silages, the fermentation is inhibited and the ultimate pH achieved is higher, and can exceed pH 5 in heavily wilted silage (see Chapter 12, Table 12.3).

Clostridial silages result if insufficient lactic acid is produced or it is produced too slowly. Clostridia require moist conditions to thrive and are not usually a problem in silages wilted to >30% DM content.

If the population of clostridia increases, a secondary fermentation can occur. Clostridia ferment WSC, lactic acid, and protein to produce butyric, propionic and acetic acid, and ammonia-N (NH_3-N) plus a number of other intermediate compounds (see Appendix 2.A3, Table 2A.4).

As the secondary fermentation proceeds, the pH rises. Final pH will be higher than for a lactic acid fermentation and depends on the final products of the fermentation. This is because the acids produced are weaker than lactic acid, and the ammonia-N has a buffering effect against these acids.

Table 2.3

Fermentation characteristics for a range of silages in the United States and Europe.

	Lucerne silage[2] (30-35% DM)	Lucerne silage[2] (45-55% DM)	Grass silage[2] (25-35% DM)	Maize silage[1] (25-35% DM)	Maize silage[2] (35-45% DM)
pH	4.3-4.5	4.7-5.0	4.3-4.7	3.8	3.7-4.2
Lactic acid (% DM)	7-8	2-4	6-10	4.9	4-7
Acetic acid (% DM)	2-3	0.5-2.0	1-3	1.4	1-3
Propionic acid (% DM)	<0.5	<0.1	<0.1	N/A	<0.1
Butyric acid (% DM)	<0.5	0	<0.5	0.25	0
Ethanol (% DM)	0.5-1.0	0.5	0.5-1.0	1.9	1-3
Ammonia-N (% total N)	10-15	<12	8-12	5.4	5-7

Source: [1]Adapted from Andrieu (1976), mean of 42 varieties; [2]Kung (2001), expected range.

Fermentation losses of DM and energy, and degradation of protein can be substantial. Clostridial silages have a rancid odour and are unpalatable to livestock.

If anaerobic yeasts are present in the forage they will ferment WSC to ethanol (see Section 2.3.4). DM is lost due to the production of carbon dioxide, but the loss of energy is not significant. Growth of yeasts is undesirable because they deplete WSCs that would otherwise be available for LAB. Other yeasts present also break down lactic acid produced by the LAB.

The fermentation characteristics for a range of silages are outlined in Table 2.3. Remember, the ideal pH of a silage is heavily influenced by the DM content of the forage. Where DM content is high, the fermentation is inhibited, resulting in higher pH values and the quantity of fermentation end products is lower.

The quality of the silage fermentation directly affects the production from animals fed that silage. Some examples of poorly fermented silages are given in Table 2.4. The level of ammonia-N (as a % of total nitrogen) in conjunction with pH are good indicators of silage fermentation quality (see Chapter 12, Section 12.4.5).

Without supplementation, poorly fermented silages will only support relatively low rates of production compared to well-preserved silages (see Table 2.5).

Once the fermentation phase is completed, the silage then enters a stable phase. Provided that oxygen is excluded, there will be little or no change to a lactate silage during this period.

Table 2.5

Effect of silage fermentation quality on liveweight gain (kg/day) in beef cattle.

Number of experiments	Silage fermentation quality: Poor	Good
36	0.27	0.50

Note: Silages produced from the same parent fodder. Good fermentation was achieved by either wilting or using a silage additive.

Source: Kaiser (1984).

Table 2.4

Composition of several silages which have undergone a poor fermentation.

	Ryegrass[1]	Cocksfoot[1]	Lucerne[1]	Kikuyu[2]	Pasture[2]	Maize[2]
Type of silage	acetate	clostridial	acetate	acetate	acetate	aerobically spoiled
Silage DM (%)	17.4	16.2	13.1	18.3	19.1	29.5
pH	5.4	5.4	7.0	5.2	4.7	6.1
Lactic acid (% DM)	trace	0.1	1.3	1.5	1.5	<0.1
Acetic acid (% DM)	11.6	3.7	11.4	4.2	4.8	<0.1
Propionic acid (% DM)	1.4	1.5	0.8	trace	0.6	trace
Butyric acid (% DM)	2.3	3.6	0.8	trace	<0.1	trace
Ammonia-N (% total N)	20.5	32.3	29.2	16.2	16.2	6.0

Source: [1] McDonald et al. (1991); [2] Kaiser et al. (1995)

2.2.3

Feedout phase

When silage is exposed to air, aerobic organisms that have been dormant during the anaerobic phase multiply (see Figure 2.7). Their activity will eventually decompose the silage. The first sign that aerobic spoilage has begun is heating of the silage at the feeding face. Experiments with silages undergoing aerobic spoilage have shown that the temperature may rise to 50°C or higher. A laboratory test would also show a rise in the pH.

This process is sometimes incorrectly referred to as 'secondary fermentation'. In fact, it is an aerobic process, more correctly referred to as 'aerobic deterioration' or 'aerobic spoilage'.

The substrates used early in the aerobic spoilage process are lactic and acetic acid, and any residual WSCs. Their relative importance as substrates depends on the type of fermentation. Unfermented WSC levels are usually higher in wilted silages where fermentation has been inhibited. Figure 2.9 shows the relationship between wilting, residual WSC in the silage and aerobic stability (time taken to commence heating).

The breakdown of proteins and amino acids to ammonia also contributes to a pH rise.

The main organisms involved in aerobic spoilage are listed on this page. It is interesting to note that some strains of LAB are able to ferment lactic acid under aerobic conditions and may play a role in the aerobic spoilage process.

Later in the aerobic spoilage process mould activity breaks down and metabolises cellulose and other plant cell wall components.

Biochemical changes

The first biochemical changes during aerobic spoilage can be summarised as:

Substrates		*Products*		*Outcomes*
lactic acid	→	CO_2	→	rising temperature
acetic acid		water		and pH; mould
residual WSCs		heat		growth commences; silage deterioration

Spoilage organisms

The common genera of the main micro-organisms involved in aerobic spoilage are:

Yeasts: *Pichia, Hansenula, Candida* (acid-utilising)
Torulopsis, Saccharomyces (sugar-utilising)

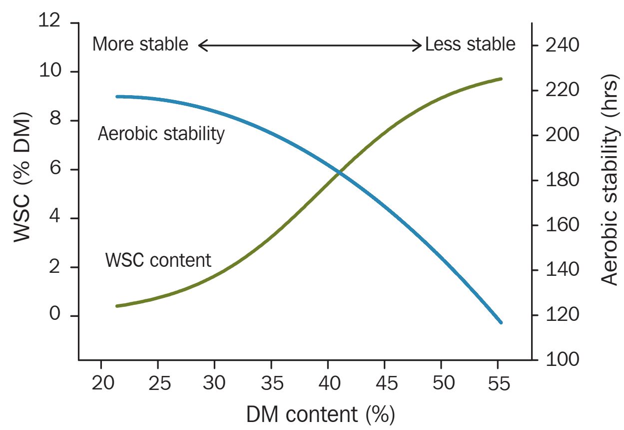
Moulds: *Monascus, Geotrichum, Byssochlamys, Mucor, Aspergillus*, Penicillium*, Fusarium**

Bacteria: *Bacillus,* some LAB, *Acetobacter* (acetic acid bacteria)

* Some species are capable of producing mycotoxins that can be harmful to livestock.

Figure 2.9

Effect of wilting on residual unfermented sugar content and subsequent aerobic stability of pasture silages.*



** Aerobic stability is the number of hours taken to reach 1°C above ambient temperature.*

Source: Adapted from Wyss (1999)

Aerobic spoilage can result in significant losses, which increase with time of exposure to air. DM losses can exceed 30% and quality losses can be significant. Not only is silage intake often depressed, animals may reject hot, spoiled silage.

The importance of air penetration and rate of feedout for silages of varying aerobic stability is highlighted in Figure 2.10. Air penetration is greater in poorly compacted silages and where there is greater disturbance of the silage face. The results shown in Figure 2.10 demonstrate that a reduction in air penetration and an increase in feedout rate can significantly reduce temperature rise, particularly with unstable silage.

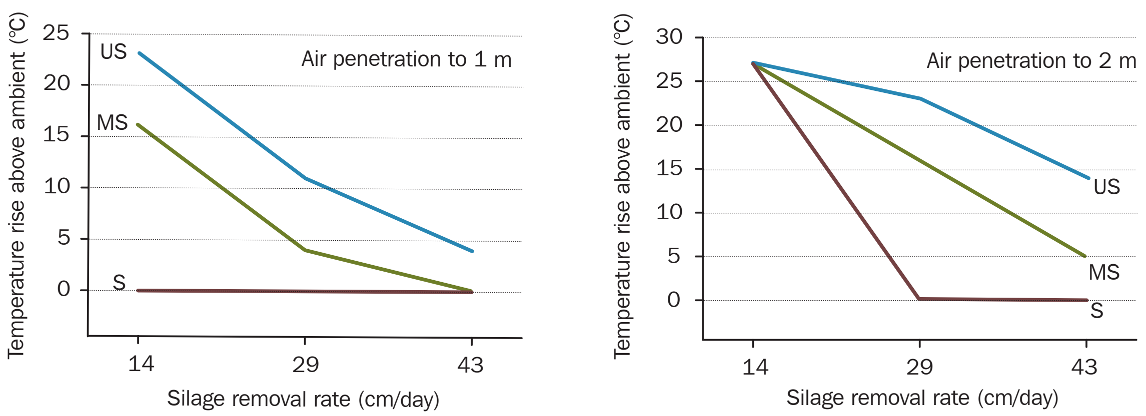
Chapter 10, Section 10.2.1, gives the losses in nutritive value in this study and more details on the effects of feedout management on aerobic spoilage.

The time between when the silage is first exposed to air and when spoilage commences at the exposed face varies from a few hours to several days. A large number of factors can reduce the susceptibility of a silage to aerobic spoilage. The key management factors are:

- rapid wilt, harvest and seal without delay;
- good compaction (low silage porosity) to reduce the air available for the aerobic organisms responsible for spoilage, and to minimise air penetration into the exposed face during feeding;
- sufficiently rapid feedout to minimise the time of exposure to air; and
- minimum disturbance of the silage face during feedout to reduce the rate of air penetration.

Figure 2.10

Effects of silage stability, depth of air penetration and rate of feedout on the temperature of the silage at the time of unloading from the silo. Average DM content of silages, approximately 35%.



US: Unstable – stable for only 1 day. MS: Moderate – stable for 3 days. S: Stable – stable for 7 days. Source: Derived from Honig et al. (1999)

Factors influencing the aerobic stability of silage

Silage factors

- **Composition.** Silages with high levels of fermentable carbohydrates, including WSCs, remaining after the fermentation (e.g. wilted silages), tend to be less stable.
- **Fermentation quality.** Silages which have a poorer fermentation quality and higher levels of volatile fatty acids (acetic, propionic and butyric) tend to be more stable. Silages can be more susceptible to aerobic spoilage where homofermentative LAB have dominated.
- **Porosity.** Silage stability declines as air infiltration increases. The susceptibility of a silage to air infiltration is influenced by the physical characteristics of the silage, silage density (kg/m^3)and DM content.
- **DM content.** Wilted silages can be more susceptible to aerobic spoilage due to higher levels of residual WSC, and greater difficulty in achieving adequate compaction. There is, however, some evidence that susceptibility to aerobic spoilage is less once DM exceeds 50%.
- **Population of aerobic spoilage organisms.** An extended aerobic stage at the commencement of the ensiling process, or air entry during storage, allows aerobic organisms to proliferate. They remain dormant during the anaerobic storage phase, until the silage is opened.

Feedout factors

- **Ambient temperature.** Silages tend to be more susceptible to aerobic spoilage during warmer weather.
- **Feedout rate.** Slow feedout of silage or bales from the feeding face increases aerobic spoilage. This is one of the most important factors influencing aerobic spoilage.
- **Management of the feeding face.** Excessive disturbance of the face during removal of silage increases air penetration, increasing the spoilage rate.
- **Mixing prior to feeding.** Mechanical processing of silage in a feedout wagon, mixer wagon or bale chopper increases aeration and can increase aerobic spoilage.

Section 2.3

Silage micro-organisms

2.3.1

Lactic acid bacteria (LAB)

Bacteria belonging to this group convert WSC to lactic acid and other fermentation products. LAB are classified as either homofermentative or heterofermentative (see Appendix 2.A4, Table 2A.5).

Homofermentative LAB convert WSC to lactic acid only.

Heterofermentative LAB convert WSC to lactic acid plus acetic acid and other compounds (see Appendix 2.A3).

Domination of the fermentation by homofermentative LAB leads to a more efficient utilisation of available WSC and a more rapid decline in pH with less loss of DM or energy. In forages with low WSC content, achieving a successful fermentation may be dependent on homofermentative LAB dominating the fermentation.

The population of LAB is low on growing crops and pastures, and is concentrated on dead and damaged plant tissue. Studies with chopped silage show that the population increases rapidly between mowing and delivery to the silage pit or bunker. Damage to the plant tissue releases nutrients and minerals and is suggested as a possible reason for this rapid increase in bacteria numbers. Some studies have shown that LAB numbers also increase rapidly during the wilting phase, although this is not always the case.

Commercial bacterial inoculants usually contain cultures of homofermentative LAB bacteria to improve the rate and efficiency of fermentation (see Chapter 7, Section 7.4.3). However, recent information indicates that production of some acetic acid may improve aerobic stability of the silage upon opening. This would be an advantage in warm Australian conditions, particularly for maize silage, which is inherently unstable. This suggests that some heterofermentative LAB may be desirable during fermentation. Further studies are required to confirm this.

2.3.2

Clostridia

Clostridia are classified as either saccharolytic or proteolytic according to whether the main substrate they ferment is WSCs and lactic acid or protein, respectively, although some species possess both saccharolytic and proteolytic activity (see Table 2A.6 in Appendix 2.A4).

Clostridia require a neutral pH (about 7.0) and moist conditions for optimal growth. As pH falls during an effective lactic acid fermentation, clostridia become less able to compete, until their growth is completely inhibited. Wilting to a DM content greater than 30% severely restricts clostridial growth.

2.3.3

Enterobacteria

These bacteria prefer a neutral pH (about 7.0) and warm conditions for optimal growth. The warm Australian conditions are ideal for enterobacteria to flourish early in the fermentation phase. In low WSC forages (e.g. tropical grasses), where pH drops slowly, these bacteria can dominate the fermentation. If they dominate, an acetate silage will be produced with a pH of about 5.0. Below this level the growth rate of enterobacteria is inhibited.

Levels of enterobacteria are low on crops and pasture, and decline during wilting. However, numbers can increase rapidly during the first few days of the fermentation and compete with LAB for available WSC. In most silages, they are only likely to be significant during the early stages of fermentation, before pH starts to decline significantly.

The main products of their fermentation process are acetic acid, lactic acid and CO_2, and increased ammonia-N levels due to the degradation of protein. Although some acetic acid production may improve aerobic stability, DM and energy losses can be significant if the fermentation is prolonged and enterobacteria are dominant. The resulting silage is also less palatable to stock.

How clostridia affects silage

Clostridia adversely affect silage preservation because:

- they compete with LAB for WSC needed to produce lactic acid;
- saccharolytic clostridia degrade WSC and lactic acid to butyric acid. This raises silage pH;
- proteolytic clostridia degrade proteins and amino acids to ammonia, amines and volatile fatty acids, reducing the utilisation of silage nitrogen by livestock;
- clostridia activity increases fermentation losses of DM and energy; and
- clostridia activity reduces silage palatability and lowers the nutritive value of the silage through the loss of energy and degradation of protein.

2.3.4

Yeasts and moulds

Yeasts and moulds are classed as fungi. Most require oxygen to grow and multiply, although a number of yeasts can grow and multiply in anaerobic conditions. Yeasts and moulds can grow over a wide range in pH (3.0-8.0) and temperature (0-40ºC). They do not contribute to silage preservation and are responsible for spoilage during the initial aerobic phase after ensiling and during feedout (see Sections 2.5.2 and 2.5.3).

Yeasts are common in soil and it is believed that contamination with soil during mechanical operations will increase numbers on the cut forage. They multiply on damaged plant tissue, with numbers usually increasing during wilting. Yeasts and moulds also multiply during the initial aerobic phase after ensiling.

Fermentation phase

Anaerobic yeasts begin to multiply when anaerobic conditions have been achieved after ensiling. They compete directly with LAB for WSC, which they ferment primarily to ethanol. Other yeasts, less able to ferment WSC, use lactic acid. Yeast activity is eventually inhibited by the increasing concentration of lactic and acetic acids.

Because it is easy to see, mould growth is an indicator of the presence and distribution of oxygen in the silo or bale at sealing. Growth can be spread throughout poorly compacted silages or appear in clumps in silages that contain air pockets at the time of sealing. In well-compacted silages, without air pockets, any mould growth is limited to the surface of the silo or bale. Surface mould growth can be eliminated with effective sealing. Because drier silages are harder to compact, they usually contain more mould growth. Further description of mould growth is provided in Chapter 9, Appendices 9.A1 and 9.A2.

Feedout phase

When the silage is exposed to air during feedout, the growth of yeasts is the primary cause of aerobic deterioration. Mould growth begins later. Silages that contain significant numbers of yeast and mould spores, carrying over from the initial aerobic phase, tend to be less stable.

Yeasts and moulds initially use residual WSC, lactic acid, other organic acids and ethanol for growth. The silage begins to deteriorate in the same way that composting occurs, with yeast and mould growth causing a rise in temperature and pH, loss of DM and energy, and reduction in silage palatability. As the decay processes continue, the moulds break down some of the structural carbohydrates in the silage.

2.3.5

Potentially harmful micro-organisms

There is no evidence to support the misconception that silage feeding has significantly greater animal health risks than feeding other forms of conserved forage. Reports of animal health problems associated with silage feeding are not common.

Animal health issues are only covered briefly in this publication. Producers who are concerned about health risks associated with the feeding of silage should seek veterinary advice.

The potential health risks most likely to be associated with feeding silage to livestock are caused by listeria (listeriosis), moulds and *Clostridium botulinum* (botulism). The risks of health problems caused by listeria and moulds can be almost eliminated by good silage-making practices, particularly effective compaction and sealing. Poor silage-making practices *may* increase animal health risks. However, the main issue is that poor practices will *always* result in significant economic penalties from increased DM and quality losses.

Listeria: Listeriosis is an infection caused by the bacteria *Listeria monocytogenes*. Listeria can cause abortions (usually in late pregnancy), brain damage ('circling disease') in sheep, or even death. Listeriosis is more common in animals with weakened immune systems – particularly new-born and pregnant stock. Sheep are inherently more susceptible than cattle.

Listeria require aerobic conditions to grow and multiply, but are able to survive under anaerobic conditions. They are intolerant of acidic conditions and, under anaerobic conditions, activity is severely restricted below a pH of about 5.5. Therefore, listeriosis is generally only associated with poor quality silages – inadequate air exclusion, poor sealing and limited fermentation (high pH). European studies have found the incidence of listeriosis is marginally more common with baled silages, where adequate compaction and air exclusion are more difficult to achieve, there is a greater surface to volume ratio and the fermentation is limited.

If listeria are present they are usually in the surface spoilage layer. If this layer is removed prior to feeding, the risk of listerosis is reduced. The most effective strategy to avoid listeriosis is effective sealing.

Moulds: Some moulds are capable of producing toxins, which if eaten, can be fatal to livestock. Inhaled mould spores are also capable of causing allergic reactions in humans – asthma and farmer's lung.

Moulds require aerobic conditions for growth. In well-made silages – rapid filling and compaction of the silo, good air exclusion and adequate sealing – any mould growth is limited and confined to the surface of the silo or bale.

If mould is observed, and potential animal health risk is a concern, take the following precautions:

- Remove the mouldy material prior to feeding, if possible.
- Feed sufficient silage to allow livestock to avoid eating the mould. Because it is unpalatable, stock will generally not eat mouldy silage, if given a choice.
- Avoid feeding the silage to very hungry livestock and to pregnant animals. Feeding mouldy silage is more likely to lead to animal health problems when it is used for drought feeding.

Plate 2.1

Mould is an indication of aerobic spoilage. The extent of mould growth in this bale is probably the result of inadequate wrapping, poor quality plastic or damage to the plastic seal.

Photograph: F. Mickan

Most authorities consider the risk to livestock from mouldy silage to be minimal and no greater than the risks associated with feeding mouldy hay. Reports of livestock deaths from either source are not common. There is no evidence to suggest that colour of the mould is any indication of toxicity.

Botulism: The disease caused by the bacteria *Clostridium botulinum*. When the carcases of dead animals are ensiled, these bacteria multiply and produce a toxin. Although the incidence is very low, eating contaminated silage or hay causes death very quickly.

The most common sources are probably rats, snakes and other small animals picked up during harvest. As a precaution, remains of dead livestock should be removed prior to sowing a silage crop or locking up pasture. Vermin that burrow into and nest in silos and bales, and then die may also be a source of contamination.

Section 2.4

Chop length

The chop length of the ensiled forage can affect the rate and extent of silage fermentation, the extent of losses during storage and animal production.

Reducing the length of chop causes more physical damage to plant cells, releasing WSCs more rapidly for the silage micro-organisms. This allows the fermentation to develop more rapidly and the LAB to ferment more WSC to lactic acid. The pH will decline more rapidly, with a reduced loss of DM and energy, and less degradation of the protein fraction.

For forages with low levels of WSC, such as legumes or tropical grasses, a finer chop length will assist in the production of more acid, which will, in turn, assist successful preservation. As well as making WSCs more available, short chopping increases bacterial activity in wilted silages by releasing moisture from the cells. This increases the amount of WSC fermented to lactic acid. The effect of chop length on the silage fermentation, as indicated by rate of pH decline, for a wilted lucerne silage is clearly demonstrated in Figure 2.11.

Reducing the chop length makes the silage easier to compact and reduces the amount of trapped oxygen in the silo. As a result, losses due to aerobic respiration and the risk of mould growth are lower (see Section 2.5.2 and Chapter 9). The advantage of a finer chop length is greater for silages that are difficult to compact, e.g. heavily wilted forage and grasses compared to legumes. However, finer chopped, low DM silages produce more effluent, at the same DM content, due to the release of moisture from damaged cells (see Section 2.1.1 and Chapter 9).

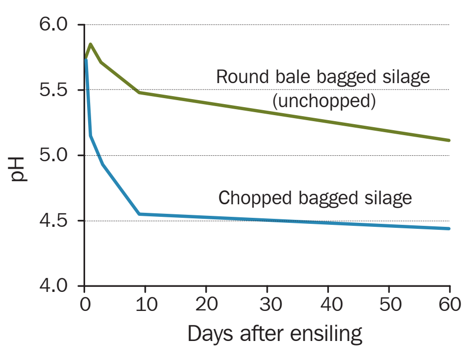
The effects of reducing chop length

Reducing chop length:

- increases the rate at which fermentation occurs;
- reduces fermentation losses of DM and energy, and degradation of the protein fraction;
- increases the chances of a successful fermentation in forages with low WSC content;
- increases amount of lactic acid produced in wilted silages;
- can result in a lower silage pH;
- reduces the volume of forage transported at harvest, and storage space required;
- makes compaction of the forage in the silo easier; and
- can increase effluent production in low DM content silages.

Silage intake by livestock has also been shown to increase with short versus long forage chop length in a number of studies. This is particularly so with sheep compared to cattle, and with young compared to older livestock. Increased voluntary intake improves animal production in almost all cases. The effects of chop length on animal production are discussed in Chapters 13, Section 13.2.5; Chapter 14, Section 14.2.5; and Chapter 15, Section 15.2.5.

Figure 2.11



Effect of chop length on the pH of lucerne silages with a DM content of 39%.

Source: Nicholson et al. (1991)

Section 2.5

Losses

Even in well-managed systems, losses of DM and energy will occur during silage making, storage and feeding. The type and extent of the losses are influenced by a number of factors:

- crop type and composition;
- weather conditions;
- silage system; and
- management.

In practice, the most important factor influencing losses is management – poor management can substantially increase losses, greatly reducing the efficiency of the conservation process.

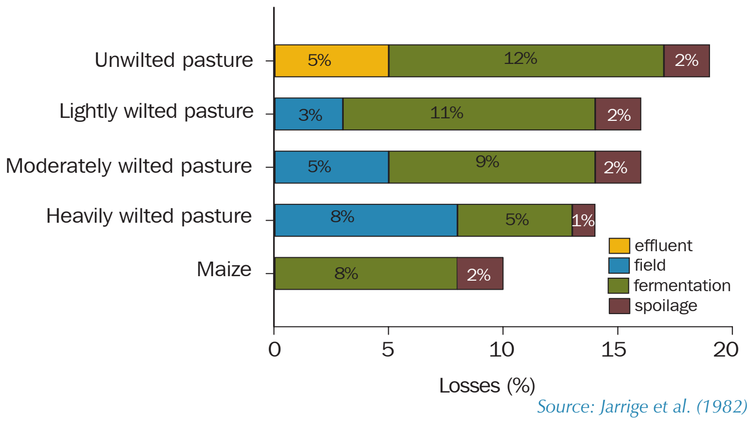
There is often considerable debate concerning the level of losses that can occur during the ensiling process. One source of confusion is whether the losses quoted are 'typical' losses observed on-farm or losses that occur with good management. Clearly, the on-farm losses are highly variable and reflect the standard of management. So it is recommended that the latter be adopted as the benchmark that producers should target. This should also be the basis for any economic appraisal of silage, although a sensitivity analysis to determine the penalty of greater losses due to poor management can be very informative (see Chapter 11, Section 11.2.4).

As there are few Australian studies on losses occurring at various stages of the ensiling process, data from Europe and the United States have to be used. Loss estimates vary considerably, and there is some concern as to whether DM losses have been over-estimated in some studies due to failure to adequately account for the volatile compounds in silage when calculating DM losses (see Chapter 12, Section 12.4.1).

The sources of DM and energy losses during the ensiling and feedout process are illustrated in Figure 2.12 and Table 2.6. The source of losses varies between silage systems and can be seen to be strongly

Figure 2.12

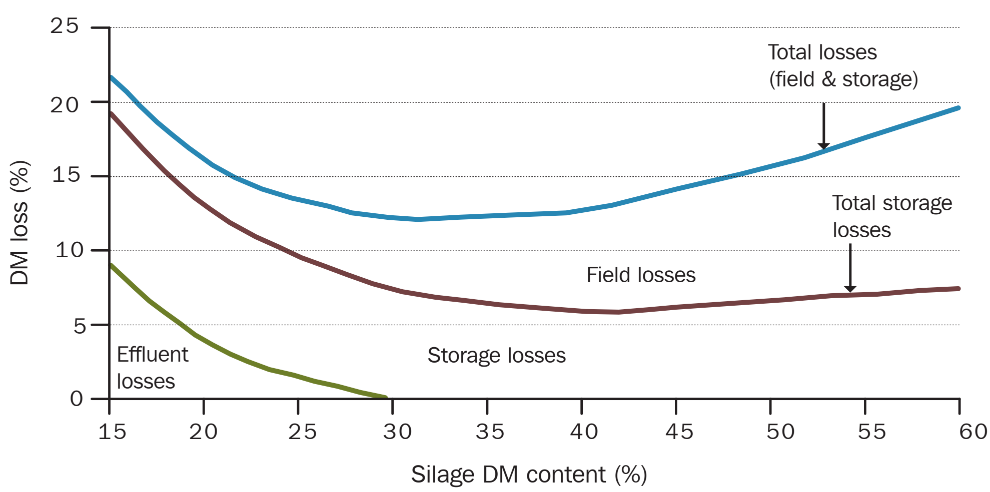
Typical DM losses from a chopped silage system with bunker storage.



Source: Jarrige et al. (1982)

Figure 2.13

Estimated DM losses during harvesting and storage of pasture silage under Australian conditions with good management.



Source: Data from various sources – Hoglund (1964); Wilkinson (1981, 1988); Jarrige et al. (1982); McDonald et al. (1991); Wilkins et al. (1999)

influenced by wilting (see also Figure 2.13). The data in Figures 2.12 and 2.13 indicate that, with good management, it should be possible to keep DM losses to 12-16% in a wilted silage system.

In a direct-cut maize silage system, where field losses are minimal, DM losses should be kept to about 10%.

With good management, quality losses during the ensiling process will be minimal. With poor management, DM losses can be considerably higher than those illustrated, and silage quality will suffer.

Energy losses are usually less than DM losses. This is because some of the fermentation products in silage have a higher energy value than the substrates from which they are produced and the gross energy content of silage is usually higher than that of the parent forage. Energy losses at various stages of the ensiling process are listed in Table 2.6, and have been classified as unavoidable or avoidable. The avoidable categories can be eliminated with good management. According to this European work energy losses need be no higher than 7%.

Losses during the ensiling process

DM losses:

The quantity of forage lost (on a DM basis) at various stages of the ensiling process:

DM loss (%) =

$$\frac{\text{Initial forage weight (kg) Final forage weight (kg)}}{\text{Initial forage weight (kg)}} \times 100$$

Note: Some publications refer to DM recovery = 100 DM loss (%)

Quality losses:

The loss of nutrients present in the initial forage. Most commonly applied to changes in digestibility, energy or the nitrogen fraction during the ensiling process, and loss of WSC during wilting.

The relative importance of field and storage losses varies with the degree of wilting and the DM content at ensiling (see Figures 2.12 and 2.13). Figure 2.13 shows the expected DM losses in the production of pasture silage, under Australian conditions, given good management. The data in Figure 2.13 are a composite of results from various overseas studies – there are no Australian data, a deficiency that needs to be addressed in future research. Total losses are likely to be lowest in the DM range of 30-40% when rapid wilting is achieved.

Table 2.6

Energy losses during ensiling and factors responsible for these losses.

Process	Classified as	Approximate losses (%)	Factors responsible
Effluent *or* Field losses by wilting	Unavoidable for most crops and pastures	5 to >7 *or* 2 to >5	DM content of forage at ensiling Weather, technique, management, crop/pasture (type and yield)
Harvesting losses	Unavoidable but manageable	1 to 5	DM content, crop/pasture type, number of mechanical operations
Residual respiration	Unavoidable	1 to 2	Plant enzymes
Fermentation	Unavoidable	2 to 4	Micro-organisms
Secondary (clostridial) fermentation	Avoidable	0 to >5	Crop/pasture type, environment in silo, DM content
Aerobic spoilage during storage (including surface waste)	Avoidable	0 to >10	Filling time, density, silo type and size, sealing, crop/pasture type
Aerobic spoilage (heating) during feedout	Avoidable	0 to >10	As for aerobic spoilage above. DM content of silage, unloading technique, weather
Total		7 to >40	

Source: Based on Zimmer (1980)

2.5.1

Field and harvesting losses

Field losses include the DM lost during various mechanised operations in the field (mowing, tedding and raking), during harvest and transport to the storage site, and due to the activity of plant enzymes. Table 2.7 outlines the various components of field losses. The extent of these losses and management strategies to reduce them are covered in more detail in Chapters 6 and 8.

Of the field losses in Table 2.7, the physical losses due to mechanical handling should be minimal, and will reflect the standard of management of the field and transport operations. Forage left in the paddock may be utilised with post-harvest grazing. If grazing is an option, items 1, 4, 6 and 8 in Table 2.7 account for little loss to the system.

Direct harvested crops, such as maize, have considerably lower field losses (<1%, see Figure 2.12) than wilted crops because there is less time for respiration and fewer handling operations.

Respiration and proteolysis can account for significant DM and quality losses, particularly during wilting (see Section 2.2.1). The quality losses will mean reduced forage digestibility and ME content and increased protein degradation. Some respiratory loss during wilting is unavoidable, but can be minimised (to about 2%) by rapid wilting.

As Figure 2.13 shows, field losses increase with forage DM content. The longer wilting period associated with higher DM content increases the susceptibility of the crop to respiration losses. At the same time the higher DM forage is susceptible to greater mechanical losses during various handling operations, particularly as DM content increases above 35 to 40%.

Table 2.7

Sources of field losses during silage making.

Operation or source of loss	Type of loss	Reason	Management solutions
Mowing	1. DM	Cut too high, sections of paddock uncut	Graze paddock after harvest to utilise uncut forage
Tedding	2. DM, quality	Damage to forage, with some loss of leaf	Avoid tedding crops that are too dry (over-wilting), especially legumes
Wilting	3. DM, quality	Respiration of WSC and degradation of protein by plant enzymes	Increase rate of wilting but some loss unavoidable
Raking	4. DM	Cut material not all raked into windrow	Graze paddock after harvest to utilise residual forage
	5. DM, quality	Damage to forage, with some loss of leaf	Avoid over-wilting and raking crop when too dry (especially legumes)
Harvesting of direct cut crops	6. DM	Some crop uncut and left in paddock	Graze paddock after harvest to utilise uncut forage
	7. DM, quality*	Some loss of chopped forage when blown into truck/cart	Minimal if using an experienced forage harvester operator. Graze paddock after harvest.
Harvesting wilted forage (windrows)	8. DM	Windrow not all picked up	Graze paddock after harvest to utilise cut forage
	9. DM, quality*	Some loss of chopped forage when blown into truck/cart	Avoid harvesting small, light windrows. Minimal if using an experienced forage harvester operator. Graze paddock after harvest.
Transport to storage	10. DM	Loss of forage from truck during transportation	Avoid overloading truck/cart and avoid harvesting crop that is too dry. Covering may be an option but probably not practical.

* *Quality losses may not occur on all occasions.*

2.5.2

Storage losses

Table 2.8 summarises the sources of DM and quality losses during storage. They are:

- effluent;
- respiration and aerobic fermentation while oxygen remains in the silo or bale (or if the seal is damaged); and
- the silage fermentation.

These losses are strongly influenced by the DM content at which the forage is ensiled. The effluent losses decline rapidly as DM content increases to 30% (see Figure 2.2). Respiration and fermentation losses decline as DM content reaches 35-45% and then slowly increase (see Figure 2.13).

Effluent losses are influenced by forage DM content, chop length, and the degree of compaction or silage density. Some additives (e.g. molasses, acids and enzymes) will increase effluent production (see Chapter 7), but the most important factor is forage DM content at ensiling (see Section 2.1.1). Chapter 9 covers the effect of management on silage effluent production more fully.

As described in Section 2.2.1, losses due to respiration of WSC by plant enzymes and fermentation by aerobic micro-organisms will continue until anaerobic conditions are achieved within the silo or bale. Heating of the freshly harvested forage in the silo or bale is an indication of respiratory losses. Some heating and losses due to respiration are unavoidable (see Table 2.6).

Direct losses of WSC represent only part of the quality loss. Heat build-up within the silo or bale as a result of respiration can further reduce digestibility and damage to the protein fraction (see Section 2.2.1 and Chapter 12, Section 12.4.4). Chapter 9, Section 9.4, covers management strategies to reduce these losses – rapid filling, good compaction or bale density, and effective sealing (without delay).

While oxygen is present during the early stages of the storage period, aerobic bacteria, yeasts and moulds will continue to grow. Where sealing is inadequate or the seal is damaged during storage, air entry will allow these organisms to grow. The growth of aerobic organisms will result in silage decay and the development of a

Table 2.8

Sources of losses during silage making.

Source of loss	Type of loss	Reason	Management solutions
Effluent losses:	DM, quality	Forage ensiled at too low a DM content (<30%).	Wilt mown crops and pastures, harvest direct cut crops at a later stage of maturity.
Aerobic losses:			
Respiration	DM, quality	Presence of air resulting in loss of WSC due to activity of plant enzymes (invisible in-silo losses)	Avoid ensiling at too high a DM content. Fill silo rapidly, compact and seal well as soon as possible. Some loss unavoidable.
Inedible waste silage	DM, quality	Presence of air for longer period will result in visible inedible waste (rotten and mouldy silage) due to growth of aerobic bacteria, yeasts and moulds.	As above, and maintain an air-tight seal throughout the storage period. Check regularly for damage to the seal and repair immediately.
Fermentation losses:	DM, quality	Fermentation of WSC. Losses minimal with a homofermentative lactic acid fermentation, and little or no quality loss. Losses of DM and quality higher with poor (including secondary) fermentations.	Promote desired LAB fermentation, wilt or use additives as required, as well as good silage-making practices.

surface waste layer, mouldy silage and pockets of rotten silage.

Some loss of DM and energy during the anaerobic fermentation of WSC to lactic acid and other products is unavoidable. However, if the fermentation is dominated by homofermentative LAB, the losses are small (see Appendix 2.A3). Higher losses will occur if heterofermentative LAB play a significant role in the fermentation. The greatest fermentation losses will occur if clostridia or enterobacteria dominate the fermentation.

2.5.3 *Feedout losses*

Losses during feedout have two sources – aerobic spoilage or heating, and wastage of silage by animals (see Table 2.9). Effective management of the feedout process can avoid most of these losses.

Once exposed to air, silage at or close to the feeding face commences to deteriorate as yeasts, moulds and aerobic bacteria become active. Heating is usually the first noticeable sign of aerobic spoilage of the silage stack or bale (see Section 2.2.3). Chapter 10 covers more fully management strategies that reduce these losses.

Crop type, DM content, silage density, the type of fermentation, the quantity of residual spores present from the initial aerobic phase, ambient temperature during feeding, rate of feedout, and silage removal technique can all affect the stability of the silage after opening. Silage additives can influence aerobic stability (see Chapter 7, Section 7.7).

Wastage of silage during feedout is difficult to estimate and few studies have been conducted. In poorly managed feeding systems, wastage is likely to reach 30-50% of silage DM fed. These losses will be influenced by:

- quantity of silage offered to livestock – if the silage is not consumed within a reasonable time then losses will increase (irregular feeding intervals or overfeeding should be avoided);
- measures taken to prevent animals from walking, camping, urinating and defecating on the silage; and
- wet weather (trampling losses are likely to be higher when silage is fed on the ground).

Animals are also likely to reject silage that is hot (aerobically spoiled), mouldy or rotten. These losses, resulting from rejection by animals, have been accounted for earlier as components of storage losses or aerobic spoilage.

Table 2.9

Sources of losses during the feedout of silage.

Source of loss	Type of loss	Reason	Management solutions
Aerobic spoilage (heating)	DM, quality	Silage unstable and heats on exposure to air. Due to growth of aerobic micro-organisms, and results in significant DM and quality losses. Aerobically spoiled silage is unpalatable. Intake is depressed.	Silages vary in susceptibility, and tend to be more unstable when fed out during warm weather. Good management at ensiling is important. Rapid rate of feedout is essential, with minimum disturbance of the silage face.
Wastage during feeding	DM	Animals drop, trample and foul silage. Overfeeding is likely to increase losses.	Silage fed on the ground is most susceptible. Losses are reduced by using suitable feed barriers, feeders, feed troughs and feed pads.

Section 2.6

Appendices

2.A1

WSC content of various forages

Calculating WSC content on a fresh basis:

$$\text{WSC (\% fresh basis)} = \frac{\text{WSC (\% DM basis)} \times \text{DM content (\%)}}{100}$$

So, for a silage with a WSC content of 10.7% (DM basis) and a 36% DM content:

$$\text{WSC (\% fresh basis)} = \frac{10.7 \times 36}{100} = 3.9\%$$

Figure 2A.1

Target DM content required to exceed the critical level of 2.5% WSC in the fresh crop, for crops with varying WSC content (% DM).

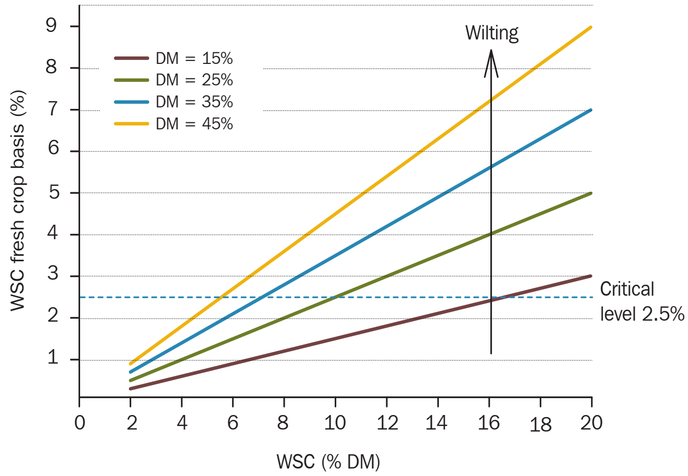


Table 2A.1

WSC content (% DM) of a range of unwilted forages.

Species	Range	Mean
Temperate grasses:		
Italian ryegrass[1]	7.5-31.5	18.1
Perennial ryegrass[1,2]	4.6-34.1	19.6
Timothy[1]	5.3-19.9	11.0
Meadow fescue[1]	3.5-26.3	9.6
Cocksfoot[1]	5.0-19.1	7.9
Cereals:		
Barley[1]	4.6-31.8	19.3
Oats[2]	7.7-35.0	20.1
Maize[1]	5.0-33.0	17.4
Grain sorghum[3]	3.5-7.3	4.4
Temperate legumes:		
Subclovers[2,4]	6.3-13.7	10.2
Medics[2]	4.2-10.6	6.6
Balansa clover[2]	5.8-14.1	10.9
Arrowleaf clover[2]	9.9-12.0	11.1
Red clover[1]	5.3-10.8	7.8
Lucerne[1]	4.5-11.6	7.2
Berseem clover[2]	6.4-12.1	9.2
White clover[1]	5.1-9.1	6.7
Sainfoin[5]	6.8-8.4	7.6
Vetch (common and purple)[2]	3.9-9.2	6.6
Peas[2]	8.6-15.8	12.3
Lupins (albus)[6]	15.3-16.5	15.9

Species	Range	Mean
Tropical grasses:		
Kikuyu grass[7]	2.3-6.8	4.5
Setaria[8,9]	3.5-6.2	4.8
Rhodes grass[8]	2.7-3.2	3.0
Signal grass[9]	8.6	–
Napier grass[9]	9.9	–
Guinea grass/green panic[9]	3.0	–
Paspalum[10]	2.7-3.4	–
Tropical legumes:		
Lablab[11]	4.6-5.6	5.1
Desmodium[12]	4.8	–
Siratro[12]	5.9	–
Lotononis[12]	9.9	–
Other forages:		
Sunflowers[1]	10.3-21.3	16.0
Japanese millet[4]	7.0-9.0	8.0
Forage pennisetum[4]	7.8-13.7	10.4
Sudan grass[3]	7.4-15.9	10.1
Forage sorghum x Sudan grass[3,4]	6.1-17.7	9.8
Sweet sorghum[3,4]	11.4-35.7	24.1
Dual purpose sorghum (grain/grazing)[3,4]	5.1-18.3	10.7
Broadleaf weeds:		
Capeweed[4]	17.2	–
Variegated thistle[4]	14.7	–
Paterson's curse[4]	11.9	–

Sources: [1] Kaiser, 1984; [2] Dear et al. (unpublished); [3] Cole et al. (1996); [4] Kaiser (unpublished); [5] Hill (1999); [6] Jones et al. (1999); [7] Kaiser et al. (2000b); [8] Catchpoole (1965); [9] Aminah et al. (2000); [10] Catchpoole and Henzell (1971); [11] Morris and Levitt (1968); [12] Catchpoole (1970)

2.A2

Buffering capacity of various forages

Table 2A.2

Buffering capacities (meq/kg DM) of a range of unwilted forages.

Forage type	Range	Mean
Temperate grasses:		
Cocksfoot[1]	209-438	302
Italian ryegrass[1]	265-589	386
Perennial ryegrass[1,2]	231-428	313
Cereals:		
Maize[1]	149-351	236
Oats – immature vegetative[1]	732-779	756
Oats – heading[1,2]	213-453	308
Temperate legumes:		
Subclovers[1,2]	420-877	647
Subclover/annual grasses[1]	383-656	506
Medics[2]	496-720	614
Balansa clover[2]	487-623	576
Arrowleaf clover[2]	484-588	548
Red clover[1]	491-617	562
Lucerne[1]	297-595	505
Berseem clover[2]	638-790	696
White clover[1]	512	–
Sainfoin[3]	467-539	496
Vetch (common and purple)[2]	504-616	549
Peas[2]	328-502	415
Lupins (albus)[4]	304-338	321

Forage type	Range	Mean
Tropical grasses and legumes:		
Kikuyu grass[5]	225-496	351
Rhodes grass[6]	435	–
Stylo[6]	469	–
Siratro[6]	621	–
Other forages:		
Japanese millet[7]	343-682	519
Forage pennisetum[7]	315-520	393
Forage sorghum x Sudan grass[7]	333-532	416
Sweet sorghum[7]	258-419	322
Broadleaf weeds:		
Capeweed[1]	1,082	–
Variegated thistle[1]	682	–
Paterson's curse[1]	1,013	–

Source: [1] Kaiser (1984); [2] Dear et al. (unpublished); [3] Hill (1999); [4] Jones et al. (1999); [5] Kaiser et al. (2000b); [6] McDonald et al. (1991); [7] Kaiser (unpublished)

2.A3

Biochemical pathways, and energy and DM losses that occur during silage fermentation

Table 2A.3

The main chemical pathways that occur during a LAB fermentation.

Reaction	Fermentation type*	DM loss (%)	Energy loss (%)
glucose → 2 lactic acid	homolactic	0	0.7
fructose → 2 lactic acid	homolactic	0	0.7
pentose → lactic acid + acetic acid	homolactic and heterolactic	0	–
glucose → 2 lactic acid + ethanol + CO_2	heterolactic	24.0	1.7
3 fructose + H_2O → lactic acid + 2 mannitol + acetic acid + CO_2	heterolactic	4.8	1.0
2 fructose + glucose + H_2O → lactic acid + 2 mannitol + acetic acid + CO_2	heterolactic	4.8	–

** Homolactic – fermentation is dominated by homofermentative LAB*
Heterolactic – fermentation is dominated by heterofermentative LAB

Source: McGechan (1990) from Roberts (1995)

Table 2A.4

The main fermentation pathways which occur during a clostridial fermentation.

Reaction
glucose → butyric acid + 2 CO_2 + 2 H_2
2 lactic acid → butyric acid + 2 CO_2 + 2 H_2
3 alanine → 2 propionic acid + acetic acid + 2 CO_2 + 3 NH_3
alanine + 2 glycine → 3 acetic acid + CO_2 + 3 NH_3
lysine → cadaverine + CO_2
valine → isobutyric acid + NH_3
leucine → isobutyric acid + NH_3

Source: Adapted from McGechan (1990) from Roberts (1995)

2.A4

Species of lactic acid bacteria (LAB) and clostridia found in silage

Table 2A.5

Some important species of lactic acid bacteria found in silage.

Homofermentative	Heterofermentative
Lactobacillus acidophilus	*Lactobacillus brevis*
L. casei	*L. buchneri*
L. coryniformis	*L. cellobiosus*
L. curvatus	*L. fermentum*
L. dulbrueckii	*L. viridescens*
L. leichmannii	*Leuconostoc mesenteroides*
L. plantarum	
L. salivarius	
Pediococcus acidilactici	
P. damnosus	
P. pentosaceus	
Enterococcus faecalis	
E. faecium	
Lactococcus lactis	
Streptococcus bovis	

Source: McDonald et al. (1991); Ross (unpublished data)

Table 2A.6

Classification of main clostridia found in silage.

Lactate fermenters (saccharolytic)	Amino acid fermenters (proteolytic)	Others
Clostridium butyricum	*C. bifermentans*	*C. perfingens**
C. paraputrificum	*C. sporogenes*	*C. sphenoides**
C. tyrobutyricum		

* *Ferment both WSCs and protein.*

Source: Adapted from McDonald et al. (1991)

Chapter 3

Silage as a pasture management tool

Chapter 3

Silage as a pasture management tool

In this chapter

The authors

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The Key Issues

- Silage can be a valuable pasture management tool, allowing farmers to maintain pasture quality and improve utilisation during periods of peak pasture growth. The key objectives are to:
  - use strategic silage cuts to maximise the utilisation of the pasture grown;
  - achieve high total forage production (grazing + silage) during peak pasture growth;
  - maintain high quality in both the silage and grazed pasture. For temperate pastures, a target silage ME of at least 10 MJ/kg DM is appropriate;
  - avoid setting aside paddocks for silage too early if this is likely to create a temporary shortage of pasture available for grazing; and
  - ensure there are no long-term adverse effects of silage cutting on pasture productivity.
- When setting aside paddocks for silage production, farmers have the flexibility to vary the closure date and the duration of closure (or cutting date) and still produce high quality silage.
- A feed budget that compares anticipated pasture growth rate with animal requirements is the best guide for determining when and how much of the grazing area should be set aside for silage. Monitoring post-grazing residues can be the simplest and most practical method in rotationally grazed pasture, as only the pasture surplus to requirements needs to be cut.
- Cutting earlier for silage usually results in a higher-yielding regrowth than after hay cutting. Highest DM production from regrowth is obtained from pastures closed earlier in the season and for a shorter duration.
- Longer-term benefits from strategic silage cutting can include increased content of clover and desirable grasses, and reduced weed content.
- Silage can be used as a weed control strategy. Both timing of the cut and management of the regrowth to prevent seed production are important. If there is significant broadleaf weed contamination or harvesting is delayed for weed control purposes silage quality may suffer. Any trade-off in animal production needs to be weighed against weed control benefits.

Section 3.0

Introduction

Successful grassland farming involves managing the grazing system to obtain a balance between pasture supply and animal demand. In all grazing systems, there are times when available pasture is either more or less than the grazing animals need. Silage can play a key role in transferring pasture from periods of surplus to periods of deficit.

Although traditionally used to fill feed gaps, silage can also be a valuable pasture management tool, allowing farmers to maintain pasture quality and improve utilisation during periods of peak growth.

The use of silage as a pasture management tool is most advanced in the dairy industry, where recent surveys have shown that 30% of dairy farmers nominate this as one of the reasons they make silage. Producers in the other grazing industries are also seeing pasture benefits resulting from early silage cuts. A number of potential pasture benefits have been identified:

- improved utilisation of the pasture grown (more animal production per hectare);
- improved perennial legume content and better regeneration of annual legumes;
- reduced weed content;
- increased pasture production through better utilisation of surplus growth (pastures maintained at a vegetative stage of growth), particularly from the regrowth following earlier silage cuts;
- increased regrowth compared to hay; and
- improved pasture digestibility over the whole farm (removing paddocks for silage production increases the grazing pressure on the rest of the farm, allowing pasture digestibility to remain high for longer).

These benefits have been seen with temperate pastures, but are also likely to apply to tropical grass pastures and to grazed summer forage crops (forage sorghums and millets). However, the legume component of perennial tropical grass/legume pastures may be adversely affected by conservation cuts, leading to reduced legume content (see Chapter 4, Section 4.9.1).

Only a small amount of research (with anecdotal support from farmers and consultants) has been conducted to quantify the benefits, so it is difficult to place an economic value on them. However, they are likely to contribute significantly to the profitability of silage at the whole farm level.

Section 3.1

Integrating silage with grazing management

Maintaining pastures at a high-quality, vegetative stage during periods of rapid growth is a major challenge. There are a number of options to improve the management and utilisation of surplus pasture:

- Year-round stocking rate can be increased. This will improve pasture utilisation, but could result in a feed shortage during periods of low pasture growth, increasing reliance on imported feed (see Chapter 1, Section 1.5).
- Buying-in livestock can temporarily increase the stocking rate during the period of peak pasture growth. However, this option is often not practical owing to limited supply of store cattle and high prices when extra stock are needed, and a glut of animals on the market and lower prices when the animals are sold.
- Requirements for pasture can be altered by changing calving or lambing times. This may be practical in some cases, but will depend on the requirements of the markets being supplied. In any event, this strategy is unlikely to utilise all the surplus pasture over the whole farm, particularly where there is a marked seasonality of pasture production (see Chapter 1, Figure 1.6).
- Removing a proportion of the grazing area for cropping is an option in some regions.
- Cut surplus pasture for silage or hay.

Slashing or mechanical pasture topping to remove surplus growth and maintain the pasture in the vegetative growth stage is not included as a management option. Both will maintain pasture quality, but will have little effect on pasture utilisation.

The choice of management options to improve the management and utilisation of surplus pasture growth will vary from farm to farm. The silage option offers considerable potential to increase the productivity of grazing enterprises, but silage cutting needs to be successfully integrated with grazing management.

Plate 3.1

Electric fencing allows portions of pastures or crops to be targeted for intensive grazing, while the balance can be closed for silage production – pasture utilisation increases and the vegetative growth stage of the pasture is prolonged. *Photograph: N. Griffiths*

The Key Objectives when integrating silage cutting with grazing management

Key objectives when integrating silage cutting with grazing management are:

1. Maximise the utilisation of the pasture grown by strategically timing silage cuts to remove surplus pasture.
2. Maximise total forage production (grazing and silage) during the period of peak pasture growth.
3. Maximise the quality of both the silage and grazed pasture. The target ME for temperate pasture silage should be at least 10 MJ/kg DM.
4. Avoid closing paddocks for silage too early if this is likely to create a temporary shortage of pasture available for grazing.
5. Ensure there are no long-term adverse effects of silage cutting on pasture productivity.

3.1.1

The importance of timing

When integrating silage cutting with grazing management producers must take a broad view – they need to optimise the yield and quality of both the silage and the grazed pasture.

Pasture management during the period of peak growth must focus on maintaining pastures at an active vegetative growth stage for as long as possible. Grazing and strategic closure and silage cutting (varying closing and cutting dates) will prolong the supply of high-quality forage.

One of the most important principles in producing high-quality silage is to cut pastures early, when they are at a late vegetative to early reproductive stage of growth. The date of head emergence will vary between cultivars for species such as ryegrass and this must be taken into account when determining closure and harvest dates. The importance of growth stage at harvest is covered in Chapters 4, 13, 14 and 15.

When closing paddocks for silage production, there is flexibility to vary the closure date and the duration of closure. Not all silage paddocks need to be closed or cut at the same time. As pastures start to accumulate surplus, paddocks can be sequentially dropped from the grazing rotation and closed. The date this happens will vary with pasture type and region, and from year to year and farm to farm. Frequent pasture monitoring will indicate when paddocks can be closed for silage.

Early removal of paddocks from the grazing rotation for silage production creates the risk of a temporary shortage of pasture for grazing. Unexpected weather – a dry spell or cold change – could affect pasture growth rates.

Paddocks closed very early will also be ready to harvest earlier in the silage season, when there is greater risk of poor weather affecting wilting.

Studies have investigated the combined effects of closure date and the duration of closure on the production and quality of both silage and pasture.

The three studies reported here focused on perennial ryegrass-based pastures for dairy production (see Tables 3.1 and 3.2, and Figure 3.1).

In the first study, the pastures were closed and removed from the grazing rotation on either 23 September or 10 October. In each case, the silage was cut four or six weeks later. Pasture and silage production was monitored for each treatment from 23 September to 16 December (see Table 3.1). Digestibility was determined for the forage cut for silage but, unfortunately, not for the uncut pasture.

In the second study, pastures were closed for silage on 16 August, 6 September or 27 September. The closure duration was also varied – the results in Table 3.2 are for closures of 6, 8, 10 and 12 weeks. Pasture and silage production was monitored between 16 August to 13 December. The regrowths were quite poor in this study. Table 3.2 also shows the estimated ME content of the forage cut for silage.

Table 3.1

Effect of time and duration of closure for silage on total forage yield over spring and silage digestibility for a perennial ryegrass/white clover pasture at Ellinbank, in Gippsland, Victoria.

Closure date	Silage closure and cutting dates			
	23 September		10 October	
Duration of closure (weeks). Cutting date in brackets.	4 (21 Oct)	6 (4 Nov)	4 (7 Nov)	6 (21 Nov)
Pasture + silage yield (t DM/ha):				
Pre-closure growth (23 September to 10 October)	–	–	1.8	1.9
Silage (t DM/ha)	2.4	3.4	1.6	2.0
Regrowth to 16 December	4.1	1.9	0.8	0.4
Total yield 23 September to 16 December	6.5	5.3	4.2	4.3
Silage DM digestibility (%)	73.5	71.6	69.2	66.1

Source: Adapted from Rogers (1984) and Rogers & Robinson (1984)

Table 3.2

Effect of date and duration of closure on pasture and silage yield and estimated silage ME over spring from perennial ryegrass based pastures in south-western Victoria.*

Closure date	Duration of closure (weeks)	Pasture and silage yield (t DM/ha)			
		16 Aug to closure	Silage cut	Regrowth to 13 Dec	Total 16 Aug to 13 Dec
16 August	6	–	1.07	1.53	2.60
	8	–	1.86	1.35	3.21
	10	–	3.14	0.84	3.98
	12	–	3.96	0.44	4.40
6 September	6	0.66	1.29	1.38	3.33
	8	0.72	2.28	0.78	3.78
	10	0.49	3.64	0.35	4.48
	12	0.66	5.60	0.04	6.30
27 September	6	1.13	1.61	0.77	3.51
	8	1.30	2.55	0.25	4.10
	10	1.31	3.72	0.05	5.08
	12	–	–	–	–

* *Estimated ME (MJ/kg DM) content of pasture cut for silage:*

>11.0 *10.5–11.0* *10.0-10.5* *<10.0*

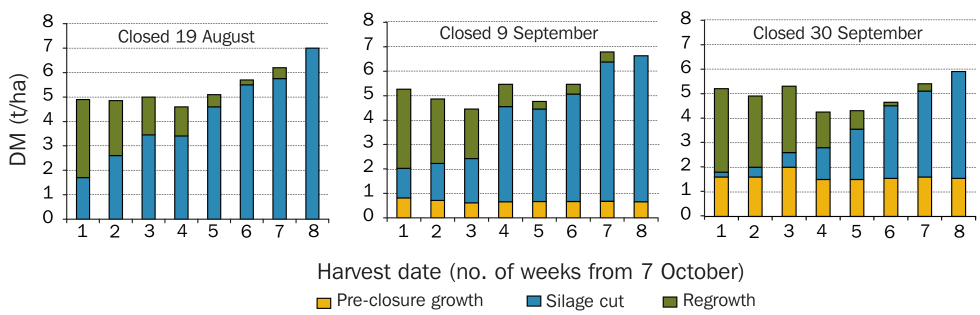
Source: Adapted from Jacobs et al. (1998) – mean results, 2 sites

In the third study, in northern Tasmania, the pastures were closed for silage production on 19 August, 9 September or 30 September. In each case, the first silage cutting treatment was on 14 October, with additional silage cuts at weekly intervals over the next seven weeks. So the duration of the closure was 8-15 weeks, 5-12 weeks and 2-9 weeks for the early, mid and late closure dates respectively. Pasture and silage production was monitored from 19 August to 2 December (see Figure 3.1).

Each study showed that both closure date and duration of closure had important effects on silage yield, the combined pasture and silage yield, and silage quality (digestibility or ME). The common principles highlighted in these studies are:

- ➤ The forage quality remains higher, longer for pastures closed early for silage production. This allows the closure period to be extended to achieve higher silage yields, without a quality penalty.
- ➤ In the two Victorian studies, regrowth and combined yield of silage and grazed pasture was higher with earlier closure (see Tables 3.1 and 3.2). This effect of closure date was less important in the Tasmanian study where the growing season is longer. In this case, the early closing was too early, producing no increase in production or forage quality despite an additional 12 days closure compared to the middle (9 September) closure (see Figure 3.2).

Figure 3.1

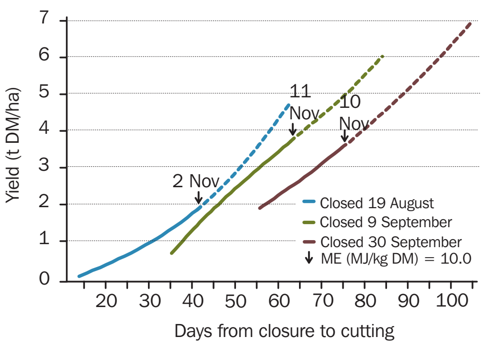


The effects of date and duration of closure on pasture and silage production over spring from a perennial ryegrass/ white clover pasture in northern Tasmania.

Source: Belton et al. (1989)

Figure 3.2

Influence of date and duration of closure on the yield and quality of perennial ryegrass/white clover pasture closed for silage in northern Tasmania. Estimated ME falls below 10 MJ/kg DM for closure periods longer than those indicated on each line in the figure.



Source: Adapted from Belton et al. (1989)

- The grass enters the reproductive stage sooner and quality declines more quickly with later closure. The closure period must be shortened to achieve a satisfactory silage ME and yields will usually be lower (see Figure 3.2).
- Regrowth yield and the total of the silage and grazed pasture yield can be lower when closure date is delayed, especially if there is an earlier finish to the season.
- As shown in Figure 3.2, some silage yield often needs to be sacrificed to produce a higher quality silage. This is discussed in greater detail in Chapters 4, 13, 14 and 15.

The application of nitrogen fertiliser is another management tool that provides additional flexibility on grass dominant pastures. Nitrogen not only provides an opportunity to increase silage yield, but also to shorten the closure period (see Chapter 4, Sections 4.2.2 and 4.3.2).

The objective should be to conserve only surplus pasture, in which case there is no pasture cost debited against silage costs, unless extra inputs, e.g. fertiliser or irrigation, have been used to increase the silage yield. However, there are some cases, for example, in the dairying areas of WA, where a large quantity of high-quality conserved forage is required for feeding during the dry summer/autumn period. Producers may knowingly restrict grazing of pasture to ensure silage production, and either accept reduced milk production or use supplements. In this case, the cost of lost milk production or bought supplements should be added to silage production costs (see Chapter 11, Section 11.2.6).

The results in Tables 3.1, 3.2 and Figure 3.1 also highlight the flexibility producers have in the selection of closure dates and the duration of closure for silage production. As a pasture surplus accumulates, producers can close more paddocks for silage production. This could lead to a number of cutting dates, spreading the workload over the silage season.

Although this would be an advantage on large farms where large quantities of silage are made, on smaller farms that lack economies of scale, harvesting a number of small batches of silage could increase silage production costs (see Chapter 11). However, with judicious planning it may be possible to synchronise cutting over a number of paddocks, as demonstrated in the example at left.

In this example, using the principles outlined earlier, the producer could aim at producing one batch of silage with a ME greater than 10 MJ/kg DM. The paddocks closed later would need to be closed for a shorter period to achieve this target, and would probably produce a lower yield of silage. A range of pasture types and/or forage crops on the one farm could be used to increase the flexibility of closure time, with less risk of yield and quality penalties.

Example of paddock planning

	Closure date	Duration of closure (weeks)	Cutting date
Paddock 1	20 August	9	22 October
Paddock 2	1 September	7.5	22 October
Paddock 3	10 September	6	22 October

3.1.2

How much pasture and when to close for silage production

The importance of integrating silage into whole farm management was discussed in Chapter 1. Stocking rates need to be increased to improve productivity and profitability on farms where pastures are under-utilised. Silage can facilitate this increase in stocking rate by providing supplementary feed at times of the year when pasture supply or quality is limiting animal production. Silage can also have a role on these farms as a special purpose feed, for example, to finish steers or lambs for premium markets.

Unfortunately, little research has been conducted in the area of timing of silage production and its integration with grazing management, and specific guidelines need to be developed for a range of pastures. In the absence of this information, how do farmers decide how much pasture should be set aside for silage production, and when this should be done?

Set area/educated guess

This is probably the most common method and, at best, will allow some expected feed gap to be filled. It is probably an appropriate strategy on under-stocked farms where only a proportion of the surplus pasture is to be utilised. However, on farms aiming for full utilisation, this is the least accurate method to determine what area needs to be cut for silage. Guessing the appropriate area will almost certainly result in too little or too much being cut. Either of these will cause a reduction in farm profit.

Setting aside too much pasture – an example

If too large an area is cut on a dairy farm and pasture intake of the herd is affected, milk production can suffer. A short-term reduction of 1 kg DM/cow in intake at a time when milk production is particularly sensitive to intake (in spring or peak lactation), could result in a decline in milk production of approximately two litres. At a nominated milk price of 30¢/L, this lost production would add significantly to the cost of the silage. Significant production responses from the silage, either increased stocking rate or production/head would be required to cover this loss.

Post-grazing residue

This method is often used in the dairy industry and while it is considerably better than the set area method, it does have limitations.

Paddocks are removed from the grazing rotation as the grazing residue left behind by the animals increases above a pre-determined target – usually greater than 4-6 cm pasture height or a residue yield of 1,500-1,600 kg DM/ha for perennial ryegrass/white clover pastures for dairy cows. Removal of paddocks from the rotation is stopped when the post-grazing residual returns to the target required for optimum pasture growth and quality. This is about 3-4 cm pasture height or a residue yield of 1,300-1,400 kg DM/ha for perennial ryegrass/white clover pastures. These guidelines will vary marginally between pasture species.

This method is reasonably accurate and easy to put into practice, but its limitation is that it is based on what has already happened (in terms of pasture growth) rather than what will happen. If weather conditions change and pasture growth declines, the result could be too much pasture being set aside for silage. Astute managers can often recognise this problem and return paddocks to the grazing rotation for grazing.

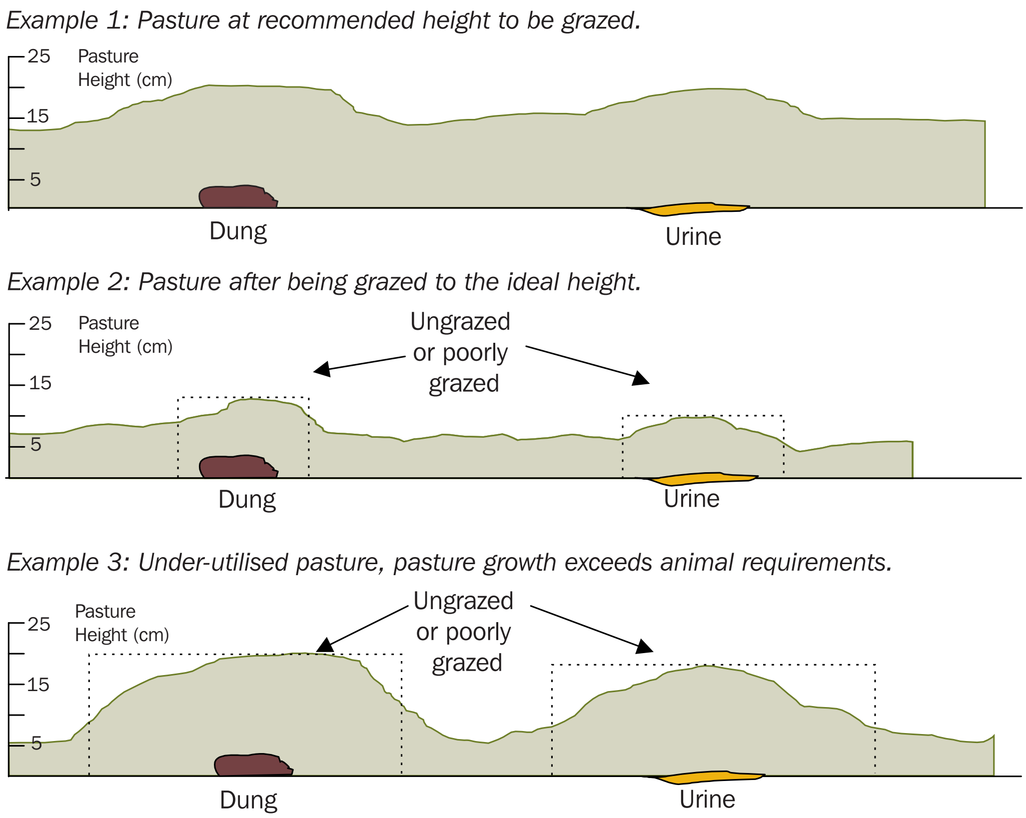
Dung and urine patches

As pasture growth exceeds the animal's requirements, the pasture around the more recent dung pats and urine patches is less closely grazed or not grazed at all. The pasture in between the patches may still be grazed to the desirable levels nominated in the post-grazing residue method, but the heavily grazed areas may be smaller.

Example 1 in Figure 3.3 represents a pasture at the ideal height to introduce stock. Example 2 represents a pasture grazed to levels to maintain pasture growth rates and quality over time. Example 3 represents an under-utilised pasture and is typical of what occurs when pasture growth exceeds animal requirements if the grazing pressure was similar to that of the previous grazing. Note the greater amount of pasture left ungrazed around the dung and urine patches.

Figure 3.3

Using the grazing of dung and urine patches to identify pasture surpluses.



Feed budgeting

Feed budgeting is a more effective means of determining the area that should be closed for silage (see Chapter 1, Section 1.4). It is predictive and can be updated as seasonal conditions change. Full feed budgets are not necessary but are often useful where there are many different classes of stock and/or large differences in pasture growth between paddocks. The more complete the feed budget, the more accurate the estimation of pasture production and potential for greater pasture utilisation.

The simplest calculation is to subtract animal requirements from the predicted pasture growth rate to give a percentage of the farm required for grazing over the silage period (see example at right).

Because weather conditions may affect the predicted growth rates, this method needs to be updated weekly if it is to remain accurate. Paddocks can be removed from or brought back into the grazing rotation if required. In this respect, the feed budgeting method is similar to the post-grazing residue method. Local agriculture department (or equivalent) advisers should be able to provide district average pasture growth rates for use in these calculations. Obviously, seasonal conditions will affect these averages and need to be taken into account.

Example (dairy farm)

- Given a stocking rate of 3 cows/ha on the farm, and a feed requirement of 15 kg DM/cow/day
- The amount of pasture required from each hectare is: $3 \times 15 = 45$ kg DM/cow/day
- Assume the predicted pasture growth rate over the anticipated closure period (allowing for any variation between paddocks) is 60kg DM/ha/day
- Then the proportion of the farm area required for grazing is $(45 \div 60) \times 100 = 75\%$

Therefore, by difference, and given these assumptions, 25% of the farm can be closed for silage.

Section 3.2

Carryover effects of harvesting silage on the pasture

The choice of cutting date will influence silage yield and quality. Although research is limited, evidence suggests that time of silage cut will also affect subsequent pasture productivity. Each of these factors can have an important influence on the profitability of silage production.

3.2.1

Short-term effects on pasture regrowth and quality

Regrowth

The influence of the time of cut on the regrowth of perennial ryegrass-based pastures was covered earlier (see Tables 3.1 and 3.2, Figure 3.1). These studies showed that better regrowth yields were generally obtained when:

- pastures were closed for silage earlier in the spring; and
- the duration of closure was shortened to improve silage quality.

Traditionally, the risk of wet weather has meant that hay is cut later in the season, usually at a later stage of growth. For both these reasons, the regrowth following a hay cut is usually considerably less than that from a silage cut. This is illustrated in two studies at Wagga Wagga, NSW – one with a high-density legume (HDL) forage crop (see Table 3.3) and a second with a mixed annual grass/subclover pasture that also contained a small perennial grass component (see Table 3.4). Early November is the traditional hay cutting time in this environment.

In the second study, a pasture was cut at four times during spring, over three consecutive years, and remained ungrazed from the time of cutting to the end of the growing season (early December). The pasture was typical of many of the degraded pastures in this region, with a low content of sown species and with a relatively low digestibility. Because it contained a high proportion of earlier maturing annual species, the regrowths were considerably less than that obtained from the later maturing forage legume crop in Table 3.3.

Despite the less-than-ideal pasture composition, the combined conservation and regrowth yield, and digestibility of the forage cut for conservation was higher for the early silage cut than for the traditional hay cut in early November (see Table 3.4). The longer-term effects of cutting on the composition of this pasture are discussed in Section 3.2.2.

Table 3.3

Regrowth yields from annual high-density legume (HDL) forage crops cut for silage or hay at Wagga Wagga, NSW.*

	Silage	Hay
Cutting date	8 Oct	6 Nov
Conservation yield (t DM/ha)	3.22	5.31
Digestibility at cutting (% OM)	76.8	69.2
Crude protein content at cutting (% DM)	19.8	12.6
Regrowth yield (t DM/ha)	2.52	0.94
Grazing days (27.5 kg lambs) on regrowth (days/ha)	2329	513

* *Mixture of berseem, Persian and arrowleaf clovers. Mean results over 3 years. A second regrowth was obtained after the silage cut in one year.*

Source: Condon (2000) and Kaiser et al. (unpublished data)

Table 3.4

Effect of time of cut in spring on the yield at cutting and from the regrowth for a mixed annual grass, subclover and perennial grass pasture at Wagga Wagga, NSW.

	Cutting time and harvest strategy			
	Early Oct (Early silage)	Late Oct (Late silage or early hay)	Early Nov (Traditional hay – district practice)	Late Nov (Late hay)
Yield at cutting (t DM/ha)	4.8	5.0	5.2	4.9
Organic matter digestibility (%)	64.9	60.6	53.7	48.3
Regrowth yield (t DM/ha)*	0.6	0.4	0.1	0
Total spring yield (t DM/ha)	5.4	5.4	5.3	4.9

* *From cutting to the end of the growing season (early December).*

Source: Bowcher (unpublished data) – mean results for 3 years

Higher-quality pastures on uncut areas

Apart from pasture yield considerations, cutting for silage, when combined with good grazing management practices, also increases the quality of forage for grazing on the remainder of the farm not set aside for silage production. This is due to the higher grazing pressure on the farm maintaining the pastures at a vegetative growth stage for longer. This means that the whole farm forage quality benefits (silage, regrowth and areas not conserved) can be substantial.

The benefit over the whole farm needs to be taken into account when assessing the economic benefits of silage production. The benefit will be greatest where pastures are fully utilised by either grazing or cutting silage. Where significant quantities of surplus pasture remain unutilised, the effect on pasture quality on the uncut area will be reduced.

Other potential short-term benefits

- Cutting irrigated pastures for silage, rather than hay, allows watering to re-commence sooner. The shorter wilting for silage means the pasture is less likely to be moisture stressed. The advantage over hay making could be as much as a 50% increase in pasture growth rate for a 30-40 day period.
- Silage cutting increases the effective grazing pressure during periods of peak pasture growth, reducing the need for slashing or mulching surplus, rank growth.
- There is anecdotal evidence for some pastures that early-cut silage, compared to late-cut silage or hay, will improve the composition of desirable species such as clover and perennial grasses in the regrowth.
- An early first cut as silage from lucerne, to control weeds, can be a viable alternative to chemical weed control and may also increase total production from a lucerne crop over the whole season. The risk of weather damage to the first cut is also reduced where it is cut for silage rather than hay.
- Regrowth following a silage cut can provide a high-quality pasture, free of internal parasites, for lambs or calves after weaning.
- In the annual pasture areas of southern Australia, the regrowth following silage can provide sheep with a grazing area free of grass seeds, reducing damage to skins and carcases, and seed contamination of wool.
- Silage cutting can remove pasture bulk, leaving an open sward suitable for over-sowing with a pasture or forage crop. This is particularly valuable for the over-sowing of a kikuyu pasture with clover or ryegrass in autumn.

3.2.2

Longer-term effects on pasture

The longer-term effects of conservation cuts on the pasture need to be taken into account when assessing the economics of silage production.

In southern Australia, there is anecdotal evidence that silage cutting can improve the legume content and reduce undesirable grasses and broadleaf weeds. These effects are likely to be influenced by many factors, including pasture species, timing of the silage cut, seasonal conditions, soil fertility and fertiliser application, and grazing management.

The issues related to nutrient removal and cycling, and soil acidification are discussed in Chapters 1 and 4.

Of the limited number of studies conducted, an experiment in Gippsland, Victoria, (see Chapter 1, Table 1.2) showed no differences in the botanical composition of perennial ryegrass/white clover pastures cut for silage or hay each year for four years.

Another study with an irrigated subclover pasture showed that time of cut for hay production in one year had little impact on pasture availability in either winter or spring in the following year (see Table 3.5). For this pasture, the decision on the best cutting time of cut should be based on the hay/silage yield, its quality and the regrowth following the cut.

Silage cutting can influence longer-term changes in the botanical composition of pastures by influencing the competition between species, e.g. reducing the dominance of grasses over legumes during periods of rapid growth or influencing the seed set of annual species in the pasture.

A good example of the effect of the timing of forage conservation cuts on a pasture containing annual species is shown in Table 3.6 (the data was derived from the experiment in Table 3.4). In this experiment, a mixed annual grass/subclover/perennial grass pasture at Wagga Wagga, NSW, was cut at four stages of growth in spring for two consecutive years. The botanical composition was measured at the beginning of the third spring.

This study showed that there can be large changes in pasture composition as a result

Table 3.5

The effect of time of cut on pasture yield in the following winter and spring from an irrigated subclover dominant pasture at Deniliquin, NSW.

Date of cut	Hay cut (t DM/ha)	Pasture yield in following year (t DM/ha) Winter (July)	Spring (October)
Uncut	–	2.2	4.9
24 Sep	5.2	2.2	4.7
10 Oct	6.7	2.1	4.8
25 Oct	6.9	1.9	4.6

Source: *Myers and Squires (1968)*

Table 3.6

The effect of grazing by wethers (10 DSE/ha stocking rate) and cutting times on species composition of a mixed annual grass/subclover/ perennial ryegrass pasture the third spring after cutting or grazing in each of the two previous springs.

Species	Initial pasture composition (%)	Grazing only	Grazed then cut in spring: Early Oct (Silage)	Late Oct (Late silage or early hay)	Early Nov (Traditional hay – district practice)	Late Nov (Late hay)
	(% of species in the pasture in Year 3)					
Phalaris + cocksfoot	15.9	15.4	18.4	14.2	14.1	16.6
Subclover	31.4	18.1	36.6	11.6	15.6	19.9
Naturalised clovers	3.9	0.5	4.5	0.3	4.0	6.6
Annual ryegrass	25.1	17.7	28.3	52.8	9.8	9.2
Vulpia (silvergrass)	16.4	26.3	2.0	10.3	53.2	41.3
Great brome	1.0	14.1	2.1	0.2	1.3	3.9
Barley grass	0.3	4.8	0.2	0	0.4	0.1
Paterson's curse	3.5	0.3	6.9	4.4	0.4	1.5
Other broadleaf weeds	2.3	2.7	1.2	6.0	0.8	0.2

Source: *Bowcher (unpublished data)*

of conservation cuts and that the timing is critical. Considering the species that accounted for a total of at least 70-80% of the pasture, the main changes in pasture composition were:

- Compared to grazing, the early silage cut significantly increased subclover and annual ryegrass content, and reduced vulpia (silvergrass) content.
- Compared to grazing, the traditional hay cut reduced annual ryegrass and significantly increased vulpia content.
- The cutting strategies had little impact on the content of perennial grasses.
- An early silage cutting strategy may favour an increase in the content of Paterson's curse if regrowth is not managed.
- Compared to the start of the experiment, all treatments reduced the pasture's subclover content, with the exception of the early silage cut.

In this study, the regrowth was not grazed. Strategic grazing of the regrowths may have influenced seed set for some species and led to an even greater impact on botanical composition.

Vulpia is an unproductive, lower-quality grass, often rejected by grazing animals. Any reduction in vulpia content will benefit pasture production. The early silage cut achieved this with an improvement in subclover content. These changes would be expected to improve both pasture yield and quality, and give significant additional economic benefit in favour of silage production.

As highlighted in Table 3.6, timing of the cut has a major impact on changes to botanical composition. The stage of growth (phenological development) of a species determines its sensitivity to cutting in terms of subsequent growth and seed production. It appears that for control of annual grasses, it is best to cut when the *most advanced* seed head is between post-flowering and early seed fill.

Plate 3.2

Timing of the silage cut can affect pasture composition. This photograph was taken in early November. The area on the left is the early October silage cut referred to in Table 3.6, while the area on the right is the early November cut treatment, immediately before cutting. Note the high quality regrowth on the early cut area, and the Vulpia population in the later cut.

Photograph: A. Bowcher

For control of Paterson's curse, the best stage appears to be when the earliest (lowest) seeds on the most advanced flowering head have reached the very early green seed formation stage (seed formation is visible in spent flowers).

Further research is needed to provide clear guidelines on the critical stages of growth for various species. This will allow farmers to identify the optimum growth stage at harvest for both desirable and undesirable species in pastures. This will be more reliable than setting cutting dates by a calendar, a method subject to regional variations and seasonal variations between years.

If silage cutting is to be used to manipulate the botanical composition of a pasture, there may be occasions where this objective could lead to pastures being cut later than if the focus was on silage quality alone. In such situations, farmers need to weigh up the relative benefits of changes in silage quality and longer-term changes in pasture composition.

Section 3.3

Weed control

A successful weed management strategy relies on a vigorous, competitive pasture to replace the targeted weed species. If the pasture is not competitive, another weed species will invade the space.

3.3.1

Weed control versus silage quality trade-off

Grasses

There is clear evidence from the study detailed in Table 3.6 that silage production can have an important role in reducing the content of grass weeds such as vulpia in pastures. Farmers have also reported that silage reduces the content of Yorkshire fog grass in perennial pastures.

The presence of grass weeds in a pasture is not likely to influence the silage fermentation because their sugar content and buffering capacity are likely to be similar to that for pasture grasses (see Chapter 2, Section 2.1.3). In addition, most grass weeds, if cut early, are likely to have a medium to high digestibility. Consequently, the presence of grass weeds is not likely to have a major impact on silage quality in an early-cut system. However, as indicated earlier, the digestibility of all species in the pasture will suffer if cutting is delayed to control a particular grass weed.

The seeds of some grass species can be a problem with a later harvest. Although the seeds are rendered non-viable by the ensiling process, they can cause wool contamination problems (Plate 3.3), and barley grass seeds can cause mouth ulcers in cattle fed short chopped silage (Plate 3.4a and b).

Broadleaf weeds

There is anecdotal evidence that silage cutting can reduce the content of some broadleaf weed species in pasture, although there is little research data available. It is generally assumed that silage making controls these weeds by reducing or preventing seed set, and/or sterilising any weed seeds that are present.

Plate 3.3

When pastures are cut late for silage or hay, grass seed contamination of wool can be a problem.

Photograph: K. Kerr

Plate 3.4a and b

Mouth ulcers (on the tongue, gums, inside the cheek, and on the roof of the mouth) developed in cattle given a short chopped oaten silage contaminated with mature barley grass seeds.

Photograph: J. Piltz

Given these potential broadleaf weed control benefits, and the general presumption that ensiling will improve the palatability or attractiveness of the weeds to livestock, there is the temptation to use silage making as a control strategy for these weeds. However, a high proportion of broadleaf weeds in a silage could reduce silage quality (see Table 3.7). This could occur in the following ways:

- The broadleaf weeds can have a lower digestibility than pastures cut early for silage. Quite small changes in silage digestibility can have a significant effect on animal production.
- Broadleaf weeds may have lower initial DM content than the pasture species or thicker stems, which can slow their drying rate. A slow, extended wilt can reduce silage quality.
- Some broadleaf weeds, particularly capeweed and Paterson's curse, have a high buffering capacity (see Chapter 2, Section 2.1.3). This will slow the rate of pH fall in the early stages of the ensiling process, increasing the risk of a poor silage fermentation and subsequent rejection of the silage by the animals.

Each of these broadleaf weed characteristics could reduce silage digestibility, intake and animal production. If silage cutting is to be used to control broadleaf weeds, there is likely to be a trade-off between any control benefits and silage quality. In addition, delaying a silage harvest to coincide with the optimum time of cut for broadleaf weed control will result in lower silage digestibility.

Another issue that has not been investigated is the risk of poisoning when toxic weeds are ensiled. It is not known whether the toxins in some Australian broadleaf weeds are deactivated during the ensiling process, so it is wise to be cautious and seek veterinary advice before ensiling forages heavily contaminated with weeds known to be toxic.

Research is needed to compare the potential benefits in controlling both grass and broadleaf weeds using silage conservation, with the potential animal production penalties. This will provide clear guidelines for producers on the acceptable level of weed contamination in silage, and when it is appropriate for farmers to modify silage management to control weeds.

Table 3.7

The chemical composition of subclover pasture compared to three broadleaf weeds cut for silage in spring at Wagga Wagga, NSW.

	Subclover pasture	Capeweed	Paterson's curse	Variegated thistle
DM content at cutting (%)	15.4	12.1	12.9	13.0
Organic matter digestibility (%)	71.1	68.0	62.6	68.9
Crude protein (% DM)	16.2	12.0	12.6	12.6
WSCs (% DM)	12.2	17.0	12.9	15.5
Buffering capacity (meq/kg DM)	852	1202	1027	691

Source: Kaiser (unpublished data)

3.3.2

Weed seed viability in silage

It is generally assumed that the ensiling process makes most weed seeds non-viable and that weed seeds are not spread in the way they are with hay feeding. Producers and researchers have based this assumption on observations, but there are no supporting Australian research data.

A Canadian study (see Table 3.8) has examined the effects of ensiling on weed seeds in some detail. In this study, none of the grass seeds survived the ensiling process – no seeds germinated or were viable. While germination levels were very low with the broadleaf weeds, viability varied from 3 to 30%, indicating that, under favourable conditions, at some point in the future these seeds could germinate.

Other studies have shown that ensiling prevents the germination of broad-leafed dock (*Rumex obtusifolius*).

The available evidence from these studies indicates that while germination of broadleaf weeds is severely restricted, the seeds of some weeds may remain viable after being ensiled.

Research is required to clarify the situation for common Australian weeds. The important issue is the effect of different ensiling conditions in Australia on weed seed survival. Conditions that may have an effect include silage fermentation, wilting and duration of storage.

Table 3.8

The effect of ensiling on the germination and viability** of weed seeds.#*

Weed		Effect of ensiling
Botanical name	Australian common name	
Grasses		**Both germination and viability reduced to nil**
Echinochloa crus-galli	Barnyard grass	
Bromus tectorum	–	
Hordeum jubatum	–	
Setaria viridis	–	
Avena fatua	Wild or black oats	
Broadleaf weeds		**Germination reduced to 0-2% and viability to 3-6%**
Chenopodium album	Fat hen	
Descurainia sophia	–	
Amaranthus retroflexus	Amaranth	
Thlaspi arvense	Pennycress	Germination reduced to 0-5% and viability to 10%
Kochia scoparia	–	
Malva pusilla	Mallow	Germination reduced to 0-3% and viability to 23-30%
Polygonium convolvulus	Black bindweed or climbing buckwheat	

* *Germination is the percentage of seeds that sprouted when subjected to a standard germination test.*

** *Viability includes the percentage of seeds that germinated as well as those that have potential to germinate when conditions are favourable.*

In this study, seeds were ensiled for 8 weeks in bunkers of barley silage with DM contents of 33-36%.

Source: Adapted from Blackshaw and Rode (1991)

Chapter 4

Silage from pastures and forage crops

Chapter 4

Silage from pastures and forage crops

In this chapter

The authors

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Key Issues ... see Page 2

Section 4.0

Introduction

The pastures and forage crops discussed here are the major sources of parent material likely to be conserved as silage.

As producers develop greater interest and experience with silage, they are likely to use a wider range of crops, e.g. forage brassicas and chicory. Unfortunately, there is very little experimental data or experience in ensiling these less commonly grown crops. In the absence of clear guidelines, assume that non-'grass' crops may have a high buffering capacity and low WSC content, and may be difficult to ensile (see Chapter 2, Section 2.1.4). They should be treated as for legumes – wilting is essential (see Chapter 4, Table 4.1; Chapter 5, Table 5.2; and Chapter 6, Table 6.3).

The crops discussed are those grown specifically for grazing, for forage production or both. Silage cutting is often integrated with grazing to improve the utilisation of surplus growth.

Silage is produced in a wide variety of climates in Australia, so specific management strategies have not been included. Local information is needed on varieties, fertilisers, irrigation management, and weed and pest management.

Seedbeds left uneven or cloddy after sowing may need rolling, before plant emergence, to prevent soil contamination of the forage at harvest. As well as creating wear problems with equipment, soil contamination can also introduce undesirable bacteria, which may affect silage fermentation (see Chapter 8, Section 8.7).

Plate 4.1

Well-managed tropical grasses have the potential to produce a large bulk of medium-quality silage. This panic pasture should have been cut several days earlier; its quality is declining quickly as it runs to head.

Photograph: M. Martin

The Key Issues

- The most cost-effective production of silage is when there is a genuine excess of forage that cannot be grazed.
- The silage's nutritive value varies with the species and variety conserved, and the growth stage at which it is cut.
- Attention to good agronomic management is essential to achieve high forage yields of high nutritive value.
- Both feed quality and quantity are important in determining the profitability of animal production from silage. Silage quality places a limit on the potential animal production per tonne of silage DM. Production of low-quality silage is likely to be unprofitable.
- Monitor soil fertility using soil tests and ensure long-term soil fertility is maintained by replacing nutrients removed in silage.
- Read all labels on pesticides and chemicals used on silage parent forage to ensure they are used correctly and stock withholding periods are satisfied.

Section 4.1

A comparison of pastures and forage crops suitable for silage production

Silage is often only made from pastures or forage crops when growth is surplus to the animals' requirements. A feed budgeting approach can be used to estimate the quantity of surplus forage likely to be available for conservation (see Chapter 1).

The cost of growing these pasture and forage crops should only be considered in a budget for silage when inputs have been increased specifically for silage production, e.g. higher fertiliser rates or increased irrigations. There are also potential pasture management and weed control benefits that can be attributed to silage which should be taken into account (see Chapters 3 and 11).

Table 4.1 summarises characteristics of pastures and forage crops commonly grown for silage production, emphasising the forage management strategies required to optimise silage quality. There is a huge range in the quality of silages being produced (see Chapter 12, Appendix 12.A1). The large range suggests many producers are losing production potential because of poor silage-making practices.

Table 4.1

Production potential, management requirements and suitability of pasture and forage crops for silage production.

Crop	Perennial ryegrass & clover	Forage ryegrass	Other temperate perennial grasses & clover	Pasture legumes & legume dominant pastures[1]	Lucerne	Kikuyu & other tropical grasses	Forage sorghum	Millet (several types)	Cowpea & lablab
Growth stage at harvest	1st head emerge on ryegrass	10-20% head emergence	Stem elongation of grass component	Early to mid flowering	Very early (<10% flower)	25-35 days growth	1 m high	Pennisetums: 1 m high Japanese: pre-boot	Flowering
Potential yield[2] (t DM/ha/cut)	2.5-4	2.5-4.5	2-4	2-3.5[1]	1.5-3.2	2-3.5	2-5	2-5	1.5-6
Potential number of cuts per year[2]	1–2	1–2	1	1–2	4-7	1-3	1-4	1-3	1
Wilting requirement	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Target range DM content (%)									
Chopped	30-40	30-40	30-40	35-40	35-40	35-40	30-40	30-40	35-40
Baled	35-50	35-50	35-50	35-50	35-50	35-50	35-50	35-50	35-50[6]
ME[3] (MJ/kg DM)	9.5-11	9.5-11	9.5-10.5	9.5-11.5	9-10.5	8.5-10	9-9.5	9-10	8.5-10.5
Crude protein[3] (% DM)	12-22	12-20	12-16	14-26	18-24	12-18	7-17	10-18	14-18
Ensilability[4]	**	**	**	*	*	*	**	**	*
Suitable for chopped bulk silage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Suitable for baled silage	Yes	Yes	Yes	Yes	Yes	Yes	Yes[5]	Yes[5]	Yes[6]

Notes:

1. *High-density legumes have potential to produce higher yields (3.5-7.0 t/ha) than pasture legumes sown at the usual rates. Management requirements for silage production and potential forage quality are as for pasture legumes.*
2. *Yields and potential number of cuts are for crops cut at the optimum growth stage. Yields at the higher end of the range can be obtained with irrigated crops or crops grown under ideal growing conditions.*
3. *The ME (metabolisable energy – see Glossary for definition) and crude protein values shown are in the range that is achievable with good management.*
4. *Ensilability: likelihood of achieving a good silage fermentation without wilting or additives. (* Low ** Medium *** High)*
5. *Baling is not recommended for tall, rank crops unless the baler is fitted with knives.*
6. *Although cowpeas and lablab may be made into baled silage, it is not the preferred option (see Section 4.12.3).*

Section 4.2

Factors affecting the yield and feed quality of silage

The principles discussed in this section apply to most of the crops and pastures used as silage parent forage. Later sections in this chapter and in Chapter 5 contain more specific information relevant to the crops and pastures most likely to be used for silage production.

4.2.1

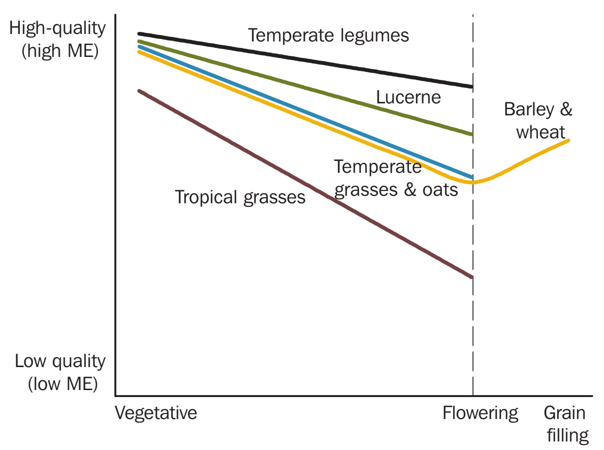
Crop or pasture type

The quality of the parent forage sets an upper limit on the quality of silage or hay that can be conserved. Young temperate grasses and legumes, such as clover and lucerne, have high forage quality (good digestibility, ME and protein levels) and have the potential to be conserved as high-quality hay or silage.

Mature temperate grasses and rank summer grasses or crops have low forage quality and can never be made into good quality silage or hay. Figure 4.1 shows the relative ranking of crops and pastures in terms of expected quality.

Figure 4.1

Forage quality (ME content) of the parent forage decreases as the plants mature.



4.2.2

Soil fertility

Soil fertility can influence potential yield, pasture growth rates and capacity for regrowth, as well as forage quality. For example, a grass pasture or crop that is nitrogen deficient will have lower protein and ME levels. Deficiencies in other nutrients that affect yield, such as sulphur, also often affect forage quality.

High soil fertility and good crop growth can sometimes contribute to lower forage quality if a crop is harvested late. For example, a very vigorous forage sorghum crop can quickly become tall and rank if harvest is delayed.

Nutrient removal and fertiliser application

Large amounts of nutrients are removed when high-yielding crops and pastures are conserved as hay or silage (see Table 4.2). For example, a kikuyu pasture yielding 4 t/ha removes 96 kg N/ha, 12 kg P/ha, 100 kg K/ha and 10 kg S/ha. Nutrients removed must be replaced if long-term production is to be sustained.

Fertiliser requirements vary with soil type and will depend on soil test analyses and nutrient removal levels. Local advice should be sought for fertiliser application rates.

Fertiliser should be applied before the start of the pasture or crop's main growing season to avoid loss of production. This is usually in autumn for the temperate species. If high rates are required, split applications, e.g. in autumn and spring, will reduce the risk of nutrient loss. A spring application will improve recovery after harvest.

Large amounts of potassium are removed when forage is harvested, but local advice should be sought before applying high rates of potassium fertiliser. Excessive levels of potassium in forage may lead to an increased incidence of grass tetany in lactating cattle.

Nitrogen fertiliser can be a valuable tool in improving carrying capacity over the whole farm. It can improve recovery after grazing and increase DM yields from shorter closure periods. If soil moisture is adequate, additional nitrogen applications during periods of active plant growth can produce a greater bulk of forage and increase the amount available for conservation.

While nitrogen application can improve production of the grass component of grass/legume pastures, a more vigorous grass component can suppress the legume portion if it is not managed correctly.

The impact of nitrogen fertiliser on perennial ryegrass is discussed in Section 4.3.2. Many of the principles covered in that section apply to other grass-dominant pastures, although more investigation is required to determine economic responses for many of the pasture species.

Effluent disposal

Silage production can be a useful tool in reducing the build-up of nutrients on land treated with effluent from dairies, piggeries and feedlots.

Effluent should not be applied to crops and pastures within six weeks of the forage being harvested for silage. Late application can result in physical contamination of the forage with undesirable bacteria, which may adversely affect silage fermentation and animal health.

To avoid contamination, the effluent should either be spread on bare ground before sowing, on very short crops and pastures early in the growing season or immediately after a silage cut. Effluent containing large particles should not be used if there is a risk these will be picked up by the harvesting equipment.

If effluent is to be used on early-cut cereal crops or grass-dominant pastures, producers should be aware that high nitrogen rates could affect the ensilability of forage (see Section 4.3.2 and Chapter 2, Section 2.1.2). Wilting guidelines must be followed to ensure a successful fermentation (see Table 4.1).

Table 4.2

Approximate nutrient removal rates (kg/t DM) when forage is harvested.

	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Sulphur (S)	Calcium (Ca)	Magnesium (Mg)
Perennial temperate grass/clover mixes	35*	3.0	20	2.5	8.0	2.4
Pasture legumes (clover, medic)	35*	3.0	25	2.5	13	3.0
Lucerne	35*	3.0	25	3.0	15	4.0
Kikuyu	24	3.0	25	2.5	2.7	3.0
Hybrid forage sorghum	24	3.0	20	2.0	3.0	3.0
Millet	25	3.0	20	2.5	3.0	3.0
Cowpeas, lablab and summer legume crops	28*	2.5	25	3.0	10	2.5

** Nitrogen requirement met by legume nitrogen fixation.*

Data derived from various computer databases

4.2.3

Weeds, pests and diseases

The quality and yield of the parent forage may decline with infestations of weeds, pests and diseases. Some weeds, such as thistles and barley grass, may contaminate wool, damage animals' mouths (causing ulcers) and affect feed intake (see Chapter 3, Section 3.3). Other weeds are poisonous, can taint milk or can be unpalatable. Some weeds, e.g. capeweed, are difficult to make into silage (see Chapter 2, Section 2.1.4).

Pastures will recover more quickly if cutting height is >5 cm.

The valuable role of silage production in weed management in pastures is discussed in Chapter 3, Section 3.3.

Select and prepare paddocks for forage conservation well in advance of harvest. Select paddocks free of problem weeds, pests and diseases or control these before they impact on yield and quality. Care should be taken when using any chemicals (see Section 4.2.6 for more detail).

Plate 4.2

Poor-quality pasture will not produce high-quality silage.

Photograph: A. Bowcher

4.2.4

Growth stage at harvest

Digestibility, ME content and protein levels of plants are highest when the plants are in the early vegetative growth stage. As grasses mature, they become more fibrous and their forage quality declines rapidly. The forage quality of legumes tends to decline more slowly. Cereals, such as wheat and oats, are of highest digestibility and protein content when young and leafy. As they mature, energy becomes concentrated in the grain, stems become more fibrous and less digestible, and some leaves die off. In some cereals, the increase in grain content can offset the quality loss due to increasing fibre content in the stem (see Figure 4.1 and Chapter 5, Table 5.2).

The best growth stage for harvest is often a compromise between quality and quantity. The recommendations for specific pastures and crops are summarised in Table 4.1 and Chapter 5, Table 5.2. Greater detail for these 'parent forages' can be found in the relevant sections of Chapters 4 and 5.

Mature crops provide a larger bulk of lower quality forage than young, vegetative crops. Late-cut crops are usually unsuitable for enterprises with high production targets such as milk or meat production. Returns from animal production on late-cut silages may not cover the cost of conservation. The matching of silage quality to animal production targets is very important and is covered in Chapters 13, 14 and 15.

4.2.5

Dry matter content and wilting

The dry matter (DM) content of a conserved forage often affects how well it is preserved. The importance of DM levels is discussed in detail in Chapters 2 and 6. The recommended DM range for ensiling pastures and crops are given in Table 4.1 and Table 5.2. It is important that the forage DM levels are within the specified range when storing. The key issues are:

- If the DM content of silage is too low (<30%), there is a risk of a poor fermentation, reduced silage quality and increased effluent losses.
- If the DM content is high (>50%), forage losses increase and silage can be difficult to compact, with a risk of poor fermentation, mould growth and overheating.
- The time taken to wilt a crop to the desired DM level is critical. During wilting, respiration continues, reducing the forage quality. If wilting continues for more than 48 hours, forage quality can drop significantly. A slow wilt allows growth of aerobic bacteria, yeasts and moulds, which further increases losses of DM and quality.

Management strategies to accelerate the rate of wilting are discussed in Chapter 6, and the use of additives to reduce spoilage or improve fermentation is discussed in Chapter 7.

4.2.6

Caution – pesticides

When using pesticides or other chemicals on crops and pastures intended for hay or silage:

- always read the label – failure to follow label guidelines is illegal; and
- always observe the withholding period.

The labels on most chemicals include a withholding period (WHP). This is the specified minimum time between chemical treatment and the commencement of a production process, such as harvesting or grazing, and relates to the label dose rates only. An Export Slaughter Interval (ESI) is the recommended withholding period for livestock and produce destined for export and is often longer than the WHP for the same chemical. Updated WHP and ESI information is available from Meat and Livestock Australia (MLA) and on the MLA website, <www.mla.com.au>.

Our trading partners do not use some of the chemicals registered in Australia. *Any* detectable level of these in animal products may exclude those products from that market.

Many chemicals do not break down during the ensiling process; observe the WHP for grazing and cut *after* that date for silage. Produce from livestock eating forage within the designated WHP is not acceptable for human consumption.

The restrictions applying to chemical use on crops and pastures can change. This is the case with endosulfan. Recent restrictions stipulate that no feed straw, fodder, trash or by-product that has had any foliar treatment of endosulfan can be fed to livestock.

A signed Vendor Declaration form, requested on purchase of forage, should stipulate chemical treatments used on the crop or pasture.

Avoid chemical residues in silage:

- Time chemical applications to ensure that WHPs and ESIs are satisfied.
- Attend to chemical records, particularly if the intended use for the crop or pasture changes. This is more likely to be important if a crop intended for grain harvest is cut for hay or silage instead. Chemicals may have been used on the crop that could compromise silage use.
- Minimise use of chemicals on crop or pasture to be ensiled.
- Do not grow forage where spray drift from nearby crops is possible. For example, forage crops could be put at risk if crops requiring high chemical usage are grown in an adjacent paddock.
- Keep up-to-date with the acceptable WHPs and ESIs for chemicals used in forage production programs. Review them regularly.

Section 4.3

Perennial ryegrass and clover

Perennial ryegrass/clover pastures are ideally suited to grazing, with the excess in spring best managed by forage conservation.

4.3.1

Variety selection

Perennial ryegrass varieties are selected for their production and persistence under grazing. Variety maturity will affect the optimum harvest date (see Table 4.3).

Late-maturing varieties can be closed up later in the growing season and still produce an acceptable yield at the optimum growth stage (early head emergence). Early-maturing varieties must be harvested sooner to produce high-quality silage. They may be more suited to areas with shorter or less reliable spring growing seasons.

Some perennial ryegrass varieties tend to be short and fine and may be difficult to harvest for silage. Erect varieties may be more suitable for silage production.

Endophyte in perennial ryegrass silage

Perennial ryegrass pastures may contain the fungal endophyte *Neotyphodium lolii*. The endophyte assists perennial ryegrass establishment and growth by protecting against a range of insect pests. However, toxins produced by this fungus can affect animal health, causing staggers, susceptibility to heat stress and reduced production.

There is evidence that the endophyte toxins will persist in silage and affect milk yield.

The level of endophyte will vary depending on perennial ryegrass variety and paddock management. The toxic effect is usually low in early spring and increases with rising temperatures and reproductive development, to a maximum at seed head emergence. Toxicity then falls in post-reproductive regrowth only to increase again in summer due to moisture stress and perhaps increasing temperature.

High nitrogen application can increase the level of toxin.

Table 4.3

Perennial ryegrass quality after three weeks regrowth, sampled in December (South Coast, NSW).

Variety	Maturity	DM digestibility (%)	ME (MJ/kg DM)	Crude protein (% DM)
Javelin	Very late	66.8	10.0	22.0
Super Nui	Mid-season	63.7	9.6	16.1
Ellett	Mid-season	63.3	9.5	20.2
Concord	Mid-season	61.1	9.2	18.6
Grassland Nui	Mid-season	60.1	9.0	17.2
Kangaroo Valley	Very early	58.8	8.8	17.7

Source: Adapted from Kemp (1994)

4.3.2

Management for silage production

- Replace nutrients removed – based on soil test results and the information in Table 4.2.
- Depending on soil test results, potassium fertiliser may be required in clover-dominant pastures.
- Where high rates of N, P or K fertilisers are required, split applications can minimise nutrient losses.
- Topdress with 50-70 kg N/ha if ryegrass dominates.
- Irrigate as required, if irrigation is available.
- Graze heavily, mulch, slash or mow back to 5 cm stubble before closure. Remove as much dead material as possible to avoid a reduction in forage digestibilty and contamination of the ensiled material with undesirable micro-organisms.

Table 4.4

A comparison of yield and ME content of perennial ryegrass six weeks after nitrogen application, harvested at the early ear emergence growth stage (western Victoria).

Nitrogen applied (kg N/ha)	Yield (t DM/ha)	ME (MJ/kg DM)
0	1.6	11.2
25	1.9	11.4
50	2.2	11.2
75	2.3	11.3
100	2.3	11.4

Source: Adapted from Jacobs (2000)

Nitrogen fertiliser applications

Pastures with adequate fertiliser inputs recover more rapidly after grazing or harvest. If not limited by moisture or other nutrients, nitrogen application to a nitrogen-deficient pasture produces a quick growth response. The pasture can be harvested sooner, at a less mature stage of growth, producing higher yields and higher quality silage.

However, with high nitrogen rates the decline in forage quality will be more rapid and timely harvest is critical. High nitrogen levels can cause plants to mature more quickly, with a greater risk of lodging.

Increases in growth rate and yield of >30% have been recorded from pastures in most regions of Australia. Growth responses have varied from 12 to 26 kg DM/kg N. Table 4.4 provides an example of pasture response to a range of nitrogen rates.

If soil moisture and other nutrients are not limiting, nitrogen application rates of 50 to 70 kg N/ha should increase yields and maintain, or improve, digestibility, ME and crude protein levels. Higher nitrogen rates may further increase yield (kg DM/ha), but DM production per kg of nitrogen applied, and therefore economic return, is likely to be less and the risk of environmental pollution is increased.

Nitrogen topdressing may reduce DM content of plants and reduce the concentration of plant sugars (water soluble carbohydrates – WSCs). Because successful silage fermentation depends on adequate WSC levels, it is important that topdressed ryegrass pasture is wilted to recommended DM levels (see Table 4.1) to concentrate WSCs and allow a good fermentation (see Chapter 2).

Low WSC levels are more likely if the pasture is harvested less than four weeks after nitrogen topdressing.

4.3.3

Growth stage at harvest

The optimum growth stage to harvest a perennial ryegrass pasture for silage is when the first seed heads start to appear. A compromise has to be made between forage quality and DM yield. DM yield will be highest when seed heads are fully developed. However, forage quality is dropping quickly at this stage and will only support low animal growth rates or milk production.

A short closure of four weeks in spring will ensure high-quality silage. A longer closure, while increasing DM yields, may lower feed quality (see Table 4.5). Forage quality will usually decline by 0.25-0.6 MJ/kg DM per week of delay in silage harvest. In most regions, perennial ryegrass silage should be harvested before mid-November.

Closure dates and lengths of closure

Optimum dates and period of closure will vary with location, seasonal conditions, varietal maturity, stocking rate and availability of surplus pasture.

When to close a pasture for silage is best judged by the growth stage of ryegrass and the amount of residue remaining in a paddock after grazing (see Chapter 3). If ryegrass has 3½ or more leaves before grazing and/or a residue of >1.5 t/ha DM remains after grazing, the pasture is being under-utilised and the surplus may be closed for conservation.

Early closure is more likely with well-fertilised pastures, low stocking rates, early-maturing varieties or in northern NSW and Queensland. An early harvest allows more regrowth and a quick return to grazing or a second silage harvest. There is also potential for higher total forage production (see Chapter 3, Section 3.1.1). A later closure time often requires a shorter closure period due to faster plant growth rates and rapid maturing of the pasture, but total DM production is likely to be less.

It is worth considering staggering closure dates to spread workload and risk of weather damage at harvest.

Plate 4.3

A clover/ryegrass pasture can produce high-quality silage.

Photograph: N. Griffiths

Legumes in perennial ryegrass pasture

Legumes in the pasture have potential to increase digestibility and crude protein levels of silage. However, WSC levels of the ryegrass/clover mix will be lower, making a quick, effective wilt more important. Clover-dominated pasture mixes should be harvested at the clover's mid-flowering growth stage.

Table 4.5

Effect of growth stage on potential yield and quality of perennial ryegrass pasture. Forage quality will vary with proportion of legume.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Vegetative (25 cm)	10.0-11.0	15-25	1.5-3.0
Head emergence (40 cm)	9.5-11.0	12-22	2.5-4.0
Flowering	8.5-10.0	10-20	2.5-5.0

Section 4.4

Other temperate perennial grass/legume mixtures

Phalaris, cocksfoot and tall fescue are important temperate grass species, usually sown with clovers (and sometimes lucerne). Grown specifically for grazing, they have potential to produce high-quality silage. They are grown for their persistence and adaptation to a wider range of soil types and growing conditions than perennial ryegrass (see Table 4.6).

A vigorous stand of these perennial grasses can dominate the pasture's legume component if not managed correctly. Silage production is a valuable management tool in helping maintain a strong legume component. Producers should aim for a pasture with at least 20% legume (see Chapter 3).

Table 4.6

Minimum annual rainfall requirement of temperate grass species.

Grass species	Minimum rainfall requirement (mm/year) Winter Dominant Zone	Minimum rainfall requirement (mm/year) Summer Dominant Zone
Cocksfoot	450	750
Tall fescue*	450	650
Phalaris	525	700
Perennial ryegrass*	700	800

* *In drier areas these species will perform better at high altitudes.*

Source: McDonald (2001)

4.4.1

Species and variety selection

Selecting the most suitable species, variety and combination of grasses and legumes depends on climate and other growing conditions. Obtain local advice for species and variety recommendations.

The choice of which variety and species to grow is usually governed by the livestock enterprises on the farm, rather than the potential of the pasture for conservation. However, particularly in areas of poor summer rainfall, high-quality temperate pasture silage is having an increasingly important role, enabling producers to achieve demanding production targets. In these situations producers need to rethink their species choice to ensure the combination of pasture species grown can produce silage cuts in most seasons.

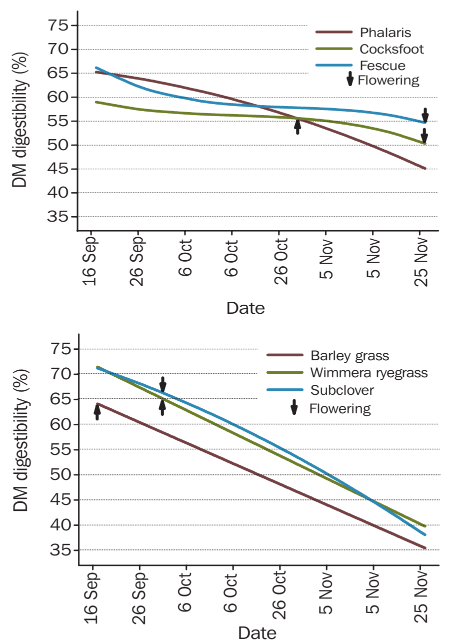
Where climate and soil conditions allow, a range of mixtures may be grown on the one farm. This will help increase pasture utilisation and aid management by extending the spring growing season. An example of this could be a mixture of the later-maturing perennial ryegrass/ subclover/white clover on the more fertile, sheltered areas, with phalaris/cocksfoot/ subclover the main mixture on the balance of the farm.

Such a combination takes advantage of the spread of maturity of the species and extends the potential production period in the event of late spring/summer rainfall. If a large amount of silage is to be cut, having a range of pastures with varying maturities extends the harvest window.

Although the flowering dates shown in Figure 4.2 do not apply in all areas, the graph does indicate the differences in maturity and digestibility levels that occur between temperate pasture species. The data also highlight the effect of maturity on digestibility level. Note that these data are from 1968 research and do not reflect the diversity of maturity now available with the wide range of current varieties. The digestibility values in this study are low, which may be a consequence of seasonal conditions.

Figure 4.2

DM digestibility and flowering date of temperate species at Northfield, South Australia.



Adapted from Radcliffe and Cochrane (1970)

4.4.2

Management for silage production

- ➤ Select pastures with good legume content.
- ➤ Ensure good pasture nutrition, replacing the nutrients removed (see Table 4.2) to sustain long-term productivity.
- ➤ Topdressing with nitrogen will increase DM production and forage quality if the grass component is dominant and the pasture has a poor legume history.
- ➤ Minimise insect damage and control problem weeds.
- ➤ During winter, in the lead-up to closure, strategically graze the pasture to prevent rank growth of the grasses and to encourage the legume component.

The temperate perennial grass/legume pastures can be returned to grazing management after silage is cut. However, be aware that the early harvest time required to produce high-quality silage

Plate 4.4

The phalaris pasture in the background has not been grazed and has become rank. Livestock will selectively graze the highly digestible, fresh growth in the foreground, which has been grazed to maintain the pasture in the vegetative growth stage.

Photograph: M. Keys

from these pastures affects the ability of the grasses to replenish root energy reserves. Heavy grazing pressure on the regrowth could severely affect the density of the grass component, particularly under poor growing conditions, such as low soil moisture or poor nutrition.

Pastures should not be cut for hay or silage during the year of establishment. Forage production from the same paddock in successive years is also not advisable if the density of the perennial grass component is low.

4.4.3

Growth stage at harvest

The forage quality of temperate grasses falls quickly after flowering (see Figure 4.3). The optimum time to cut is a trade-off between quality and yield – at about the commencement of stem elongation for the grass component of the pasture mixture. Note that this is earlier than the ear emergence growth stage recommended for perennial ryegrass.

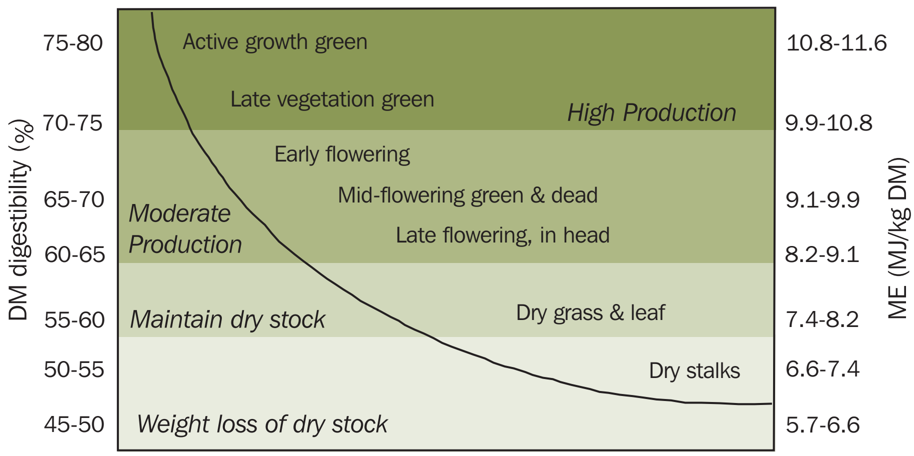
A pasture with a high legume component has a wider harvest window than a grass-dominant pasture. The higher proportion of legume slows the decline in forage quality when harvest is delayed.

A similar situation occurs in long-season areas where mild growing conditions encourage late tiller development of the pasture's grass component. The decline in quality of the grass component will be slower than in short-season areas where the harvest window is quite narrow.

Both these situations may apply if microclimates exist on the one farm. Areas of more fertile soil or those protected from harsh weather conditions will often have a prolonged production period.

Figure 4.3

As temperate grasses mature, forage DM digestibility and ME levels decline.



Source: Adapted from Bell (2000)

Closure dates and period of closure

The wide range of locations, seasonal conditions, growing conditions, pasture types and grazing pressures affecting the temperate grass/legume mixtures used for silage production in Australia makes pinpointing optimum dates or periods of closure difficult. Often the closure date coincides with when there is adequate pasture growth to support the grazing stock on the balance of the farm.

In the lower altitude zones, warmer spring growing conditions will produce good growth rates, with pastures reaching yield targets and the preferred growth stage for cutting about 6-7 weeks after closure.

Slower plant growth and the use of later-maturing varieties in the higher altitude zones requires a longer period of closure – about 8-10 weeks.

The earlier-maturing pastures, e.g. phalaris-based pastures, must be closed early enough to allow adequate growth before the onset of maturity. However, by closing a pasture too early there is a risk of the grass component reaching the preferred cutting stage too early in the season, when the risk of poor wilting conditions is greater.

A range of pasture mixtures of different maturities allows for a spread of closure and harvest dates.

Section 4.5

Forage ryegrass

Forage ryegrasses include annual, biannual, Italian, short rotation, *westerwolds* and *multiflorum* types. These ryegrasses are commonly sown as an annual forage crop, but may grow for two years. They usually have better seedling vigour and are more productive than perennial ryegrass in the year of establishment. Winter and early spring DM production is also usually greater than that of perennial ryegrasses.

The self-regenerating, annual Wimmera ryegrass forms an important component of subclover pastures in the temperate and Mediterranean zones of southern Australia. The management and cutting strategies to produce high-quality silage from these pastures are similar to those for forage ryegrasses. Silage production can reduce seed reserves of annual ryegrass and affect regeneration the following season (see Chapter 3, Section 3.2).

Ryegrass can be made into hay or silage. Hay making is governed by weather conditions, usually late in the season when the weather is warm and the ryegrass is mature. This hay is usually of poor quality. Silage, on the other hand, is made earlier, when the quality of the pasture is higher.

When surplus pasture is available, it is best to make silage from forage ryegrass and graze perennial ryegrass stands.

Forage ryegrasses do not contain the ryegrass endophyte that may be a concern with perennial ryegrasses (see Section 4.3.1).

4.5.1

Variety selection

Forage ryegrasses have a wide range of maturities, varying from early seeding varieties such as annual ryegrass, which may have seed heads emerging in September, through to very late seeding varieties, which may still be vegetative in December.

New varieties regularly become available as seed producers strive for high yields and better disease tolerance. Contact your local adviser for preferred varieties in your area.

Ryegrasses usually contain high levels of WSC, with forage ryegrasses higher than perennial ryegrass and tetraploid varieties higher than diploids. Tetraploid forage ryegrasses usually have higher WSC levels than other types of pasture and can be expected to have the most effective silage fermentation, provided adequate wilting is achieved.

While the maturity rating of varieties varies, the optimum growth stage to harvest for silage is consistently at the early head emergence growth stage (10-20% seed heads visible). Regions with irrigation or a long spring growing season can grow varieties with a range of maturities to spread their silage harvest season.

4.5.2

Management for silage production

- Fertilise as required ensuring good pasture nutritition; replace nutrients removed in forage harvested (see Table 4.2).
- Topdress with 50-70 kg N/ha to ensure rapid growth (see Section 4.3.2).
- Graze heavily, mulch, slash or mow back to a 5 cm stubble if required. Remove any heavy mulch to allow rapid, even regrowth and to avoid contamination of silage with dead or decaying material.
- Irrigate as required, if available.

4.5.3

Growth stage at harvest

The effect of growth stage on forage quality and yield is demonstrated in Table 4.7. The yield/quality compromise for forage ryegrasses is at 10-20% head emergence, shown in Plate 4.5.

Plate 4.5

The optimum growth stage to harvest ryegrass for silage is at early seed head emergence and is a compromise between yield and quality.

Photograph: N. Griffiths

Table 4.7

The effect of growth stage on quality and yield of forage ryegrass.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Vegetative (30 cm)	9.7-11.0	14.0-22.0	2.0-3.0
Boot or head emergence (45 cm)	9.0-10.5	12.0-20.0	2.5-4.5
Flowering	8.0-9.0	8.5-18.0	2.5-5.5
Mature seed	6.0-8.0	3.5-7.5	2.2-5.0

Section 4.6

Pasture legumes (clover, medics and high-density legumes) and mixed annual legume/grass pastures

Clover-dominant pastures are grown to produce very high-quality forage that can be grazed or conserved as hay or silage. Clovers are usually grown in a mixture with various grasses, although they may be grown as a pure sward. This applies particularly to the annual forage clovers such as Persian, berseem or arrowleaf, also known as high-density legume crops (HDLs) when sown at high seeding rates.

Clover silage is potentially of high quality, however, it requires a rapid and effective wilt. Despite their high forage quality, clovers tend to have low WSC content. They must be wilted to concentrate WSC to allow successful silage fermentation (see Chapter 2, Section 2.1.2).

Good-quality silage is usually easier to make when the pasture contains a mixture of clover and grasses. However, with good management excellent silages can be made from pure legume crops and pastures.

> There is no clear evidence of pure legume silage causing bloat. Although producers have reported that animals seem 'full', with distended rumens, this appears to be a result of high silage intake rather than gas production in the rumen.

Plate 4.6

Red clover.

Photograph: N. Griffiths

4.6.1

Species and variety selection

These comments provide a brief overview of characteristics of several species of clover. The late-maturing species are better suited to silage production than the early-maturing species. They have a longer growing season and reach the preferred growth stage for cutting later in the season when wilting conditions are more favourable. The late-maturing species are also likely to produce more regrowth after cutting. Obtain local advice for species recommendations.

White clover

White clover is a perennial, winter-active species. Survival over summer depends on water availability and temperatures. A surplus for silage is most likely to be available in late spring.

White clover is almost always sown in a pasture mixture. It can become dominant in some situations, for example, in spring when sown over a kikuyu pasture and on the northern Tablelands of NSW when good moisture conditions promote growth in spring.

All white clover varieties have high feed value. Erect, large-leaved types will develop a larger bulk and are more suitable for harvest as silage or hay than small-leafed, prostrate-growing varieties.

Red clover

Red clover is a short-lived perennial with more active summer growth than most white clover varieties. Red clover may be sown in a pasture mixture or as a pure stand. It is sometimes used as a short-term alternative to lucerne. Red clover is more erect and can produce a larger bulk of DM for harvest than white clover.

Persian clover

Persian clover (previously referred to as Shaftal clover) is an annual forage type clover, producing very high-quality forage. Persian clover will tolerate wet conditions and some waterlogging.

There are two subspecies of Persian clover. The major subspecies is late maturing with thick hollow stems and very low levels of hard seed. Varieties include Maral, Leeton, Laser and Lightning. These types tend to have an erect growth habit and high yield potential, suitable for silage production. They require a mower-conditioner to crush stems and increase the drying rate.

The other subspecies are earlier maturing, more prostrate in growth and are not as well suited to silage production. Varieties include Kyambro, Nitro and Prolific. They have high hard seed levels.

Persian clovers have been successfully grown alone or with forage ryegrass or oats.

Berseem clover

Berseem clover is a late-maturing annual forage clover with tolerance to wet conditions and some waterlogging. It has soft seed and is usually planted each year. Berseem is an alternative to the erect types of Persian clover in areas with a long spring growing season.

Subterranean clover

Subclover, the most widely grown annual clover in southern Australia, will tolerate moderate levels of soil acidity. The available varieties have a wide range of maturities and growth characteristics. Silage is more likely to be made from high-yielding, late-maturing varieties grown in regions with a long spring growing season. A silage harvest in the establishment year is likely to significantly affect stand density in subsequent years.

Plate 4.7

Berseem clover.

Photograph: N. Griffiths

Subclover is often grown in mixes with perennial or annual temperate grasses (see Sections 4.4 and 4.5). Potential DM yield is boosted by including a grass component with subclover.

Balansa clover

Balansa is an annual clover usually grown in pasture mixes. It is early maturing with very high, hard seed levels and good tolerance to disease and waterlogging. Balansa has a prostrate growth habit during winter followed by a period of rapid erect growth when flowering in spring. This rapid growth can produce a large bulk of forage suitable for conservation as silage or hay.

There is little potential for regrowth and seed set after harvest, even if balansa is harvested early in spring. Regeneration will depend on hard seed reserves from previous years. A silage harvest in the establishment year will limit seed production and is not recommended if the aim is for regeneration the following year.

Plate 4.8

Balansa clover.

Photograph: N. Griffiths

Arrowleaf clover

Arrowleaf clover is a late-maturing annual clover suited to well-drained soils. It is deep rooting and performs best in sandy or gravelly soils with neutral to acid pH. Arrowleaf clover can regenerate from hard seed. It can produce a bulk of spring growth suitable for storage as hay or silage. Thick stems can make drying difficult and require conditioning.

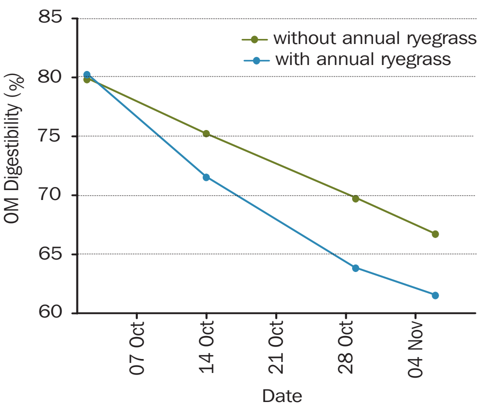
Crimson clover

Crimson is a soft seeded annual clover suited to a wide range of soil types, similar to subclover. It will tolerate some waterlogging but prefers well-drained soils.

Although not widely grown in Australia, crimson clover is an erect species, reputed to be well suited to silage making.

Figure 4.4

The effect of annual ryegrass content on organic matter digestibility changes in an HDL crop – arrowleaf, berseem and Persian clover, sown with and without Wimmera ryegrass (Wagga Wagga, NSW).



Source: Kaiser et al. (unpublished data)

High-density legumes (HDLs)

HDL is a mix of annual clovers, sown at high sowing rates, to provide a one or, potentially, two-year break crop in a cropping rotation. The term was first used to describe pure legume pastures, such as white clover, sown at high sowing rates in the dairying regions of Queensland and northern NSW.

Species commonly used in a mix are Persian, berseem, arrowleaf or balansa clovers. A total of 10-20 kg/ha of seed is desirable to maximise DM production. Because HDLs are often used as a break crop, cultivar selection is usually based on soft seed levels to prevent regrowth in the following crop. Cultivar selection will also depend on soil pH and drainage.

HDLs are used for grazing, silage, hay or green manuring. There may be potential for grazing prior to harvest if they are sown early and there is enough moisture for adequate growth. The high nitrogen input from HDLs, even after cutting for silage or hay, contributes to higher yields in the following cereal crop(s). Cutting HDLs for silage also provides a viable management option for herbicide-resistant weed problems in cropping rotations, provided cutting takes place before weeds set seed and there is no seed set from weed regrowth.

Figure 4.4 highlights the advantage of including legumes in grass/legume pasture mixes destined for forage production, as a means of improving quality and delaying the decline in quality as the pasture matures.

4.6.2

Management for silage production

- Most species benefit from early sowing to allow good growth before winter.
- Ensure adequate fertiliser rates at sowing; replace nutrients removed in silage (see Table 4.2).
- Control problem insects and weeds.
- Irrigate as required, if available.

4.6.3

Growth stage at harvest

The best time to harvest clover pastures for silage is at the early to mid-flowering growth stage. White and subclover can be harvested at mid or late flowering and retain very high forage quality.

Some of the forage types of clover such as red, berseem, arrowleaf, balansa and crimson will develop a higher proportion of stem and associated lower feed value if they are cut too late. With these species, cutting at the bud or an early flowering growth stage is preferred so as to maximise forage quality (see Table 4.8).

Table 4.8

Yield (t DM/ha), organic matter digestibility and crude protein of legume forage crops harvested at three stages of crop growth (Wagga Wagga, NSW).

Species*	2 October harvest			23 October harvest			6 November harvest		
	Yield (t/ha)	OMD (%)	Crude protein (% DM)	Yield (t/ha)	OMD (%)	Crude protein (% DM)	Yield (t/ha)	OMD (%)	Crude protein (% DM)
Karridale subclover	4.8	76	19.8	6.2	72	13.3	6.6	69	11.8
Balansa	5.7	83	16.7	6.6	72	13.6	6.2	65	10.8
Arrowleaf	4.7	79	20.6	7.5	73	15.2	7.3	66	12.4
Berseem	3.9	77	18.3	7.5	69	13.1	5.4	65	14.1
Murex medic	4.9	77	21.9	8.8	70	13.8	7.8	55	12.4
Barrel medic	3.7	78	20.0	3.7	71	15.5	3.8	50	12.7
Tetraploid ryegrass**	7.0	74	6.1	10.0	62	4.9	9.2	50.5	3.7

** All species were sown at high sowing rates.*

*** Tetraploid ryegrass – var. Richmond*

Source: Adapted from Dear et al. (unpublished data)

Section 4.7

Lucerne

Sodium supplements may improve animal production when the diet contains a significant proportion of lucerne silage.

Lucerne is the traditional, preferred summer-growing hay crop. However, lucerne silage is becoming more popular, particularly in cooler months and wet seasons when high losses are likely from attempts to make hay.

Lucerne silage is a high-quality forage. Silage has the advantage over hay of lower field losses, resulting in potentially higher digestibility and crude protein levels. Silage is removed from the paddock one or two days sooner after cutting than hay, allowing earlier irrigation and return to production.

4.7.1

Variety selection

There are numerous lucerne varieties available commercially, with varying growth patterns, disease resistance, insect tolerance and tolerance to a range of soil types, growing conditions and management regimes. Selection will depend on the variety best suited to the environmental and management pressures of each individual situation. Local advisers should be consulted for specific recommendations.

Plate 4.9

Lucerne can be cut for hay or silage when the first flowers are visible to optimise forage quality. Harvesting lucerne before flowering will increase forage quality but may shorten stand life. *Photograph: N. Griffiths*

4.7.2

Management for silage production

- Lime application is recommended, before sowing, if soil tests indicate soil acidity.
- Ensure good plant nutrition; replace nutrients removed in silage (see Table 4.2). Use split applications where high rates of fertiliser are needed.
- Control all weeds for pure lucerne silage, although some growers will use an early silage cut as a method of weed control. If the lucerne is harvested when the grass weeds are in boot or early heading growth stage they may assist silage fermentation.
- Control insect pests. Ensure that any insecticides being used are registered for use on crops to be cut for hay or silage and that withholding periods are satisfied before harvesting. A silage harvest may provide effective insect control, for example, late infestations of aphids or lucerne leaf roller.
- Beware of the potential to spread diseases when moving machinery to new paddocks.
- Lucerne may be oversown with forage ryegrasses or oats for silage production.
- Irrigate as required, if available.

Table 4.9

The effect of growth stage on forage quality and yield of lucerne.

Growth stage (plant height)	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Vegetative (30 cm)	10.0-11.0	22-28	0.75-1.4
Late vegetative – budding (45 cm)	9.0-10.0	18-24	1.2-2.4
Early flowering (50 cm)	8.0-9.5	15-22	1.5-3.2
Late flowering (60 cm)	6.0-8.0	6-15	1.8-4.0

4.7.3

Growth stage at harvest

Lucerne is best harvested for silage between full bud and commencement of flowering. In highly winter-active varieties, new growth from the crown is also an indicator that the crop is ready to cut.

An irrigated lucerne trial at Kyabram, Victoria, (see Figure 4.5) demonstrated that cutting at early flowering is a compromise, with yield continuing to increase and quality declining as lucerne matures.

The decline in forage quality with crop maturity applies equally to irrigated and dryland lucerne stands. Table 4.9 shows the range in yield, ME level and crude protein content, which can be expected over a range of growing conditions.

Cutting height

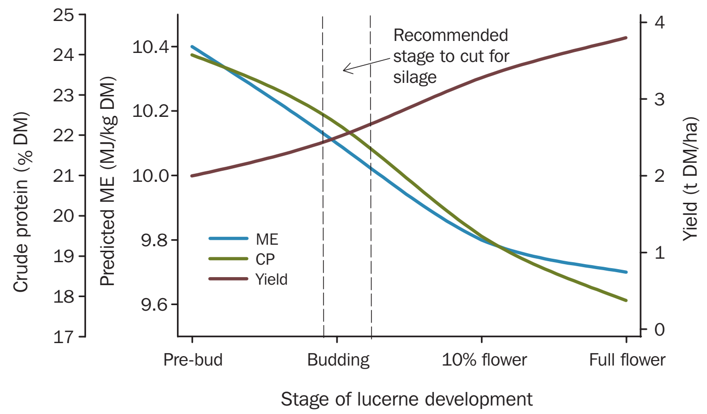
Cutting height for lucerne is usually set at 3-5 cm. Raising the cutting height will reduce yield and increase forage quality by increasing the ratio of leaf to stem. A taller stubble may improve regrowth but can contaminate the next harvest if cutting returns to a lower height. Cutting too low will damage the high crown of highly winter-active varieties, leading to disease infection and reduced stand life.

Cutting frequency and persistence

Although cutting early will improve quality of lucerne forage, frequent early cutting affects yield potential and stand persistence. The adverse effect of frequent, early cutting on stand persistence was demonstrated in the Kyabram study (see Table 4.10). As is the case with most perennial pasture species, the ability of a lucerne plant to recover after grazing or cutting, and to persist, depends on the level of carbohydrate reserves in the roots. If the plant is not allowed to progress to flowering at some stage of the growing season, root reserves will decline and long-term production and persistence is jeopardised.

Figure 4.5

The effect of growth stage on yield, ME content and crude protein level of lucerne harvested at Kyabram, Victoria.



Source: Adapted from Slarke and Mason (1987)

Table 4.10

The effect of cutting frequency on yield and persistence of lucerne stands after two years of harvesting at Kyabram, Victoria.

Growth stage	Total yield per season (t DM/ha)	Cuts/ season*	Relative plant frequency (%)
Pre-bud emergence	13.5	6.8	41
Budding	15.0	5.9	57
10% flowering	16.4	5.0	71
Full flower	16.3	4.3	73

** The number of cuts averaged over two seasons.*

Source: Adapted from Slarke and Mason (1987)

Section 4.8

Kikuyu grass

Kikuyu is the tropical grass most frequently conserved as silage in Australia. Managed correctly, it can produce large quantities of medium-quality silage (9-10 MJ/kg DM). Kikuyu has a relatively high crude protein level compared to other tropical grasses. Its low WSC content means wilting is essential to concentrate WSCs and improve fermentation (see Chapter 2, Section 2.1.2).

Harvesting kikuyu for silage has become a popular management tool to control excess growth (see Chapter 3). An autumn silage cut is an excellent preparation for over-sowing kikuyu pasture with ryegrass or clover.

Because kikuyu silage is usually only medium quality, it must be conserved cheaply to have a useful place in farm management. Nitrogen fertiliser, harvesting and baling are the main costs in making kikuyu silage.

Plate 4.10

For the best-quality kikuyu silage, graze hard then slash or mulch and remove old growth before fertilising for rapid, medium-quality regrowth.

Photograph: N. Griffiths

4.8.1

Management for silage production

- Ensure good plant nutrition to maintain vigorous pasture; replace the nutrients removed in silage (see Table 4.2).
- Topdress with 50-70 kg N/ha after closure to improve yield. Higher rates may produce economic responses if moisture is not limiting.
- Graze heavily, mulch, slash mow or forage harvest back to a 5 cm stubble, leaving the pasture free of trash for a quick, even regrowth. It is critical to remove any trash or rank growth that is likely to contaminate the silage and affect digestibility and the silage fermentation.

Over-sowing with white clover will improve the quality of forage from a kikuyu-based pasture. Kikuyu/white clover mixes need to be managed carefully, with cutting or strategic grazing, to prevent the kikuyu from becoming too dominant.

Depending on soil nutrient status, phosphorus, sulphur and/or potassium may be required to improve production from companion clover or over-sown winter grasses.

4.8.2

Growth stage at harvest

The best quality kikuyu silage is made from young, leafy growth, approximately 25-30 cm high, 25-35 days after closure (see Figure 4.6). A 20-day closure period is possible under ideal growing conditions.

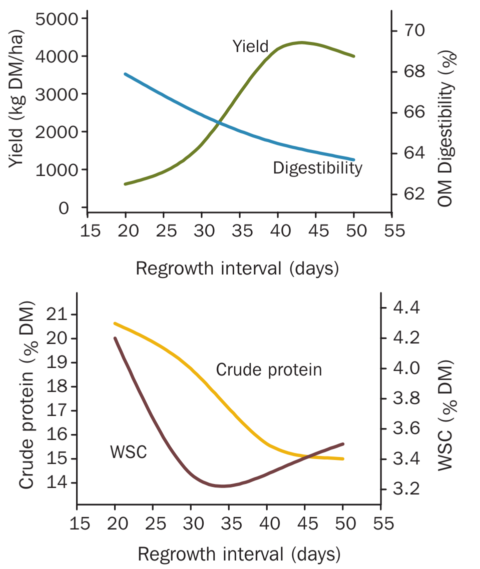
Delaying harvest past the recommended 25-35 day regrowth period results in a decline in energy and protein levels (see Table 4.11). Experience on the south coast of NSW indicates that organic matter digestibility falls at a rate of about 2.5 percentage units per week.

When kikuyu (or other tropical grasses) becomes rank, quality is low and its fibrous nature makes it difficult to compact in the silo.

Wilting requirement

Kikuyu's WSC content is well below the desired level of 2.5-3.0% in the fresh forage (see Chapter 2, Section 2.1.2). Therefore, a rapid wilt is recommended for successful preservation of the kikuyu forage. Aim for 35-40% DM for chopped bulk silage, or 35-50% DM for baled silage. The importance of wilting rate in silage production is covered in Chapter 6. If a rapid wilt is not possible, a silage additive, such as molasses, may be required (see Chapter 7, Section 7.4).

Figure 4.6



The effect of regrowth interval on yield, organic matter digestibility, WSC content and crude protein level of kikuyu harvested at Berry, NSW.

Source: Kaiser et al. (2000a)

Sodium supplements may improve animal production when the diet contains a significant proportion of kikuyu silage.

Table 4.11

The effect of growth stage of kikuyu on silage quality and potential yield.

Growth stage	ME (MJ/kg DM)	Crude protein (%)	Potential yield (t DM/ha)
Vegetative (25-35 days growth)	9-10	15-20	2.0-3.5
Late vegetative (40-50 days growth)	8-9	11-15	2.5-5.0
Rank (>50 days growth)	6-8	6-10	3.0-8.0

Section 4.9

Other tropical grasses

Tropical grasses such as setaria, paspalum, Rhodes grass, panic (Guinea grass) and pangola grass may be conserved as silage. However, good management is required to ensure the quality of the silage produced is good enough to make the exercise profitable.

Most tropical grasses can produce a large bulk of forage during their growing season. However, this bulk quickly becomes fibrous, with a low leaf:stem ratio and low nutritive value. Forage conservation is often difficult because the surplus growth is usually available in the wet season when it is difficult to predict the few fine days needed to cut and wilt the grass.

Plate 4.11

As with most tropical grasses, the quality of Rhodes grass falls rapidly as growth becomes rank and plants run up to head. *Photograph: M. Martin*

Currently, many producers opt to leave surplus pasture growth as dry standing feed, allowing stock to select the best diet they can from a large bulk of poor quality material. However, converting the excess feed into silage at a vegetative growth stage, before quality deteriorates, could improve livestock production.

A conservation strategy involving silage may also have a role in pasture management (see Chapter 3). Regular cutting of higher-quality forage, in conjunction with increased grazing pressure on other areas of the property, would prolong higher quality vegetative growth stage of the pasture.

A study at Lawes, in south-east Queensland, showed the potential value of this approach for several tropical grass species (see Table 4.12). When the grasses were cut at 28-day intervals, from October to March, the ME was maintained at a relatively high level (9 MJ/kg DM). When the grasses were left uncut and ungrazed, the ME values declined to very low levels over a 98-day period – from October to February.

When rapid pasture growth rate exceeds demand, it may be more beneficial to leave areas ungrazed and uncut to concentrate on maintaining maximum quality on a smaller area of the farm.

Table 4.12

The effect of cutting interval on estimated ME levels (MJ/kg DM) of five tropical grass species grown at Lawes, south-east Queensland.

Source: Adapted from Minson (1972)

Regrowth intervals	Setaria	Paspalum	Rhodes grass	Guinea grass	Pangola grass
28 days (average October to March)	9.2	8.5	8.9	8.8	9.0
28 days (from October close)	9.5	8.3	8.8	9.2	9.7
70 days (from October close)	7.9	7.2	8.1	7.3	8.2
98 days (from October close)	7.3	6.2	7.0	6.9	6.9

4.9.1

Management for silage production

There is a lot of debate about the profitability of silage production from tropical pastures. However, by concentrating on leafy forage, with a short regrowth interval, it should be possible to produce medium-quality silage with an ME content of 9-9.5 MJ/kg DM (see Table 4.12).

Additional economic benefits are likely through the strategic use of silage cutting as a pasture management tool (see Chapter 3). Silage cutting can be a worthwhile management strategy on improved tropical grass pastures, as has been proven with kikuyu.

- Fertilise to promote growth. Seek local advice.
- Prepare pasture by heavy grazing or mulching to remove rank, low-quality growth. It is essential to identify pastures earmarked for conservation early so they can be managed to avoid contamination of the silage with decaying grass.
- Perennial grass/legume mixtures may not be more digestible than early-cut grass, but crude protein levels are likely to be higher, which should result in an increased animal intake and production. The pasture's legume component is likely to decline with repeated silage harvests, although reports from the Northern Territory indicate Wynn cassia has thickened and become dominant after harvesting a mixed pangola grass pasture for silage for two or three years.
- After harvesting silage, return the pasture to the normal grazing rotation, unless another silage harvest is planned from the same area.

4.9.2

Growth stage at harvest

The major problem with silage production from tropical grasses is that they are often cut too late. It is worth sacrificing significant yield to produce silage of higher digestibility. It is preferable to cut forage before stem elongation commences, well before seed heads emerge. Less than 4 weeks growth is preferred for most pasture types.

The quality penalties suffered with late cutting of kikuyu (see Section 4.8.2), apply to tropical grasses in general. Table 4.13 shows the reduction in forage quality that can be expected if harvest is delayed.

The low WSC levels in tropical grasses makes wilting essential. However, it is important to avoid excessive wilting (see Chapter 2 and Section 4.8.2).

Tropical grasses are more fibrous than many temperate grass species, making silage compaction in a pit or a bale more difficult. Fine chopping or the use of a baler with chopping/cutting capacity can improve compaction.

Table 4.13

The effect of growth stage on ME and crude protein levels of three tropical grass species.

Species	Growth stage	ME (MJ/kg DM)	Crude protein (% DM)
Rhodes grass	Early vegetative	8.7	16.0
	Late vegetative	7.2	12.0
	Flowering/stemmy	6.5	9.0
Setaria	Early vegetative	8.7	16.0
	Late vegetative	6.5	10.0
	Flowering/stemmy	6.0	8.0
Paspalum	Early vegetative	8.5	17.0
	Late vegetative	7.8	12.0
	Flowering/stemmy	7.0	9.0

Source: Estimates from Camdairy®, Hulme et al. (1986)

Ammoniated forage

Ammonia is sometimes used to increase digestibility and preserve low-quality roughage, such as cereal straw (see Chapter 5, Section 5.3.4). This technique may also be effective with tropical grasses that have become rank.

Mature tropical grasses should be wilted to 55-75% DM before applying anhydrous ammonia or urea. (Urea must be mixed evenly at a rate of 40-50 kg/tonne of DM.) The forage is then packed and sealed to exclude air and prevent ammonia loss. The urea is hydrolysed to produce ammonia, which then reacts with moisture to form ammonium hydroxide. Unlike silages, ammoniated forages do not ferment and have a final pH of 9 to 10 (compared to a pH of about 4 for silages).

Ammoniation of tropical grasses requires further research and development to determine if, and where, it can be safely and profitably used in Australian agriculture. It must be noted that ammoniation of mature tropical grasses would only ever be a salvage exercise. The forage produced has only medium digestibility. Storing vegetative grass as silage is the preferred option.

Section 4.10

Hybrid forage sorghum

Fine-stemmed forage sorghums and Sudan grass hybrids are preferred for baled hay or silage, although most varieties can be used for chopped silage. Forage quality is usually only medium, but deteriorates rapidly if growth is not controlled and the crop is allowed become rank.

Although growing forage sorghums specifically for silage is an option when a large bulk of medium-quality silage is required, sweet sorghum is often preferred for silage production (see Chapter 5, Section 5.6). Surplus growth from forage sorghum crops grown for grazing may be ensiled in favourable seasons.

Sorghums have been grown with legumes, such as lablab, in an attempt to increase protein levels. The reduction in sorghum sowing rate required to enable the legume component to be competitive produces significantly lower yields. The yield penalty and management difficulties encountered when growing a blend of forage species makes the sourcing of an alternative protein component for the diet the preferred option.

Plant breeders have been able to improve the forage quality of forage sorghums using the brown midrib (*bmr*) gene. The *bmr* gene may reduce yields, but this disadvantage is usually outweighed by an increase in forage quality. The first commercially available *bmr* sorghum x Sudan grass hybrid was released in Australia in 2001.

Prussic acid poisoning can be a risk to animals grazing moisture-stressed sorghum crops in the vegetative growth stage. It is not likely to be a concern with forage sorghum silage, which is usually made in good growing seasons, when there is a forage surplus. Furthermore, up to 50% of the prussic acid is lost in the ensiling process (see Chapter 5, Section 5.5).

Hybrid forage sorghums and forage pennisetums

Forage type	Cultivars available	Uses
'Forage sorghum'		
Sudan grass (*S. sudanese*)	Open pollinated and hybrid	Dual purpose – multiple grazings and/or conservation (hay and silage) cuts.
Sorghum × Sudan grass (*S. bicolor x S. sudanese*)	Hybrid	Dual purpose – multiple grazings and/or silage cuts.
Sweet sorghum* (*S. bicolor*)	Open pollinated and hybrid	Generally single direct cut for silage, or grazed as a standover crop. Grain content varies.
Multiple purpose sorghum* (*S. bicolor*)	Hybrid	Often used for silage. Grain content generally high; low grain forage types are no longer widely grown. Can produce two cuts in northern Australia or can be used for various combinations of grazing, silage and grain. Similar to but often with a shorter growth habit than American 'forage sorghum'.
Grain sorghum*		
Conventional grain types (*S. bicolor*)	Hybrid	Shorter growing types selected for grain production but sometimes used for silage.
Forage pennisetum		
(*Pennisetum spp.* but mostly *P. americanum*)	Open pollinated and hybrid	Dual purpose – multiple grazings and/or silage cuts.

* Chapter 5 covers the suitability of these crops for silage production.

Source: Kaiser and Piltz (2002)

4.10.1

Management for silage production

- Good establishment requires soil temperatures at sowing depth to be above 16°C and rising, at 9:00 am.
- Ensure good plant nutrition; replace nutrients removed in silage (see Table 4.2).
- Graze or cut to ensure even regrowth.
- Topdress with nitrogen before closing for silage. Apply 50-100 kg N/ha per cut, for rapid recovery.
- Irrigate as required, if available.
- After cutting for silage, forage sorghum can be returned to grazing management or closed for another silage cut.

4.10.2

Growth stage at harvest

Harvesting when the crop is about 1 m high is a compromise between quality and quantity. Forage quality often drops quickly when forage sorghums exceed 1.2 m high or seed heads emerge.

Table 4.14 shows the effect of crop height and growth stage on potential yield and expected forage quality of forage sorghums. Table 4.16 gives the results of a trial comparing yield and quality of forage sorghum and millets.

Raising the cutting height can improve the quality of the forage harvested. However, disposal of the residue may create problems if a winter crop is to follow.

Inclusion of sulphur and sodium supplements in rations containing sorghum silage may improve animal production.

Plate 4.12

Brown midrib sorghum (a leaf is shown on the left) has the potential to produce higher quality silage than conventional forage sorghums.

Photograph: K. Kerr

Table 4.14

The effect of forage sorghum growth stage on silage quality and potential yield.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Vegetative (60 cm)	9.5-10.0	12-18	1.0-2.5+
Vegetative (100 cm)	9.0-9.5	7-17	2.0-5.0+
Vegetative or heading (>200 cm)	7.0-8.0	4-11	6.0-12.0+

Section 4.11

Millet and forage pennisetum

Many millets can be grown for forage, with the option to graze or cut and conserve any surplus. These include Japanese (*Echinochloa esculenta* cv. Shirohie), white pennisetum or Siberian (*Echinochloa frumentacae*) and forage pennisetum (formerly referred to as pearl millet).

Millets are usually cheaper to grow than forage sorghums and should produce higher-quality forage, although they do not have the yield potential of the forage sorghums. Seek local advice regarding the best performing millets for your area.

Plate 4.13

To produce high-quality forage from forage pennisetums (pearl millet) they should be cut before seed heads emerge. *Photograph: N. Griffiths*

4.11.1

Management for silage production

- Sowing requirements depend on variety; seek local advice.
- Japanese and Siberian millets tolerate waterlogging; forage pennisetums do not.
- Japanese millet can be planted early in spring, when morning soil temperature at 10 cm is at least 14ºC.
- Siberian millet and forage pennisetums (pearl millet) need warmer conditions for best growth. They should not be planted until morning soil temperatures are at least 18ºC.
- Fertilise as required; replace nutrients removed in silage (see Table 4.2).
- Depending on variety, millets should be grazed early to encourage tillering. Early-maturing varieties will thin out severely if grazed late, and the crop is tall.
- If grazing, topdress with nitrogen fertiliser at 50-100 kg N/ha at closure.
- If not grazing, ensure that adequate nitrogen is applied at sowing or by topdressing after establishment.
- To maximise regrowth potential and total forage yield Japanese millet must be kept in a vegetative growth stage.
- If regrowth is required from forage pennisetums, leave high stubble when cutting (15-20 cm). Other management requirements for forage pennisetums are similar to those for forage sorghums.
- Being finer stemmed than sorghum, the residue of millet crops is more easily managed when preparing for a winter crop.

Table 4.15

The effect of growth stage of Japanese and forage pennisetums on forage quality and yield.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Japanese/Shirohie millet:			
Vegetative	9.0-10.0	8.5-18.0	1.0-4.0
Heading/flower	8.0-9.0	7.0-15.0	2.0-6.0
Milk/dough-grain	6.0-8.0	5.0-11.0	2.5-8.0
Forage pennisetums (pearl millet):			
Vegetative	9.0-10.0	10.0-18.0	1.0-5.0+
Heading/flower	7.5-9.0	7.5-10.0	2.5-10.0+

4.11.2

Growth stage at harvest

Because most millets produce low grain yields, harvesting at mature growth stages is likely to produce a bulk of lower-quality forage. Ideally, forage should be harvested before seed heads emerge.

Table 4.15 shows the potential yield and probable ranges in quality of Japanese and forage pennisetums, harvested at various growth stages. Actual values will vary between varieties.

The results from a forage study at WaggaWagga, NSW, (see Table 4.16) highlight the differences between Japanese millet, forage pennisetums and forage sorghums.

No detailed information is available for Siberian millet, although experience in northern NSW and Queensland suggests good ‘palatability’, high yield potential and good regrowth after grazing.

Table 4.16

Yield and nutritive value of irrigated summer crops harvested at three stages of growth.

Crop	Stage of harvest	Days from sowing	Crop height (m)	Yield (t DM/ha)	OM Digestibility (% DM)
Forage sorghum	Vegetative	53	1.3	4.0	67.5
(Speedfeed)	Early flower	66	1.7	9.4	64.8
	Late dough	89	2.0	18.0	61.6
Japanese millet	Vegetative	53	0.6	3.2	66.3
(Shirohie)	Early flower	67	1.1	6.9	66.1
	Late dough	89	1.2	10.1	62.5
Forage pennisetum	Vegetative	67	1.0	6.8	69.3
(Supermill)	Early flower	82	1.7	10.3	65.6
	Late dough	103	1.9	17.1	64.4

Source: Kaiser (unpublished data)

Section 4.12

Cowpeas, lablab and summer legume crops

Summer-growing forage legumes such as cowpea and lablab are useful in rotations as a source of high-quality summer forage. They are best grazed, but can be conserved as silage if surplus forage is available. Grain legumes such as mung bean and adzuki bean can also be conserved as silage but will be lower yielding than the forage crops. These grain crops would only be conserved as silage or hay as a salvage operation if they were not expected to produce a satisfactory grain yield.

Until improved summer or tropical legumes are available, soybeans are the preferred summer legume if a legume crop is to be grown to make silage. Soybeans are discussed in detail in Chapter 5, Section 5.7. Table 4.17 compares the estimated yield and forage quality for cowpea, lablab and soybean crops.

Summer legumes can be made into hay, but they are often very difficult to dry adequately, with high leaf and pod loss a problem. Consequently, silage is a better alternative. Most legume crops have a relatively low WSC level and high buffering capacity, which means they must be wilted to achieve acceptable silage fermentation.

Plate 4.14

Cowpeas. *Photograph: N. Griffiths*

Table 4.17

Yield and quality comparisons between cowpea (at two growth stages), lablab and soybeans.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Cowpea – early flower	9.0-10.5	14-18	1.5-3.0
Cowpea – pod full	8.0-9.5	9-14	3.0-6.0
Lablab	7.0-10.5	12-18	3.0-8.0
Soybean	8.0-9.5	15-20	4.0-10.0

TOPFODDER

Table 4.18

Forage quality at 70 days after sowing (DAS) and at commencement of flowering for lablab accessions grown at Grafton, NSW, compared to the commercially available varieties Highworth and Rongai.

	Lablab accessions			Highworth	Rongai
	Minimum	Maximum	Mean		
Days from sowing to flowering	40	137	89	114	133
70 DAS:					
Crude protein (% DM)	11.6	23.4	16.7	16.5	16.9
70-day DM digestibility (%)	59.6	76.5	68.5	66.8	66.0
70-day ME (MJ/kg DM)	8.2	10.6	9.5	9.2	9.1
Flowering growth stage:					
Crude protein (% DM)	7.9	19.3	13.9	14.0	12.1
DM digestibility (%)	61.4	78.3	68.9	72.8	72.4
ME (MJ/kg DM)	8.7	11.1	9.8	10.1	10.5

Source: Desborough (unpublished data)

4.12.1 Species and variety selection

Although there are only a small number of lablab and cowpea varieties commercially available, trial results indicate the promising potential of some of the recent selections. The results in Table 4.18 demonstrate the quality advantages of some lablab accessions over the currently available varieties.

Table 4.19 shows the yield advantage of later-maturing cowpea varieties, Caloona and Meringa, and the potential of the phytophthora-resistant (PRFC) selections. The quality penalty suffered by delaying harvest until podding is clear from the data. However, the low yields at the earlier growth stage means an early harvest is not likely to be economically feasible.

4.12.2 Management for silage production

- Variety selection and sowing time depend on location; seek local advice.
- Fertilise to ensure good plant nutrition.
- Inoculate with the appropriate rhizobia inoculant at sowing.
- Cowpeas or lablab may be grazed and then closed for silage, although a one-off silage harvest should give higher yields.
- These crops do not recover for further grazing after harvest.

Table 4.19

The DM yield, crude protein content and DM digestibility ranges of 10 cowpea selections 50 days after sowing (DAS) and at podding, compared with the commercially available varieties Red Caloona, Banjo, Caloona and Meringa, at Grafton, NSW.

Growth stage	Red Caloona	Banjo	Caloona	Meringa	Range for PRFC selections
50 DAS:					
Yield (t DM/ha)	2.1	2.7	1.8	2.3	1.5-2.1
DM digestibility (%)	76.4	80.8	75.3	74.5	76.0-77.1
Crude protein (% DM)	14.4	14.4	16.4	17.0	16.2-18.8
Podding growth stage:					
Yield (t DM/ha)	3.7	4.8	5.5	6.5	4.9-6.3
DM digestibility (%)	68.3	73.3	64.7	65.4	66.4-69.7
Crude protein (% DM)	14.8	12.0	15.1	14.0	12.5-13.9

Source: Desborough (unpublished data)

4.12.3

Growth stage at harvest

The early flowering growth stage is the preferred time to harvest cowpeas and lablab for high-quality silage production. However, yields are likely to be low. Delaying until the mid-pod-fill stage will increase yield potential, although there is a quality decline as the plants mature (see Table 4.19).

Cowpeas produce moderate levels of DM at podding, the recommended growth stage for harvest, but protein levels at that growth stage are low compared with other forage legumes.

The vines of late-maturing lablab can be very long and tangled, making harvesting difficult. Risk of leaf loss is also a problem in late-harvested cowpea and lablab crops.

Although forage legume crops may be made into baled silage, it is not the preferred option for species or varieties with tough stems. These are difficult to compact and easily puncture the plastic wrap. If baling is the only option, ensiling will be more successful if a baler with a chopping mechanism is used and forage is baled at high density. Chopping the legume forage will improve the rate of sugar release, thereby improving the fermentation process.

Chopping the forage also reduces leaf selection by livestock at feeding.

Plate 4.15

Lablab. *Photograph: N. Griffiths*

Chapter 5

Crops and by-products for silage

Chapter 5

Crops and by-products for silage

In this chapter

The authors

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Key Issues ... see Page 2

Section 5.0

Introduction

The crops covered in this chapter produce one silage cut only, with little chance of regrowth for grazing. Therefore, all growing and harvesting costs must be included when assessing a crop's potential for silage production.

Specific agronomic information for each crop type is not included. Seek local advice on issues such as varieties, fertiliser recommendations and irrigation, weed, disease and pest management strategies.

All high-yielding forage crops have high plant nutrient requirements. Tests are needed to check the nutrient status of the soils. The nutrient removal data in Table 5.1 provides a guide to ensure adequate fertiliser is applied to produce high forage yields and sustain long-term production.

If crops need to be mown prior to harvesting for silage, measures must be taken to minimise the risk of soil contamination during harvesting. Soil contamination may introduce undesirable micro-organisms that can affect the ensiling process and increase storage losses. Rolling uneven seedbeds at the time of sowing will reduce the amount of soil picked up by harvesting equipment.

The use of chemicals on forage crops should be carefully monitored. Withholding periods (WHPs) on chemical labels must be observed to avoid the risk of unacceptable chemical residue levels in silage. Produce from livestock fed silage with unacceptable residue levels is unsuitable for human consumption. Sections 4.2.6 and 5.8.1 discuss the importance of WHPs.

Table 5.1

Approximate levels of nutrients removed in forage DM harvested (kg/t DM).

Crop	Nitrogen	Phosphorus	Potassium	Sulphur	Calcium	Magnesium
Maize[1]	10	1.8	9.8	1.0	1.6	1.7
Whole crop cereal	24	3.0	20	2.5	3.0	3.0
Sweet sorghum	28	3.0	20	2.5	3.0	3.0
Soybeans	35	3.0	25	2.0	13	4.0

Source: [1] Kaiser and Piltz (1998a). Other data derived from various computer databases

The Key Issues

- To maximise economic returns, the crops grown specifically for silage production should be high yielding and produce a high-quality forage.
- The nutritive value of silage varies with the species conserved and the stage of growth at which it is harvested.
- Attention to agronomic detail is required to achieve yield potential and satisfactory economic return.
- Timely harvest and good management of the forage prior to storage will maximise the quality of the forage.
- By-products are residues from the agricultural and food processing industries. They may be available in large quantities in some areas for a limited time of the year. Most plant by-products can be stored as silage, if adequately compacted and stored under anaerobic conditions.
- The nutritive value of by-products must be sufficiently high to make their conservation as silage economically feasible. They should be stored at a DM content that favours good silage fermentation and minimises the risk of environmental pollution from silage effluent.
- The nutrient levels (including minerals) in all by-products should be checked to ensure that their inclusion in a diet does not cause a nutrient deficiency or imbalance.
- Care is needed to ensure that crops and by-products do not contain unacceptable chemical (or heavy metal) residues. Obtain a Vendor Declaration or a written record of their chemical status.

Section 5.1

A comparison of crops suitable for silage production

Table 5.2 summaries the characteristics of the crops most commonly grown for silage production and highlights key targets needed to produce high-quality silage. Many producers are losing production potential because of poor silage-making practices. This is highlighted by the huge range in the quality of silages being produced (see Chapter 12, Appendix 12.A1).

Table 5.2

Yield and quality potential of crops grown for silage production, identifying requirements to ensure quality silage.

Crop characteristics	Maize	Whole crop winter cereal Oats	Whole crop winter cereal Wheat & Barley	Whole crop winter cereal /legume mixtures	Grain sorghum	Sweet sorghum	Soybeans
Growth stage at harvest	milk line score 2-3	boot to flowering	boot or mid-dough	boot to dough of cereal component	milky dough (middle of head)	head emergence to dough	65% pod fill
Potential yield[1] (t DM/ha/cut)	12-25	5-15		5-15	4-10	10-25	4-10
Potential number of cuts per year	1	1		1	1	1	1
Wilting requirement	no	boot yes/dough no		yes	no	no	yes
Target range DM content (%)							
Chopped	33-38	35-40		35-40	30-35	25-35	35-40
Baled	NR	35-50		35-50	NR	NR	35-50[4]
ME[2] (MJ/kg DM)	10-11	9-10.5		9.5-11	9.5-10.5	9-10	8-9.5
Crude protein[2] (% DM)	4.5-8.5	6-16		8-18	6-9.5	4-8	15-20
Ensilability[3]	***	boot **/dough ***		**	***	***	*
Suitable for chopped bulk silage	yes	yes		yes	yes	yes	yes
Suitable for baled silage	no	yes		yes	no	no	yes[4]

1. *Yields at the higher end of the range can be obtained with irrigated crops or crops grown under ideal growing conditions.*
2. *These ME (metabolisable energy) and crude protein levels are achievable with good management. See Glossary for definition of ME.*
3. *Ensilability is the likelihood of achieving a good silage fermentation without wilting or a silage additive. (* Low, ** Medium or *** High).*
4. *Baled silage is not the preferred option for soybeans (see Section 5.7.3).*

Section 5.2

Maize

Maize is a premium silage crop, producing a large bulk of high-energy forage. It is expensive to grow and requires good management to produce high yields of high-quality product. The economic viability of maize silage is very dependent on yields and energy values. The major limiting factors are poor weed and insect control, inadequate fertiliser, low plant populations or adverse seasons.

Most maize varieties used for forage production have a growing period of 100 to 150 days. Prolonged ground preparation and sowing periods will affect variety choice. The crop requires specialist row-crop planting and harvesting equipment and is suitable only for chopped silage stored in a pit or bunker. A maize crop intended for silage can be harvested for grain if circumstances change.

Maize should be grown in rotation with lucerne or another suitable crop or pasture to reduce the build-up of insect, disease and weed problems.

Plate 5.1

Maize can produce high yields of high-energy forage. *Photograph: N. Griffiths*

5.2.1

Hybrid selection

Select hybrids with high potential forage yield, good forage quality and adequate disease tolerance. Refer to local recommendations, taking into consideration the following:

- The forage quality of leaves and stems (the stover) may vary between hybrids, although hybrids with the highest grain yield usually have the highest overall forage quality. If information is available, select hybrids with highest whole-crop forage quality. This will maximise animal production potential.
- Medium-maturity (early-mid to mid-season) varieties are usually preferred. Late-maturing hybrids (>130-135 days) tend to have lower digestibility and occupy the ground for longer. Early-maturing hybrids usually have lower yield potential, but higher quality, due to a higher grain content (see Table 5.3).
- Early-maturing hybrids have a role where a short growing season is expected due to rotation requirements, sowing time, poor subsoil moisture, or the risk of frost or wet weather at harvest. Higher plant populations may partially compensate for their lower yield potential.

Table 5.3

Effect of hybrid maturity group on the organic matter digestibility and ME content of forage maize harvested at a MLS of 2-3 in two experiments at Nowra, NSW.

Adapted from Kaiser and Piltz (2002)

Maturity group (mean days sowing to harvest)	Experiment 1 No. of hybrids	Experiment 1 OM Digestibility (%)	Experiment 1 ME (MJ/kg DM)	Experiment 2 No. of hybrids	Experiment 2 OM Digestibility (%)	Experiment 2 ME (MJ/kg DM)
Early (115 days)	3	69.3	10.3	4	69.7	10.4
Mid-season (126 days)	10	67.1	10.0	10	67.2	10.0
Late (143 days)	3	66.7	9.9	9	62.8	9.3

- ➤ Some hybrid selections have a stay-green characteristic: they retain green leaf and do not dry as quickly as other varieties. This may be an advantage in providing a wider harvest window so that the crop may be harvested at optimum DM content. However, it can be a disadvantage late in the season when there are harvest delays while waiting for the crop to dry. Limited data suggests that stay-green varieties have lower stover digestibility.
- ➤ Brown midrib hybrids will be an advantage for animal production if selections become commercially available. Introduction of the brown midrib gene reduces the plant's indigestible fibre content.

The yield and quality potential of the maize forage is limited by the choice of hybrid. Figure 5.1 highlights some of the environmental and management factors that also influence the yield and quality. Under good growing conditions maize has potential to produce high yields of high-energy silage. Where rainfall is unreliable, sorghum may be a better option.

5.2.2

Crop management for silage production

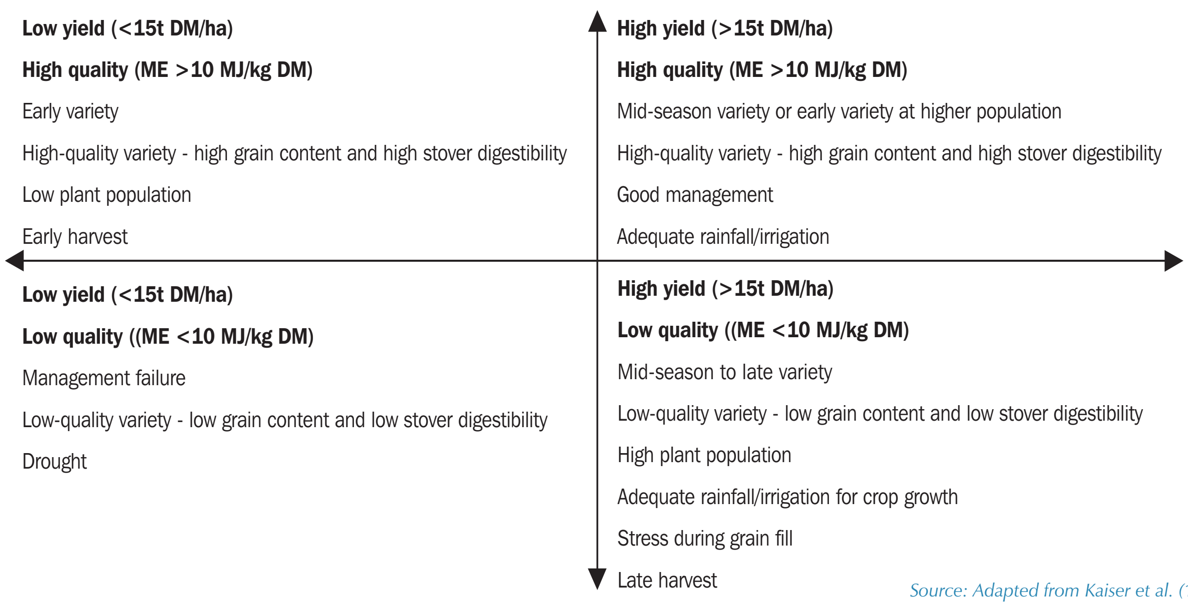
Plant population

Silage maize crops are usually planted with a 10-20% higher population than a maize grain crop. A plant population of 65,000 plants/ha is adequate for most forage crops.

Yields can be increased by raising the population to 80,000-90,000 for early maturing varieties, or medium-maturing varieties under irrigation or ideal growing conditions. However, there is a risk of reduced forage quality due to lower grain production where very high populations are used. Most varieties also show a greater tendency to lodge at higher plant densities.

Figure 5.1

Varietal, environmental and management factors which can each influence yield and ME of a maize forage crop.



Source: Adapted from Kaiser et al. (1993)

Row spacing

Maize is usually sown at a 750 mm row spacing. Yield increases of approximately 4% have been achieved with 375 mm row spacings, without altering plant populations. Under ideal growing conditions, where moisture and nutrients are not limiting, closer row spacing may also allow an increase in plant population and higher yield potential. Note that conversion to narrow row spacings requires modifications to sowing and harvesting machinery.

Sowing details

- Do not sow maize until soil temperature is at least 12ºC and rising. Temperature should be taken at 9:00 am on three consecutive mornings at planting depth. Germination and establishment will be faster with warmer soil temperatures.
- Sow into good soil moisture, at correct depth. Correct sowing depth varies depending on soil type, grain size and soil moisture.
- Follow local recommendations for fertiliser requirements. Table 5.1 provides a guide to the quantities of nutrients removed from a paddock when a maize forage crop is harvested.
- Weeds are controlled by inter-row cultivation or use of pre-plant or pre-emergent herbicides. Ensure that herbicide residues do not affect other crops or pastures grown in rotation.
- Monitor crops for insects and control if necessary. Crop establishment can be adversely affected by insect damage, particularly by African black beetle.
- Ensure all herbicides and insecticides are used according to the label guidelines.
- Irrigate as required, if available.

5.2.3

Growth stage at harvest

The milk line score (MLS) describes the maturity of the grain in the cob. Unless the crop is severely drought affected, it is a reliable indicator of crop DM content and the ideal stage to harvest maize silage.

The MLS varies from 0 (no visible milk line at the tip of the kernel) to 5 (the milk line reaches the base of the kernel and a black or brown layer forms across it). At this stage, the crop is at physiological maturity and grain filling is complete. Under most circumstances, MLS progresses one unit in 7-10 days.

At MLS 2.5 the milk line is halfway down the grain (see Plate 5.2). This is the best stage to harvest maize for silage as there is a good balance between yield, quality and ensiling characteristics. The DM content of the forage should be 33-38%.

A milk line score of 2.5 often coincides with the cob husk turning from green to white, dying-off of lower leaves and denting of grain. However, these indicators will vary depending on hybrid selection and growing conditions.

Table 5.4 shows the variations in yield, DM, grain content, crude protein and ME levels that can be expected at different MLSs.

Many producers, concerned about a risk of wet weather, harvest too early. In this case, DM content is likely to be too low to ensure successful ensiling. There is a risk of lower yield and grain content, poor fermentation and effluent losses, resulting in lower quality silage. These problems are likely to occur if the crop is harvested at MLS 1 and DM is <28%. Producers who regularly harvest crops too early should consider growing early-maturing hybrids.

If harvest is delayed to physiological maturity (MLS 5) or until the crop DM is >38%, the chopped material will be difficult to compact, resulting in poor fermentation and poor quality silage.

For planning purposes, most varieties will be ready to harvest about 50 days after mid-tasselling.

Plate 5.2

Cob of corn showing milk line score 2.5. Aim to harvest with a 2.5 milk line score. Note: When assessing MLS ensure the glumes at the base of the kernel are pushed back to expect the full kernel.

Photograph: P. Stuart

Potential yield and forage quality of maize forage cut at MLS 2 to 3 achievable under good management.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Milk line halfway (milk line score 2-3)	10-11	4.5-8.5	12–25

Table 5.4

The relationship between MLS and forage maize yield and composition for early and mid-season variety, dryland maize crops grown at Nowra, NSW.

	Milk Line Score at harvest				
	>0-1	>1-2	>2-3	>3-4	>4
Yield (t DM/ha)	15.7	16.9	16.7	18.0	16.0
DM content (%)	27.3	29.8	33.2	39.1	44.0
Grain content (% DM)	33.4	39.7	42.8	45.8	48.0
Crude protein (% DM)	7.2	7.1	6.9	6.7	6.6
ME (MJ/kg DM)	10.3	10.2	10.1	10.0	9.8

Source: Adapted from Piltz (1993)

5.2.4

Harvesting the crop

Cutting height

Cutting close to the ground will increase the DM yield of a crop. However, raising the cutting height improves the quality of harvested maize forage, mainly due to an increase in grain content.

Nominating an optimum cutting height is difficult considering the large variations in varieties and growing conditions. As a guide, raising cutting height from 15 cm to 45 cm is expected to reduce yield by up to 15% and increase digestibility by 2% units.

Cutting too high can create residue disposal problems if another crop is to be sown soon after harvest. However, it can be a useful option to avoid weed contamination that would otherwise reduce the silage quality.

Plate 5.3

Fine-chopped maize is easily compacted. *Photograph: K. Kerr*

Chop length

Maize is usually harvested with a precision-chop harvester set at a 5-10 mm *theoretical* length of chop (TLC). However, the accuracy of the machine settings is highly variable. Producers should calibrate their machines and aim for an *actual* chop length of 10-15 mm for most particles. Very fine chopping will crack more grain, but increase power requirements.

If harvesting is delayed and crop DM is >38%, chop length should be as fine as possible to aid effective compaction. In some dairy diets, fine chop length reduces the effectiveness of fibre. However, if fibre content is a concern, there are effective alternatives to solve this problem without resorting to an increase in chop length (see Chapter 13, Section 13.4.2).

If forced to harvest early, when the DM is <28%, adequate compaction can be achieved with a longer chop of 15-20 mm. However, harvesting at low DM is not advisable and can result in poor fermentation and unacceptable effluent losses (see Chapter 2, Section 2.1.1).

Grain processors

Grain processors are designed to increase the amount of grain cracked during harvesting, with the aim of improving digestibility of the grain component of the silage. They are most effective with hard grain hybrids, longer chop length or with crops cut at a more advanced stage of maturity.

It has been argued that grain processors allow a longer chop length (with most particles >20 mm) while still cracking some grain. The longer chop length has the advantage of increasing the effectiveness of the fibre component in some dairy diets, while cracking the grain improves grain digestibility. However, unless the DM is unacceptably low (<28%), long chop length will cause compaction problems and is not recommended. Poor compaction will result in poor fermentation, higher in-silo losses, lower quality silage and increased risk of aerobic instability (see Chapters 2 and 10).

Results of studies investigating the digestibility of the grain fraction in maize silage fed to young cattle are presented in Chapter 14, Section 14.2.5. These demonstrated that poor digestibility of the grain fraction of maize silage was not a problem with short chop length. The forage harvester used in these studies was set at a TLC of 4.2 mm and produced an actual chop length with most particles in the range of 5-20 mm, with 74% of grain damaged. When the resulting silage was fed, the digestibility of the remaining whole grain was 97%. Similar results were noted in other studies with dairy cows.

Comparing grain yield to forage yield

An economic comparison of maize grain yield and silage production is worked through in Chapter 11, Section 11.4.1. Calculations are based on harvested grain moisture content of 14%. The grain yield of a maize crop is approximately 55% of the forage DM yield. Therefore, a crop that yielded 10 t/ha of grain would have produced about 18 t/ha of silage DM. Alternatively, a crop that produced 10 t/ha of silage DM would have yielded 5.5 t/ha of grain.

For other grain versus silage yield comparisons, see Chapter 11, Figure 11.2.

Ensiling high-moisture maize grain and earlage

High-moisture grain and earlage may be a more economic alternative to harvesting the whole maize crop if the storage site is a long distance from the growing site.

High-moisture grain

High-moisture grain is harvested soon after the maize reaches physiological maturity (MLS 5). This is usually 2-3 weeks after the normal silage harvest and one month before the normal grain harvest. The ideal DM content of the grain for storage is 68-72%, with an acceptable range of 65-74%.

A propionic acid-based additive is desirable to avoid mould development. The grain must be processed or rolled for effective compaction and fermentation.

Earlage

Earlage production involves chopping whole cobs, without the stem and leaves. This forage is then treated in the same manner as maize silage. The ear is harvested when the grain DM content is 65-74% (with an ideal range of 68-72%). Processing and ensiling difficulties occur when the grain is too dry.

Maize ensiled as earlage provides a high value alternative stockfeed to conventional silage or grain. It is more commonly used in beef feedlots.

5.2.5

Ensiling stressed crops

Drought-stressed maize crops

Four or five days of visible moisture stress will reduce the yield potential of a maize crop. However, drought-affected maize crops can be successfully ensiled.

The effect drought has on yield and forage quality will depend on the timing and severity of the moisture stress:

- Moisture stress throughout the growing period reduces yield, grain content and digestibility.
- Moisture stress during grain fill will probably produce acceptable yields, but with reduced grain content and digestibility.
- Moisture stress during the vegetative growth stage, followed by good conditions during grain fill leads to reduced yield, but increased grain content and increased digestibility.

Drought-stressed maize can be harvested at a DM content of 30-40%. Harvest should be delayed if there is a chance of rain and the crop still has green leaf. While plants have green leaf there is a possibility of recovery and increased DM yield.

If harvesting a drought-affected crop early for silage, ensure the withholding period for any insecticides or herbicides used on the crop have been satisfied.

When a crop grown with high nitrogen inputs becomes drought stressed, nitrate poisoning may be a risk if the crop is grazed or green chopped. Ensiling the crop reduces this risk. Nitrate concentrations in silage will be reduced by an estimated 40-60% within 3-4 weeks of storage. Nitrate levels are highest in the lower, older parts of the plant, so if poisoning is a concern the risk can be reduced by raising the cutting height of the harvester.

Because drought-affected crops can have highly variable nitrate, protein and ME levels, it is advisable to test the ensiled material before feeding.

Maize is not recommended for marginal rainfall environments and is not an option where there is a risk of a dry finish. In these circumstances sorghums may be a better alternative in the silage program.

Frosted maize crops

Frost is often an issue when the crop is sown too late or when a late maturing variety is sown. An early frost may stop plant growth but the crop can still be ensiled. A killing frost will prevent further grain fill, which may reduce feed quality, but it can also speed up drying of the crop.

Frosted maize must be allowed to dry to at least 30% DM. Harvesting too early will lead to wet silage, which is often unpalatable and of poor quality. If allowed to dry too much (>38% DM), compaction may be difficult, also resulting in a poor-quality silage.

When testing DM content, the whole plant must be chopped and a sample dried in a microwave oven (see Chapter 6, Section 6.4.2). Leaves may look brown and dry but stems may still contain significant moisture.

Flooded crops

Flooding can affect maize and other crops in various ways that can have important implications in silage production. This is covered in Chapter 8, Section 8.6.

Section 5.3

Whole crop winter cereals

Oats, wheat, barley, triticale and cereal rye can all be made into silage. Depending on variety and management, they may be grazed prior to closure for silage. If conditions change, these crops can be harvested for grain.

Forage quality will vary, depending on variety, management and growth stage at harvest. Forage quality can be improved by sowing with a legume. Early sown cereal/legume mixtures can include a clover, and may be grazed, while later sown crops can include field peas or vetch, suitable for one harvest only.

Cereal crops are often used for hay production. However, as shown in Appendix 12.A1, the potential quality of the equivalent silage is significantly higher.

5.3.1

Species and variety selection

The choice of species and variety to grow for silage is complex. The large variations in harvest index (the ratio of grain to leaf and stem) between species and varieties, makes it difficult to make broad recommendations. Not only are research data for Australian varieties limited, most cereal silage research in Australia has been conducted on oat crops. More work is needed to assess the silage value of recently released varieties of all cereals.

The preferred varieties are forage types with superior forage yield and digestibility. Varieties with high forage production should be an advantage if the requirement is for a high digestibility, early-cut silage. Grain yield potential becomes a consideration if the requirement is for a larger bulk of high energy silage, which can be produced from cereals harvested at the dough stage. This later silage cut has the advantage of requiring no wilting, being suitable for direct cut (see Table 5.2).

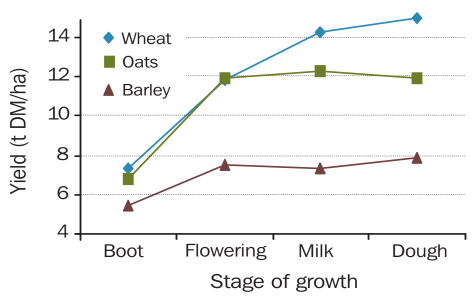
The relative whole crop yields of oats, barley and wheat were investigated in a trial in South Australia, in 1977 (see Figure 5.2). These and other trial results suggest that oats is the preferred option for early-cut, wilted silage, with wheat, barley and triticale likely to produce higher energy silage than oats if harvested at the dough stage. The varieties used in the 1977 experiment were not all forage types, which would explain the relatively low yield of barley seen in Figure 5.2.

Of the cereal varieties investigated to date, late-maturing forage oat varieties have consistently produced higher forage yields late in the season. They are at the recommended growth state for harvest (boot to ear emergence) when wilting conditions are likely to be more favourable.

The main emphasis in most cereal breeding programs has been grain, rather than forage production. However, new varieties are constantly being released. Forage types with improved yield and digestibility should be evaluated for silage production.

Awned cereal varieties are usually not a problem when ensiled, although wastage does increase when these varieties are baled and is more significant with late-cut material of higher DM content.

Figure 5.2



Yield of cereal crops grown at Northfield, SA, harvested at different stages of growth.

Source: Cochrane and Radcliffe (1977)

Nitrate poisoning can be a risk if soil nitrogen level is high and the crop is stressed as a result of drought or long periods of cloudy weather. Nitrate levels in forage usually drop by approximately 50% when it is made into silage, significantly reducing the risk of nitrate poisoning.

Late nitrogen application may depress forage WSC levels (see Chapter 4, Section 4.3.2).

5.3.2

Crop management for silage production

Fertiliser requirements

Growing a crop to produce high yields of high-quality forage and maximum economic return requires good growing conditions, with adequate fertiliser application.

While grazing or grain harvest retains 30-50% of plant organic matter in the paddock as dung or straw, silage removes most of the plant material. To maintain soil fertility, nutrients removed in silage must be replaced (see Table 5.1).

Nitrogen-deficient crops are likely to benefit from topdressing with 50-100 kg/ha of nitrogen, when they are closed for silage. Early topdressing with nitrogen (at the tillering stage) will increase yield potential, while topdressing late (stem elongation to boot) may not produce an economic yield response. Adequate soil moisture, rainfall or irrigation is required to obtain full benefit from high nitrogen inputs.

Sowing details

- Optimum sowing date varies with species and variety choice and location; seek local advice.
- A high sowing rate is needed to ensure high yield potential. This rate is approximately 50% higher than rates used for grain-only crops.
- Weeds can be controlled by various herbicides. *Caution*: *Silage harvest timing may not satisfy the withholding periods recommended for herbicide use on crops intended for grain harvest.*

5.3.3

Growth stage at harvest

The growth stage to harvest cereals for silage is a compromise between forage quality and yield.

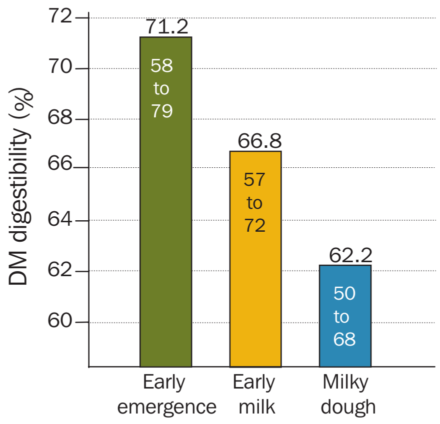
Guidelines on optimum growth stage for the various cereals, other than oats, are based on limited research that examined a small sample of the varieties available at the time. Very little information is available on triticale or cereal rye. More research is required on all cereal types, over a greater range of sites, to substantiate the guidelines that have been adopted.

The decline in digestibility of oat crops is rapid with advancing maturity (see Figure 5.3). This study showed large variations in digestibility between varieties and between years, at each harvest.

The information in Figure 5.4 suggests that the effect of growth stage on digestibility differs between cereals. This study indicates that the digestibility of both wheat and barley crops increases as grain filling commences, whereas the

Figure 5.3

Mean and range in DM digestibility of oat varieties grown over four years at Mount Barker, WA, and harvested at three stages of growth.



Source: R. McLean (unpublished data) – based on 18-23 varieties grown in each year digestibility of oats continues to fall. Protein content falls with advancing crop maturity with each of the cereals, with oats tending to have lower protein contents than wheat and barley. These results indicate that oats should always be cut at an early growth stage – between boot and ear emergence.

Research to date indicates that wheat and barley provide more flexibility, with the option to cut early, at the boot stage, or later, at the dough stage, when yield is likely to be higher. However, wheat and barley crops should not be harvested at flowering to early milk stage, when digestibility may be lower (see Figure 5.4).

Although valuable silage can be produced from cereals cut within this range, maximum animal production per tonne of silage is expected with an early harvest and maximum production of DM per hectare is expected with the later harvest.

At the mid-dough stage, winter cereals may be direct harvested, although wilting of the forage is essential if the DM of the standing crop is <30%. Check DM levels using the 'Microwave Oven Method' (described in Chapter 6, Section 6.4.2) to ensure levels are close to 35-40% for chopped silage and 35-50% for baled silage.

Plate 5.4

This barley crop is in the mid-dough stage. The recommended growth stage to harvest wheat and barley is at the boot or mid-dough stage.

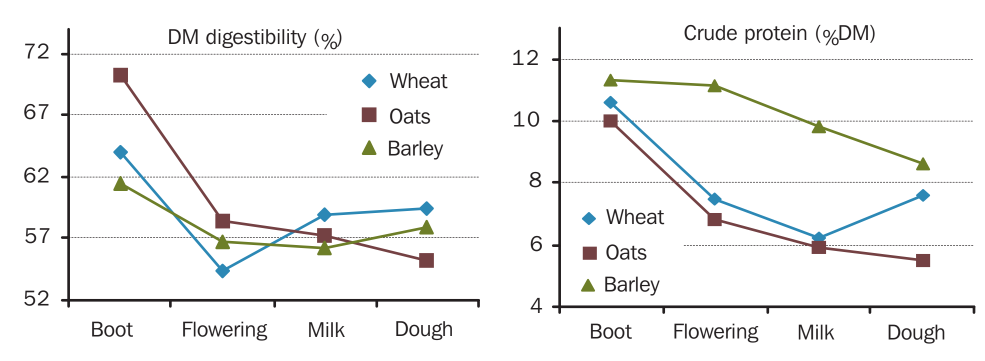
Photograph: K.Kerr

As winter cereals mature the stems become hollow, which may affect compaction. The problem can be minimised by chopping to 10 mm lengths or by baling at the lower end of the recommended DM range.

Potentially, winter cereals can be harvested over many weeks. Oats and barley should be ready to harvest before wheat or triticale. There is also a range of maturities between different varieties of each species. A choice of growth stage and varietal maturity means that cereal crops could potentially be harvested for silage over a 4-6 week period.

The limited information available on cereal rye suggests that the preferred growth stage to harvest for silage is the boot stage. Feed quality of cereal rye deteriorates more quickly with maturity compared to other cereals.

Figure 5.4



Changes in DM digestibility and crude protein content at different growth stages in wheat, barley and oat crops grown in South Australia.

Source: Cochrane and Radcliffe (1977)

Table 5.5

The approximate duration of key stages of grain development in cereal crops.

Growth stage	Approximate duration of growth stage
Boot stage	7-10 days
Heading and flowering	10-14 days
Milk grain	7-10 days
Dough grain	7-10 days (plants yellowing, leaves dying)

Mid-dough is about 3-4 weeks before normal grain harvest.

Despite this flexibility, an individual crop is likely to have a harvest window of only seven days in which it will be at the desired growth stage. Table 5.5 shows the number of days a cereal crop is at the growth stages when harvesting is likely to occur.

The quality and quantity of silage produced from winter cereals varies with growing conditions, species and variety. The values in Table 5.6 indicate the expected ranges under good management.

Harvesting early, at the boot stage, will maximise the quality of silage and reduce the number of days the crop occupies land. However, DM yield per hectare will be 40-60% lower than at the dough stage.

Late-harvested, winter-cereal silage may be particularly useful if fed when stock are grazing young pasture, which has a very high protein and low fibre level.

Delaying harvest not only results in loss of quality, it also increases the risk of lodging, particularly in heavy crops of the taller varieties.

Table 5.6

The effect of growth stage on potential yield and feed quality of winter cereal silage.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Late vegetative or boot*	9.5-10.5	8-18	1.5-7.0
Flowering	9.0-9.5	6-12	3.0-11.0
Dough grain	8.0-9.5	4-10	3.5-15.0

** The preferred growth stage to harvest oats.*

5.3.4

Increasing the feed quality of winter cereal silage

Low protein is the major feed quality limitation of winter cereal silage, particularly when crops are harvested late, at the mid-dough growth stage.

Cereal/legume mixtures

Forage protein content may be improved by growing legumes such as annual clovers, field peas or vetch with the crop (see Section 5.4). The level of improvement will depend on the proportion of legume to winter cereal, with a legume component of 40-50% needed to make a significant difference. A legume component is likely to lower the forage's DM and WSC content and increase the requirement for wilting, particularly if the legume proportion increases to 50% or above. Chapter 6, Section 6.6 includes strategies to increase wilting rates.

Ammoniated whole crop cereals

Digestibility and protein level of late-harvested (late-dough stage) cereal crops can be increased with the addition of urea to produce ammoniated whole cereal forages. Cereals used for the production of ammoniated forages should be harvested at a higher DM content (>50%) than normal silage.

Urea is added at a rate of 40-50 kg per tonne of forage DM as the crop is cut or stacked. This process is only suitable for operations, such as chop silage, which allow even mixing of the urea.

Ammoniated forages produced following urea treatment are different to whole crop silages. Silages are fermented products and have low pH (4-5), whereas the ammoniated forages are chemically preserved products with a high pH (about 9). The applied urea is converted to ammonia gas, which reacts with water to form ammonium hydroxide. Ammoniated forages are sealed with plastic in the same way as silage.

Adding urea to late-cut, whole crop cereal silage at the time of feeding is an alternative to the production of ammoniated forages. This will increase the nitrogen level in the animal's diet, but there is not the increase in digestibility that occurs with ammoniated forage.

In both cases, poor mixing of the urea can result in variable feed quality or the risk of stock poisoning.

5.3.5

Drought-stressed crops

Harvesting drought-stressed crops for silage, as a salvage operation, has been successful for most crop types including cereals, grain legumes and canola. Refer to Section 5.5 before harvesting drought-affected sorghum crops.

The management of drought-affected crops for silage is the same as for the usual silage making, although these crops are rarely at the recommended growth stage. It is important to make an early decision and cut the crop before quality deteriorates.

Although forage yield is often lower than the potential, quality of the silage can be high. Drought-stressed crops usually ensile well because WSC levels are often higher. Although DM levels are also higher than usual, crop appearance can be deceptive and DM levels may need to be checked.

Section 5.4

Whole crop cereal/legume and legume

Cereal/legume mixtures produce forage yields similar to those of cereal crops, with a significantly higher protein content. Legumes also have a higher nutritive value than grasses or cereals, sustaining higher intake and animal production at a given digestibility.

5.4.1

Legume selection

The climbing legumes, peas (field pea) and vetch (common and purple), are ideal companion crops for cereals. Alone or in mixtures with cereals, they are generally more productive for silage than smaller-seeded legumes, such as clovers (see Chapter 4). They are also more suitable for later sowing and more competitive when grass weeds are a problem. This can be important in cropping areas where forage legume-based crops are used as a break crop in rotations.

In higher rainfall areas, high-density clover mixtures (HDLs) may be a better option as they can provide two or more silage cuts. However, they are not as competitive when grown with a cereal and usually only make a significant contribution to the mixture when a low cereal sowing rate and wide row spacing are used. The forage yield of cereal/clover mixes is also likely to be lower than that of cereal/climbing legume mixes.

Other winter forage legume crops, such as faba beans or lupins, either grown alone or in combination with a cereal, may have potential for silage production and need to be evaluated. Experience in the UK indicates that forage varieties of faba beans and lupins have similar yield potential and quality to peas.

Tables 5.7 and 5.8 give the yield potential and quality of pea, vetch and mixtures of these with oats. Peas are usually more productive than vetch, either when grown alone or in combination with oats.

Seek local advice on the most suitable pea and vetch varieties for silage production. Later maturing varieties are likely to have higher yield potential and so should be most suitable. They will reach the optimum stage of crop development later in the season when weather conditions for silage making are usually more favourable.

The legume and cereal/legume crops need to be wilted prior to ensiling.

Table 5.7

Production and quality of pea and vetch crops at Campbell Town, Tasmania.

Crop*	Yield (t DM/ha)	Crude protein (% DM)	DM digestibility (%)	Estimated ME (MJ/kg DM)
Peas – Morgan	11.8	14.5	73.7	10.8
– Secada	9.3	13.2	70.6	10.3
Vetch – Popany**	5.6	18.3	75.6	11.1
– Morava**	7.7	16.3	66.7	9.6

* *Crops harvested at the late pod swell stage.*

** *Popany is a variety of purple vetch; Morava is a variety of common vetch.*

Source: Dean (2001)

5.4.2

Legume content

The crop's legume content can be manipulated by varying the relative seeding rates of the legume and cereal components. The target legume content will vary with the production goals. Where a high-ME, high-protein silage is required, a high legume content is needed. This will be particularly important if protein supply for livestock production on the farm is limiting at certain times of the year, and the alternative is expensive, purchased protein meals. High legume content is also important where forage legume crops are grown in cropping rotations and improving nitrogen return for subsequent crops is a consideration.

Where moderate levels of forage protein (10-12%) are satisfactory, a lower legume content will suffice. Generally 40-50% legume, on a DM basis, is required to meet this objective (see Table 5.8).

5.4.3

Crop management for silage production

Lodging

Lodging can be an important issue with climbing legumes. Where lodging occurs in high-yielding pure legume crops:

- a significant proportion of forage can be below mowing height and harvesting losses can be high;
- risk of leaf disease in the legumes is increased;
- forage digestibility can decline; and
- silage preservation can be at risk because the forage is contaminated with decaying material (and aerobic spoilage organisms) from the base of the crop.

Management factors likely to affect lodging are not well understood but are known to include time of sowing and variety selection. Pure pea or vetch crops are not recommended in areas where lodging is a problem; the preferred strategy is to sow a small cereal component to provide a 'climbing frame'.

Table 5.8

Production and quality of oat, peas, vetch and oat/pea and oat/vetch mixtures at Wagga Wagga, NSW. All crops harvested at the flowering stage of the oat crop (23 October).

	Oats*	Oat/pea	Oat/vetch	Pea	Vetch**
Legume content (% DM)	–	48	42	100	100
Yield (t DM/ha)	11.9	14.8	13.6	11.7	8.6
Organic matter digestibility (%)	63.1	67.9	62.9	72.7	68.7
Estimated ME (MJ/kg DM)	9.2	10.0	9.2	10.7	9.8
Crude protein (% DM)	4.4	12.2	10.4	18.3	23.2

** Received an additional 40 kg N/ha.*

*** Mean results for Popany (purple) vetch and Golden Tares (common) vetch. The field pea variety sown was Dundale.*

Source: Dear et al. (unpublished data)

Sowing rate

Research is required to determine optimum sowing rates for cereal/legume mixtures. Local advice should be sought. Typical sowing rates currently used in the mixed farming regions of central and southern NSW are 40 kg oats/ha with either 50-70 kg peas/ha or 20-30 kg vetch/ha. Where high legume content is required, the cereal component can be dropped to 10-20 kg/ha and the legume component increased to 60-80 or 30-40 kg/ha for peas and vetch respectively. In areas where lodging is not likely to be a problem for pure legume crops, pea and vetch sowing rates used are 80-100 and 40-50 kg/ha, respectively.

The economic feasibility of the pea/cereal mixtures must be considered if a high pea seeding rate is to be used. The high cost associated with high pea sowing rates may be reduced if small-seeded, forage-type peas, which have shown potential in research trials and can be sown at lower sowing rates, become commercially available.

Plate 5.5

Sowing legumes in mixtures with cereals can increase the protein level of the forage. Purple vetch (var. Popany) was grown with wheat in this example. *Photograph: K. Kerr*

Fertiliser requirements

Soil tests, nutrient removal data in Table 5.1 and local advice should be the basis of fertiliser application rates. Adequate phosphorus, sulphur and potassium are essential if legume crops are to achieve their yield potential. A small amount of nitrogen may be an advantage in low fertility paddocks to ensure a vigorous cereal component. However, high rates of nitrogen should be avoided as this may increase competition from the cereal component, reduce the legume content and reduce nitrogen fixation by the legume.

Table 5.9

Effect of harvest date on the organic matter digestibility (%) and estimated ME content of oat, pea and oat/pea crops at Wagga Wagga, NSW.

Harvest date:	2 October		23 October		6 November	
	Growth stage of oats					
	Early ear emergence		Flowering		Milky dough	
Crop	OMD (%)	ME (MJ/kg DM)	OMD (%)	ME (MJ/kg DM)	OMD (%)	ME (MJ/kg DM)
Oat	68.9	10.1	63.1	9.3	55.7	8.2
Oat/pea	74.1	10.8	67.9	10.0	60.0	8.7
Pea	71.4	10.3	72.7	10.7	70.2	10.3

Source: Dear et al. (unpublished data)

5.4.4

Growth stage at harvest

As with all crops, the optimum stage of harvest is a compromise between yield and quality. The best strategy with cereal/ legume mixtures is to base cutting time on the stage of growth of the cereal component (see Section 5.3.3). Table 5.9 shows the influence that the growth stage at harvest of oat, pea and oat/pea crops has on digestibility. Optimum stage of growth has not been adequately defined for pure pea and vetch crops, although peas are generally harvested during pod filling of the earlier pods.

As the data in Tables 5.9 and 5.10 show, the harvest window is widened when legumes are mixed with cereals. Forage of satisfactory quality is available at the 'flowering' stage of the oat/pea crop. Wheat/legume or barley/legume mixtures may produce forage of satisfactory quality at the dough stage, but research is required to confirm this.

Table 5.10

Estimates of ME, crude protein and DM yields of cereal/legume mixtures at varying legume contents.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Cereal/ legume – cereal dominant:			
Boot to flowering for cereal component (all cereals)*	9.5-10.5	12-18	3-8
Milk to dough for cereal component (wheat or barley)*	9.0-9.5	10-18	5-15
Cereal/ legume – legume dominant:			
Boot to flowering (all cereals)*	10.0-11.0	14-20	3-7
Milk to dough (wheat or barley)*	9.5-10.5	12-18	5-12
Legume crop:			
Early pod filling	10.0-11.0	15-20	5-12

** Growth stage of the cereal component.*

Section 5.5

Grain sorghum

Grain sorghum has potential to produce high-quality silage containing 40-50% grain. The dual-purpose sorghums, sweet sorghums and grain sorghums are a useful alternative to maize for silage production in drier areas and on poorer soils.

Grain sorghum silage will usually be of higher nutritional value than silage made from forage sorghums (see Chapter 4, Section 4.10, for discussion of forage sorghums).

Warning – Prussic acid (HCN)

All sorghum crops have the potential to cause prussic acid poisoning. Grain sorghum and sweet sorghum have the highest poisoning risk, while Sudan grass has the lowest. Sub-lethal symptoms (depressed milk production and low weight gains) are much more common than death from acute poisoning.

The risk of prussic acid poisoning is greatest when plants are stressed from drought, frost, flood or foliar herbicides, such as 2,4-D. Prussic acid levels are highest in young plants or regrowth <60 cm high.

Mowing and haymaking do not reduce the risk of prussic acid poisoning sufficiently to render the forage safe. There is some evidence to suggest that up to 50% of the prussic acid is lost during the ensiling process. However, depending on the initial prussic acid level, ensiled sorghum may still pose a risk. If in doubt, test for prussic acid potential before feeding and seek advice.

The following strategies will mininise the risk from prussic acid:

- select low prussic acid varieties;
- avoid high rates of nitrogen fertiliser if moisture stress is possible;
- ensure the crop is not phosphorus deficient; and
- avoid harvesting short, stressed crops.

5.5.1

Hybrid selection

Taller growing hybrids and dual-purpose (graze + grain, or silage + grain) sorghums are suitable for silage production, producing a silage containing 25-30% grain. Seek local advice to select varieties with high forage yield potential.

A comparison of grain, dual-purpose and sweet sorghums grown in wet and dry seasons at Moree, NSW, is presented in Table 5.11. Despite the lower yield from the moisture-stressed grain and dual-purpose crops in the first growing season, ME content was only marginally lower than that in the favourable season. Late rain in the dry season enabled the later maturing sweet sorghums to produce high yields in both seasons. Although the ME content of the sweet sorghums was lower than that of the grain sorghums, the high yield of these crops make them the more attractive option in lower rainfall environments.

Grain sorghum silage will often have a slightly lower digestibility and ME content than maize silage if both are grown under favourable conditions. However, where crops are moisture stressed, the grain content of maize declines while that of sorghum can be relatively unaffected. As a

Table 5.11

Yield and quality of grain sorghums, dual-purpose sorghums and sweet sorghums grown at Moree, NSW, in wet and dry seasons.

	Grain (5 hybrids)	Dual-purpose (2 hybrids)	Sweet (2 hybrids)
Dry season (73% of normal November-April rainfall):			
Yield (t DM/ha)	4.2	4.2	20.8
Grain content (% DM)	43.9	33.5	3.2
Estimated ME (MJ/kg DM)	10.0	9.9	10.0
Crude protein (% DM)	8.4	8.0	7.2
Wet season (138% of normal November-April rainfall):			
Yield (t DM/ha)	6.2	7.0	17.6
Grain content (% DM)	33.8	31.8	0
Estimated ME (MJ/kg DM)	10.2	10.3	9.5
Crude protein (% DM)	8.3	6.9	4.5

Source: Cole et al. (1996)

result, the maize crop's ME content can fall sharply and be lower than that of sorghum grown under the same conditions. For this reason, sorghum should replace maize in environments with lower or unreliable rainfall.

If harvest for silage is not possible, the sorghum crop may be harvested for grain. However, in the study shown in Table 5.11, the gross margin for sale of the crop for silage was 38% higher than that for grain production.

Grain sorghum can be grown with soybeans to produce a silage with higher crude protein than grain sorghum alone. However, producers must be prepared to make compromises on yield and management. The soybean content must be of the order of 40% to make an impact on protein levels. This would require lower sorghum sowing rates and result in a significant yield penalty. Inter-row cropping and weed management difficulties are also a consideration. A more practical and economic option is likely to be growing a sorghum silage crop and purchasing protein to improve protein levels in the ration.

5.5.2

Crop management for silage production

- Ensure high plant population for high yield potential. Actual seed rate varies with seed size. Aim for sowing rates of 5-7 kg/ha for dryland crops, or 9-12 kg/ha if irrigated.
- Requires soil temperatures at 10 cm depth of at least 16ºC, at 9:00 am at time of sowing, for rapid germination.
- Adequate fertiliser and/or good soil fertility is needed to grow a high-yielding crop. Use soil testing and a crop nutrient budget to help calculate specific nutrient requirements (see Table 5.1 for nutrient removal levels).
- Control weeds if necessary. If using herbicides consider possible residue effects on subsequent crops and the withholding periods and minimum residue limits (MRLs) for the silage.
- A range of insects and diseases may attack grain sorghums. Hybrids with resistance to important pests such as sorghum midge are available. Alternatively, use insecticides when necessary. Ensure withholding periods are satisfied before the crop is harvested.
- Irrigate as required, if available, although maize is likely to be a more profitable option under irrigation.
- Another crop or pasture is usually sown after grain sorghum. However, in some areas, regrowth after harvest can produce a second (ratoon) crop, although the yield may only be about 50% of the first harvest.

Sulphur and sodium supplementation will improve animal production when feeding sorghum silage.

5.5.3

Growth stage at harvest

Grain sorghum is best harvested when grain in the middle of the head is at the mid-dough stage of maturity and before leaves start to die off. At this stage, the crop should be between 30 and 35% DM. If harvested early, the crop will not achieve its yield potential. If allowed to dry out much more than 35% DM, compaction may become more difficult and digestibility of grain will decrease as it hardens. Silage quality and yields likely to be achieved with well-managed grain sorghum crops are shown in Table 5.12.

If harvesting is delayed and the grain becomes hard, grain digestibility falls and animal production will decline. Research has shown improved production from animals fed late-harvested sorghum silage when it was rolled to crack the grain. This suggests that there is a role for grain processors in harvesting sorghum silage (see Chapter 14, Section 14.2.5). Experimental results in Chapter 14 showed only 43% of grain was damaged during harvest of sorghum for silage production. When the silage was fed to young cattle the whole grain fraction had a digestibility of 83%, less than the 97% achieved for the whole grain fraction of similarly treated maize silage.

The difficulties associated with cracking grain to improve digestibility of late harvested sorghum highlights the importance of timely harvest, before the majority of the grain hardens.

Although prussic acid poisoning can be a risk if animals graze vegetative, moisture-stressed sorghum crops, it is not likely to be a concern with sorghum silage, harvested at the dough stage.

Height of cut

Grain sorghum is usually cut to a stubble height at 10-15 cm. Increasing the cutting height will increase the proportion of grain to stover and therefore, the quality of the silage. However, feed quality is often not increased enough to compensate for the reduction in yield. Consideration must also be given to managing the extra trash left in the paddock after a high cut.

Plate 5.6

The crop in the foreground is grain sorghum, while the tall crop in the background is sweet sorghum. The yield potential of sweet sorghum is considerably higher than that of grain sorghum. *Photograph: K.Kerr*

Table 5.12

Potential quality and yield of grain sorghum for silage harvested at the recommended growth stage.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Dough grain	9.5-10.5	6.0-9.5	4.0-7.0
			6.0-10.0*

** Yields under irrigation or high rainfall conditions.*

Section 5.6

Sweet sorghum

Sweet sorghums have the potential to produce high yields of medium quality forage, which can be chopped as silage or carried over into winter for use as green chop. It has a reputation for being cheaper, easier to grow and often higher yielding than maize, but is usually lower in ME content than maize silage when both crops are grown under favourable conditions. Under poor growing conditions sweet sorghums can produce higher yields of silage, with a higher ME content than maize.

Table 5.11 presents a comparison of the yield and quality of sweet, dual-purpose and grain sorghums at Moree, NSW.

5.6.1

Crop management for silage production

- Seek local advice for specific agronomic details.
- There is wide variation in yield and feed quality between cultivars. Select varieties with higher WSC content. These are likely to have a higher digestibility and produce a better silage fermentation.
- Sow from November to January. Good germination requires 10 cm soil temperatures of at least 16ºC, at 9:00 am.
- Use sowing rates of 5-10 kg/ha for dryland crops, 15-20 kg/ha if irrigating.
- Adequate fertiliser, weed control and good plant establishment are essential to achieve high yields.
- To maintain soil fertility replace nutrients removed in the forage (see Table 5.1 for details).
- Use irrigation as required, although a maize silage crop will give a better economic return under irrigaion than sorghum.
- Lodging can be a problem. To reduce the risk, grow as a row crop, avoid very high populations, and choose a variety less susceptible to lodging.
- When sweet sorghum has been harvested for silage, a paddock may be fallowed or planted to a rotation crop or permanent pasture. In summer rainfall areas with long growing seasons, some varieties may regrow for a second silage harvest.

Table 5.13

Yield and quality at growth stages from milk to hard grain for eight sweet sorghum varieties grown at Nowra, NSW.

Source: Based on Havilah and Kaiser (1992)

	Growth stage			
	Milk	Dough	Late dough	Hard grain
Yield (t DM/ha)	17.0	17.2	16.3	16.8
DM content (%)	24.1	24.7	25.5	27.2
WSC (% DM)	25.8	24.8	21.3	22.8
Organic matter digestibility (%)	67.4	68.1	66.9	66.5
Estimated ME (MJ/kg DM)	10.0	10.2	10.0	9.9
Crude protein (% DM)	5.8	5.2	5.4	5.0

Sulphur and sodium supplementation will improve animal production from sorghum silage.

5.6.2

Growth stage at harvest

Sweet sorghum's high sugar content (often 25-35% WSC – see Table 5.13) maintains digestibility over an extended period, providing a large harvest window. The crops in Table 5.13 took more than six weeks to progress from the milk to the hard grain growth stage.

Table 5.14 gives potential yield and silage quality levels that can be expected with well-managed sweet sorghum crops. ME and crude protein levels are likely to drop marginally when harvest is delayed.

The juicy, sweet stems of sweet sorghums result in a slow fall in DM content. Sweet sorghum can be direct harvested between the boot/head emergence stage through to the hard grain stage. Crop DM content is often in the range 25-30%. The high WSC content means the forage ensiles easily without the need for wilting.

Table 5.14

Yield and quality ranges for sweet sorghums cut at the milk to hard grain growth stages.

Growth stage	ME (MJ/kg DM)	Crude protein (% DM)	Potential yield (t DM/ha)
Milk to hard grain	9.0-10.0	4.0-8.0	10-25

Section 5.7

Soybeans

Soybean forage has a high protein content and has potential to produce medium-quality silage. Soybeans have the highest yield and forage quality potential of the summer legume crops currently used for silage production, although ME levels are only medium.

5.7.1

Variety selection

Because the development of soybean plants is dependent on day length, variety recommendations will vary with latitude.

There are no varieties specifically selected for silage production in Australia. The highest yield and feed quality will come from early to mid-season varieties suited to each area. Later-maturing varieties which are sown early may have a higher yield potential but they are usually tall and may lodge, resulting in loss of lower leaves, difficulty in harvesting and lower feed quality. Some late-maturing cultivars may be suitable for silage production if early sowing is avoided, but they need to be evaluated for susceptibility to lodging.

Sown early, the best performing early to mid-season varieties will have high growth rates and production, with potential for early silage harvest (early February). This allows the option for sowing a second summer crop or early winter crop.

Table 5.15 gives yield and quality results for a range of early and late-maturing soybean varieties. Significant differences between cultivars have been observed in both yield and quality. More research is required to identify the most suitable cultivars for silage in different regions.

Table 5.15

DM yield and forage quality of early and late maturing soybean cultivars at two growth stages, at Grafton, NSW (1993/94).

	Days to:		Yield (t DM/ha)		Crude protein (% DM)		DM Digestibility (%)	
	R3*	R6**	R3	R6	R3	R6	R3	R6
Early-maturing cultivars sown early:								
Average	60	86	2.97	6.16	17.9	18.8	63.3	60.8
Range	51-76	78-100	1.6-5.2	4.1-7.5	16.0-20.3	15.2-20.7	60.0-66.7	55.9-63.3
Late-maturing cultivars sown late:								
Average	59	83	3.82	8.36	17.3	17.5	59.9	62.6
Range	52-67	75-89	2.8-5.0	6.5-11.6	12.8-20.4	14.7-21.0	51.8-63.3	59.3-64.8

R3 – Podding has commenced; pods 5 mm in length.*

R5 – Seeds begin to develop.

*R6** – Seeds fill the pod; pods are still green.*

Source: Desborough (unpublished data, 1998)

5.7.2

Crop management for silage production

- Use local guidelines for variety selection, sowing rate and row spacing.
- Sowing rates of 70-90 kg/ha will produce the desired 300,000-350,000 plants/ha.
- Inoculate seed.
- Soybeans are best planted at 18 or 36 cm row spacing at a sowing depth of 3-5 cm.
- Good germination requires 9:00 am soil temperatures of at least 15ºC at a depth of 10 cm.
- Fertilise as required at planting. Inoculated soybeans do not need nitrogen fertiliser although some growers use a 'starter' fertiliser to improve establishment. Replace nutrients removed in silage (see Table 5.1 for details).
- Weed and insect control may be necessary. Be aware of herbicide registrations and withholding periods. Some herbicides used on soybeans have a very long withholding period before grazing or harvest for silage. Some do not have a registered withholding period and so should not be used on crops to be harvested for forage.

5.7.3

Growth stage at harvest

The growth stage for making silage has not been adequately defined for the soybean cultivars most suitable for silage production. However, from the point of view of yield, cutting when the seed 65% fills the pod (between growth stages R5 and R6 – see Plate 5.7) appears to be reasonable. At this stage, the crop has almost achieved its yield potential and pods and leaf will be retained when the crop passes through a roller conditioner.

Delaying the harvest to the pod fill (R6) growth stage, when lower leaves start to turn yellow, will achieve maximum DM yield, but there is an increased seed and leaf loss during harvesting. Although harvesting later avoids the need to wilt, this will result in unacceptable loss of seed and leaf and a loss in forage quality.

Earlier harvesting when pods are elongating (R3) will produce good quality silage, however yield is likely to be only 30-40% of the potential, as indicated in Table 5.16.

Wilting will be needed to achieve the desired 35-40% DM for chopped silage and 35-50% DM for baled silage. Cutting the soybean forage with a mower-conditioner (roller-type conditioner) will increase the wilting rate of the thick stems.

Table 5.16

The effect of growth stage on potential yield and quality of soybean silage.

Growth Stage	ME (MJ/kg DM)	Crude Protein (% DM)	Yield (t DM/ha)
Podding commences (R3)	8.0-9.5	15-20	1.5-4.0
60% pod-fill	8.0-9.5	16-20	4.5-9.0
Seeds fill pod (R6)*	8.0-9.5	16-20	5.0-10.0

* *Trial results do not reflect the potential reduction in quality due to seed and leaf loss that can occur in commercial silage making of late harvested soybeans.*

Depending on the drying conditions, a wilting period of about 24 hours is usually needed to achieve the desired DM content.

Handling and harvesting wilted material in the evening can reduce leaf shatter, which may be a problem on very hot days.

Although soybeans may be made into baled silage, it is not the preferred option. The high DM required for baled silage is not only likely to cause higher field and harvest losses, but also increased leaf and pod shatter, resulting in greater in-silo and feedout losses.

The stalkiness of the soybean forage makes bale compaction difficult and can result in puncturing of the plastic wrap. Although this problem can be reduced by using balers fitted with chopping mechanisms, compaction will still be a problem unless the material is baled at very high density.

Another source of in-silo losses with unchopped baled silage is poor fermentation due to the slow release of sugars, which is often a problem with unchopped material, particularly with legume forage.

Feedout losses with soybeans can be reduced by 15-25% if soybeans are chopped at harvest or before feeding. The chopped stalks are more likely to be consumed by animals.

If harvest is delayed soybean forage can have relatively high oil content. Conventional laboratory testing of soybean silage may not adequately account for oil content and needs further development to ensure ME values are not underestimated.

High oil content can affect soybean silage fermentation, although this has not been a problem with soybean silage harvested at the recommended growth stage. Oil content should also be considered if soybean silage is likely to be a significant component of ruminant diets. High oil levels can affect rumen fermentation.

Plate 5.7

Soybean pods showing seed development. The pod on the left is at the stage recommended for mowing, between growth stages R5 and R6 with seed filling 65% of the pod cavity. The pod on the right is at stage R6, with seed completely filling the pod cavity.

Photo: P. Desborough

Section 5.8

Plant by-products

By-products are often used in periods of drought, short-term feed shortages, or opportunistically as supplies become available. By-products, which include plant residues and food processing by-products, can be valuable sources of energy and protein.

Although poultry litter and animal by-products have been used as protein sources, it is now illegal to include them in rations due to animal and human health concerns.

The use of by-products and alternative feeds has increased substantially in recent years. In the past they have been more commonly used as supplements to fibrous, low-quality roughage, especially during droughts. However, with more widespread use of feed-mixer wagons and total mixed rations, and a better understanding of their nutritive value, by-products are now more commonly used in full production rations.

Because by-products are often highly variable in their nutrient and DM content, these should be monitored by regular feed testing. Where the composition of batches varies widely, regular adjustments to the diet or ration may be required or animal production may suffer.

Some by-products, used as 'fillers' in diets, cannot be ensiled and may have low nutritive value. The by-products considered in this section have medium to high nutritive value, low DM content and are suitable for silage production.

Before using by-products the following factors need to be considered:

- Does it contain potentially toxic or banned compounds (e.g. chemical residues and anti-nutritional factors)?
- What and how variable is its nutrient content (e.g. energy, protein and fibre levels)?
- Is the material palatable and acceptable to the animals?
- Does it contain metals, plastic or other physical contaminants?
- How much material will be available and when?
- What is the true cost when transport cost, bulk density and DM content is taken into account?
- Can it be successfully ensiled?
- What extra handling and storage facilities are needed?

5.8.1

Risk of chemical residues

The withholding period (WHP) on most chemical labels is the specified time between chemical treatment and the commencement of a production process, such as harvesting or grazing. It relates to the label dose rates only and is a minimum requirement. Within this period animal products are not suitable for domestic consumption in Australia.

An Export Slaughter Interval (ESI) is the period following treatment when produce is unsuitable for export processing. It is often longer than the same chemical's WHP.

Some by-products may be contaminated with residues from pesticides or other chemical treatment during processing. Unacceptable residue may still be present in the waste plant material after processing or in crop residues when fed.

Residue risks may increase in by-products because some chemicals are concentrated in the plant waste fraction. A harvest withholding period does not guarantee that other parts of the crop, such as stubble and trash, are suitable for stockfeed. Materials such as grape marc, pomace, citrus peel, vegetable skins and outer leaves of leafy vegetables often have higher residue levels than the commodity they are derived from.

Some chemicals registered for use on fruit and vegetables are not registered for use on stock feeds or directly on livestock. Consequently, there may be no minimum residue limits (MRLs) set for the chemical in animal products. In this case, any detectable level of that chemical in animal products breaches food standards and they cannot be used for human consumption. MRLs acceptable in Australia may not meet standards of our trading partners.

The label directions for some agricultural chemicals ban the grazing of treated crops and/or the feeding of the wastes of treated crops to livestock. This applies to endosulfan. Upgraded restrictions on endosulfan use prohibit the feeding of any feed straw, fodder, trash or by-products from crops or pastures treated with endosulfan. In some States it is an offence for any person to feed wastes from the treated crop contrary to label directions. Producers should check with their appropriate State agencies concerning the local regulations.

There is a further risk from by-products grown on contaminated land. For example, organochlorine residues have been found when animals were fed by-products, such as sugarcane tops or vegetable wastes, harvested from contaminated land.

Before buying or accepting the waste material, representative samples should be analysed for pesticide residues by an accredited laboratory. Advise laboratories of the chemicals to be tested for when the samples are submitted. With the increasing demand from end users, some by-product suppliers are routinely testing their product for chemical residues.

A signed formal Vendor Declaration Form may be available to provide information on the chemical treatment history of the product in question and to verify the chemical residue status.

Updated WHP and ESI information can be obtained from Meat and Livestock Australia (MLA) and on the MLA website <www.mla.com.au>

For more detailed information relevant to NSW, see Blackwood, I. and Byrne, D. (2002) *Buying Stock Feeds: minimising chemical residue risks,* Agnote DAI-265, NSW Agriculture. <www.agric.nsw.gov.au/reader/14071>.

Risk management

Buyers of by-products that may or do contain chemical residues should take precautions by also recording:

- Date the by-product is received
- Type of feed
- Source of supply
- Analyses carried out
- Which animals received the feed
- Dates when the by-product was fed
- Length of feeding period

It is also advisable to store a by-product sample for about 12 months.

Note: If available, buyers should obtain a signed declaration stating if any (and which) residues are present, based on a chemical analysis from an accredited laboratory.

Table 5.17

Nutritive value of a range of by-products and by-product silages (mean values with range in brackets).

By-product (number of samples)	DM content (%)	Crude protein (% DM)	ME (MJ/kg DM)
Citrus pulp[1] (26)	15.2 (9.4-23.8)	8.7 (6.0-12.9)	12.5 (9.9-14.1)
Citrus pulp silage[1] (3)	15.6 (15.1-16.5)	9.5 (8.9-9.8)	11.9 (10.5-13.1)
Brewers' grains[1] (27)	25.4 (13.9-33.0)	21.7 (16.9-25.2)	10.7 (9.7-11.9)
Brewers' grains silage[1] (3)	29.7 (27.9-33.0)	22.0 (20.7-23.3)	10.6 (9.9-11.1)
Grape marc[1] (3)	35.8 (28.1-46.4)	17.9 (11.7-23.3)	8.1 (4.3-11.1)
Apple pomace[2] (3)	24.5 (21.0-27.6)	7.1 (6.0-8.0)	9.6 (8.4-11.0)
Tomato pulp[1] (8)	27.0 (16.6-30.2)	20.5 (17.7-22.4)	7.7 (4.8-9.5)
Potato mash[1] (45)*	23.1 (10.9-62.3)	11.2 (6.7-25.8)	13.3 (10.8-14.8)
Corn trash*[2] (1)	19.6	7.0	9.3

* *Fat level assumed = 2%.*

Source: [1] FEEDTEST (2000), Department of Primary Industries, Hamilton, Victoria; [2] Adapted from Low, S.G (1984)

Table 5.18

The nutritive value of selected by-products from the international literature.

By-product	DM content (%)	Crude protein (% DM)	ME (MJ/kg DM)
Apple pomace (dehydrated)[1]	–	4.9	11.0
Banana stems[2]	10	2.0	5.5
Banana skins[2]	15	4.2	6.7
Banana – rejected whole (ripe)[2]	30	5.4	11.5
Brewers' grains[1]	21	25.4	10.4
Carrot[1]	12	9.9	13.8
Citrus pulp[2]	23	7.5	10.3
Citrus pulp silage[1]	21	7.3	12.6
Orange pulp[1]	13	7.5	12.6
Sweet corn trash silage[1]	32	7.7	10.6
Sweet potato leaves[2]	12	20.0	5.8
Sweet potato tubers[2]	30	7.0	13.5
Grape marc[2]	37	13.8	4.9
Grape marc (dehydrated)[1]	–	13.0	4.3
Olive cake[2]	46	4.0	3.8
Pineapple pulp (dehydrated)[1]	–	4.6	10.8
Potato tubers fresh[1]	23	9.5	13.2
Potato tuber silage[1]	25	7.6	13.4
Potato process residue (dehydrated)[1]	–	8.4	14.9
Tomato pomace (pulp)[2]	23	21.5	8.0
Tomato pomace (dehydrated)[1]	–	23.5	8.9

Source: [1] NRC (1989); [2] Chedly and Lee (2000)

5.8.2

By-products suitable for silage production

Many by-products have low DM content, making long-term storage difficult. However, if good silage-making practices are adopted most by-products can be successfully ensiled.

The most important goal is to establish an anaerobic environment as quickly as possible and to promote lactic acid fermentation. If there is a possibility there are insufficient lactic acid bacteria present, it may be necessary to apply a silage inoculant (see Chapter 7, Section 7.4.3). Effective sealing of the by-product stack with plastic sheeting is essential to prevent large storage (and quality) losses.

Most by-products are primarily sources of energy and have a low protein content. However, some, such as brewers' grains, are also sources of protein.

A range of by-products has been ensiled, for example:

- Citrus pulp
- Brewers' grains
- Apple pomace
- Grape pomace/marc
- Pineapple pulp
- Tomato waste
- Sweet corn stover
- Sweet corn trash (from processing plant)
- Vegetable residues (e.g. asparagus butts)
- Fresh fruits and vegetables (e.g. potatoes, bananas).

Table 5.17 shows the analyses for a range of by-products and their silages. Analyses were carried out at a number of feed testing laboratories, and additional data are available from the NSW Agriculture web site <www.agric.nsw.gov.au/reader/1950>. Table 5.18 gives nutritive value data for by-products reported in the international literature.

Although most of these products have low DM content, ensiling is usually successful if WSCs levels are high. Except for brewers' grains, the principles of storage and feeding for the higher energy by-products are similar to those required for citrus pulp (see Section 5.8.3).

The high moisture content of many by-products makes transport costly so they should be costed against alternative feeds on a delivered basis (cents/MJ, ME or cents/kg protein). Even when supplied 'free' ex-factory, the transport and handling costs may result in an expensive feed. In these circumstances the factory may need to pay for disposal of their by-product.

5.8.3 Citrus pulp

Citrus pulp – a by-product from the production of orange, lemon and grapefruit juices – consists of peel, pulp and seeds. It is high in moisture, fibre, WSCs and calcium (Ca), but low in protein and phosphorus (P). The resulting silage tends to be unstable after opening, deteriorating quickly. Quality will vary with:

- type of fruit;
- method of processing; and
- seed content (high in protein and fat).

Analyses available for ensiled citrus pulp indicate that it produces good quality silage and up to 15-20% can be included in beef feedlot rations. The high calcium and low phosphorus in the pulp may increase the Ca:P ratio of the ration, particularly when fed with a legume such as lucerne, and may need balancing with a feed low in Ca and high in P, to avoid milk fever in lactating cattle.

Plate 5.8

Citrus pulp in bunker.

5.8.4

Brewers' grains

Brewers' grains are the extracted residues from the barley malting process or in a mixture with other cereal grains or grain products. Brewers' grains tend to be high in both energy and protein, but can be extremely variable in composition.

Temperatures reach 70-75ºC during the processing of brewers' grains, killing most bacteria and heat damaging some of the protein, making it less rumen degradable. The process also removes much of the fermentable carbohydrate.

Because of their high moisture content, brewers' grains must be ensiled if they are to be stored over a long period. It is advisable to store it in a pit or bunker no higher than about 2.5-3.0 m. If stored higher, the surface and face will crack when the stack slumps at feedout. This allows air to enter, resulting in mould growth and spoilage. Sealing the stack with plastic could reduce this problem.

Molasses has been sprayed on the stack to seal the surface and to avoid 3-5 cm of spoilage. The stack is then sealed with plastic about 24 hours after spraying the molasses, earlier if rain is imminent.

For long-term storage, anaerobic conditions are essential to preserve the product, maintain palatability, and prevent aerobic spoilage and mould growth and toxin production. When stored without a seal there can be significant degradation and loss of protein and significant top spoilage (mould growth).

5.8.5

Grape marc

The ME value of grape residue (marc) can be highly variable, although the crude protein content is high (see Table 5.17). However, grape marc contains high levels of tannin, which results in much of the protein being bound and not available to the animal.

Cattle may not be able to digest whole seeds in the marc. However, the oil in grape seeds will contribute to a higher energy value if the seeds are crushed. Energy value is also influenced by whether the grape marc has been distilled to remove additional ethanol. If the grape marc is stacked to allow further fermentation of residual sugars, and then distilled, the energy value of the distilled product will be lower.

Grape marc can also contain high copper levels from pesticide applications to the grape crop.

5.8.6

Other by-products

Apple pomace

Apple pomace or pulp is the residue after the juice is extracted for cider or vinegar. It can be fed fresh, ensiled or dried, and has been included in beef diets at levels of 15-20% and up to one-third in dairy rations.

Tomato pulp

Tomato pulp is the residue from tomato processing factories. Although its protein content is high, its energy values are extremely variable. An analysis before purchase, or at least before feeding, is essential to allow for proper balancing of the feed ration. There is negligible information on feeding tomatoes to animals.

Bananas

Whole bananas have a high energy value and have been ensiled successfully. Soluble sugar content is lower and starch content higher in green fruit than ripe fruit. Both green and ripe fruit have been reported to produce well-preserved, low pH silages. However, ripe fruit tend to produce a silage with higher levels of fermentation products, particularly lactic acid.

Potatoes

Potatoes are high in moisture and energy (starch), low in fibre and have moderate protein levels. Potato mash has been used in some areas as a seal on pasture silage stacks as it forms an airtight seal when thick enough. The seal offers some feed value when fed out with the pasture silage.

Dry material such as hay or heavily wilted pasture may have to be mixed with the potatoes before ensiling so that the DM level is about 35%.

Potatoes (and some other vegetables) can accumulate cadmium.

Corn trash

Corn trash is the residue from both canning and frozen product processing. Its energy value can be high, although this depends on the proportion of broken grain and cobs. It can have a relatively high WSC content and is usually not difficult to ensile successfully. However, it often has a very low DM content, which makes it expensive to transport any distance and can result in considerable effluent flow from the stack.

Sugarcane

Failed sugarcane crops (e.g. frosted crops) can be salvaged as fresh chopped forage or ensiled. The quality of the forage can be extremely variable and will depend on the stage at which the crop is cut. It is generally considered to be low-quality roughage.

A summary of sugarcane feed test analyses from the NSW Agriculture website <www.agric.nsw.gov.au/reader/150>, showed an average DM digestibility of 49.9%; crude protein, 3.57 (% DM); and ME, 7.59 (MJ/kg DM).

When ensiling sugarcane, ensure a short chop length to aid compaction and reduce silage losses. Seal the silo quickly to prevent growth of organisms (e.g. yeasts) that may ferment sugars to ethanol.

Check the chemical status of the crop before buying or accepting the forage.

The by-product of the sugarcane process, bagasse, is of very low nutritive value and is not recommended for ensiling.

Chapter 6

Mowing and wilting pastures and crops

Chapter 6

Mowing and wilting pastures and crops

In this chapter

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The Key Issues

Crops and pastures are mown and wilted to increase the DM content of the ensiled forage. Wilting should occur as rapidly as possible to minimise the loss of DM and quality in the field. Monitor weather forecasts to decide when to mow.

- Mow in the morning after the dew has lifted, later if harvest is possible within 24 hours.
- Ensure mower blades are sharp and set to cut at the correct height.
- Ensure tractor power is sufficient to maximise mower output.
- Wilt to the correct DM content as quickly as possible:
  - Low-yielding crops wilt more quickly than high-yielding crops.
  - Vegetative (leafy) plants wilt more rapidly than more mature (stemmy) plants.
- Increase wilting rate by:
  - conditioning the plants at mowing,
  - maximising the surface area of the swath, leaving the mown swath as wide and thin as possible, OR
  - spreading or tedding immediately after mowing, AND
  - respreading or tedding when and if necessary after the dew lifts.
- If possible, harvest no later than 48 hours after mowing.
- The fastest wilt is achieved with a thin swath, warm temperatures, low humidity, long periods of sunshine, and with a breeze.

Section 6.0

Introduction

Most crops and pastures cut for silage have to be mown and windrowed so that the forage can be harvested by machinery fitted with windrow pick-up attachments. This includes all balers, most fine and precision chop forage harvesters, and double chop and flail harvesters operating in Australia (see Chapter 8). Direct harvest (e.g. 'Kemper') fronts are available for some forage harvesters, but they are not common and are only suitable for harvesting certain crops when the DM content of the standing crop is already at the desired level.

The DM content of most standing crops and pastures is low (<20%) when they are at the growth stage recommended for silage cutting (see Chapter 4, Table 4.1, and Chapter 5, Table 5.2). The forage must be wilted prior to ensiling to ensure a good silage fermentation and to eliminate effluent losses (see Chapter 2, Section 2.1.1).

Wilting occurs between mowing and harvest, and describes the process of plant moisture loss prior to the forage being harvested or baled. Crops and pastures should be wilted as quickly as possible to the desired DM content, to minimise loss of DM and quality.

The period of wilting required will depend on the original DM content of the crop, extent of wilting required, quantity of material (yield), time of day when cut, prevailing weather conditions, wetness of the ground surface and mechanical treatments used to enhance the speed of wilt. These factors are discussed in this chapter.

Safety First

- Operate all equipment to the specifications laid down in the manufacturer's manual and/or warning stickers on the machinery.
- Never approach machinery until all mechanical motion has completely stopped.
- All PTO shafts, belts, chains, etc, must have strong, tamper-proof coverings that are only removed for servicing and repair work after machinery has been turned off and all moving parts are stationary.

What it means ...

- Swath – the material left by a mower or mower-conditioner.
- Tedded swath – mown material that has been spread or respread by a tedder.
- Windrow – the mown material that has been raked in preparation for harvest.
- Harvesting – the picking up and baling or forage harvesting of the mown material from a windrow.
- DM loss – the quantity of material lost during the conservation process, e.g. for every tonne of forage cut, if DM loss is 10%, then 100 kg of DM has been lost. DM loss is sometimes confused with DM content, which is the DM present in each unit of forage.
- Quality loss – the reduction in the content of nutrients (e.g. ME, crude protein) during the conservation process.

Section 6.1

Assessing likely weather conditions

Ideally, forage should be cut and harvested under good drying conditions, without risk of rain damage.

Before mowing, use weather forecasts to select a 'harvest window' when weather conditions are likely to be favourable for silage making. As well as local and regional weather forecasts, the Internet provides up-to-date forecasts. The Australian Bureau of Meteorology has a website containing valuable weather information <www.bom.gov.au>.

A number of other commercial and free sites also exist, including:

- <www.myweather.com.au>
- <www.theweather.com.au>

Plate 6.1

Perennial ryegrass pasture cut with a mower-conditioner set to produce a wide swath (left of photograph) and a narrow swath (right).

Photograph: F. Mickan

Section 6.2

Time of day to mow

Photosynthesis is the process by which plants use solar radiation (sunlight) to produce WSCs. Respiration is the process by which plants break down WSCs to produce energy for growth. It is the reverse of photosynthesis. Under normal growing conditions, both processes occur in plants.

How WSC content varies during the day

As discussed in Chapter 2, Section 2.1.2, the conversion of WSCs to lactic acid is essential for a good silage fermentation. High WSC content allows production of more lactic acid, more quickly, thus increasing the chance of a rapid and favourable fermentation.

Accumulation of WSC is greater than respiration during sunny periods, while respiration leads to a reduction in WSC content when it is overcast or at night. So, WSC content is usually lowest in the morning and accumulates during daylight hours. On cool, overcast days WSC content may not vary much at all during the day.

Respiration continues after mowing if plant moisture content is high and while WSCs are still available. For a short period after cutting, a small accumulation of WSC may occur at the top of the swath, which is exposed to sunlight, but this contribution to the WSC content is negligible.

It is not possible to provide general guidelines to cover every silage-making scenario as the effect of weather conditions on wilting rate is a major consideration. Although it is sometimes suggested that mowing should start mid-afternoon to maximise available WSC, in all cases the primary aim should be to achieve the target DM content (see Chapter 4, Table 4.1, and Chapter 5, Table 5.2) with a rapid wilt. This, not the WSC content of the uncut forage, should determine cutting time.

How time of day of cut affects wilting rate

Cutting early in the day maximises the amount of moisture loss that can be achieved on the day the forage is mown. Cutting later in the day often results in the forage requiring an extra day of wilting to reach the desired DM content, and can increase respiration loss of forage DM and quality. The following points should be considered:

- Mowing should not begin until the dew has lifted. This surface moisture evaporates much more rapidly from the standing crop than from mown material.
- If the day of cutting is very hot, dry and windy, and similar conditions are expected the following day, it may be advisable to delay cutting until early to mid-afternoon, to reduce the risk of the forage becoming too dry by the following morning.
- Some forages, such as legumes and young, leafy crops or pastures, wilt more rapidly (see Section 6.5), and require a short wilting period, particularly if the yield is not high. For these, cutting later in the day may reduce the risk of over-drying, and excessive mechanical damage and leaf loss in subsequent operations.
- Where there is a definite risk of over-drying, mowing may be staggered and the swath width should be narrowed. It is important to match mowing and harvesting operations so that cut material is not left too long.

Extending the wilting period also increases the risk of rain before harvesting. This can be particularly important in coastal areas that are prone to unpredictable, afternoon rain during the summer silage-making season.

Timing the cut

When to cut is often a compromise between quality and yield.

The digestibility of most temperate pastures and crops used for silage production is highest in early spring, before maximum yield is achieved. This often coincides with lower temperatures, shorter days and, in southern Australia, a greater chance of rainfall. As a result, many farmers delay harvest until later in the season – towards what is often the more traditional haymaking season. When planning harvest times, consider the following points:

- Cutting earlier in the season, the forage has a higher nutritive value. Cutting later, when the crop or pasture is more mature, will give higher yields, but the forage will be of lower quality (see Chapters 4 and 5).
- Cutting early increases the risk of losing quality because of poor wilting conditions and rainfall but, in most cases, the average loss in quality is unlikely to be as great as the decline in ME content when cutting is delayed by three or more weeks.
- In many cases, and depending on forage type, even with reduced yield the animal production per hectare of cut forage is higher from silage produced early in the season. With very mature forage, the quality decline may be so great that the silage is only suitable as a maintenance ration (see Chapters 13, 14 and 15).
- The costs of production are very similar per tonne of silage conserved for early-cut, lower-yielding and late-cut, higher-yielding crops or pastures. When costed on an ME basis, the higher-quality, early-cut silage is less expensive (see Chapter 11, Section 11.3.5).
- Early cutting should produce a greater quantity of high-quality regrowth and a greater total forage yield (silage and regrowth) (see Chapter 3, Section 3.1.1).

Section 6.3

Mowing

The mower's efficiency will have a major impact on the success and speed of the wilting process. Mowing rates should be more than 1.5-2.0 ha/hour. It is important to avoid any factors that may extend the mowing period, such as using small mowers, blunt mower blades or under-powered tractors. It may be more economical to employ a contractor with the latest and largest machinery to mow and condition the crop. (The economic reasoning behind the use of contractors is discussed in Chapter 11, Section 11.2.3.)

Using conditioners and increasing swath width can increase wilting rate (see Section 6.6). Formation of lumps in the swath behind the mower must be avoided because the material takes longer to dry and can slow down the harvesting operation.

Table 6.1

Suggested cutting heights for various forage types.

Forage type	Height of cut (cm)
Pastures	4-7
Summer forage crops (e.g. sorghum)	10-15
Lucerne	5-7 (above plant crowns)
Cereals	7-10 (>15 for increased quality)
Maize	10-40 (see Chapter 5, Section 5.2.4)
Kale	7-8
Peas	10-12
Lablab	10-12
Soybeans/canola	6-10

6.3.1

Height of cut

The ideal cutting height depends on a number of factors, including the type of pasture or crop, yield and quality, potential for regrowth, wear and tear on blades and machinery, soil and manure contamination and provision of a stubble on which the mown material can lie for drying.

The optimum height of cut to maximise regrowth will vary with the pasture or crop, but is usually 4-7 cm for pastures and 10-15 cm for summer forages such as sorghum. Cutting crops and pastures with multiple-cut potential too short (<5 cm) may slow the rate of regrowth and reduce total yield over the season. Table 6.1 gives suggested cutting heights for various crops and pastures.

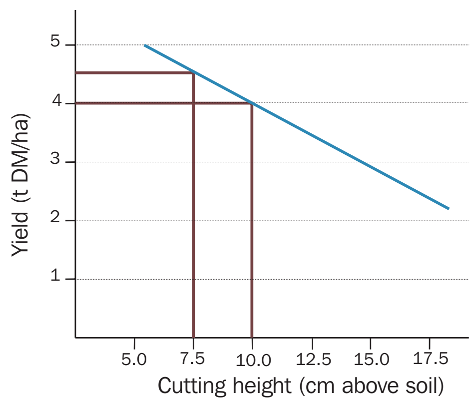
Although cutting material very short will slightly increase yield, depending on the plant species, this may be offset by the poorer quality of the lower stems and leaves. If cutting height is increased to avoid low-quality stems, stubble management strategies may be needed if the paddock is to be returned to crop or pasture in the near future.

Figure 6.1 shows the results of some recent American research on cutting height with lucerne. On average, total yield for each cut increased about 0.5 t DM/ha for each 2.5 cm reduction in cutting height. The shorter cutting height did not reduce the yield of the next harvest when cut at the mid-bud to early flowering stage. Although quality decreased slightly with decreasing cutting height, when both quality and quantity were taken into account, the potential milk yield rose when cutting height was reduced.

It is important to have the mower properly adjusted for height and to maintain sharp blades. Poorly maintained and badly adjusted equipment needs more power and so increases operating costs. Mowers set at too great an angle will 'scalp' the sward and leave a 'mane' of crop between the cutting discs. This can substantially reduce regrowth.

Poorly adjusted mowers also cause problems if they come into contact with the soil regularly, increasing the wear and tear on blades. This increases 'down time', with more frequent sharpening or changing of the blades. At very low cutting heights, the contact between blades and the soil can put undue stress on the gears driving the rotors, reducing the mower's potential life.

Figure 6.1



Effect of cutting height on lucerne yield per cut.

Source: Adapted from Wiersma et al. (2001)

Cutting low also increases the risk of soil and manure contamination of the silage. This can introduce undesirable bacteria to the forage and adversely affect the silage fermentation. It may even have implications for animal health (see Chapter 2, Section 2.3.5).

Exposed stones can damage mowers, forage harvesters and chopping balers. Rolling after sowing can be an advantage where the surface is uneven or stones or clods are present.

Leaving a stubble ≥10 cm high provides support for the mown material, reducing contact between the swath and the ground. This increases the drying rate, allowing greater movement of air under and through the swath. The mown material is also kept above the ground, reducing the movement of moisture into the cut forage.

6.3.2

Types of mowers

Mower types include:

- reciprocating finger-bar (sickle bar);
- flail;
- drum;
- rotary disc; and
- mower-conditioners (roller type, tyned or flail type).

Mowers and mower-conditioners are usually mounted to a tractor three-point linkage or trailed. The development of combination front- and rear-mounted mowers, trailed tandem-mounted and self-driven mowers have increased mowing rates.

Reciprocating finger-bar mowers

Lucerne growers often favour reciprocating finger-bar (also called sickle or cutterbar) mowers because they leave a 'cleaner cut' or reduced fragmentation of the stubble. They have a relatively low power requirement, about 1.5 kW/m width of cut, but forward speed is restricted to 3-8 km/hr, giving a mowing capacity of about 0.6 ha/hr in good cutting conditions.

They have generally been superseded by rotary disc and drum type mowers that have a faster cutting speed, less chance of 'blocking' in wet or lodged material, and greater durability on stony ground.

Flail mowers

Flail mowers are modified flail harvesters, which leave the mown crop on the ground in a windrow. After wilting, the chute is changed to allow the material to be picked up and delivered to a cart. Output ranges from 0.4 to 1.2 ha/hr for a 1.5 m width of cut, and up to 1.5 ha/hr with a 1.8 m width of cut, but requires at least 35 kW to operate at 8 km/hr.

They are no longer common, due to their inefficiency as mowers, lack of speed and high power requirement. The action of flail mowers can cause the forage to be contaminated with soil or manure.

Drum mowers

Drum mowers usually consist of one or more pairs of large drums, each fitted with several knives. The two drums in each pair rotate in opposite directions, forcing the mown material between them and leaving the swath in a windrow. Drum mowers have a much greater capacity than finger-bar mowers but require 4-8 times the power, typically 7-15 kW at the PTO per metre width of crop cut. The swaths left behind these mowers tend to 'sit higher' than those left by rotary disc mowers.

Leaving the mown material in a windrow is a disadvantage. To increase wilting rate, the material should be tedded immediately after mowing (see Section 6.6).

Disc mowers

Multi-disc mowers are the most popular mowers due to their speed of operation and durability. Disc mowers consist of several pairs of small rotating discs, each usually fitted with two knives. The pairs of discs rotate in opposite directions, like drum mowers, but because the discs are much smaller in diameter, the material is essentially left where it is cut. Disc mowers are fitted with swath plates, which allow the swath width to be adjusted, from a narrow windrow to one almost the width of cut.

Disc mowers have a similar throughput capacity to drum mowers. Cutting widths and work rates of individual mowers have increased substantially in recent years. They (and drum mowers) can be operated at forward speeds of 10-13 km/hr, giving a cutting rate of 1.0-1.5 ha/hr/m width of cut, depending on crop and ground conditions, and operator skill.

There is some evidence that forage cut with a disc mower dries more quickly than that cut with a drum mower. In these studies, both in Australia and overseas, the principal advantage appears to be the wider swath width. One disadvantage is that the forage drops to the ground with minimal disturbance, so the thickest and wettest parts of the crop remain at the base of the swath, on the ground. In very heavy crops, the base of the swath can be still very moist after several days unless the drying conditions are very good or the crop is tedded after mowing (see Section 6.6).

Mower-conditioners

In the past, conditioners required two operations, with separate implements, to pick up and condition the crop. With higher capacity tractors and a need for greater efficiency, mowers (usually disc type) that incorporate conditioners have been developed. There are now mower-conditioners with a cutting width of about 5.5 m that are capable of cutting 1.0-1.5 ha/hr/m width of cut. They require up to twice as much power as mower-only machines, to maintain output and performance, typically 15-25 kW at the PTO per metre width of crop cut.

There are essentially two main types of conditioners – roller and flail.

Roller conditioners operate by either ‘crushing’ or ‘crimping’ the cut forage with rubber and/or steel rollers of various designs. The crimping types leave a number of breaks at intervals along the stem, whereas the crushing types split the stem along its length.

The flail-type conditioners use a variety of metal, polyethylene or nylon spokes or tynes, which may be either straight or vee shaped, a series of rotating nylon brushes, or various combinations of these.

Conditioners vary in their suitability for various crops and pastures. Research has shown that roller conditioners are the most suitable for ‘stemmy’ crops, such as sorghum, cereals and stemmy leguminous crops with a tall growth habit such as balansa, Persian, berseem and arrowleaf clovers and lucerne, but can be used for all crops and pastures.

As a general rule, the tyned conditioners should only be used for grass-type pastures and crops such as ryegrass, early cut millet and cereals, and non-stemmy legumes, such as sub and white clovers and medics. Conditioners fitted with nylon brushes have a role in ‘softer’ pasture-type forage. The way the machine is set up and the skill of the operator will have a bearing on the effectiveness of the operation. Machines adjusted incorrectly may either over- or under-condition the forage.

Plate 6.2

Disc mower. *Photograph: F. Mickan*

Plate 6.3

Disc mower, with flail conditioner. *Photograph: F. Mickan*

Plate 6.4

Rear view of disc mower with roller conditioner. *Photograph: F. Mickan*

Conditioners increase the rate of wilting in two ways. They damage the outer waxy protective layer (cuticle), allowing moisture to pass through the plant surface more freely. They also damage the stem, increasing the rate of moisture loss from these areas.

Forage should not be over-conditioned; this will cause increased loss of DM. The leaf fraction, which is the highest quality component of the forage, is particularly susceptible to over-conditioning.

If a separate conditioner is used, this operation should follow as soon as possible after cutting to be most effective and to minimise DM losses.

Many mower-conditioners and conditioners now have adjustable swath boards or deflector plates to allow mown forage to be left in very wide swaths. The ideal drying swath will have the stems of the crop on top of the swath, be widely spread and left 'fluffy' to allow airflow through the swath and for the moisture to escape. The advantages of rapid wilting, and the use of mower-conditioners and other practices to increase wilting rate are discussed in Sections 6.5 and 6.6.

The demand for greater capacity has resulted in longer cutter bars on mower-conditioners. Combinations of front- and rear-mounted mower-conditioners or tandem-mounted mower-conditioners have also increased cutting widths. These can have overall mowing widths above 7 m, and cutting rates up to 10 ha/hr.

The latest development has been the self-driven mower-conditioners, incorporating two side mower-conditioners and a front mounted mower-conditioner with cutting widths of about 9 m and cutting rates of up to 10 ha/hr.

Intensive mechanical conditioning

Recent research in the United States, Canada and Australia has compared drying rates of forage using various machines – those that heavily condition crops at mowing, and high-performance or intensive mechanical conditioners (maceration, mat making or super conditioning). These high-performance conditioners are in the early stages of development. Table 6.2 shows the relative drying rates that can be expected from a range of machines designed to increase forage drying rates.

The maceration system combines four steps into one machine: mowing, macerating it through a series of serrated rollers, compressing the mashed forage into thin mat, and depositing it on the stubble for field drying. Macerated forage can dry 2-3 times faster than conventional windrows. Although use of maceration systems has been shown to improve quality of lucerne hay produced, with significantly less field losses, its role in silage production is still being evaluated.

Table 6.2

Increase in drying rate achieved using various machines.

Type of machine	Increase in drying rate (%)
Windrow inverter	20-30
Tedder	30-60
Mower-conditioners	20-40
Maceration, super conditioning, mat making	100-200

Source: Adapted from Savoie et al. (1993)

Section 6.4

Dry matter content

All forages are composed of dry matter (DM) plus water. Therefore, a silage which has a DM content of 45%, contains 55% moisture, for a total of 100%. When completely dried in an oven, only the DM remains. It is the DM that contains the energy, protein, fibre, minerals and vitamins that livestock require for maintenance and production (see Chapters 13, 14 and 15).

6.4.1

Target DM content at harvest

A good silage fermentation depends on the forage being harvested in a target DM range (see Chapter 2, Section 2.1). The target DM content will vary with factors such as crop type, growth stage at harvest, and the type of equipment and storage method being used. Table 6.3 shows recommended DM content and wilting requirements of a range of crop and pasture types. Chapters 4 and 5 give more detail on recommended DM content and growth stage at harvest, potential yield and quality of specific crops and pastures.

The DM content for baled silage is usually higher than that recommended for silage harvested with a forage harvester and stored in pits or bunkers. Figure 6.2 shows the target DM content for various forms of forage storage options. The maximum DM content recommended for most Australian

Table 6.3

Wilting requirement and target DM content at time of ensiling for a range of crops and pastures.

Crop type	Wilting requirement	Target DM (%) content at ensiling	
		Forage harvested	Baled
Lucerne Legume-dominant pastures Legume forage crops Grain legume crops Cereal/legume mixtures	Yes	35-40	35-50
Temperate grass/ clover mixtures	Yes	30-40	35-50
Kikuyu grass	Yes	35-40	35-50
Whole crop cereal	Boot – Yes Dough – No*	35-40	35-50
Forage sorghum	Yes	30-40	35-50
Japanese millet Forage pennisetum	Yes	30-40	35-50
Grain sorghum	No*	30-35	NR
Sweet sorghum	No*	25-35	NR
Maize	No*	33-38	NR
Brassica spp. (canola, kale)	Yes	30-35	35-45

** Direct harvested.*

NR – not recommended.

See Chapters 4 and 5 for more detail.

silage storage systems does not exceed 50% DM, the level for most baled silage systems.

If the forage becomes over-dry, very fine chopping and using balers that can compact the material well may allow an adequate preservation of the silage. However, harvesting at DM contents above the target ranges in Table 6.3 is not recommended because of the high field losses that can occur (see Chapter 2, Section 2.5.1).

In reality, if most of the crop is to be harvested at the desired DM content, harvesting will usually start when it is slightly lower than recommended. Minimising time delays – by using extra or larger equipment, or contracting operations, for example – ensures quality losses during harvesting are kept low, and that most or all the silage is harvested within the target DM range.

Effluent loss can be a major problem with low DM silage (see Chapter 2, Section 2.1.1), but is less significant when DM content of the silage is more than 28-30%.

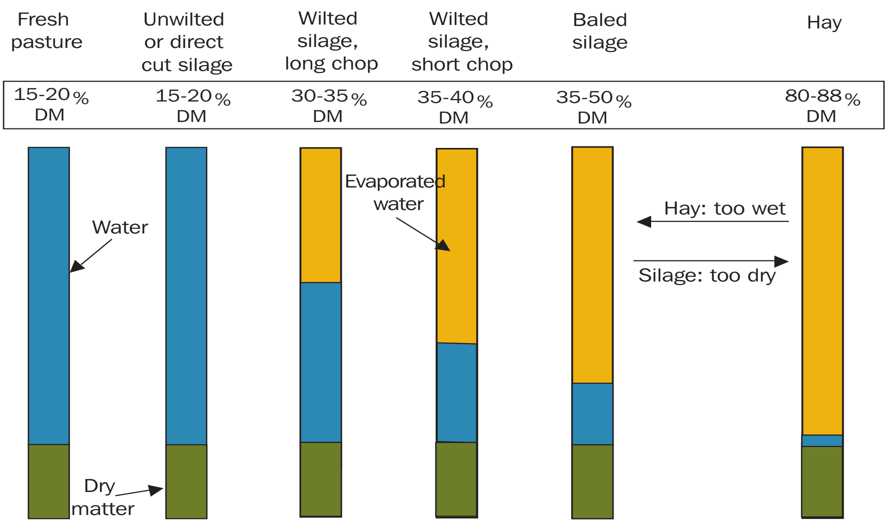
The contamination of waterways and groundwater with silage effluent is a potential problem that can be avoided with good wilting management (see Chapter 2, Section 2.1.1). Contamination of water systems is a growing concern, receiving increasing attention from the various environment protection authorities.

As well as being an environmental concern, effluent loss results in a decline in silage quality. Silage effluent contains many nutrients, with up to 5-10% solids, comprising soluble crude protein (20-30%), soluble sugars (4-30%), fermentation products (0-30%) and ash (20-30%) on a DM basis. A silage of 20% DM may lose 5% of its DM as effluent, most of which is highly digestible.

- Legumes have relatively low WSC content and, for chopped silage, need to be wilted to DM levels at least 2-5% units higher than grasses or cereals, at the lower end of the target range.
- More mature plants with lower leaf:stem ratio need to be ensiled at the lower end of the recommended DM ranges to ensure adequate compaction (see Table 6.3).
- Haylage is an American term used to describe high DM silage (50-60% DM) stored in large tower silos using the Harvestore® system. The enormous weights inside the towers compacts the silage.
- Some producers have successfully ensiled large square bales at 55-70% DM. However, field losses (DM and quality) at these high DM levels are greater.

Figure 6.2

The target range of DM content for various forms of forage.



6.4.2

How to determine DM content of forages

Sending samples of fresh forage to feed analysis laboratories for accurate DM assessment is not practical. Simple and relatively quick DM assessment can be done on-farm using one of two methods:

1. Hand squeeze method.
2. Microwave oven method.

At the time of publication, hay moisture meters, although accurate for measuring low moisture content in hay, for example, were not sufficiently accurate for forages in the DM range recommended for silages. However, further evaluation is required.

Standard kitchen ovens are not suitable for drying forage samples. As well as the risk of the sample burning, the process is very slow and may take 10 to 24 hours to dry completely.

The sample of forage to be dried must be representative of the mown material, with samples from various locations in the paddock and to the full depth of the windrows. Areas not representative of the paddock, such as capeweed infestations or wetter sections, should be sampled and treated separately. These sections of the paddock may need to be harvested last, particularly within a baled silage system.

Plate 6.5

Silage quality and DM losses can be high if the forage is not adequately wilted. These bales were ensiled when DM was too low.

Photograph: F. Mickan

Hand squeeze method

This is a quick and easy method for use in the field. It is more accurate than 'wringing' a handful of unchopped grass. Initially, you may need to calibrate this method (or some other test devised by your own experience) by using a microwave oven to determine the correct DM content, or be guided by someone with experience in using the technique.

1. Take representative samples of the mown forage across the paddock. (In uniform crops, a small section may be forage harvested and a sample collected.)
2. Mix the samples thoroughly and take a sub-sample.
3. Cut the sub-sample into 1-2 cm lengths.
4. Tightly squeeze a handful into a ball for about 30 seconds.
5. Quickly open hand.
6. Estimate approximate DM content from Table 6.4.

Table 6.4

DM content determination from hand squeeze method.

DM content	Condition of the sample
Below 25%	Free moisture runs through fingers as material is being squeezed. When pressure is released, the ball of chopped forage holds its shape. A lot of free moisture is present on hand.
25-30%	Ball just holds its shape. No free moisture expressed. Hand moist.
30-40%	Ball falls apart slowly. No free moisture. Little or no moisture on hand.
Above 40%	Ball springs apart quickly.

At the same moisture content, stemmy material will tend to feel drier than leafy material. For example, grasses and lucerne will feel drier than clover. Forage that has surface moisture from heavy dew or rain, may feel wetter than it is. In both cases, the effect will be less for chopped material than for longer material.

Microwave oven method

A reasonably accurate estimate of DM content may be obtained using a standard domestic microwave oven. Digital scales, which measure to units of one gram, are essential.

Follow steps 1 and 2 of the hand squeeze method, then:

3. Cut the sub-sample into 3-4 cm lengths.
4. Tare a container suitable for use in a microwave. The size of the sample to be weighed should be equivalent to the amount that could be heaped onto a large dinner plate (about 150 g). Weigh the sample of the chopped forage in the tared container, measuring to the nearest gram. Record this as the *initial wet weight*. Spread the material evenly over the container and place in oven with a glass of water (see 'Warning' at left).
5. Dry on full power (high) for intervals of 3-5 minutes to begin with until the sample begins to feel dry (time depends on sample size, shortness of chop and initial DM content), reducing to 30 seconds to one minute as the sample becomes drier. Samples should be turned and 'fluffed-up' at each weighing to improve evenness of drying. This initial drying may require up to 10 minutes of microwave time for very wet samples.
6. Record weight of the sample and continue to heat, initially for 30-second periods, at reduced power. Record weight at the completion of each period in the microwave.
7. If the weight of the sample does not change after two or three drying intervals, it is 100% dry (to within 1-2% units). This is the *final dry weight*. If the sample chars or burns, use the previous recorded weight. Occasionally, the weight may increase if the sample absorbs some moisture from the glass of water; if this happens use the last recorded weight.
8. See box below for the method to calculate DM content.

Warning

Place a 250 mL glass three-quarters full of water in the oven during drying to prevent the forage sample charring or igniting as it becomes completely dry. Maintain the water level during oven use.

You may need to replace the water with cold water if it starts to steam or boil as this steam may be absorbed by the drying forage.

8. Calculate the DM content

$$\text{DM (\%)} = \frac{\text{Final dry weight (g)}}{\text{Initial wet weight (g)}} \times 100$$

Example: $\frac{48 \text{ g}}{112 \text{ g}} \times 100 = 42.8\%$ DM

Remember: Tare the container (set the sclaes at zero before adding the sample) or subtract its weight from both the initial and final weights.

Forage and silage DM content is usually expressed as a percentage of the total weight. It is calculated using the following equation:

$$\text{DM (\%)} = \frac{\text{dry weight (g)}}{\text{wet weight (g)}} \times 100$$

DM content may sometimes be expressed as g/kg. In this case, the following equation is used:

$$\text{DM (g/kg)} = \frac{\text{dry weight (g)}}{\text{wet weight (g)}} \times 1{,}000$$

Conversion: 1% = 10 g/kg

Section 6.5

Wilting

Wilting is the process where moisture evaporates from the mown forage to increase DM content to the desired level for harvesting.

To minimise losses (DM and quality) the mown material must be wilted as quickly as possible to the target DM content (see Table 6.3). Ideally, wilting should take no longer than 48 hours. The longer the wilting period needed to achieve the target DM content, the more extensive the DM and quality losses due to continued plant respiration and microbial (bacterial and mould) attack. The risk of rain will also increase.

Wilting beyond the target DM content also results in higher quality and DM losses due mainly to leaf loss before and during harvest (see Section 6.7).

Weather conditions directly affect wilting rate. Warm days with low humidity and extensive periods of solar radiation (sunlight), accompanied by wind, result in the fastest rates. During cool, overcast weather, when the humidity is high, wilting rates are slowest because of low evaporation rates. Weather conditions also affect loss of forage DM and quality during the wilting period (see Section 6.7).

Wilted silages are usually more palatable and result in greater animal intakes than unwilted silages produced from the same forage. However, whether or not animal production is improved will depend on the length of time taken to wilt the forage (see Section 6.5.2).

6.5.1

How wilting occurs

Moisture loss from mown forage is initially quite rapid. It occurs primarily through the stomata (microscopic pores) that are concentrated on the leaves and, to a lesser extent, the stems. Most of the water loss from both grasses and legumes is from the leaves, although some moisture (up to 30% in grasses) is drawn from the stems and evaporates through the leaves.

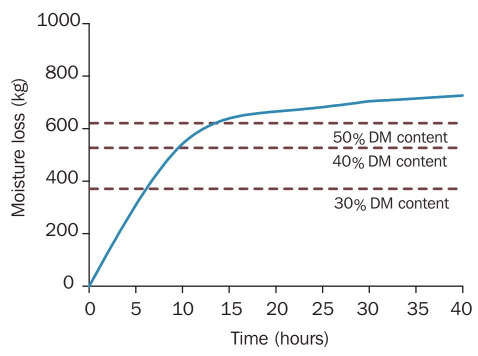
After the forage is cut, the stomata usually close to conserve moisture. This is a plant survival mechanism and occurs more quickly on a hot, drying day than a cooler, overcast day. The delay in closing of the stomata will depend on plant moisture content and the humidity within the swath, but usually occurs between 30 minutes and two hours after cutting. For most species, this stomatal closure occurs before 30% of the initial moisture has been lost.

When the stomata are fully closed, water vapour can still move through the epidermis or cuticle (outer skin) of the leaves, leaf sheaths and stems, although the rate of moisture loss is reduced to about 10% of that of open stomata.

A young, vegetative crop or pasture contains significantly more leaf than stem; as plants mature, the proportion of leaf declines. Typically, lucerne contains 55-60% leaf at the vegetative stage of growth, declining to 35-40% when in the full bloom to early pod stages. In perennial ryegrass, the percentage of leaf falls from 85% at the early vegetative stage to 20% when fully in head. As plants mature, the proportion of soluble cell contents in the stems also falls as more structural fibre is produced. These changes explain the more rapid wilt achieved with leafier material compared to more stemmy material.

Figure 6.3

Simulated water loss over time from 1 tonne of fresh grass with a DM content of 18.9% (81.1% moisture) at mowing.



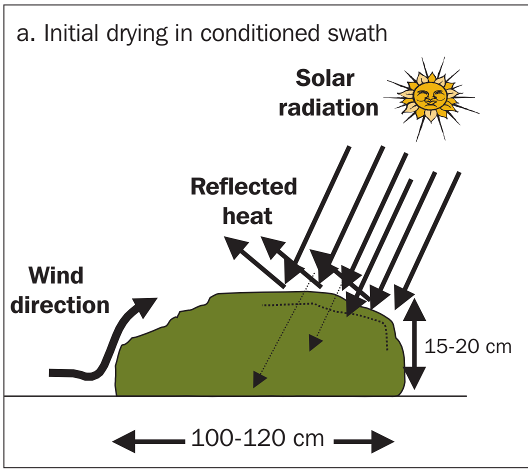
Source: Adapted from Jones and Harris (1980), using thin layer, temperature 20°C, relative humidity 50%, air speed 1 m/sec

Rate of moisture loss slows further as the forage DM content approaches 40-50% DM (50-60% moisture). This is largely due to the moisture now being drawn from inside the stems and larger plant fractions. This change in rate of moisture loss occurs at about the ideal moisture content of heavily wilted silage (see Figure 6.3).

Baled silage produced at 50% DM content will require more extended wilting, with a relatively slow rate of moisture loss during the later stages of wilting. As a result of the longer wilting period needed for baled silage, DM and quality losses during wilting are likely to be greater for these systems. The leaf fraction of some plant species may become quite dry during this period, increasing the risk of mechanical

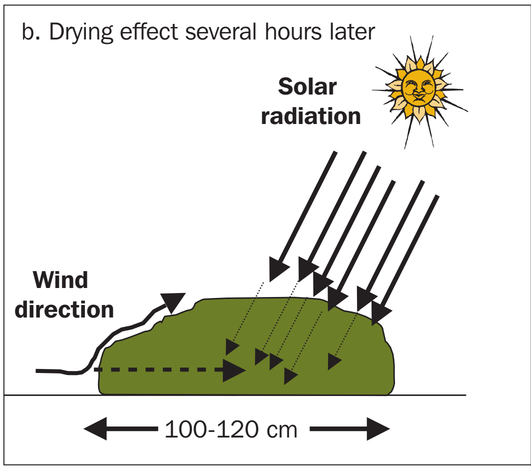
Figure 6.4

Drying dynamics in a conditioned swath.



Initial drying in conditioned swaths - depth of 15-20 cm:

- Heat generated in the swath due to continued plant respiration rises to the surface.
- Approximately 50% of solar radiation reaches ~2-3 cm into swath and about 10% to the base.
- About 20% radiation initially reflected.
- Wind initially deflected over the swath.



Later drying in conditioned swaths - depth of 15-20 cm:

- Much more solar radiation reaches the swath base.
- Little solar radiation reflected.
- More wind flows through the swath.
- Swath dries out more rapidly than if mown and left behind standard mower, with no conditioning.

losses during harvest. This is especially a problem with legumes.

The early and later stages of drying in a mown swath are presented diagrammatically in Figure 6.4. In the early stages of drying, about 20% of the sun's heat is reflected from the swath's surface, so is not available for drying. Radiation at about 2 cm below the surface is half that at the surface and only 10% at the base. There is minimal air movement in the middle of a swath, even on windy days.

The density of the swath is reduced as moisture is lost and drying continues at greater depth. As shown in Figure 6.4b, this allows greater penetration of solar radiation into the swath and more airflow through the swath.

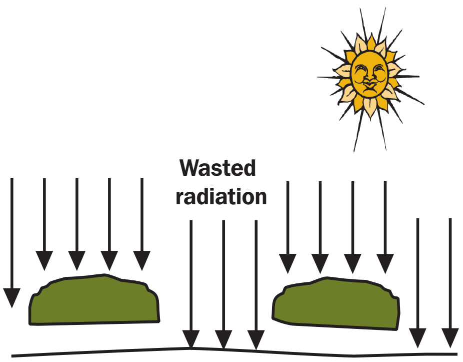
Figure 6.5 shows the impact the swath width has on drying rate. If the swaths occupy only 50% of the ground, only 50% of the solar energy is available (see Figure 6.5a). If the swaths are spread over most of the ground surface, density is reduced and exposure to wind and the drying force of solar radiation is increased, thereby maximising drying rate (see Figure 6.5b).

The humidity in and around the swath becomes quite high as moisture evaporates. Forming a low-density swath, which allows airflow through and around it, will reduce the relative humidity and improve moisture loss.

Figure 6.5

The effect of swath width on solar radiation interception and drying rate.

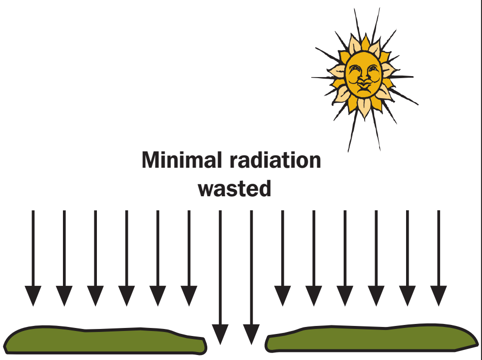
a. Utilisation of solar radiation in narrow, deep swaths



Narrow and deep swaths (very dense)

- Approximately 50% of solar radiation is not utilised for drying.
- Drying rate is slow.

b. Utilisation of solar radiation in wide swaths



Wide and thin swaths (much less dense)

- Approximately 85% of solar radiation is utilised for drying, increasing drying rate.

6.5.2

The effect of wilting on animal production

In a number of overseas studies, the effects of wilting on animal production have been variable. There have been no similar studies in Australia.

A large number of studies in Europe have compared unwilted and wilted silages produced from the same crop. Most silages studied were produced from perennial ryegrass pastures, although some contained other grasses or white clover.

These results, shown in Table 6.5, suggest that the benefits of wilting were inconsistent, and it did not guarantee any improvement in liveweight gain or milk production. However, it was found that achieving animal production benefits from wilting, as indicated by increased intake, depended on three main factors – wilting rate, final DM content and silage fermentation quality.

Further details of the effects of wilting on beef cattle production, and the study in Table 6.5, are discussed in Chapter 14, Section 14.2.3, and in Chapter 13, Section 13.2.3, and Chapter 15, Section 15.2.3, for dairy cattle and sheep production, respectively.

Table 6.5

A comparison of production from dairy and beef cattle fed wilted silages compared to unwilted silages produced from the same forage.

	Response to wilting	
	Average	Range
Dairy and beef:		
% increase in DM intake	16.4	-14 to 85
Dairy:		
Milk production (kg/day)	0.22	-2.0 to 2.2
% increase milk production (kg/day)	1.4	-10.0 to 16.7
Milk fat (kg/day)	0.03	-0.08 to 0.15
Milk protein (kg/day)	0.02	-0.07 to 0.11
Beef:		
Liveweight gain (kg/day)	0.03	-0.23 to 0.25
% change in liveweight gain	7.1	-22.2 to 64.1
Carcase weight gain (kg/day)	-0.04	-0.13 to 0.03

Source: Adapted from Wright et al. (2000)

Wilting rate

DM intake was found to be higher for silages that achieved the target DM content for ensiling more quickly (see Figure 6.6). Producers should aim for a wilting period of less than 48 hours. Where wilting is extended, the intake of wilted silage will not differ greatly from the unwilted silage. An extended wilt will increase loss of forage quality (ME) and could cause total ME intake to be reduced for wilted compared to unwilted silages.

A survey of 140 dairy farms in western Victoria (summarised in the box below) found that the average time taken to wilt was 3-6 days and the average DM content of the forage at ensiling was 45.5%. The length of wilt was longer for baled systems compared with chopped silage in order to achieve a higher DM content.

These results highlight that the majority of producers in this survey may be over-wilting and that wilting period is much too long. These producers are likely to be suffering production losses.

Summary of wilting survey results

- Average wilting period – 3.6 days.
- Average DM content of forage at ensiling – 45.5%.
- Average of 4.2 days wilting period for baled silage to achieve 49.6% DM.
- Average of 2.2 days wilting period for chopped silage to achieve 35.7% DM.

Most forages in this survey were perennial ryegrass pastures.

Source: Jacobs (1998)

Final DM content

As a general rule, for forages within the recommended DM range, DM intake increases with DM content. At high DM contents (>55%), additional field losses may reduce the silage ME content. As a result, there may be no further increase or even a relative decline in DM intake (see Figure 6.7).

If wilting is ineffective and there is little increase in DM content, intake will be very similar or less than that of unwilted silage produced from the same forage.

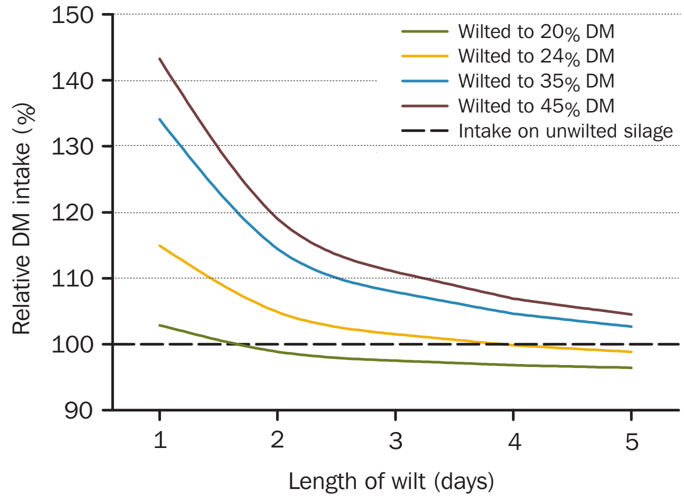
Silage fermentation quality

Where the unwilted silages were poorly preserved, as indicated by a high ammonia-N content, or where the unwilted silage contained significant amounts of acetic acid, the increase in intake due to wilting was greater. Temperate grasses (see Table 6.5) contain more WSC than legumes or legume-dominant crops and pastures, or tropical species. The increase in intake due to improved silage fermentation quality is likely to be greater with low WSC content forage.

Chapter 2, Section 2.2.2, and Chapter 12, Section 12.4.5, contain further information on silage fermentation quality.

Figure 6.6

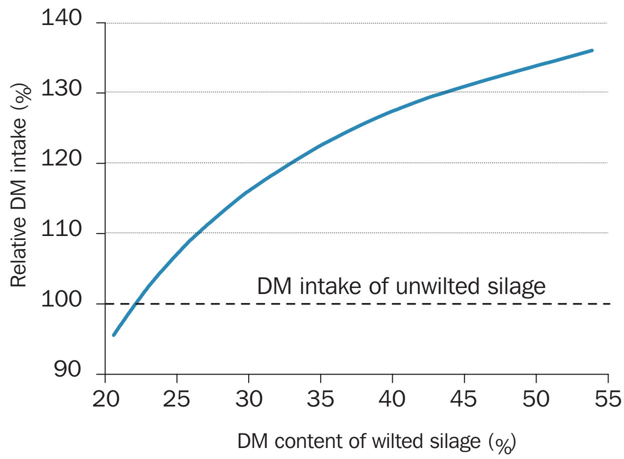
Effect of length of wilt on relative DM intake of wilted perennial ryegrass silage by cattle compared to unwilted silages with a DM content of 18%.



Source: Adapted from Wright et al. (2000)

Figure 6.7

Effect of DM content of wilted perennial ryegrass silage on DM intake compared to unwilted silage (18% DM content) from the same forage.



Source: Adapted from Wright et al. (2000)

Section 6.6

Increasing wilting rate

A rapid wilting rate is necessary to maximise the potential benefits of wilting. A number of management strategies and mechanical processes are available to increase wilting rate. They can be used independently or in combination.

Cut at an earlier growth stage

Cutting early, when crops are lighter (lower yielding) and of higher quality, will increase the wilting rates. For heavier crops, DM and quality losses during the wilting process are likely to be higher because they dry more slowly than lighter crops. This can be particularly important early in the season, when drying conditions are less favourable and even light crops do not dry as rapidly.

Given the choice, it may be worthwhile to harvest a greater area of early-cut (lower yielding) forage to ensure rapid wilting. Although, when costed on a $/kg DM basis, the silage produced from the lighter crop is more expensive, on a quality basis ($/kg ME) it may be cheaper. Chapter 11, Section 11.3.5, discusses this quality/cost comparison in detail.

Before mowing, consider the impact of cutting time and growth stage at harvest on regrowth potential and consequences for feed budgeting (see Chapter 3).

Mow after the dew lifts

Overnight dew on a standing crop or pasture can contain up to 2 t/ha of 'free' moisture. Mowing should be delayed until most of it has evaporated. If not, the moisture 'trapped' under the mown swath will delay drying. Drying will be even slower if the swath is left flat, rather than loose and 'fluffy'.

Condition forage

Using a conditioner at mowing can increase the drying rate by 20-40%. Table 6.6 shows the increase in wilting rate due to conditioning, for a range of swath widths and drying conditions. See Section 6.3.2 for the various types of conditioners and their mode of mechanical operation.

The increase in wilting rate of conditioned forage is due to increased rate of moisture loss through damaged stems, leaves and other plant parts. In addition, the swath produced tends to be loose or fluffy, allowing more air to pass through, which also helps to promote rapid drying.

Conditioning can have the following disadvantages, but these are outweighed by the benefits:

- In the event of rain, conditioned material will reabsorb more moisture than unconditioned forage.
- Over-conditioning or using the wrong type of conditioner can increase DM loss, mainly leaf.

Table 6.6

Results from Irish studies showing the effect of conditioning, swath type and sunshine on ryegrass DM content (%) after 8 and 32 hours.*

Treatment	Dull sunshine				Average sunshine			
	Unconditioned		Conditioned		Unconditioned		Conditioned	
	8 hr	32 hr	8 hr	32 hr	8 hr	32 hr	8 hr	32 hr
Double swath	14.4	15.5	14.6	16.0	15.6	18.2	16.1	19.3
Single swath	15.5	18.0	16.0	19.0	18.3	24.6	19.4	27.3
Spread swath	17.6	22.9	18.6	25.3	23.5	38.0	26.1	44.7

Double swath – two swaths combined immediately after mowing.

** The initial grass DM content was 13.2% yielding 3.96 t DM/ha. No rain fell during the experiment.*

Note: With the more favourable wilting conditions usually experienced in Australia, the drying is likely to be faster, and after the same length of time the final DM contents would be substantially higher than in these Irish studies.

Source: Patterson (1998)

- In very hot weather, particularly with light crops, the forage can dry too quickly. Cutting later in the day, reducing swath width and lessening the severity of conditioning will minimise the losses.

Increase swath width

The rate of moisture loss is greater from a flat swath spread over the total mower width than from a high, narrow swath. A wider swath allows more of the mown forage to be exposed to solar radiation (see Figure 6.5) and significantly increases the wilting rate.

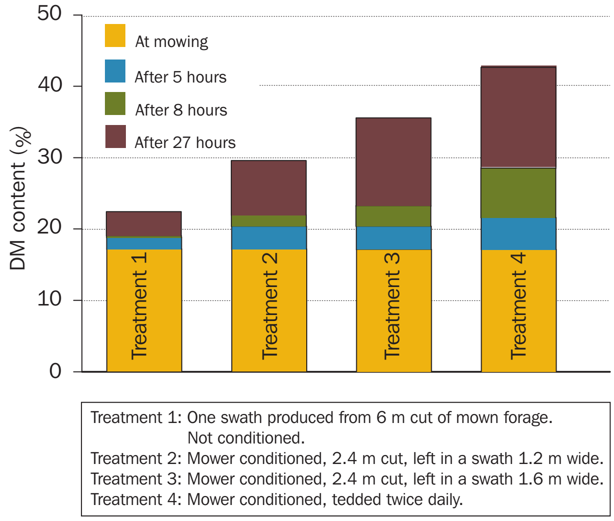
The rate of moisture loss differs throughout the swath, being highest at the outer surfaces and lowest internally, where a 'microclimate' develops and further restricts moisture loss. In fact, the sun has far more drying power than wind, although the two in combination are most effective.

In Irish studies, with heavy ryegrass crops, conditioning the forage and having a wide swath increased wilting rate (see Figure 6.8).

At Berry on the NSW south coast, kikuyu grass was either windrowed at mowing or left in a wide swath. The windrowed kikuyu took 54 hours to achieve the same DM content as the kikuyu in the wide swath achieved after 30 hours (see Figure 6.9).

Figure 6.8

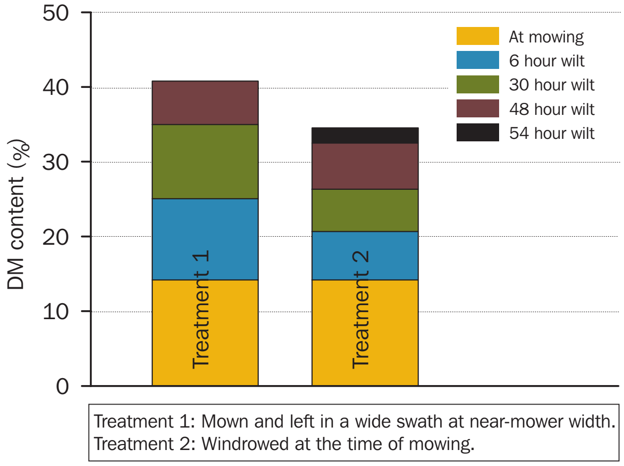
Effect of swath treatments on the DM content of ryegrass (originally 17.2% DM content with a yield of 3.87 t DM/ha) after 5, 8 and 27 hours.



Source: Forristal, O'Kiely and Lenehan (1996)

Figure 6.9

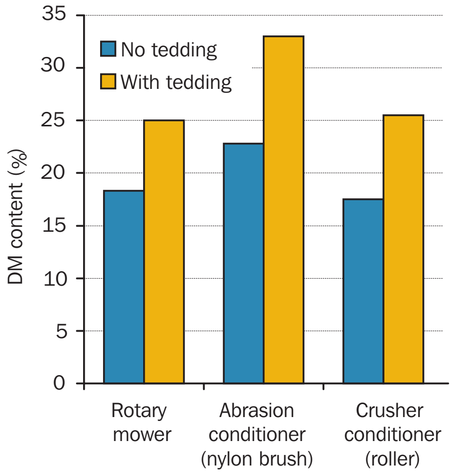
Effect of swath width on the drying rate of kikuyu grass at Berry, NSW.



Source: Kaiser et al. (unpublished data)

Figure 6.10

Effect of drying treatments on DM content of pastures.



Source: Wilkinson (1995) citing the results of a Dutch study

Plate 6.6

Tedding the mown forage spreads the swath and increases wilting rates.

Photograph: F. Mickan

Tedding

Tedding is the mechanical action of a tedder rake, which spreads the mown material. It should be done as soon as possible after mowing and may be repeated. Tedding or spreading the mown material straight after mowing will increase the rate of drying by 30-60%, depending on such factors as crop yield and climatic conditions.

Early in the season, when drying conditions are not ideal, two or three teddings may be necessary to achieve the desired DM content, especially if the crop is to be harvested as baled silage. The initial tedding should be at a relatively slow speed to ensure the crop is well spread. Later teddings may be at faster speeds, but not so vigorous as to cause leaf loss. Leaf losses are minimal when the tedder is used straight after mowing and if tedded later at low DM contents (see Section 6.7.3). Particular care needs to be taken with forages such as lucerne, where the leaf may be much drier than the stems.

Tedding a crop mown by a mower-conditioner may increase the drying rate by a further 20-30%, depending on factors such as crop yield, conditioner type and drying conditions. Tedding increased the wilting rate in the previous Irish study (see Figure 6.8) and a Dutch study (see Figure 6.10). These improvements occurred with both conditioned and unconditioned forage.

In studies on the south coast of NSW, the time taken to wilt grass to greater than 30% DM content was reduced substantially by leaving the swath at mower width and tedding the grass during the afternoon (see Figure 6.11).

Use windrow inverters

Windrow inverters have been developed specifically to invert the windrow, picking it up and gently replacing it back on the ground to the side of its original location. Research has shown that the rate of drying can be increased by about 20-30% (see Table 6.2). The windrow is 'fluffed up', reducing the density and encouraging a greater rate of drying in the centre.

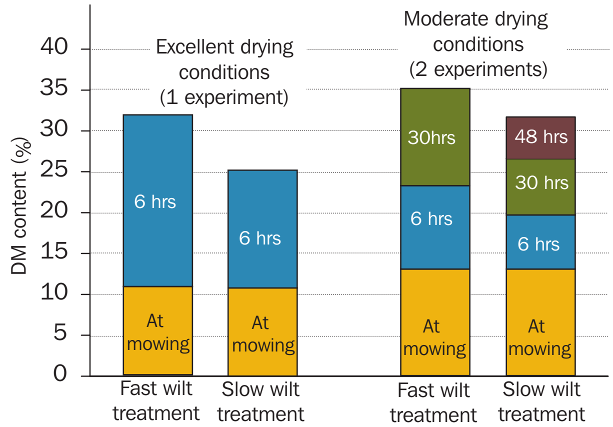
Invert windrows with rakes

If machinery is not available to increase the rate of drying by conditioning or spreading, the last resort for material that has been left in a windrow is to invert the windrows by using a rake. Rakes are not designed to handle very moist material so the 'turning' of the windrow is usually not successful. How effectively the material is inverted depends on the type of rake, DM content of the cut material, speed travelled, set-up of the rake and the experience of the operator.

A common problem experienced when using rakes to invert windrows is that the windrows become very 'ropey', being twisted and becoming narrower, leading to uneven drying. They are difficult to re-rake and harvest. These windrows are even more difficult to handle if rain falls before the harvest is completed.

Figure 6.11

Effect of swath treatment on the DM content of kikuyu grass after different wilting intervals



Fast wilt treatment - mown material left at the width of the mower and tedded once per 24-hour period.
Slow wilt treatment - material left in windrow and not tedded.

Source: Kaiser et al. (unpublished data)

Chemical conditioning

Chemical conditioning, sometimes called 'K-hay', involves spraying a drying agent such as potassium carbonate onto plant stems at cutting. The waxy cuticle or layer on the outside of the stem is dissolved, reducing resistance to water loss from the plant after mowing.

Early research in Australia and the United States has confirmed that 5 kg potassium carbonate in 200 litres of water/ha has been very beneficial for hay production with lucerne and medic crops and, to lesser extent, other legumes such as red clover. They are less effective in high-yielding crops and where drying conditions are favourable.

Drying agents have proven of no benefit on kikuyu forage and limited benefit in pastures and other crops. Although no research has examined its usefulness for silage, the lower DM content required for silage and continued developments in conditioning machinery suggest chemical conditioning may not have a role in silage production.

Section 6.7

Field losses

Once cut, a crop immediately begins to lose both DM and energy (ME).

There are three sources of field loss:

- Plant respiration loss
- Weather damage loss
- Mechanical loss.

Some losses, such as leaf shatter, are visible during mechanical operations. Other losses, such as plant respiration, residual plant enzyme activity and microbial degradation, are invisible.

DM and energy losses increase as the forage is wilted to higher DM contents, and are higher for hay compared to silage. Losses are higher when wilting is slow and if rain occurs. Additional information on the various sources and extent of losses throughout the silage making process are discussed in Chapter 2, Section 2.5.

DM and quality losses are usually greater in younger versus older crops, in legumes versus grasses, from long versus short wilting periods, from prolonged rain falls, from incorrect timing of mechanical handling and incorrect equipment set-up.

Factors affecting extent of field losses

- Higher-yielding crops and pastures wilt more slowly, increasing field losses.
- The type of machinery used for mowing and conditioning (and operator proficiency) will affect mechanical losses.
- Losses increase with the number of mechanical (tedding and raking) operations, and depend on the DM content at the time.
- Losses are less with rapid compared to slow wilts.
- Wide, thin swaths wilt more rapidly than narrow windrows, reducing losses.
- Increasing amount, frequency and intensity of rainfall will delay wilting and increase losses.
- Rainfall late in the wilting process, at higher DM contents, will cause higher losses.
- Losses increase as the forage is wilted to higher DM content at harvest.
- Time and effectiveness of follow-up drying weather.
- Type of machinery used in follow-up drying and harvesting.

6.7.1

Plant respiration losses

Plant respiration converts WSCs into water, carbon dioxide and heat, resulting in a loss of DM and energy (hence ME content) in the forage.

Respiration rate is highest at cutting when plant moisture content is high; as the moisture content decreases so does the respiration rate. Temperature also directly influences the respiration rate – it is higher at higher temperatures. The effect of DM content and temperature on respiration rate is shown in Chapter 2, Figure 2.6.

Although some respiration losses are unavoidable, a rapid wilt will minimise them. Respiration losses are typically about 2-8% of the DM, but may reach up to 16% under poor drying conditions when making hay. Although losses may not be as high when making silage, prolonged wilting and periods of rain, particularly soon after cutting, will cause significant losses.

6.7.2

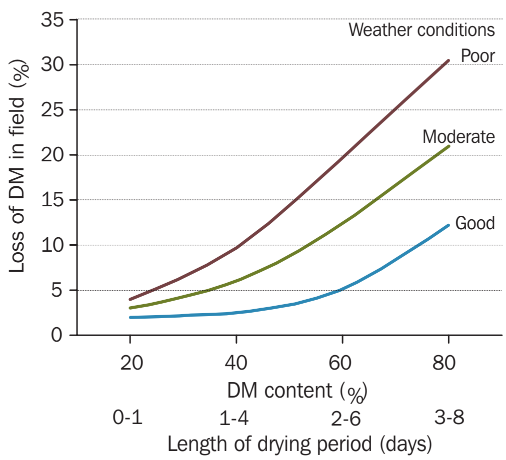
Weather damage losses

Cloudy skies, cool temperatures, high humidity, no breeze, heavy dews and rainfall typify poor wilting conditions. They lead to significant increases in field losses (see Figure 6.12) and increased growth of undesirable moulds, bacteria and yeasts in the swath before harvest. A large proportion of the WSC content may also be lost during respiration. If ensiled at low DM content, as a salvage operation, this loss of fermentable substrate may result in a poor fermentation and unpalatable silage. See Chapter 7 for recommended treatments using additives.

As well as slowing wilting rate, rainfall can also cause direct losses of DM and nutrients due to leaching, leaf shatter and increased mechanical losses if additional tedding/raking operations are required.

Table 6.7 summarises the results of a number of European studies with ryegrass pastures, where the loss of forage DM was determined for good, moderate and poor weather conditions. The ryegrass was tedded to increase drying rate, and the total number of tedding operations increased with deteriorating weather

Figure 6.12



Effect of weather conditions and final forage DM content on loss of DM during wilting for grass.

Source: Wilkinson (1981), citing Zimmer (1977)

Table 6.7

Effect of length of wilt and amount of rainfall on DM losses in ryegrass during wilting.

	Weather conditions		
	No rainfall	Rain on only 1 day	Rain on more than 1 day
Number of studies	2	3	3
Length of wilt (days)	2.0	4.7	8.3
Total rain (mm)	0	1.9	23.5
Average maximum temperature (°C)	25.0	17.6	17.7
Number of teddings:			
total	2.0	3.3	3.7
per day	1.0	0.76	0.5
Increase in DM content (%)	31.3	33.4	29.8
DM losses (%):			
total	6.5	8.1	13.1
per 1% increase in DM content	0.21	0.25	0.43

Source: Van Bockstaele et al. (1979)

conditions. The losses would have included direct losses due to rainfall, increased respiration loss and mechanical loss, but did not take into account the likely decline in energy content (ME) of the remaining DM.

These studies showed that the length of the wilting period more than doubled and total DM losses rose 25% when there was only a small amount of rain on one day. Significant rainfall, where rain fell on more than one day, led to a more than four-fold increase in the length of wilting period, and DM losses doubled.

Table 6.8 shows the effect of rainfall over 24 hours and crop maturity on DM losses in lucerne/red clover hay. Leaf loss, and leaching and respiration losses, rose substantially from no rain to 63 mm rain. The losses were highest in the less mature crops (bud stage) due to their higher proportions of soluble nutrients. The same trends are likely with rain-damaged lucerne silage, although the extent of losses are likely to be less.

Mown forage lying in a narrow swath absorbs less moisture than material in wide swaths. However, the wide swaths are quicker to dry out after the rain stops. Although not always practical, if rain is imminent, the mown material should be windrowed to reduce moisture uptake. The windrows should be spread out after the rain stops to increase the rate of drying.

Crops which have been conditioned or tedded soon after mowing will re-absorb more moisture after rainfall than an unconditioned swath.

The tedding and conditioning operations aim to maximise the drying rate to reduce DM and quality losses, and to greatly reduce the time the crop is at risk or exposed to rainfall before harvest. However, there will be occasions when the tedded and conditioned forage will be rain affected, increasing DM and quality losses.

Table 6.8

Effect of stage of maturity and quantity of rain on DM losses in lucerne/red clover hay in America (% DM lost).

Loss	Stage of maturity	No rain	25 mm rain	42 mm rain	63 mm rain
Leaf loss	Bud	7.6	13.6	16.6	17.5
	Full bloom	6.3	9.1	16.7	19.8
Leaching and respiration	Bud	2.0	6.6	30.1	36.9
	Full bloom	2.7	4.7	23.5	31.8
Total	Bud	9.6	20.2	46.6	54.4
	Full bloom	9.0	13.7	40.2	51.5

Source: Holland and Keszar (1990) citing Rohweder (1983).

6.7.3

Mechanical losses

Mechanical losses of DM occur at mowing and conditioning, and at each raking and tedding operation. Figure 6.13 shows the level of DM loss that can be expected in lucerne harvest operations. This study highlights that losses caused by raking or tedding increase with increasing DM content of the forage. Raking into windrows should be carried out before the DM content reaches 50%.

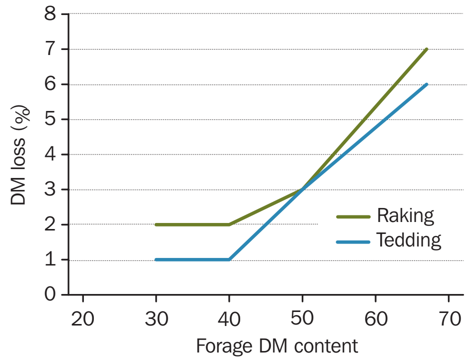
Leaf shatter losses in lucerne and most other legumes may be four times greater after mowing, conditioning and tedding than for grass or cereal crops.

In the case of lucerne, there should be minimal mechanical treatments after mowing and conditioning, and preferably none, as even freshly mown crops suffer some leaf loss with tedding. Conditioning with a roller-type conditioner to speed moisture loss from the stems is recommended. Lucerne leaves dry 3-5 times faster than the stems and quickly become brittle. Over-wilting of lucerne and other legumes should be avoided.

The leaf fraction of legumes remains on the plant in well-managed silage systems, even baled silage at 50% DM content. However, under extreme drying conditions, particularly in unconditioned crops, the leaf may become brittle at DM contents of 35% or less.

Figure 6.13

Loss of DM at each raking or tedding operation for lucerne at various DM contents.



Mowing losses:

Mower without conditioner 1%

Mower with roller conditioner 2-3%

Mower with flail conditioner 4%

Source: Adapted from Pitt (1991)

Plate 6.7

Large losses of the valuable leaf fraction can occur when lucerne and most legumes are over-wilted. *Photograph: A. Kaiser*

Chapter 7

Silage additives

Chapter 7

Silage additives

In this chapter

The author

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The Key Issues

Silage additives can be used when ensiling problem or 'at risk' forages to improve silage fermentation quality, reduce ensiling losses and improve silage nutritive value. However, inoculants have been shown to improve animal production, even where a silage is well preserved without an additive.

Additives do not compensate for poor silage management; in fact good management is required to get the best economic response to additives.

The following issues need to be addressed when using additives:

- Clearly identify the problem. Is an additive needed? If so, select an appropriate additive. There should be technical evidence that the additive is likely to be effective for the use intended and that it will provide an economic benefit.
- Use the correct application rate, minimising application losses. The additive may have no benefit if insufficient is applied.
- Use an efficient application system to minimise any slowdown in harvesting.
- Ensure thorough mixing of the additive throughout the forage.
- Check whether the additive is corrosive to machinery. Harvesting equipment should be washed down after using corrosive products.
- Follow recommended storage guidelines.
- Follow safety recommendations to avoid human health risks.
- Check that the additive does not contain chemicals restricted for feeding to livestock.

Section 7.0

Introduction

There are a number of different silage additives and various reasons for using them. The most common reason for using additives is to lower the risk of poor fermentation quality, high losses and reduced nutritive value that can occur when ensiling problem or 'at risk' forages.

There are other reasons to use additives, such as providing additional nutrients (e.g. adding urea when ensiling crops with a low crude protein content) and improving aerobic stability during feedout.

Traditionally, additives have been used to solve these problems. However, recent evidence indicates that inoculants may give improved animal production, even in situations where silage would have been well preserved without an additive.

In Australia, there are probably fewer than 20 additives currently available. In Europe, surveys showed that more than 100 commercial silage additives, containing a range of chemicals and biological products, were available during the 1990s. Additives are regularly used in parts of Europe where poor wilting conditions adversely affect fermentation of low-DM, low-WSC forages.

Inoculants are likely to be the most widely used additives under Australian conditions.

Section 7.1

Should an additive be used?

Before using an additive, three key issues need to be considered:

1. Why use an additive? What is the objective? Is there a significant risk of a problem or poor preservation if the additive is not used?
2. Is there clear technical evidence that the additive is likely to be effective?
3. Is it likely to provide an economic response (reduced losses and/or improved animal production)?

A number of other factors will affect the choice of a particular product, including:

- the quantity of active ingredient applied per unit of forage (similar products can be compared);
- the availability of advice on storage, handling and application procedures; and
- disadvantages associated with particular additives (e.g. corrosion of machinery, safety issues, ease of application).

Most additives target a particular silage fermentation/feedout problem and can only usually be expected to have benefits where preservation would have been poor without them. However, there is growing evidence that certain additives, especially inoculants, can improve nutritive value and animal production from wilted and higher DM silages.

If silages are likely to be well preserved, additives have little opportunity to give a worthwhile response. Unsurprisingly, the literature indicates quite variable responses to additives. The challenge for producers is to identify the situations where an economic response can be expected.

Where there is a role for additives

In most Australian situations, wilting will be the first strategy used to ensure successful silage preservation. Good management to accelerate wilting rates is important (see Chapter 6, Section 6.6). However, effective wilting is not always possible. Management changes need to be considered in areas where low DM content is a frequent problem. Selecting later-maturing crops or pastures, and delaying sowing of some crops, may shift the main silage cutting period to later in the season when wilting conditions are likely to be more favourable. During periods of poor weather, it may be possible to delay cutting by 2-3 days until wilting conditions improve.

Where wilting is not possible, silage additives can offer a viable alternative. Situations where there is a clear role for additives are summarised below.

> Additives do not compensate for poor silage management. Good management is required to get the best response from additives.

Potential role for silage additives in Australia

Crop and ensiling conditions	Additive type
1. Low-DM forage (nil or short wilt), low-WSC (sugar) content, poor wilting conditions.	Molasses (with or without inoculant) or acid or acid salt.
2. Low-DM forage (nil or short wilt), high-WSC content, poor wilting conditions.	Inoculant (homofermentative LAB) or acid or acid salt.
3. Good conditions for wilting, good silage preservation expected, and silage aerobically stable when opened.	Additive not essential for satisfactory preservation. There is some evidence that inoculants (LAB) may improve silage nutritive value.
4. Good silage-making conditions, good silage preservation expected, but significant risk of aerobic spoilage during feedout.	Inoculant specifically designed to improve aerobic stability, or organic acid salt, or inoculant + organic acid salt. Further research is required to evaluate these additives.

Section 7.2

Application of additives

Uniform application is important to maximise the efficacy of additives. This is best achieved during the harvesting operation:

- Forage harvesters – apply additive into the chopping chamber or at the rear/ base of the delivery chute.
- Balers and forage wagons – apply additive as swath passes through pick-up mechanism. Mixing will be less effective than with a forage harvester.

Some additives can be applied in the silo, particularly where large volumes/ quantities are required (e.g. molasses). Where high volume additives are used in a baled silage system, the only option is to apply the additive to the swath prior to harvest, which may result in some loss of the additive.

There are many commercial applicators available. Check that the one selected is suitable for the intended additive and that application rates can be varied sufficiently. When applying additives, it is necessary to check the rate of harvesting, calibrate the applicator accordingly, and monitor the system to avoid blockages.

Warning

- Safe use of silage additives is important, particularly when using chemical additives. Follow the manufacturer's guidelines for safe handling.
- Use protective clothing and equipment.
- Carry water to immediately rinse off any chemical splashing onto exposed skin.
- Avoid working with chemicals in confined spaces, particularly the additives containing volatile compounds.
- Ensure chemicals are safely stored.
- Clean all equipment and machinery after use.

Plate 7.1

Inoculant application system on a precision chop harvester. The inoculant is sprayed onto the forage as it enters the chopping chamber. Arrows indicate the nozzles.

Photograph: J. Piltz

Section 7.3

Types of additives

Silage additives can be classified into five groups based on their mode of action:

1. Fermentation stimulants – promote the desired lactic acid fermentation.
2. Fermentation inhibitors – directly acidify or sterilise the silage, inhibiting the growth of undesirable organisms.
3. Aerobic spoilage inhibitors – specifically designed to improve aerobic stability.
4. Nutrients – added to improve the nutritive value of the silage.
5. Absorbents – used to prevent effluent loss by raising the DM content of the silage and/or by absorbing moisture.

Table 7.1 gives examples of products in each category. The categories overlap, as some additives will serve more than one purpose. For example, most of the fermentable carbohydrate sources in the stimulants category will also provide additional ME and also fall into the nutrients category. Some of the fermentation stimulants and fermentation inhibitors can also inhibit aerobic spoilage.

Table 7.1

Classification of silage additives, based on their mode of action.

Additive class	Potential response*	Examples of additives
Fermentation stimulants:		
(a) Fermentable carbohydrates		
Sugar sources	A,B,C	Molasses, sucrose, glucose, citrus pulp, pineapple pulp, sugar beet pulp
(b) Enzymes**	A,B	Cellulases, hemicellulases, amylases
(c) Inoculants**	A,B,C	Lactic acid bacteria (LAB)
Fermentation inhibitors:		
(a) Acids and organic acid salts	A,B,C,D	Mineral acids (e.g. hydrochloric), formic acid, acetic acid, lactic acid, acrylic acid, calcium formate, propionic acid, propionates
(b) Other chemical inhibitors	A,B,C,D	Formaldehyde, sodium nitrite, sodium metabisulphite
Aerobic spoilage inhibitors	B,C,D	Propionic acid, propionates, acetic acid, caproic acid, ammonia, some inoculants
Nutrients	C	Urea, ammonia, grain, minerals, sugar beet pulp
Absorbents	B	Grain, straw, bentonite, sugar beet pulp, polyacrylamide

Potential responses:
A – improve fermentation quality; B – reduce in-silo losses; C – improve nutritive value; and D – reduce aerobic spoilage.
** Not all additives listed are consistently effective.*
*** Inoculants and enzymes are also referred to as 'biologicals'.*

Section 7.4

Fermentation stimulants

Fermentation stimulants promote the desired lactic acid fermentation and improve silage preservation by either providing additional fermentable sugars for the silage bacteria, or by increasing the population of desirable bacteria in the ensiled forage.

Table 7.2

Molasses application rates (kg/tonne fresh crop) required to increase the WSC content to 3% of fresh crop for forages varying in DM and WSC content.

WSC (% DM)*	Forage DM content (%)** 15	20	25	30	35
2	53	51	49	39	37
4	47	43	39	29	26
6	41	35	29	20	15
8	35	27	20	10	3
10	29	20	10	Nil	Nil
12	23	12	Nil	Nil	Nil
14	18	4	Nil	Nil	Nil

* Refer to Chapter 2, Section 2.1.2, for information on the WSC content (DM basis) of various forages.

** 20% additional molasses allowed for forages with DM contents ≤25%.

7.4.1

Sugars

The target WSC (plant sugar) level for the successful preservation of forages is >2.5% in the *fresh* forage (see Chapter 2, Section 2.1.2). Additives containing sugars (see Table 7.1) will improve the fermentation in forages with WSC levels of <2.5% in the fresh crop (e.g. low DM forages such as legumes, nitrogen fertilised grasses, kikuyu grass and other tropical grasses). The result is increased lactic acid production, lower ammonia-N content and lower silage pH. The risk of the fermentation being dominated by undesirable bacteria is reduced and DM losses during storage are also reduced.

Molasses

Molasses is the most common sugar additive and has been used for many years. The average composition of sugarcane molasses is:

- 70-75% DM content;
- WSC levels (mostly sucrose) of 83-85% of the DM; and
- specific gravity, 1 litre = 1.4 kg.

Typical application rates for molasses are 20-40 kg/tonne fresh crop, although experience indicates that 50-60 kg/tonne may be more appropriate for forages such as kikuyu grass that have a very low WSC (see Table 7.2). Molasses application rates can be varied to match the crop's expected WSC content. About 16.3 kg (11.6 litres) molasses per tonne fresh crop is required to raise the WSC content in the crop by 1% unit.

Best responses to molasses are obtained with forages with a low WSC content. Tables 7.3 and 7.4 give results from a number of studies using molasses additives. Addition of molasses improved silage fermentation (as indicated by lower pH and ammonia-N levels, and higher lactic acid), resulting in increased intake and animal production.

The addition of molasses can also increase silage digestibility as shown in a study with lablab (see Table 7.4). In this study, organic matter digestibility increased by an average of three percentage units, which is likely to be equivalent to an increase in ME content of 0.4-0.5 MJ/kg DM.

There is evidence that molasses application will increase effluent losses, with up to about 20% of the applied molasses being lost in the effluent. If possible, a short, light wilt is recommended, so the forage will be ensiled at a higher DM content, reducing the quantity of molasses required and reducing effluent losses. Table 7.2 gives guidelines on the quantity of molasses required when ensiling crops varying in DM and WSC content. The application rates required have been increased by 20% for forages with a DM content of 25% or less to allow for the increased effluent losses referred to above.

The relatively high rate of application and viscosity of molasses make it more difficult to apply than other additives. It is often mixed with water (up to a 1:1 ratio) to improve the ease of application and applied to harvested forage at the silage bunker/stack. Tractor-mounted tanks with applicators have been developed for this purpose.

Similar equipment is available for applying molasses to the windrow. Although this involves an additional operation during silage making, it is probably the only option where molasses is being used in a baled silage system.

Table 7.3

*Liveweight gain responses to molasses additives with steers fed lucerne silages.**

Mean quantity molasses applied (kg/t fresh crop)	Liveweight gain (kg/day)	
	Untreated control	Molasses additive
33.2	0.75	1.11

* *Mean results from three studies.*

Source: Ely (1978)

Other by-products

Other by-products, such as citrus pulp or pineapple pulp, can be used as WSC sources. However, they tend to be opportunistic products and are only available seasonally, to a limited number of producers. Because it is difficult to mix these by-products with chopped forage, they are generally layered in the silage stack. Their low DM content could increase effluent flow from the silage.

Table 7.4

Effect of a molasses additive on the composition and digestibility of unwilted and wilted lablab silages.

Silage composition	Unwilted silages		Wilted for 2 days	
	No additive	Molasses (36 kg/t fresh crop)	No additive	Molasses (36 kg/t fresh crop)
DM content (%)	24.6	25.9	36.4	37.0
Crude protein (% DM)	16.9	16.3	15.6	15.0
pH	4.4	4.0	4.5	4.2
Lactic acid (% DM)	6.1	9.6	4.9	7.3
OM digestibility (%)	57.2	60.7	56.6	59.0

Source: Morris and Levitt (1968)

7.4.2

Enzymes

Enzyme additives are used to break down complex carbohydrates in the forage, releasing simple sugars (all WSCs) that can be utilised by lactic acid bacteria (LAB) to improve silage fermentation quality. Table 7.5 shows the most commonly used enzymes.

Commercial enzyme additives usually provide a combination of enzyme activities. Few enzyme-only commercial additives are available. Enzymes are more often used in combination with inoculants.

Observed responses

Enzyme additives have been evaluated in many experiments, with variable results. American researchers reviewed the available evidence and found that:

- Acid detergent fibre (ADF) and neutral detergent fibre (NDF) were reduced in approximately 50-60% of experiments.
- Silage fermentation was improved in less than 50% of experiments (lower pH and ammonia-N, and higher lactic:acetic acid ratio).
- DM losses during storage were unchanged in more than 70% of studies.
- Aerobic stability was unchanged in two-thirds of the studies.
- DM digestibility was generally unaffected by enzyme treatment (see Table 7.6). A reduction in fibre content following enzyme treatment might be expected to increase digestibility. However, the enzymes may only be 'pre-digesting' those components of the fibre fraction that would normally be digested by the animal.

Responses to enzyme additives in animal experiments have been variable (see Table 7.6). In addition, one WA study showed no change in liveweight gain in young cattle when a pasture silage was treated with an enzyme additive (the same study as that reported in Chapter 1, Table 1.1).

When interpreting these results, remember that if a silage is likely to be well preserved without an additive, there is little opportunity for a worthwhile enzyme additive response. This may have been the case in some of the studies in Table 7.6.

Table 7.5

Enzymes commonly used as silage additives and the sugars released by their action.

Enzyme	Sugars released for fermentation*
Fibre-digesting enzymes:	
Hemicellulases (xylanases)	Convert hemicellulose to pentoses (xylose, xylans, arabinose). Results in a drop in NDF content.
Cellulases	Convert cellulose to mainly glucose (and maltose). Results in a drop in both NDF and ADF content.
Starch-digesting enzymes:	
Amylases**	Convert starch (present in legumes and tropical grasses) to glucose and maltose.

* *NDF and ADF are neutral detergent fibre and acid detergent fibre, respectively (see Chapter 12, Section 12.4.3).*

** *Few commercial additives contain amylases.*

Table 7.6

Summary of responses to enzyme additives in animal experiments conducted 1990-95.

Source: Kung and Muck (1997)

	Intake	Liveweight gain	Milk production	Feed efficiency	DM digestibility
Number of studies	29	10	12	11	78
Proportion showing positive response (%)	21	40	33	27	9

Table 7.7 gives an example of a study showing a positive milk production response to an enzyme additive. In this study, the wilted grass/legume pasture silage made up 50% of a total mixed ration, with concentrates providing the remaining 50%. The enzyme additive did not improve silage fermentation quality, but did increase intake and milk production, although the efficiency of milk production was reduced.

The most suitable role for enzymes may be in combination with inoculants. In fact, many silage inoculants also contain enzymes. While the enzymes may contribute to improved preservation, it is the LAB component of the enzyme/ inoculant mixture that is likely to provide the greatest benefit (see Table 7.8). The main reason for this is that, in the past, owing to their cost, insufficient enzymes were included in silage additives to provide a worthwhile response. This problem may be overcome with further improvements in enzyme technology

Factors influencing the response

The effectiveness of enzyme additives and their speed of action are influenced by:

Enzyme type and application rate: An enzyme's effectiveness will increase with the quantity applied and its activity. Unfortunately, the inclusion level or activity for enzymes in commercial additives is often not stated. This is exacerbated by the lack of a standardised method for measuring activity.

It is the cellulase, rather than the hemicellulase, portion of the enzyme additive that is most important and is likely to release most of the additional WSCs when an additive is used. During a typical silage fermentation, the forage's natural hemicellulase will degrade about 40% of the hemicellulose without extra activity from an enzyme additive.

Table 7.7

Response by dairy cows to an enzyme additive applied to a grass/clover silage that made up 50% of the diet.

	Untreated control	Enzyme treated*
Silage composition:		
DM content (%)	30.7	28.1
pH	4.25	4.04
Lactic acid (% DM)	9.7	7.4
Acetic acid (% DM)	1.9	2.6
Ammonia-N (% total N)	8.7	10.1
Animal production:		
DM intake (kg/day)	20.9	22.9
Milk (kg/day)	30.6	31.4
Fat (kg/day)	1.05	1.07
Protein (kg/day)	0.90	0.93
Efficiency of milk production (kg milk/kg DM intake)	1.47	1.38

* *Enzyme additive contained cellulase, xylanase, cellobiase and glucose oxidase.*

Source: Stokes (1992).

Table 7.8

Effect of enzyme additives on the composition and nutritive value of silages fed to lambs.

	Untreated control	Enzyme*	Enzyme + Inoculant*
Silage composition:			
DM content (%)	18.0	20.2	16.9
pH	4.20	3.72	4.00
Ammonia-N (% total N)	8.7	6.1	8.3
Lactic acid (% DM)	7.0	11.0	9.9
Acetic acid (% DM)	6.2	3.2	4.8
Lamb production:			
Silage intake (g DM/day)	785	770	811
Liveweight gain (g/day)	72	82	96
Feed efficiency (kg liveweight gain/t silage DM)	92	106	118

* *Enzyme additive supplied cellulase and hemicellulase. Inoculant supplied lactic acid bacteria (LAB).*

Source: Gonzalez-Yanez et al. (1990)

Lactic acid bacteria (LAB): Not all homofermentative LAB can ferment the pentose sugars released by hemicellulases. Mixed enzyme/inoculant additives containing hemicellulase should include LAB (*Enterococcus*, *Pediococcus*) that can utilise these sugars.

Forage type: Research with additives containing cellulases and hemicellulases has shown greater improvement in silage fermentation and greater reductions in fibre content (NDF and ADF), with immature grasses compared with more mature grasses, and with grasses compared with lucerne. Improved responses with lucerne have been achieved by adding amylases and pectinases to the enzyme mix.

Temperature: Enzyme activity increases with temperature, although excessive heating in the silage stack or bale reduces enzyme activity. Cellulases are generally active in the 20-50ºC temperature range, with optimum activity at the upper end of this range.

pH: Cellulase activity is optimal at a pH of 4.5. This is a disadvantage as optimum activity is not reached until the latter stages of the fermentation process. However, the optimal pH can vary with cellulase source.

Amylases generally reach optimum activity at pH 6.0, although some amylases will tolerate lower pH.

DM content of the forage: The activity of enzymes declines as forage DM increases. Because enzyme additives degrade the cell wall fraction in forages, resulting in increased effluent losses, enzyme application to low DM forages should be avoided.

There is evidence of reduced storage losses with wilted grasses and lucerne in the range 30-40% DM, when they are treated with enzymes. The reduced losses are possibly due to improved compaction of treated forage, resulting in less air infiltration.

Time: Cellulases and hemicellulases are active over a prolonged period but, as indicated, their activity is related to pH.

The role for enzyme additives

In the past, enzyme additives have not been effective at the rates recommended. The application rates were too low to quickly release sufficient additional WSCs at the onset of silage fermentation to prevent poor fermentation of 'at risk', low DM forages. In those circumstances, cost-effective animal production did not occur. However, recent developments in biotechnology may improve enzyme efficacy and reduce the cost of enzyme treatments, allowing them to be used at higher rates.

7.4.3

Inoculants

Silage inoculants are used to ensure that there are sufficient homofermentative LAB present to achieve the desired lactic acid fermentation (see Chapter 2, Section 2.3 for information on silage micro-organisms).

The goal is to apply enough inoculant to supply sufficient desirable bacteria to outnumber the natural microbial population and dominate the fermentation. Table 7.9 lists the most common LAB used in silage inoculants.

Mixtures of LAB are often used because different bacteria have different optimal conditions (DM, temperature and pH) for growth. For example, *Pediococcus* are fast-growing species that dominate the early stages of the fermentation.

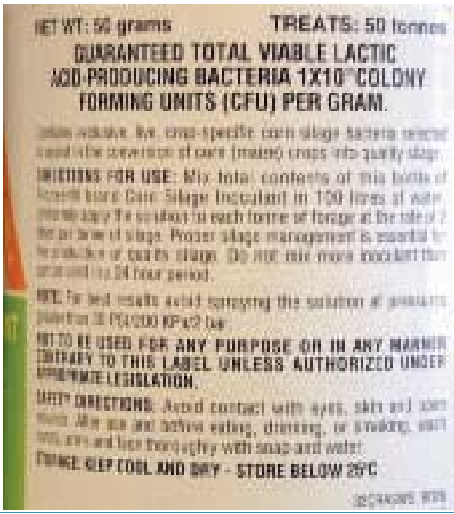
There has been some interest in the use of heterofermentative LAB and propionic acid bacteria to improve aerobic stability of silages (see Section 7.7.2).

Observed response to inoculants

The responses to inoculants have been variable, but there is now growing evidence of positive benefits. A number of reviews have summarised the responses in both silage fermentation and animal production studies:

- Inoculants have improved the silage fermentation in more than 60% of studies, resulting in lower pH, higher lactic acid level, higher lactic acid:acetic acid ratio and lower ammonia-N content. Most consistent beneficial responses have been observed with grass, lucerne and clover silages; with maize and whole crop cereal silages showing less benefit. However, the latter crops are often well preserved without the use of additives.
- In-silo losses of DM have been reduced in up to 74% of studies. From European and North American studies it is apparent that the average reduction in DM losses over all studies with inoculants is approximately 2-3%. In large-scale silage operations, this improvement in silage recovered at the time of feeding could be economically significant.

Plate 7.2



Typical labelling for silage inoculants.

Photograph: K. Kerr

Table 7.9

Lactic acid bacteria commonly used in inoculants. Ongoing research is likely to expand this list.

Homofermentative	Heterofermentative
Lactobacillus plantarum	*Lactobacillus buchneri*
Lactobacillus acidophilus	
Lactobacillus salivarius	
Pediococcus acidilactici	
Pediococcus pentosaceus	
Enterococcus faecium	

Table 7.10

Summary of responses to silage inoculants in animal experiments conducted 1990-95.

	Intake	Liveweight gain	Milk production	DM digestibility
Number of studies	67	15	36	82
Proportion showing positive response (%)	28	53	47	31

Source: Kung and Muck (1997)

Table 7.11

Effect of a formic acid additive and inoculants on silage preservation and lamb production on perennial ryegrass silage.

	Untreated	Formic* acid	*L. plantarum**	*L. plantarum** + *P. pentosaceus*
Silage composition:				
DM content (%)	16.8	18.2	16.3	18.1
pH	4.55	4.44	4.40	4.09
Ammonia-N (% total N)	13.0	10.9	13.1	8.8
Lactic acid (% DM)	5.9	5.1	7.1	8.4
Acetic acid (% DM)	4.6	3.5	4.5	3.0
DM loss (%)	17.8	18.3	15.3	13.6
Lamb production:				
Silage DM intake (g/day)	681	692	753	792
Total DM intake (g/day)	857	868	929	968
Liveweight gain (g/day)	71	94	124	129
Feed efficiency (kg liveweight gain/t silage DM)	83	109	133	133

** Formic acid applied at 3 L/t; L. plantarum at 10^5 cfu/g; mixed inoculant at 10^6 cfu/g.*
cfu = colony forming units.

Source: Henderson et al. (1990)

- Silage inoculants, based on homofermentative LAB, did not consistently improve aerobic stability. Improved stability has been observed in about 30% of studies, and reduced stability (mostly with maize and whole crop cereals) in a similar number.
- Table 7.10 summarises the responses to silage inoculants in animal studies. Positive intake and digestibility responses were only observed in about 30% of studies. However, liveweight gain and milk production responses were observed in about 50% of the cattle studies. Other surveys indicated that feed efficiency was improved in more than 40% of studies.

Examples of animal production responses to silage inoculants are provided in Tables 7.11, 7.12 and 7.13. For the lamb study in Table 7.11 the inoculants improved the silage fermentation, reduced silage DM losses, and improved intake, liveweight gain and feed efficiency when compared to an untreated control.

The cattle experiment in Table 7.12 is an Australian study with maize silage. Although the control silage was well preserved, as indicated by the low pH and ammonia-N content, the inoculants improved liveweight gain and feed efficiency. There was no difference in animal production between the silage produced with the general purpose

Table 7.12

*The effect of silage inoculants on liveweight gain and feed efficiency in yearling beef cattle fed maize silage.**

	Untreated control	Broad spectrum inoculant (Pioneer 1174)	Maize-specific inoculant (Pioneer 1132)
DM content (%)	36.6	36.2	36.3
pH	3.66	3.55	3.59
Ammonia-N (% total N)	7.24	6.18	5.20
Cattle production:			
Liveweight gain (kg/day)	1.19	1.27	1.33
Feed efficiency (kg DM/kg gain)	7.55	6.88	6.73
(kg liveweight gain/t silage DM)	132	145	149

** Diet: maize silage 85.4%, cottonseed meal 13%, urea 1.6%.*

Source: Kaiser and Piltz (1998b)

Table 7.13

Effect of formic acid and inoculant treatments on silage fermentation and beef and dairy production.

	Untreated	Formic acid	Inoculant
Silage fermentation: (n=17)*			
pH	4.0	3.8	4.0
Ammonia-N (% total N)	10.0	6.8	9.4
Lactic acid (% DM)	10.2	9.0	10.1
Animal production:			
Growing cattle (n=6)*			
DM intake (g DM/kg liveweight)	15.7	16.8	16.4
Liveweight gain (kg/day)	0.87	0.93	0.92
Dairy cattle (n=11)*			
DM intake (kg/day)	9.4	10.5	10.2
Milk fat and protein yield (kg/day)	1.34	1.44	1.44
Overall (n=17)*			
Relative DM intake	100	110.1	107.2
Relative animal production	100	107.3	106.7

** Indicates the number of comparisons.*

Source: Mayne and Steen (1993)

inoculant and that produced using LAB strains specifically selected for use with the maize.

Table 7.13 summarises the results of a number of studies investigating the response by beef and dairy cattle to additives applied to low DM (16.1%) and low WSC (2.2% fresh weight) grass.

Although the inoculants had no effect on silage fermentation, feed intake and production were improved. Animal production responses in the absence of a silage fermentation response have been observed in a number of studies with inoculants, and may be due to more efficient utilisation by animals of the energy and protein in inoculated silages.

This may be explained by recent evidence suggesting that inoculants may reduce the breakdown of amino acids in silage (see Chapter 14, Table 14.9).

Factors responsible for the variable response to inoculants

Species and strain of bacteria: There is evidence of differences between inoculants due to the type of homofermentative LAB and isolates (strains) of the same species. In one study, three LAB strains each improved the silage fermentation, but only one had a positive effect on silage intake (see Table 7.14). The reason for this difference is not understood. There is also evidence that particular strains of LAB

Table 7.14

Intake and digestibility of perennial ryegrass silage treated with three different silage inoculants and fed to sheep.

	Untreated	*L. plantarum* (MTD1)	*Pediococcus* (6A2)	*L. plantarum* (6A6)
Silage composition:				
DM content (%)	18.6	18.6	17.3	19.4
pH	3.78	3.60	3.50	3.60
Lactic acid (%)	11.0	12.2	9.9	10.1
Acetic acid (%)	2.2	0.7	1.0	1.0
Ammonia-N (% total N)	5.9	4.0	5.2	4.9
Sheep production:				
Relative intake (control = 100)	100	111	93	94
Digestibility of organic matter (%)	74.3	74.8	74.7	75.6

Source: Rooke and Kafilzadeh (1994)

may be more suitable for use with specific crops. In the future, it is likely that producers will be offered a range of commercial inoculants containing specific LAB strains selected on their suitability for specific crops.

Application rate: The number of LAB applied in the inoculant, compared to the natural population already present on the forage, is a critical factor controlling the success of inoculation. In research studies, the term 'inoculation factor' (IF) is used for this comparison – IF is the ratio of LAB applied to the LAB already present on the forage.

The LAB on the forage are influenced by:

- WSC content of the forage – LAB are higher on higher WSC forages;
- exposure to solar radiation – LAB increase more quickly in wilted material on cloudy *vs.* sunny days;
- time – LAB count increases with wilting time;
- mechanical damage – LAB increase rapidly when the material is damaged during mowing and conditioning; and
- temperature – LAB growth is reduced when temperatures fall below 15.5°C.

An IF of 2:1 is needed to achieve an improvement in silage fermentation, and 10:1 is thought to be needed for a response in animal production, although animal responses have been observed with lower ratios. In practice, the natural (or 'epiphytic') population is not known when inoculants are applied under field conditions. Hence a *minimum* application rate has been adopted:

$1x10^5$ (100,000) colony forming units (cfu) per gram of fresh forage

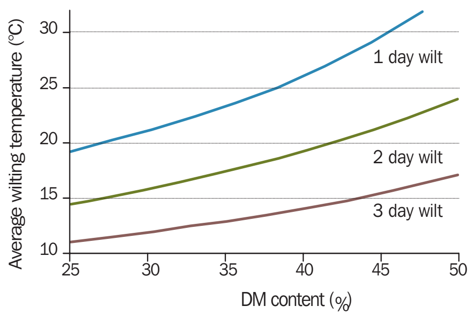
Crop DM and WSC content: Inoculant response is influenced by the WSC and DM content of the forage. Responses to inoculants may not occur with low-WSC content and high-buffering capacity legumes unless the forage is wilted rapidly, to a DM content of at least 30%. Where it is not possible to achieve this level of wilting, the addition of a readily fermentable sugar will enhance the response to inoculants.

Inoculants are not likely to be successful with low-WSC, low-DM grasses. However, European research has shown that inoculants will usually improve the fermentation with grass that has undergone a moderate to rapid wilt to >20% DM, provided the sugar content is >1.5% on a fresh crop basis.

Figure 7.1 summarises the field conditions influencing the response to inoculation of lucerne – temperature (average of maximum and minimum), DM content and wilting time. The area beneath the line indicates conditions where a cost-effective response to an effective inoculant, applied at 10^5 cfu/g, might be expected (under American conditions). For example, if the average temperature is 20°C and DM content of the wilted forage is 40%, inoculant application would be worthwhile if there is only one day between mowing and harvest (i.e. a 1 day wilt). If the forage has been drying for two or more days, the inoculant would not be profitable.

Figure 7.1

Field conditions (area below each line) where cost-effective responses to inoculants are likely to occur when ensiling lucerne.*



Source: Adapted from Muck (1993)

** A 3:1 return on the cost of inoculant and application.*

This guide may be applicable to other legumes and to low-sugar grasses, although this has not been tested.

Other factors: Most inoculants are supplied as freeze-dried products and are mixed with water before being applied. Recent evidence indicates that incubating the freeze-dried culture for 12-16 hours in a mix of warm water and a supply of nutrients may improve preservation, with less breakdown of the protein fraction.

Applying other additives with inoculants is likely to modify the response to inoculants. As discussed earlier, adding a source of readily fermentable sugars is likely to stimulate the response. Adding enzymes to promote the release of sugars from the fibre or starch fractions could have the same effect. In practice, many commercial inoculants contain enzymes.

Some additives contain a mixture of inoculants and chemicals designed to improve aerobic stability. These mixed additives overcome the inability of most homofermentative LAB inoculants to improve aerobic stability (see Section 7.7.2).

Finally, some researchers have suggested that bacteriophages (viruses that attack bacteria) present in either an inoculant or a crop could adversely affect the viability of inoculants in some situations. Companies producing inoculants take considerable precautions to keep bacteriophages out of their products. Under practical conditions, it is not known whether bacteriophages are a significant problem, but their presence might account for the failure of an inoculant in the small number of cases where there is no alternative explanation.

The role for inoculants

Although responses have been variable, the factors influencing the response to inoculants are now better understood (see 'Guidelines for using inoculants', below), and there is growing evidence that they can improve animal production. Economic responses are unlikely unless there is good management during the ensiling process.

Where farmers are ensiling a high quality crop with adequate WSC and DM content, and using good silage making practices, inoculants have the potential to yield an economic response when the silage is fed to responsive animals (growing or lactating) and it makes up a significant proportion of the diet.

Guidelines for using inoculants

- Where possible, select an inoculant for which the manufacturer supplies supporting evidence on its effectiveness. Where similar products are available, compare prices on the basis of cfu applied/g fresh forage.
- Where possible, select an inoculant that contains LAB derived from the same (or similar) crop to the one you intend to ensile.
- In the Australian environment, a product with the capacity to improve aerobic stability will be a distinct advantage.
- Inoculants should supply at least $1x10^5$ cfu/g fresh forage. Many commercial inoculants now supply at least $1x10^6$ cfu/g fresh forage.
- Uniformity of application is important. Application to the forage at the time of baling or chopping is preferable. Liquid application will generally provide more uniform distribution than applying a powder or pellets.
- When mixing inoculant solutions avoid using chlorinated water as this could adversely effect the viability of the bacteria. A swimming pool chlorine tester can be used to test water. If chlorine levels are >1 ppm, leave the water to stand overnight and retest. Once opened, inoculants should be used within 24-48 hours.
- Storage and transportation of inoculants is important. Check with the supplier for information on shelf life. They need to be stored in cool, dry areas away from direct sunlight.

Section 7.5

Acids and organic acid salts

These additives have a role under poor wilting conditions. They are used in Europe for low-WSC, low-DM forages that are at risk of a poor fermentation (see Chapter 2, Section 2.2.2).

Direct acidification through an acid additive results in an immediate drop in pH, and the fermentation and growth of undesirable bacteria is restricted.

A wide range of chemicals has been used as silage additives. Their key properties vary considerably and factors such as cost, effectiveness, safety, volatility, corrosion of machinery and required application rate will affect the choice of additive.

Safety is a key consideration with the acids, as they are caustic to the skin and eyes. Formic acid is also volatile and, if inhaled, can damage the lungs and nasal passages. Always wear protective clothing when handling these acids and use a breathing mask when handling organic acids, such as formic, acetic and propionic acid. Corrosion of silage-making equipment is another problem with the acid additives.

The salts of the organic acids are much safer to handle and less corrosive. However, they need to be applied at higher rates to be effective.

7.5.1

Formic acid

The most commonly used and widely tested acid additive is formic acid (85% w/w solution).

The application rate varies from 2 to 6 L/t fresh crop, depending on the crop's WSC and DM content. The higher rates are used for low DM content legumes. At lower rates of application, a lactic acid fermentation develops after the initial fall in pH. Higher application rates result in a greater initial drop in pH and a more restricted lactic acid fermentation. As is the case with most silage additives, the best results are obtained with forages that would produce a poor fermentation in the absence of additives.

Some of the effects of formic acid addition are illustrated in Table 7.15. In this study with lucerne, increasing the rate of formic acid restricted the fermentation, as indicated by the increase in WSC content and decline in acid production. Compared to the control, the additive favoured a lactic acid fermentation. In addition, formic acid reduced protein degradation in the silage, as indicated by the higher

Properties of common acid and acid salt additives

Formic acid: Strong but volatile, with possibility of some losses during application. Direct acidifying effect and antibacterial effect. Increases effluent flow from the silo.

Sulphuric acid: Stronger and cheaper than formic acid. A 45% w/w solution has a similar acidifying effect as the same volume of 85% w/w formic acid. Less volatile but more corrosive than formic. Feeding sulphuric acid silages results in a high sulphur intake, reducing copper availability. Supplementation may be needed to balance copper levels in the diet.

Propionic acid: A weaker, more expensive acid than formic, but more effective against clostridia, *Bacillus* spp. and moulds. Can also restrict growth of yeasts, thereby improving aerobic stability.

Acrylic acid: Expensive, with greater anti-clostridial activity than other acids.

Phosphoric acid: Similar properties to sulphuric acid but more expensive.

Salts of formic acid: Main salts used are calcium formate and ammonium tetraformate. Do not have the same acidifying effect as free acids, but are effective against clostridia and are less corrosive. Need higher rates than the free acid. A calcium formate/sodium nitrite mixture has been used as a silage additive in Europe.

Salts of other organic acids: Propionate salts are used in additives to improve aerobic stability. Mixtures of the salts of formic acid and octanoic acid are effective in restricting the silage fermentation.

Table 7.15

The effect of formic acid additives on the composition of precision chopped lucerne silages.

	Untreated control	Formic acid (85% w/w) at: 1.5 L/t	3.0 L/t	6.0 L/t
DM content (%)	19.1	19.0	20.0	19.8
pH	4.74	4.19	3.96	4.25
Total N content (%)	3.03	3.07	2.97	3.08
Protein N (% total N)	37.1	42.5	50.5	54.3
Ammonia-N (% total N)	12.9	8.3	4.2	4.5
WSC (%DM)	0.5	0.7	3.1	5.4
Lactic acid (% DM)	3.7	5.0	3.5	1.9
Acetic acid (% DM)	8.1	3.4	2.6	1.5
Propionic acid (% DM)	0.6	0.5	0.1	0.1
Butyric acid (% DM)	0.1	0.1	0	0.1

Source: Barry et al. (1978)

proportion of protein N and lower proportion of ammonia-N.

Formic acid treatment can significantly improve animal production from silage, particularly where the control silage produced without additive is poorly preserved. Table 7.16 summarises data from four New Zealand experiments with sheep and five with cattle, where the control lucerne silages were poorly preserved. There was a clear animal production benefit from formic acid use.

Where silages are well fermented there is unlikely to be a response to formic acid. This is demonstrated in a study that summarised the results from a number of experiments with growing cattle (see Table 7.17).

The role for acid or organic acid salts

Acid or acid salt additives are not commonly used and are currently difficult to buy in Australia. However, there is a role for the use of these additives with low sugar crops when effective wilting is not possible. Molasses is an alternative, if it is available. Cost is a major consideration.

Table 7.16

*The effect of formic acid treatment on silage composition and animal production on lucerne silages.**

	Untreated control	Formic acid (3.6-4.9 L/t)
Silage composition:		
DM content (%)	23.0	24.1
pH	5.22	4.36
Ammonia-N (% total N)	24.2	9.4
Animal production:		
Organic matter digestibility (%)	58.8	65.7
Intake (g DM/kg liveweight)	14.4	19.8
Liveweight gain, sheep (g/day)*	-32	19
Liveweight gain, cattle (kg/day)*	0.06	0.44

**Mean results from four sheep and five cattle experiments.*

Source: Lancaster et al. (1977)

Table 7.17

Liveweight gain (kg/day) response in cattle to formic acid additives as influenced by fermentation quality of the untreated control silage.

	Untreated control: No supplement	Untreated control: Barley supplement	Formic acid treated: No supplement	Formic acid treated: Barley supplement
Poorly preserved control silages	0.27	0.51	0.45	0.68
Well-preserved control silages	0.45	0.85	0.45	0.81

Source: Parker and Crawshaw (1982)

Section 7.6

Other chemical fermentation inhibitors

Chemicals in this group are general sterilants, which inhibit the growth of all micro-organisms or have specific activity against particular spoilage organisms. Apart from formalin (usually 35% w/w solution of formaldehyde) and sodium nitrite, few of the chemicals tested experimentally are used in commercial additives.

Formaldehyde has been extensively used in Europe although its use is now banned in some countries. It has generally been applied in a mixture with sulphuric or formic acid. Apart from its antimicrobial action, formaldehyde binds with forage proteins, preventing their degradation during the ensiling process, and also later in the rumen when the silage is fed to cattle and sheep. This increases the total supply of protein to the animal. To achieve this effect, the optimum rate of formadehyde is about 15 g/100 g crude protein in the forage.

Formaldehyde is a suspected carcinogen and should be handled with caution. On balance, the potential benefits from this additive over alternative additives probably do not justify the risk and its use is not recommended in Australia.

Any producer intending to use additives containing formaldehyde should check with the appropriate State agency to check on restrictions to its use.

Section 7.7

Aerobic spoilage inhibitors

Chapters 2 and 10 cover the problem of aerobic spoilage of silage and the importance of good management during ensiling and subsequent feedout. Aerobic spoilage losses can be significant in the warm Australian environment, particularly from maize, sorghum, whole crop cereal and wilted temperate grass silages, unless good silage management practices are adopted.

Additives specifically designed to improve aerobic stability can be part of a management strategy aimed at reducing feedout losses.

Results of a number of German experiments, which examined the efficacy of a range of aerobic spoilage inhibitors, are summarised in Table 7.18. It is uncertain whether these improvements will be duplicated under Australian conditions. However, in the absence of Australian data, overseas studies provide a guide.

7.7.1

Acids, acid salts and other chemical additives

The use of this category of additives to improve the silage fermentation was discussed in Section 7.5. Some will also improve aerobic stability. Propionic acid is an effective aerobic spoilage inhibitor, but needs to be applied at relatively high rates, and is expensive, corrosive and difficult to handle. Propionic acid/acetic acid mixtures are an effective, lower-cost alternative. The usual application rate for maize forage is 0.2-1.0% of the fresh weight.

Salts of propionic acid, particularly ammonium salts, appear to be as effective as the acid form. They have also been combined with the salts of other organic acids – benzoic, formic, sorbic and octanoic.

Of the other chemical additives, sulphites (e.g. sodium bisulphite) have been used with some success in controlling aerobic spoilage, when applied at the time of ensiling or when mixing total mixed rations based on silage. Sulphites have been widely used in the food industry to prevent aerobic spoilage of food and drink.

Table 7.18

Improvements in aerobic stability resulting from the use of various additives.

Crop	Additive (and active ingredients)	Application rate (fresh crop basis)	Number of experiments	Improvement in stability (days)*
Grass	Heterofermentative LAB**	10^5 cfu/g**	1	2.9
Maize	Heterofermentative LAB	10^5 cfu/g	5	3.7
	Benzoate/propionate	4 kg/t	2	5.9
	Formate/propionate	4 kg/t	1	4.7
	Urea	2 kg/t	2	4.2
Whole crop cereals	Heterofermentative LAB	10^5 cfu/g	1	2.1
	Urea	2 kg/t	1	6.6

** Additional days before spoilage commences.*

*** LAB = lactic acid bacteria; cfu = colony forming units.*

Source: Honig et al. (1999)

7.7.2

Inoculants

There is significant evidence that silage inoculants based on homofermentative LAB have little beneficial effect on aerobic stability and may even produce more unstable silages. Well-preserved silages with a high content of lactic acid, and low content of volatile fatty acids tend to be unstable (see Chapter 2, Section 2.2.3).

It is now accepted that the presence of some acetic acid will improve aerobic stability. This has led to the investigation of the role of heterofermentative LAB in silage inoculants. One such bacteria, *Lactobacillus buchneri*, usually increases the acetic acid content in the silage, reduces the growth and survival of yeasts, and improves the aerobic stability of a range of silages.

Fermentation losses can be higher with heterofermentative lactic acid fermentations, but improvements in aerobic stability are likely to more than compensate with problem silages. A recent study shows intake and liveweight gain of lambs improved when maize silage was inoculated with *L. buchneri* (see Chapter 15, Table 15.12). A response was also observed in a dairy experiment summarised in Chapter 13, Table 13.15. Further work is required to evaluate animal production responses.

Propionic acid bacteria have also been investigated for use as aerobic spoilage inhibitors. *Propionibacterium* can produce acetic and propionic acids from lactic acid and glucose. There is some evidence that propionic acid bacteria inoculants may inhibit yeast and mould growth, but the results have been variable. They only appear to have a beneficial effect where the pH falls slowly and/or when the final pH is above 4.2-4.5. In most circumstances they seem unable to compete with the LAB. At this stage, there is insufficient evidence to promote their use in silage inoculants.

Combining homofermentative LAB inoculants with organic acid salts has been another strategy adopted to provide an additive that improves both silage preservation and aerobic stability. The results in Table 7.19 show that the use of an inoculant alone decreased the proportion of very stable silages, but a high proportion of well-preserved (low ammonia-N), very stable silages were produced when combined with formate and benzoate. Mixed LAB/organic acid salt additives are available on the European market.

Table 7.19

Effect of an inoculant and chemical additives on silage preservation and aerobic stability.

Additive (fresh weight basis)	Proportion of silages (%)		
	Ammonia-N ≤8% total N	Very stable (≥7 days)	Very unstable (≤3 days)
No additive	17	79	3
Inoculant	43	25	34
Inoculant + sodium formate (3 kg/t)	69	33	15
Inoculant + ammonium formate (2.4 kg/t) + sodium benzoate (0.6 kg/tonne)	83	71	10

Source: Weissbach (1996) based on Schneider (1996)

7.7.3

Non-protein nitrogen (NPN)

Anhydrous ammonia and urea are used to improve aerobic stability and increase the nitrogen content of silages made from low-protein forage. They are more often used with maize silage, but are also used with sorghum and whole crop cereal silages, and high moisture grain. Thorough mixing is necessary to avoid variable silage quality and minimise the risk of stock poisoning.

Urea is the preferred additive if the main goal is to raise the nitrogen content, as recovery of applied nitrogen is higher (see Table 7.20) and it has had a more consistent beneficial effect on animal production than ammonia. However, rather than applying urea at the time of ensiling, it can just as easily be added at feedout, which may be more practical in some situations. In experiments where direct comparisons of the two times of application have been made, no difference in animal production has been observed.

When adding urea at the time of feeding, good mixing is important to ensure that all animals receive adequate, but not surplus, urea (and so avoid the risk of urea toxicity).

Anhydrous ammonia is usually more effective than urea for control of aerobic spoilage. However, there are safety issues to consider. Anhydrous ammonia is hazardous if it is inhaled or comes into contact with the eyes or skin.

Both additives prolong the fermentation, because of their buffering effect, resulting in greater total acid production. However, in-silo losses are often increased, resulting in lower DM recovery. The buffering effect of these additives can be a problem when ensiling forages with a low WSC content and/or a high buffering capacity (see Chapter 2, Section 2.1.3). Their use on such forages is not recommended.

The reduced DM recovery and inconsistent animal production responses are likely to limit the widespread adoption of these NPN additives, unless there are major problems with aerobic spoilage.

Table 7.20

A comparison of anhydrous ammonia or urea as additives for maize silage.

	Anhydrous ammonia	Urea
Nitrogen content (%)	82	46
Equivalent crude protein content (%)	515	287
Application rate – kg/t DM	8-10	15-17
– kg/t fresh crop (DM = 35%)	3.0-3.5	5-6
Not recommended for crop DM exceeding (%)	40-42	45
Recovery of applied N (%)	50-75	95

7.7.4

Site of application for aerobic spoilage inhibitors

Applying the additives at the time of ensiling is the best strategy for reducing aerobic spoilage losses, and inhibiting the growth of lactate fermenting yeasts, moulds and acetic acid bacteria. Maximum protection is achieved by treating all the forage being ensiled.

Depending on the type of silo and filling procedure, additive application may be restricted to the top layer, 0.5-1.0 m. This reduces the risk of aerobic spoilage of the upper, poorly compacted part of the silo, while the lower portion is protected by the better compaction at depth.

However, surface application of additives prior to sealing is not effective for silages prone to aerobic spoilage. It may reduce mould growth and spoilage on the surface, but will not protect silage immediately below the surface.

Spraying an additive on the silage face will not reduce aerobic spoilage. Air infiltration past this layer will result in heating of silage as far as 0.5-1.0 m behind the face of unstable silages.

Additives can be used to prevent subsequent heating of silage or total mixed rations in the feed bunk or on the feed pad. Although there has been some interest in additive application at the time of feeding, the efficacy of this strategy will depend on when the spoilage problem occurs. If silage is heating in the bunker, significant losses of DM and quality have already occurred, and application of silage additives at feeding will have little benefit, other than to perhaps prevent further heating in the feed bunk.

Some silages that are stable in the bunker will heat soon after they are removed and exposed to air. This exposure occurs during the mixing and feedout process. Incorporating an additive at the time of feeding can reduce aerobic spoilage. This strategy can successfully reduce heating of the silage and total mixed ration in the feed bunk (see Table 7.21 and Chapter 10, Table 10.1).

Table 7.21

Effect of a sulphite additive applied at the time of feeding on the aerobic stability of maize and grass silages.

	Maize silages (2 experiments)		Grass silages (4 experiments)	
	Untreated	Treated (0.6-0.8 L/t silage)	Untreated	Treated (0.8 L/t silage)
Days to 2°C rise in temperature	1.7	10.4	3.9	6.0
Days to maximum temperature	6.2	10.5	7.4	8.3
Maximum temperature rise (°C)*	29.5	4.5	28.8	8.5

* *Silages stored at 20°C.*

Source: O'Kiely (1996)

Section 7.8

Nutrients

Nutrient additives are substances which, when added to the forage at ensiling, improve the silage' s nutritive value. Most additives in this category play a dual role. For example:

- Molasses (see Section 7.4.1) can be used as a fermentation stimulant, but also provides energy and can be expected to increase the ME content of the silage.
- Non-protein nitrogen (e.g. urea) is added to low crude protein crops, such as maize, but also has a role in reducing aerobic spoilage (see Section 7.7.3).
- Grain can be added at the time of ensiling to increase silage ME level and also as an absorbent to reduce silage effluent losses in low DM silages.

7.8.1

Grain

Cereal grains are sometimes used as silage additives. Their main role is to improve the ME content of silages and provide a pre-mixed ration, which some producers see as a benefit. Grain can also play a valuable role as an absorbent when ensiling low DM silages (see Chapter 7, Section 7.9).

It is advisable to roll the grain before mixing it with the forage at the time of ensiling (see Table 7.22) to avoid any reduction in grain digestibility, which can result when animals consume whole grain. This was demonstrated in the study summarised in Chapter 14, Table 14.10.

To minimise potential spoilage of grain during the ensiling process, it would be prudent to avoid placing grain where losses may occur – near the surface, sides or bottom of the silo.

With higher DM silages (>30%), if the only objective is to increase ME content, adding grain at the time of ensiling may not be the best strategy. Rolled grain could be added to the silage at the time of feeding, avoiding the risk of in-silo losses.

Adding grain at ensiling can have other advantages. It can raise the DM content when added to wet forages, reducing the risk of a poor fermentation and reducing effluent losses (see Table 7.22). The improvement in the silage fermentation is predominantly due to the increase in DM content, as grain contains only a small proportion of WSC and most LAB have a limited capacity to ferment starch. In the study in Table 7.22, adding grain at the time of ensiling significantly reduced effluent and total in-silo DM losses and improved cattle production when compared to adding an equivalent amount of grain at the time of feeding.

An alternative strategy is to add formic acid at ensiling to improve the silage fermentation, and then add grain at the time of feeding. However, this would be a more expensive strategy than adding the equivalent amount of barley at ensiling, and would not reduce effluent losses.

7.8.2

Minerals

Minerals are added to forage at the time of ensiling to improve the mineral content, such as the addition of limestone (a calcium source) (at a rate of 5-10 kg/t fresh crop) to maize. Addition of magnesium when ensiling pastures in areas with a high incidence of grass tetany in cattle is another possibility.

Because addition of minerals may increase buffering capacity, it is advisable to avoid adding minerals to low-WSC, low-DM forages.

Table 7.22

Effect of adding rolled barley to ryegrass at ensiling on silage quality, in-silo losses and cattle production.

	Control	Formic acid (5 L/t fresh crop)	Rolled barley (45 kg/t fresh crop)
Effluent loss (L/t fresh grass ensiled)	51	60	27
Total in-silo DM losses (%)	25	13	14
Silage composition:			
DM content (%)	15.9	16.0	19.5
pH	4.34	3.94	4.16
Crude protein (% DM)	19.9	19.6	18.0
Ammonia-N (% total N)	10.9	5.7	9.4
Lactic acid (% DM)	8.2	4.7	7.2
Acetic acid (% DM)	4.0	1.3	3.4
Sheep digestibility data:			
DM digestibility (%)	66.5	70.8	73.5
Estimated ME content (MJ/kg DM)	9.8	10.9	11.2
Daily N retained (g)	7.4	14.0	12.8
Cattle production:			
Silage intake (kg DM/day)	7.23	7.64	8.84
Total intake (kg DM/day)	8.50*	8.91*	8.84
Liveweight gain (kg/day)	0.82	0.96	1.00
Feed efficiency (kg liveweight gain/t feed DM)	96	108	113

** Equivalent amount of barley added to the control and formic acid silages at the time of feeding.*

Source: Jones et al. (1990)

Section 7.9

Absorbents

There should be little need to consider absorbents unless DM levels are less than 20-25%. Under Australian conditions, most silages should have a DM content above 25%. A rapid wilt to at least 25-30% should minimise effluent losses.

In Europe, dry fibrous products (dried sugar beet pulp, distillers' dried grain, chopped straw) are used as absorbents. Some of these are commercially available in a pelleted form. However, apart from straw, other suitable products are not readily available in Australia, and transportation costs are likely to make straw uneconomic as an absorbent. In any event, the addition of straw is undesirable, as it will lower the ME content of the silage.

The most promising alternative for Australian producers appears to be rolled grain, which will also raise ME content. This is clearly demonstrated in Table 7.22.

Addition of barley was also found to reduce effluent losses and improve the silage fermentation (see Table 7.23), although the whole grain component may not be well utilised by cattle (see Chapter 14, Table 14.10).

Table 7.23 also highlights the significant quantities of nutrients that can be lost in effluent.

Oats may be an alternative to barley as research indicates that cattle are able to digest oat grain efficiently when it is fed whole.

Table 7.23

The effect of adding whole barley to pasture silage on silage composition and effluent losses.

	Level of barley addition (kg/t fresh crop)			
	0	75	150	225
Silage composition:				
DM content (%)	16.8	25.6	26.2	32.3
pH	4.25	4.19	4.09	4.22
Nitrogen (% DM)	2.77	2.69	2.37	2.24
Ammonia-N (% total N)	3.8	2.9	3.4	3.4
Lactic acid (% DM)	2.6	3.4	5.1	4.6
Acetic acid (% DM)	2.4	1.6	0.9	0.8
In vitro DM digestibility (%)	63.0	68.0	70.4	72.8
Effluent losses and composition:*				
Effluent loss (L/t fresh crop)	93.9	42.3	7.0	0
DM content (g/L)	59.9	66.9	32.6	–
Nitrogen (g/L)	0.8	1.1	0.6	–
WSC (g/L)	7.1	7.8	4.8	–
Lactic acid (g/L)	1.5	1.9	1.1	–

** Collected over 11 weeks.*

Source: Jacobs et al. (1995)

Section 7.10

Assessing the economic benefits of additives

Assessing the likely economic benefits is an important part of the decision on whether to use an additive.

The data from Section 7.4.3 and in Table 7.12 are used to illustrate how this assessment can be made. The calculations in Table 7.24 are based on each tonne of DM ensiled.

Table 7.24

Calculating the economic return from a silage additive – an example based on the application of a silage inoculant to a maize crop at ensiling.

	Untreated	Inoculated
Conservation response for 1 t forage maize DM ensiled:		
In-silo losses (% of DM)	10.0	8.5
Silage DM recovered (kg)	900	915
Animal production responses:		
Feed intake (kg DM/day)	9.0	8.8
Liveweight gain (kg/day)	1.19	1.30
Feed efficiency (kg liveweight gain/t DM fed)*	132	147
Overall efficiency (kg gain/t crop DM ensiled)	140	157
Gain from each tonne of maize silage DM fed (kg)	155	172
Value of increased production/t crop DM ensiled – 17 kg liveweight @ $1.50/kg	–	$25.50
Cost of additive treatment:		
Inoculant (@ $3/t fresh crop – includes application)	–	$3.00
Crop DM content (%)	37	37
Total cost ($/t DM ensiled)	–	$8.11
Net benefit ($/t DM ensiled):	**–**	**$17.39**

** Diet 85.4% maize silage, 14.6% supplements.*

Chapter 8

Harvesting silage

Chapter 8

Harvesting silage

In this chapter

The authors

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The Key Issues

The objective with an efficient harvesting system is to minimise costs, and DM and quality losses. The important steps in the harvesting process are:

Before harvesting begins

- Plan and prepare well before harvesting begins.
- Decide which system of forage conservation to use, e.g. hay or silage, baled or forage harvested.
- Harvest the crop at the correct stage of maturity for optimum quality and yield.
- Determine to what extent contractors will be used, if at all.
- Monitor weather forecasts.

When harvest begins

- Mow and wilt the crop to the desired DM content.
- Harvest as soon as the required wilt is achieved, preferably within 48 hours of mowing.
- Compact well for high silage density.
- Seal the stack immediately after harvesting is completed. Use a temporary cover if there is a break in filling of the stack or pit.
- Seal bales as soon as possible after baling.
- Ensure the stacks and bales are effectively sealed – the seal is airtight.
- Regularly inspect storage sites and repair holes in the plastic, immediately, with recommended tape.

Section 8.0

Introduction

The method of forage conservation chosen will depend on many factors – type of farming operation, future plans (either to extend or reduce the size or scope of operations), economics and lifestyle choices. These issues are discussed in detail in Chapters 1 and 11.

Many producers adopt a small-scale, low-input cost system to begin with, to gauge how silage will affect their existing enterprises. This usually involves a small number of individually wrapped round bales that can be produced and handled using equipment that is on-hand, with only the wrapping operation being contracted out. Although this silage system is usually quite expensive per tonne of DM conserved, only a small initial financial outlay is required.

It is possible to produce well-preserved, high-quality silage using any of the systems discussed in this chapter. However, for forages of similar feed quality, there can be differences in animal production due to the form of the silage (baled versus chopped silage, short versus long chop). These issues are discussed further in Chapters 10, 13, 14 and 15.

Harvesting losses are higher for forages that are wilted to higher DM contents (see Chapter 6, Section 6.7).

Safety first

The operator(s) of machinery should, at all times, operate the equipment to the manufacturer's specifications as directed in the manual supplied with the machine and as per warning stickers on the machinery.

Operators should never approach machinery until all mechanical motion has completely stopped. All PTO shafts, belts, chains, etc, must have strong tamper-proof covering, only being removed for servicing and repair work when the moving parts are stationary.

Section 8.1

Planning and preparing for harvest – a checklist

Too many producers leave preparations for the silage harvest far too late. Delays before and during silage making can increase costs and reduce silage quality.

Paddock preparation

- Ensure that paddocks are cleared of any objects that may damage harvesting machinery. This can include tree limbs and branches, machinery (e.g. harrows) or steel posts.
- Remove any animal carcases; they can damage machinery and contaminate the silage, posing an animal health risk from botulism (see Chapter 2, Section 2.3.5, and Chapter 8, Section 8.7).
- Make sure any holes and depressions in the paddock are filled in or are well marked.
- Ensure access for transport between the paddock and storage area is unimpeded by narrow lanes and gateways (fences may need to be cut), and that laneways are trafficable and safe.
- Manage the grazing program so that the better-drained paddocks are dropped out of the grazing rotation early and are ready to be harvested first.

Equipment preparation

Preparing and maintaining equipment will minimise breakdowns and time delays and maximise work rates:

- Ensure that all machinery has been serviced and adjusted properly, and any broken or worn parts are replaced.
- Ensure that there are sufficient spare parts on-hand for those components that regularly break or need replacing.
- Ensure the agents for machinery parts not held on-farm can be contacted and that parts are available.
- Ensure there is enough twine, net wrap and plastic on hand to complete the job.

Site preparation

- Clean out earthen pits well in advance.
- Correct any problems from previous season, e.g. water seepage, poor accessibility or vermin infestations.
- Storage sites for wrapped or stacked bales, or above-ground bunkers, should be cleaned up to remove long grass and rubble to provide an even work area and to minimise shelter for vermin.
- Avoid grazing or grading pit or bunker sites just before harvest to prevent dust, mud or faeces collecting on tractor tyres and contaminating chopped bunker silage.
- If bale stacks are to be covered with plastic sheeting, dig trenches (20-30 cm deep) along one side and one end to make it easier to align the bales, and bury and seal the plastic (see Chapter 9, Figures 9.10 and 9.11).
- Fence off the storage site to prevent damage from animals during and after harvest. If space is limited, erect the fence immediately harvest is finished.

Contract silage making

- Contact contractors well ahead of the harvest period to ensure they are available. Keep them up-to-date with:
  - expected date harvesting is likely to begin (based on the maturity of the pasture or crop);
  - the number of paddocks and total area to be harvested;
  - equipment and labour you can provide (these resources must be available and fully operational to avoid delays and potential conflicts);
  - equipment and labour the contractor is to provide or arrange.

Chapter 11, Section 11.2.3, discusses the use of contractors compared with buying your own equipment, organising the contractor and contractor agreements.

Section 8.2

Harvesting options

In this chapter there is no attempt to detail the price of machinery, the operating costs or throughput capacity, and there are no recommendations on which is the 'better buy'. The choice of silage system and equipment required will vary widely between operations. A checklist of points to consider before buying equipment is:

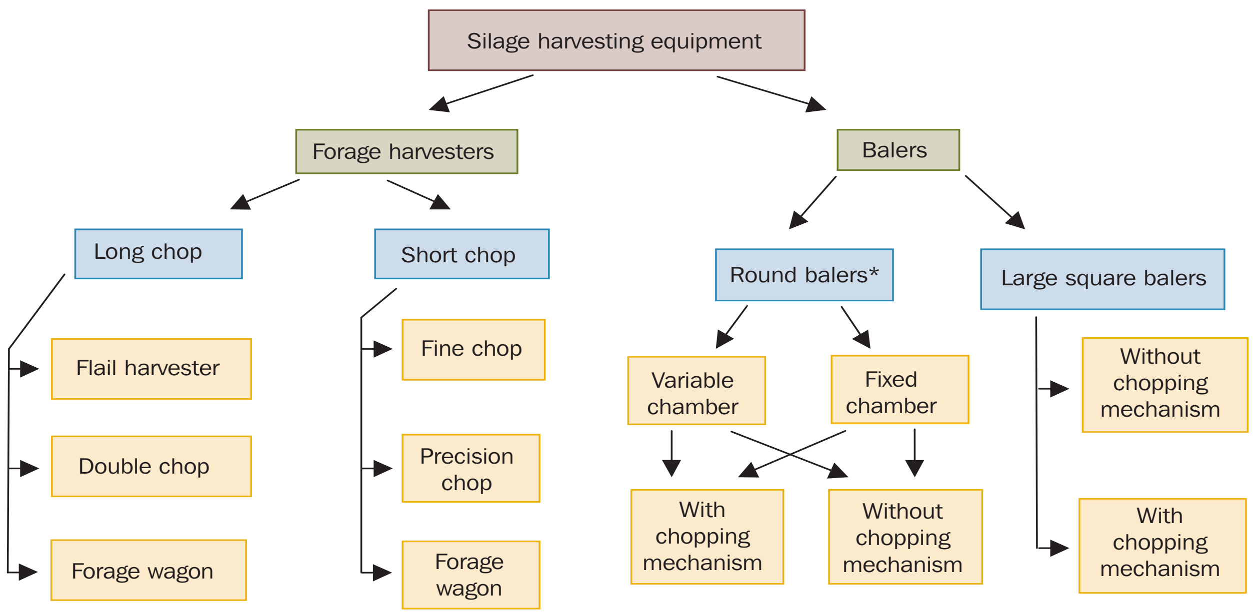
- Cost
- Throughput capacity
- Possibility of contract work to off-set cost
- Dealer proximity and service
- Resale value
- Ease of use and maintenance
- Labour requirement
- Operating costs
- Is using a contractor a better option?

There is a wide range of equipment and systems available for making chopped or baled silage to suit all farm sizes, with more robust, higher-capacity equipment more suited to contractors.

The equipment available for harvesting can be categorised as either forage harvesters or balers. Within each of these there are a number of categories/types of machinery (see Figure 8.1).

Figure 8.1

Types of silage harvesting equipment currently available.



* Combination baler/wrappers now commercially available

8.2.1

Forage harvesters

Forage harvesters are designed to either pick up mown forage from a windrow, direct-harvest standing crops, or both. In the latter case, this is achieved by changing the pick-up mechanism on the front of the forage harvester.

Most forage harvesters on the Australian market are precision chop machines, which are capable of picking up mown forage from a windrow and/or direct harvesting, depending on the front attachment. There are also a number of forage wagons available.

Forage harvesters and forage wagons are discussed in this section.

Flail harvesters

- Outdated.
- Consist of a rotor with several banks/rows of free-swinging flails designed for direct cutting of forage. Some capable of picking up windrowed forage.
- Sucking action of the flails often picks up soil, contaminating the silage.
- Variable chop length – from about 100 to >250 mm.

Double chop harvesters

- Superseded flail harvesters but are now outdated.
- Mown swath is picked up by various flail arrangements on a rotor, and then conveyed to a flywheel type chopper for extra cutting.
- Chop length highly variable, shorter than flail harvester.

Plate 8.1

Self-propelled forage harvester loading into a semi-trailer. *Photograph: K.Kerr*

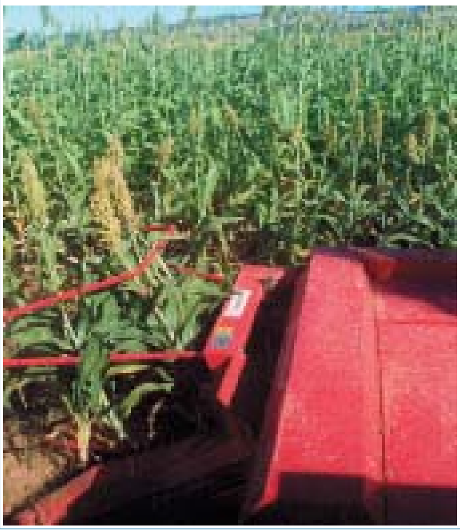
Fine chop forage harvesters

- Usually fitted with windrow pick-up front.
- In most models the cutting mechanism is a rotating cylinder with fixed flails that cut the forage against a shear bar.
- Require more power to operate than precision chop forage harvesters for the same throughput (t/hour).

Precision (metered) chop forage harvesters

- Can be fitted with various fronts for harvesting of crops or windrowed forage.

Plate 8.2



A precision chop forage harvester fitted with a row crop front harvesting sorghum.

Photograph: K. Kerr

Plate 8.3

Forage wagon.

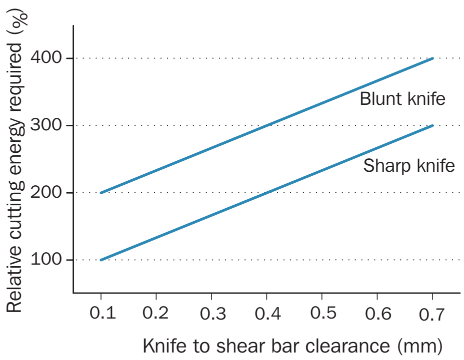
Photographer: J. Piltz

- Available as tractor-mounted, trailed or self-propelled units.
- Forage is delivered into the chopping chamber, at a steady rate, where knives fixed to a rotating cylinder cut the material against a shear bar. Chop length is uniform, and can be altered to suit requirements.
- Contain either two, four or eight knives or banks of knives.
- Can be fitted with 'cracker plates' or other devices to further damage grain. These require increased tractor power to operate.
- Capable of high throughput.
- The most widely used forage harvester.

> The Theoretical Length of Chop (TLC) or nominal chop length setting on a forage harvester may not be the same as the actual length the forage is chopped – see Section 8.3.

Figure 8.2

Effect of knife sharpness and clearance from the cutterbar on energy requirements for precision chop forage harvesters.



Source: Adapted from McClure (1990)

Forage wagons (self-loading forage wagons)

- Self-loading machines where the forage is picked up from a windrow and harvested into an attached wagon. The chopped forage is unloaded directly from the wagon at the storage site.
- Most wagons have chopping mechanisms that are only capable of producing longer chop length forage of highly variable length. However, there are wagons that have precision chop machines attached which are capable of producing chopped forage identical to precision chop forage harvested material.
- Because harvesting stops during unloading and travelling to and from the storage, work rate is relatively slow. These units are really only practical when the storage site is close to the paddock being harvested.
- Advantage – less labour and machinery is required.

Effect of knife sharpness and adjustment

Regular sharpening of the knives and adjustment of the cutter bar is essential. Blunt knives and poor adjustment of the distance between the knives and cutter bar will:

- increase the power required at the cutting chamber (see Figure 8.2); and
- result in a less uniform chop length, with an increase in average chop length (Chapter 2, Section 2.4, and Chapter 8, Section 8.3, discuss the importance of chop length).

Metal detectors

Foreign metal objects, broken machinery fragments and rocks can cause substantial damage to precision chop forage harvesters – chipping and breaking knives. Large, solid objects can even damage the chopping chamber and knife holders.

Wire picked up during harvest will be chopped into small pieces. Damage to the knives may only be minimal and go unnoticed, but there is a potential health risk to animals that consume the contaminated silage.

Machines can be fitted with metal detecting units, which immediately disengage the feed and chopping mechanism when metal is detected. These units can be a valuable investment, preventing substantial machinery damage and downtime.

Most machines are now fitted with banks containing several knives rather than a number of individually mounted blades. Damage is often confined to one or two smaller knives, which is easier and less expensive to repair.

Grain processors

The high energy levels of maize and grain sorghum silages are due to a high grain content.

Machinery manufacturers have produced a range of add-on equipment that can be fitted to forage harvesters to damage whole grain, increasing utilisation of the grain component by cattle. These include recutter screens and cracker plates. More recently, larger forage harvesters have been fitted with rollers.

Use of grain processors for maize silage is common in the United States, where the trend is for chopping at longer particle lengths. However, when the forage harvester is set up to harvest maize with a short chop length, a significant proportion of the grain is damaged without the need for additional processing. In Australian studies, the grain in maize silage which had been finely chopped (4.2 mm theoretical length of chop – TLC) was well digested by cattle (See Chapter 14, Section 14.2.5).

There may be a benefit in using grain processors when harvesting grain sorghum for silage. Even at short chop lengths, much of the sorghum grain escapes damage because of its small size.

Chop length and digestibility of the grain in maize silage are discussed in more detail in Chapter 5, Section 5.2.4, and for maize and sorghum silage in Chapter 14, Section 14.2.5, where results of the Australian studies mentioned above are presented.

Reducing chop length or using a grain processor will increase the tractor power required to harvest maize for silage. The additional advantages of reducing chop length – increased load capacity during carting, improved compaction in the pit or bunker, and an improved fermentation are discussed in Section 8.3. These advantages will help offset the additional expense.

8.2.2

Balers

Variable versus fixed chamber round balers

Variable-chamber balers compress the bale from the initial filling of the chamber and make a bale with a 'hard' centre. Fixed-chamber balers do not begin compressing the bale until the whole chamber is full; as a result the bales are not packed as densely in the middle as at the outsides – they have 'soft' centres.

The soft-centred bales produced by the early model fixed-chamber balers were not ideal for silage production. Air trapped in the centre of the bales increased the risk of poor fermentation and mould growth. The problems increased with drier or more heavily wilted forages. New models produce higher-density bales, with firmer centres and less risk of fermentation problems. No research data are available on the quality of silage produced from these bales at higher DM contents (>50%).

Plate 8.4

Round baler. *Photograph: K. Kerr*

Plate 8.5

Square baler. *Photograph: F. Mickan*

Square balers

The bales made by square balers are called 'large squares' to differentiate them from the traditional small square hay bales.

Bale sizes (width x height) vary, depending on which of the many commercially available square balers are used. Most produce bales with a maximum length of about 2.4 m, but this is often adjusted to 1.5 m when making silage for wrapping and ease of handling.

Most large square bales produced by current-model balers have the advantage of being denser than round bales, but do require more power to produce. The shape of the square bales is more suited to a range of storage systems, with better utilisation of space and ease of sealing effectively. The storage systems commonly used are covered in Chapter 9, Section 9.5.

Chopping balers

Round and square balers are available with a series of knives that chop the forage just after pick-up and before entering the baling chamber. Most have a nominal chop length (Theoretical Length of Chop) of about 75 mm; the actual chop length will depend on whether the forage has passed lengthways (unchopped) through the chopping mechanism or across the knives (chopped). The length of the chopped material will usually vary between about 40 and 110 mm. The baler can be operated with or without engaging the knives.

The Orkel® is another version of the chopping baler, incorporating flails to chop the forage. An advantage of this type of baler is claimed to be in the flail action, which chops the forage more than knives (used by most other balers); the forage stems are split, releasing more WSCs for fermentation.

Potential benefits in chopping the forage at the time of baling include:

- ➤ less air is trapped in the bale – reduced respiration and risk of mould growth (see Chapter 2, Section 2.5.2);
- ➤ greater release of water soluble carbohydrates (WSC) resulting in a more rapid fermentation and reduced fermentation losses (see Chapter 2, Section 2.4);
- ➤ increased bale density (and weight) – reduced storage (plastic, wrapping) and transport costs for each tonne of silage;
- ➤ increased intake by animals, less selection and reduced wastage (see Chapter 10, Section 10.3);
- ➤ possibly more thorough mixing of silage additives sprayed onto the material before chopping (although there is no hard evidence to support this); and
- ➤ chopped, baled forage is easier to process in mixer wagons.

In a Danish study, whole crop barley was ensiled with a variable-chamber baler either with or without chopping knives. As can be seen in Table 8.1, chopping the bales increased silage density, reduced losses, and there was a slight improvement in fermentation quality (lower pH).

Combined round baler and wrapping machines

In an attempt to reduce labour costs, several manufacturers have developed machines that bale the forage and then wrap the bale. The wrapper can be built within or behind the baling chamber, or trailed behind as a separate unit.

A disadvantage of these machines is that the bale has to be moved after wrapping, increasing the risk of damage to the plastic wrap. Chapter 9, Section 9.5, covers recommendations for wrapping and storing bales.

Table 8.1

Whole crop barley silage ensiled with a variable-chamber round baler either with or without chopping knives.

	Silage density (kg DM/m³)	DM loss (%)	Silage pH
Chopped	192	7.0	4.38
Unchopped	176	8.3	4.53

Note: Average silage DM was 38%.

Source: Ohlsson (1998)

Net wrap versus twine

Round silage bales can be tied using twine or net wrap. Net wrap, although more expensive than twine, is a more convenient and faster method of tying round bales.

Net wrap is recommended for use in very stemmy crops such as lucerne, cereal crops and summer forages, or over-mature pastures, to help avoid stems poking holes in the plastic seal.

Sisal twine that has been treated with oil should not be used as it can chemically react with the plastic, with holes forming along the string line.

Heavy-duty twine must be used on square-baled silage.

Plate 8.6

Because the plastic wrap is easily punctured, it is best to wrap bales at the storage site. Wrapped bales should be handled with exteme care and using special equipment such as this bale handler/stacker. *Photograph: J. Piltz*

Section 8.3

Factors affecting the efficiency of forage harvester systems

8.3.1

The importance of DM content and chop length

Increasing the DM content and/or decreasing the chop length will increase the amount of material that can be transported by trucks, carts and trailers. However, once forage DM content approaches 40-45% the carrying capacity may plateau or even decline because the chopped material does not pack down as much. Shortening the harvest chop length will result in an increase in load weights for a range of DM contents. Table 8.2 shows the combined effects of increasing DM content and reducing chop length.

The density at which silage is stored varies with chop length and DM content. Stack height and the degree of compaction will also affect density. In the UK, silage density is often estimated by the following equation, based on the silage DM content:

$$\text{Density of fresh silage (kg/m}^3\text{)} = 496 + \frac{4{,}590}{\text{DM \%}}$$

Example: Density of stack with 35% DM silage =

$$496 + \frac{4{,}590}{35} \cong 630 \text{ kg/m}^3$$

Chop length is referred to in terms of Theoretical Length of Chop (TLC) and is sometimes called nominal chop length. TLC is the machine setting or design specification. However, in practice, the actual chop length can be 2-3 times longer due to factors such as speed and power of equipment, clearance settings and sharpness of blades.

In the United States study presented in Table 8.3, increasing TLC from 6 mm to 38 mm reduced silage density by nearly 14% and forage wagon capacity by more than 30%. Increasing TLC also increased the percentage of forage particle lengths above 38 mm.

The shorter the chop, the greater the power requirement. Twenty-two per cent more PTO power was required when the TLC was reduced from 38 mm to 6 mm. Table 8.4 shows the increase in kilowatt-hours per tonne (kW/t) of maize chopped as the TLC is reduced.

Besides increasing power requirement, forage harvester throughput can decrease if chop length is decreased, even by small amounts.

Table 8.2

*Effect of harvesting equipment and crop DM content on the quantity (tonnes) of chopped forage transported in each trailer load.**

Crop DM content (%)	Harvester type	DM capacity (t)	Relative capacity (%)	Number of loads per ha
Direct cut (20%)	Flail	0.43	100	14.0
	Double chop	0.71	165	8.5
Wilted (30%)	Flail	0.64	149	9.4
	Double chop	0.96	223	6.3
	Precision chop	1.07	249	5.6
Wilted (40%)	Precision chop	1.00	233	6.0

** Trailer capacity of 14.2 m³; assumes a yield of 6 t DM/ha.*

Source: Adapted from MAFF (1976)

Table 8.3

Percentage (%) of particles longer than 38 mm for a range of theoretical chop lengths.

	Theoretical length of chop (mm) 6	13	25	38
Percentage of particle size >38 mm (%)	10	18	40	70

Source: Savoie et al. (1989)

Table 8.4

Chop length and power requirements to harvest maize.

Nominal Chop Length* (mm)	Energy Requirement (kW/t)
7	1.6
4	2.1
Recutter screen	3.5

** Theoretical length of chop.*

Source: Honig (1975)

8.3.2

Distance travelled between harvesting and storage

Harvesting systems using a precision chop forage harvester usually rely on independent trucks or carts to take the chopped forage from the paddock to the storage site. If there are several transport vehicles, it is usually not necessary for harvesting to stop between loads.

Sometimes, particularly in the past, carts have been hooked behind forage harvesters and towed. This reduces labour requirements, but there is a delay when hitching and unhitching trailers/wagons.

Because trucks can travel faster than tractors towing wagons, when using trucks the travelling distance to the storage site can be greater without delaying harvest.

Systems that use a forage wagon have to stop harvesting while the chopped forage is delivered to the storage site and unloaded. It is critical that the storage site is near/in the paddock to be harvested to minimise harvesting downtime.

In all cases, even if it does not affect harvesting time, there are costs associated with the distance travelled.

Plate 8.7

When harvesting with a forage wagon, the storage site should be close to the paddock being harvested to reduce downtime.

Photograph: F. Mickan

Advantages of short chop length

A short chop length is an advantage when ensiling most crops:

- It increases the amount of DM transported per trailer or truck load.
- The forage is more evenly and easily spread in the bunker or pit.
- The forage is more easily compacted.
- Less storage capacity is required.
- More WSCs are released resulting in greater bacterial activity – improved fermentation (see Chapter 2, Section 2.4).
- Well suited to mechanised feeding systems and mixer wagons.
- There is increased intake by some classes of livestock (see Chapter 13, Section 13.2.5; Chapter 14, Section 14.2.5; and Chapter 15, Section 15.2.5).
- The rate and extent of aerobic spoilage at feedout is reduced.
- Forage is easier to remove at feedout.
- It can improve animal production when self-feeding (accessibility).

(The last three points are discussed in more detail in Chapter 10.)

Note: Extremely short chopped material will not be a concern in Australian feeding systems unless this silage supplies a large portion of the dietary fibre in diets for dairy cows (see Chapter 13, Section 13.2.5) or where large losses might occur if the silage is fed directly onto the ground.

Section 8.4

Factors affecting the efficiency of bale systems

The efficiency, and therefore the cost, of bale silage production is affected by:

- Size and density of the bale, which depends on:
  - baler type and operator technique
  - characteristics of forage, i.e. DM content, forage length and ease of compaction.
- Speed of baling, efficiency of bale transport, and time taken to wrap or cover and seal bales, which depends on:
  - baler type and adjustment, tractor capacity and operator technique
  - transport distance from paddock to storage site
  - method of wrapping or sealing.

Plate 8.8a

Low-density bales are prone to greater air infiltration, increased risk of losses during storage and are harder to handle.

Photograph: F. Mickan

Plate 8.8b

Lower storage losses and reduced handling and storage costs are advantages of well-formed, dense bales.

Photograph: F. Mickan

Table 8.5

The influence of DM content and speed at baling on round bale density.

Source: Summary by Ohlsson (1998)

DM content (%)	Bale density (kg DM /m³) Low speed[1]	Bale density (kg DM /m³) High speed[2]
30	140	134
36	181	167
57	182	176

1. Speed at baling = 6.0-6.4 km/hr
2. Speed at baling = 8.0-8.8 km/hr

8.4.1

The effect of DM content on bale density

Weight is not always a good indicator of bale DM density. DM density is the weight of DM in a bale of a given size (volume). Bales of the same size produced from high DM forage will weigh less at the same DM density as bales produced from lower DM forage because of the reduced water content. Maximising DM density will reduce handling and storage costs, and reduce the amount of air trapped in the bale.

Increasing DM content of the forage at baling has been shown to increase the DM density of round baled silage (see Table 8.5). However, at DM contents higher than recommended, round bale DM density can decline because the drier forage is more difficult to compact.

The effect of DM content on the density of square bale silage is not known. However, it is reasonable to expect that increasing DM content will increase bale density within the recommended DM content range at harvest.

Plate 8.9

Stemmy crops can puncture the plastic wrapping particularly if harvested when too dry. *Photograph: F. Mickan*

The density of silage in bales is less than in well-compacted chopped silage pits or stacks.

The recommended DM content ranges for baled silage are provided in Chapter 4, Table 4.1, and Chapter 5, Table 5.2. Baling at DM contents higher than recommended will increase field and harvesting losses. The stems of some forages are less pliable and so are more likely to puncture the plastic during wrapping if allowed to over-dry.

The DM content of large square-baled silage should be similar to that of round-baled silage, although some contractors are storing large squares at DM contents above 55% DM. This may be possible because the high density of the large square bales limits the amount of air that is trapped, allowing preservation of the high DM forage. However, ensiling large square-bale silage at these higher DM contents is not recommended because of the increased losses during wilting and mechanical handling.

Poor compaction can be a problem with thick, stemmy crops, and it is difficult to produce dense bales from such forage. Reduced bale density results in more air infiltration and an increased risk of losses during storage. Cost per tonne of ensiled forage also increases with more bales/ha to be baled and wrapped.

If the silage is wet, <30% DM content, the bales will be heavy and harder to handle, and there is an increased risk of a poor fermentation.

When ‘wet’, wrapped round bales are stored on the round side, there is a risk of the bales ‘slumping’ and the plastic splitting. Store round bales on the flat end.

8.4.2 Chopping at baling

Chopping balers improve efficiency of the silage-making system by increasing the density (and weight) of bales, so reducing transport and storage costs. In five Irish studies, unchopped and chopped round bales were produced with the same fixed-chamber round baler. As can be seen from the data in Table 8.6, chopping increased bale DM density by 11.5% and reduced the number of bales produced per hectare by a similar amount.

Table 8.6

*Effect of chopping on the weight of bales produced from ryegrass pasture with a DM content of 41%.**

	Unchopped	Chopped
Average bale weight (kg DM)	206	228
Density (kg DM/m^3)	151	168
Number of bales/ha	24.3	21.8

* *Mean of five experiments. Bales produced with a fixed-chamber, roller-type baler.*

Source: Adapted from O'Kiely et al. (1999)

Plate 8.10

Wrapped round bales should be stored on their end to maximise the number of plastic layers exposed to UV sunlight and protect against sharp objects on the ground. This also reduces the risk of bales slumping.

Photograph: K. Kerr

8.4.3

Baling technique

The weight and density of the bale produced will depend on the type of baler used (see Section 8.2.2). However, the expertise of the operator also has a major effect on the end product.

Tractor power must at least match the baler's requirement to be capable of producing firm bales, with an acceptable throughput. The density control mechanism must also be adjusted correctly to match the forage type and DM.

Baling more slowly will produce heavier bales (see Table 8.7). In three of the Irish studies mentioned previously, the impact of increasing tractor speed on bale density (and weight) was measured. When tractor speed was increased from 6.4 to 8.8 km/hr bale weight fell 3.8%.

Figure 8.3

Direction of driving for windrows narrower than the pick up.

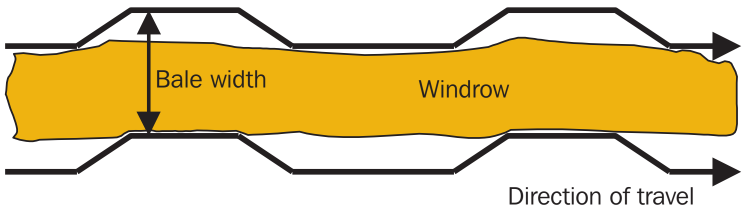


Table 8.7

The effect of tractor speed on the weight of round bales produced from ryegrass pasture with a 38% DM content.

	Speed (km/h) 6.4	8.8
Average weight of bales (kg DM)	212	204
Density (kg DM/m³)	156	150
Number of bales/ha	22.4	23.4

* *Mean of three experiments. Bales produced with a fixed-chamber, roller-type baler.*

Source: Adapted from O'Kiely et al. (1999)

8.4.4

Presentation of windrow to the baler

Uniformly shaped round or square bales, with tight, square edges are easier to wrap, stack and seal. Driving technique and windrow shape and density are important in producing well-made bales. The ideal is a regular, dense, rectangular-shaped windrow.

For evenness of baling and maximum bale density and weight, round balers should approach the windrow square-on, so that the windrow feeds evenly into the baler (see Figure 8.3). Because the windrow is often narrower than the bale chamber, it is necessary to drive from side to side, but rapid zigzagging should be avoided as this will produce misshapen bales which are difficult to wrap and store.

The windrow for square balers is ideally even or perhaps slightly thicker at either edge and should be wider than the baling chamber. This ensures that the bales are even and don't have soft sides. Windrows formed by V-rakes or tedder rakes are best for square bales.

8.4.5

Bale size

Bale size will greatly influence the final bale weight. Increasing the bale size will result in fewer bales per hectare or per tonne of silage. Fewer bales will reduce handling and transportation costs. Increasing bale size will also reduce the surface area to volume ratio, and for wrapped bale silage, reduce the amount of plastic used per tonne of silage stored.

The size of the bales produced will depend on the dimensions and adjustment capability of individual balers. Round balers in Australia have chamber widths of either 1.2 or 1.5 m, which limits the width of the bale, and can produce bales that are 1.2, 1.5 or 1.8 m in diameter. Variable chamber balers can be adjusted to produce bales of reduced diameter. Increasing bale diameter will have a greater impact on bale weight than changing bale width from 1.2 to 1.5 m. The effect of altering round bale size on bale weight was calculated and is given in Table 8.8.

Table 8.8

*Effect of bale dimensions on the fresh weight (kg) of round bales.**

Bale diameter (m)	Bale (chamber) width (m) 1.2	1.5
1.2	544	680
1.5	849	1,060
1.8	1,384	1,729

* 45% DM content and a density of 180 kg DM/m^3.

Note: In practice the actual bale density will depend on the baler type, pressure setting, DM of the forage and the speed of baling.

The weight of square bales will depend on the dimensions and also the amount of pressure used at baling. In most cases, the length of square bales for silage is reduced to about 1.5 m, which is less than the maximum length which can be produced by the balers. The reduction in length is necessary for wrapping and makes handling of the bales easier. The major difference in weights of square bales between balers will be due to the height and width of the bales that are produced.

Section 8.5

Harvesting losses

Physical loss of DM during harvesting falls into the following categories:

- Pick-up losses – forage that is not picked up from the windrow or, in the case of direct harvested crops, isn't cut, and is therefore left in the paddock.
- Chamber and ejection losses – applies to baled systems only.
- Drift losses – forage harvested material that is blown away or overshoots during the filling of transport vehicles.

Pick-up losses during baling and forage harvesting are usually small. An Irish study, comparing round balers and forage harvesters, showed pick-up losses were less than 1% with perennial ryegrass (see Table 8.9). Total baling losses were greater for chopped round bales than unchopped round bales from the same baler due to higher chamber losses. Even so, total losses were only about 1%.

Mechanical losses are usually greater with legumes, particularly if the valuable leaf fraction has been allowed to become over-dry and brittle. However, total losses of DM with lucerne made into round bale silage are still low if the wilting period is short and the lucerne does not become over-dry (see Table 8.10). In these studies, losses were higher on one occasion where wilting was delayed due to poor weather, and the lucerne then became much drier. Rain can leach the leaf fraction of the forage; it then dries more rapidly and can become over-dry and brittle.

Losses were also higher for chopped round bale silage in this study, and were likely to have been due to increased chamber losses. Chamber losses with hay are predominantly (up to 80%) leaf and are likely to be similar with silage, particularly at higher DM contents.

The losses with a square baler are not known, although pick-up losses are likely to be similar to round bales. Chamber losses will probably be lower because the forage is not rubbing against the baling chamber, as is the case with round balers.

Drift loss for most forage-harvesting situations has been estimated at 1-3%. Although not measured, estimates suggest that as DM content rises from 25% to 50%, drift losses could increase from 0.5% to 5%. Drift losses increase with wind speed. Anecdotal evidence also suggests that the wind effect is greater and drift losses higher with low-yielding crops. Poor operator technique or trying to overfill the transport vehicle will also increase drift losses.

Table 8.9

Comparison of forage DM losses (%) at harvesting with a round baler, either chopped or unchopped.

	Unchopped	Chopped
Pick-up loss	0.66	0.67
Chamber loss	0.15	0.33
Ejection loss	0.02	0.03
Total loss	0.83	1.03

Perennial ryegrass based pasture, harvested at 26% DM content.

Note: Pick-up loss from a precision chop forage harvester was 0.60%.

Source: Forristal et al. (1998)

Table 8.10

DM losses from lucerne at baling and DM density of unchopped and chopped round bales.

Study	DM content at baling (%)	Hours of wilting	DM losses (%)		Bale density (kg DM/m³)	
			Unchopped	Chopped	Unchopped	Chopped
1	35	7	0.5	0.7	175	182
1	49	28	0.6	1.2	195	203
2	61	104*	2.0	4.7	156	162
3	38	5	0.7	1.7	149	153
4	44	5	0.6	1.3	231	237

** Rain for four days.*

Source: Adapted from Borreani and Tabacco (2002)

Section 8.6

Harvesting when conditions are less-than-ideal

The importance of weather forecasts when deciding when to mow a silage crop is discussed in Chapter 6. Section 6.7.2 covers the effect of humid or wet weather on drying rates and field DM losses.

'Difficult' harvesting situations will occur from time to time; some of which are out of the control of the producer. Possible solutions to some of the more common problems appear below.

Situation	Potential problems	Possible solution	
		Forage harvester system	Bale system
1. Forage too wet	Poor fermentation, effluent production at <30% DM, loss of DM and quality (see Chapter 2, Section 2.1.1).	Use an additive if effective wilting is not possible (see Chapter 7).	Baling wet forage should be avoided.
2. Forage too dry	Compaction is difficult, air not excluded, respiration prolonged, loss of DM and energy, mould growth; silage unstable at feedout (see Chapter 2).	Reduce chop length; pay extra attention to rolling of stack; alternate loads of dry material with lower DM forage (if available); as a last resort, water may be sprayed on the stack (see Appendix 8.A1). Consider hay as an option.	Bale before dew lifts. Use baler with a chopping mechanism. Adjust baler to increase bale density. Consider hay as an option.
3. Prolonged silage harvest due to machinery breakdown or low harvesting capacity/poorly matched equipment.	Prolonged respiration, DM and quality losses.	Seal material within 3 days of mowing. Plastic sheeting over stacks each night will minimise air movement into the stacks. If harvesting is interrupted, seal the portion of the stack already formed, creating a separate compartment when harvesting recommences. Reopening the end of the stack to store fresh silage is a more practical option, but needs care to avoid spoilage. In this case, some spoilage is likely at the interface between the two batches.	Bales should be wrapped within 1-2 hours of baling. If bales have to be left unwrapped, overnight, losses will occur. It is sometimes recommended that round bales be pushed onto their end; bales will hold shape and are easier to wrap.
4. Rain during harvest	a) Forage becomes too wet (a lot of rain is needed to significantly increase the forage DM). b) Reduced trafficability. c) Contamination of the forage with mud (especially in bunkers or buns).	Keep harvesting, stopping if field operations cause the harvested forage to be contaminated with mud. A 'sacrifice' pad of fresh forage at the entrance to the bunker/bun can reduce contamination. If wet harvests are common, consider concrete flooring.	Keep harvesting, stopping if field operations cause the harvested forage to be contaminated with mud.
5.Transportation of forage over long distances (mainly applies to baled silage).	Prolonged respiration, DM and quality losses. Cost of transporting lower DM forage long distances must be considered.	Minimise transportation time. Cover load to reduce transport losses and aeration of forage. Compact and seal quickly on arrival.	Bales have been transported long distances (>500 km). *Wrapped bales* – high risk of damage to plastic seal. Extreme care needed during any handling between wrapping and final storing. Inspect bales at the storage site and repair any damage to plastic. *Unwrapped bales* – Some DM and quality losses are likely. Critical to minimise interval between baling and loading onto transport (ideally 1-2 hours). Cover load to minimise airflow. Transport without delay to final storage site. Wrap and/or seal bales immediately on arrival.
6. Flooded crops	Mud on forage can introduce undesirable micro-organisms, which can adversely affect silage fermentation. Any flood debris must be removed to avoid damage to machinery.	Depending on the crop/pasture type, other options are to cut for hay, grow crops through to grain harvest, wait for rain to wash off mud or graze pastures. For silage making: • raise cutting height to avoid thick mud; • remove flood debris; • use silage inoculant to ensure desirable bacteria are present; and • if only part of crop is flooded, store that portion separately to avoid contamination of the unaffected portion.	

Section 8.7

Contamination of silage

Contamination of forage with soil, dead animals or straw and rank grass during harvest should be avoided. Undesirable bacteria may be introduced that will adversely affect the silage fermentation, aerobic stability of the silage at opening, and the health of animals fed the silage.

Soil

Soil-borne bacteria (e.g. clostridia) can cause undesirable fermentations or lead to diseases in livestock (listeriosis, caused by listeria) (see Chapter 2, Section 2.3.5). Dirt and mud may be carried into the stack as clods picked up by the harvester, from the wheels of unloading trailers or the rolling tractors.

Rolling paddocks after sowing to break up or bury large clods can reduce soil contamination of the mown forage. Setting the tedding and raking machines at the correct height will also reduce soil contamination.

A cement apron in front of the stacks will prevent the forage coming in contact with the soil during loading and unloading. Ideally, the tractor rolling and spreading the forage should remain on the stack surface until filling is completed.

Old straw and rank grass

Old straw, rank or rotting stems of previous crops and lodged plants are usually contaminated by a range of bacteria, yeasts and moulds (see Chapter 2, Section 2.3.4). Harvesting this material can adversely affect fermentation and reduce aerobic stability at feedout.

Ensiling a significant proportion of this inferior quality material will also decrease the energy (ME) content of the silage.

Dead animals

Animals are at risk from botulism if they eat silage that contains dead animals trapped in the forage at harvest. All animal remains should be picked up before mowing, although it is often difficult to see bird, snake or rodent carcases as they are picked up during harvest (see Chapter 2, Section 2.3.5).

There is also a risk of botulism when burrowing animals die in the stored silage.

The risk of botulism increases with lower DM silages.

Effluent

Risk of contamination from animal effluent (e.g. from piggeries, dairies or feedlots) used on silage crops or pastures can be minimised if it is not applied within six weeks of the crop being harvested. The risk is further reduced if it is applied onto bare ground, before the crop is sown or while the crop is very short.

Contamination risks increase if the effluent contains large particles that may be picked up by the harvesting equipment. See Chapter 4, Section 4.2.2, for more detail on guidelines for the use of effluent.

Toxic weeds

There are inadequate Australian data on the impact of ensiling on the poisoning risk of toxic weeds. The level of risk will vary with the type of weed, the amount fed to the animal and the concentration of weed in the silage. The type and class of animal is also likely to affect the risk level.

Weeds suspected of being toxic should be controlled, or infested portions of the paddock avoided at harvest. Producers should seek appropriate advice on weeds of concern.

Also to be considered when harvesting broadleaf weeds is the potential for reduced quality and the effect on silage fermentation (see Chapter 3, Section 3.3.1).

Section 8.8

Appendix

8.A1

Adding water to lower the DM content of over-dry forages

Step 1.

Weight of forage DM (kg) = Weight of original fresh forage x $\frac{\% \text{DM}}{100}$

Step 2.

Total final fresh weight of material (forage + added water) = Weight of forage DM x $\frac{100}{\% \text{DM desired}}$

Step 3.

Amount of water to add = Total final weight of material – weight of original fresh forage

Example:

How much water should be added to 1 tonne (1,000 kg) of 70% DM forage to obtain a 50% DM forage.

Step 1.

1,000 kg x $\frac{70}{100}$ = 700 kg DM

Step 2.

700 kg DM x $\frac{100}{50}$ = 1,400 kg

Step 3.

1,400 – 1,000 = 400 kg water to lift DM content to 50%

= 400 litres of water

Chapter 9

Silage storage

Chapter 9

Silage storage

In this chapter

The authors

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Key Issues ... see Page 218

The Key Issues

Successful storage depends on:

1. Producing an airtight storage unit as quickly as possible after completion of harvesting.
2. Maintaining an airtight seal until feeding commences.

Chopped (forage-harvested) silage

- Ensure harvested forage is at correct DM content for length of chop used.
- Spread harvested forage evenly (to a depth of about 15-30 cm) before rolling.
- Continually roll the forage during harvesting, and ensure forage is well compacted to expel as much air as possible.
- Long, narrow, deep stacks are more effective than short, wide, shallow stacks.
- Until harvest is complete, cover the stack at night, weighting the plastic along the perimeter.
- When harvesting is completed seal the stack as soon as possible after adequate compaction.
- Bury the edges of the plastic in the ground to ensure an airtight seal. This is more effective than simply covering the plastic with soil.
- Regularly inspect the stack for holes during storage. Repair holes as soon as noticed using tape specifically made for silage plastic.

Baled silage

- Bale at the correct DM content.
- Bales should be well compacted (of high density) to minimise air pockets.
- Ensure the storage site is clear, control weeds, rodents and remove objects that may pierce the plastic. Do not store under trees or too close to fence lines.
- Seal the bales with plastic as soon as possible after baling.
- If possible, seal the bales at the storage site rather than in the paddock where they are baled.
- If wrapped bales must be moved, use handling equipment that will not damage the plastic.
- Regularly inspect bales for holes during storage. Repair holes with tapes specifically made for stretchwrap plastic as soon as they are noticed.

Section 9.0

Introduction

Although many high-quality crops are harvested efficiently, there can be significant losses of DM and quality if the silage storage system is inadequate. These losses are due to excessive respiration (overheating), effluent loss and aerobic spoilage in the stack or bales (see Chapter 2, Section 2.5). They can be minimised by good management during filling and storage.

There is a range of storage systems used for preserving silage. These include under- and above-ground systems, with the capacity for handling both chopped and baled forage.

All systems are capable of producing high-quality silage. However, above-ground storage that relies on a plastic cover for protection is usually only suitable for short-term storage. Storage time may be increased by providing a second protective cover over the silage plastic, to reduce breakdown by sunlight (ultra-violet radiation). As long as there is no physical damage to the plastic, this may extend the storage time by 3-5 years.

The system chosen for a particular enterprise will depend on the purpose for which the silage is being used, available equipment, expertise and personal preference.

Safety first

- Whether storing silage in pits, bunkers or bales, take all necessary precautions to avoid injury when using heavy machinery. Safety issues should not be ignored. Ensure all operators read and fully understand any information provided by the manufacturer on the machinery's safe operation.
- When preparing pits or bunkers, excavation is a safety issue. Check the guidelines that apply in your State. In NSW, for example, the NSW Code of Practice: Excavation 2000 provides legal guidelines and responsibilities for persons engaged in excavation work. It is available from the Workcover Authority of NSW or from its website <www.workcover.nsw.gov.au>
- Guidance notes on Hay and Silage Bales and Trenching Codes of Practice are available from <www.workcover.vic.gov.au> and Codes of Practice for Transport of Silage and Hay from the Australian Fodder Industry Association (AFIA) website <www.afia.org.com.au>
- Seek help from Workcover, or the relevant State authority, to ensure all equipment and practices are safe and satisfy recommended guidelines and regulations.

Figure 9.1 categorises the storage options.

When choosing a storage system it is also necessary to consider how the silage is to be fed out. Poor planning of the feedout phase through inappropriate design or location of the storage facility, or an inadequate feedout system, can result in an expensive silage system. The feedout aspect is covered more fully in Chapter 10.

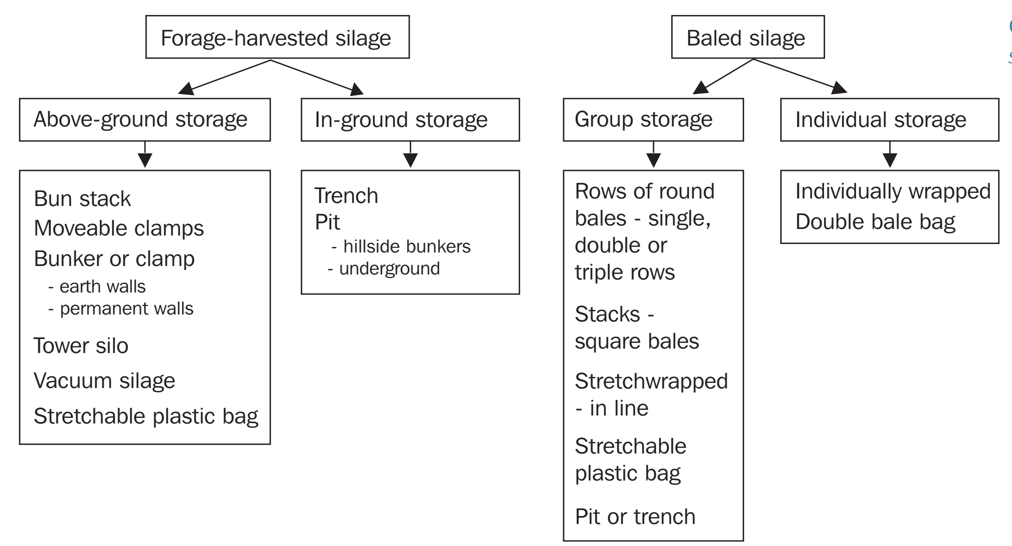


Figure 9.1

Categories of silage storage systems available.

Section 9.1

Storage systems for forage-harvested (chopped) silage

Buns are silage units formed above the ground, with no structural support. Sometimes referred to as stacks or bun stacks.

Bunkers refer to above ground storages with structured walls.

Pits refer to storages in the ground or built into the sides of hills.

Chopped or forage-harvested silage is handled and stored in bulk. It can be harvested using forage wagons, flail, single and double chop, and precision (metered) chop forage harvesters. For more details on the various types of forage harvester, see Chapter 8, Section 8.2.1.

The silage is chopped to various lengths, depending on the machine setting.

Plate 9.1a

A small-scale silage bun system used to store small amounts of silage. The area around the storage site is clear – minimising potential vermin habitats. A large number of tyres have been used to weigh down the plastic, maintaining contact between the plastic and the silage. *Photograph: K. Kerr*

Plate 9.1b

Large-scale bun system. In this case the number of tyres is inadequate. At least twice the number are needed to ensure a good seal. *Photograph: M. Martin*

Silage buns or stacks

Advantages	Disadvantages
• No construction cost. • Can be located with less regard to terrain than trenches or pit silos (rocky soil, subsurface water). • Are easily adaptable to self-feeding using electric fencing. • Easily sealed using a blade or bucket.	• Because of the high surface area to volume ratio, the amount and total cost of plastic used per tonne of ensiled forage is high, and any surface wastage represents a large proportion of the ensiled forage. • Can be dangerous for tractor operators during rolling. • Not suitable for long-term storage (>2-3 years) unless the plastic is protected from sunlight.

9.1.1

Silage buns or stacks

Silage buns, also called stacks, are usually a short-term method of storing chopped silage. They are often sited in or near the paddock being harvested, but can be near an intended feedout point.

Buns should be sited:

- on a reasonably level area of ground, ideally with a slight slope to allow rain water to drain away freely, particularly during feedout;
- away from depressions where water may pond or areas where water may run during heavy rain; and
- away from trees (tearing of the plastic sheeting by falling limbs and bird damage is more significant if buns are sited near trees).

Silage buns are very simple to construct. The harvested forage is dumped on top of the ground, then compacted by rolling with a tractor. During rolling, the shape of the bun is formed by pushing the uncompacted forage with a blade or bucket.

The forage should be covered with a plastic sheet as soon as harvesting and rolling are completed. An airtight seal is achieved by burying the edges of the plastic sheet. If compacted and sealed effectively, the silage is preserved with little visible waste.

Buns are produced either by filling from one end (Dorset wedge technique, see Section 9.3) or by topping up over the length of the stack. The latter method is primarily used for buns formed using forage wagons, where the harvested material is offloaded as the wagon is driven across the bun.

As there are no walls, the height to which the bun can be safely constructed is limited. The amount of surface area to volume (the surface area to volume ratio) is high and, as a result, the risk of in-silo spoilage is also high. The effect of surface area to volume ratio on storage losses is discussed in Chapter 11, Section 11.2.4.

Circular buns are popular in some areas. They are round stacks of forage, which may be as high as 2-3 m at the centre. Being round, their surface area to volume ratio – and therefore plastic costs – are higher than that of long, narrow buns.

Because there are no walls to provide physical support, silage buns can be unstable, and tractors may tip or bog during rolling. Care must be taken when rolling or delivering and dumping on the stack. Drivers should be experienced or closely supervised by someone who is.

Vacuum silage

Vacuum silage is no longer common, although it has been used in Queensland and found to be economically and practically feasible for short-term storage. Forage is sealed in an airtight plastic cover, which is then evacuated (air removed) with a pump. However, a well-preserved silage can be produced without the added expense of evacuating if the stack is well compacted and sealed quickly.

Vacuum silage requires some compaction by rolling to provide a firm base for machinery to pass over the stack. Additional compaction also occurs when spreading the chopped forage around the stack. However, most of the compaction is achieved in the evacuation process. The system only works well with young, leafy material that is easily compacted. Forage with woody stems may puncture the plastic cover during evacuation of the air. This risk increases as chop length increases.

9.1.2

Portable clamps or walls

Portable clamps or walls can be removed (or left in place) after the stack is completed. They suit stacks where the tractor and cart can travel over the stack's length when delivering the harvested forage.

They can be very dangerous if the walls are not strong and stable enough for the size and weight of machinery used to fill and compact the stack.

They are usually built from metal pipe or tube and sheets of tin or strong plywood. The walls – usually 1.5-2.0 m high – must have sturdy guide rails to prevent the wheels of the rolling tractor slipping over the edge.

Anyone intending to build or use portable walls should seek expert advice to ensure adequate strength, stability and safety.

Although some producers have used large round or square bales of hay as 'side walls', they are not recommended as it is difficult to create an airtight seal:

- the edges are usually poorly compacted;
- a lot of air can be trapped between the forage and the bales; and
- bales can easily puncture or tear the plastic during rolling and sealing.

The use of portable clamps or walls is not recommended because of the risks involved in filling and compacting the stack.

Portable clamps

Advantages	Disadvantages
• Inexpensive to construct and may be used for several batches per season. • Allow a greater depth of silage, reducing plastic costs per tonne and proportion of the ensiled forage lost due to surface waste. • Adaptable to self-feeding. • Easily sealed using a blade or bucket, if the walls are removed.	• Can be extremely dangerous to the tractor operator. • Need to be assembled and later disassembled for each silage stack. • Difficult to obtain a good seal around the edges if the walls are not removed. • Not suitable for long-term storage unless the plastic is protected from sunlight.

Bunkers

Advantages	Disadvantages
• Can be built in areas where the soil is rocky or the water table is high. • Can be built reasonably inexpensively. • Can be adapted for self-feeding. • Can be long lasting. • Reduced plastic costs per tonne of ensiled forage. • More effective compaction possible, reducing losses. • Concrete bunkers allow all-weather access. • Depending on design, can be expanded at relatively low cost by using a common wall.	• Need to be well sealed where the plastic overlaps or losses can be high. • Do not always shed rainwater effectively. Pools of water can lie on the plastic surface, seep through and cause losses. • Not suitable for long-term storage unless the plastic is protected from sunlight. • Concrete bunkers can be expensive to construct, but can be justified if used regularly.

Plate 9.2a

Low-cost, above-ground bunker – earthen floor, mesh and plastic in walls. Second-hand conveyor belting may be used as walls.

Photograph: A. Kaiser

Plate 9.2b

Low-cost system with earthen floor and corrugated iron walls. Corrosion of metal will be a problem if the bunker is not lined.

Photograph: F. Mickan

Plate 9.2c

Higher-cost, but more durable concrete bunker system.

Photograph: F. Mickan

9.1.3

Above-ground bunkers or clamps

Bunker or clamp silos are permanent structures constructed above ground (see Plate 9.2a, b & c) commonly used in operations where a lot of silage is made and fed.

They are an option in areas where a high water table makes underground storages an impossibility.

Bunkers are rectangular in shape and can be open at either one or both ends. The walls can be made of various materials including concrete, earth, timber (such as railway sleepers) or steel. Floors are earthen or concrete. The durability of the structure will vary with the building materials used. Silage acids will corrode materials over time.

It is essential that producers seek engineering advice on construction to ensure the stability of these structures.

Factors to consider when constructing bunkers or in-ground pits:

- The cost of building bunkers or in-ground pits is a fixed cost. The potential life of the storage is important when considering location.
- If the storages are used regularly, as part of the annual forage conservation program, the construction costs per tonne of silage can be low.
- The storages can be re-used many times if the pit or bunker is well constructed and the surrounding soil is stable.
- Professional advice should be obtained when constructing these storages.

9.1.4

In-ground pits

In-ground storages are suitable for both long- and short-term storage of silage. Silage being used in the short-term need only be sealed with plastic as for the bunker system. For long-term storage, the plastic has to be covered with a layer of soil (see below).

Regular monitoring is recommended to ensure burrowing animals have not disturbed the soil layer, allowing air and water into the silage.

A layer of plastic on top of the silage will prevent soil contaminating the silage, and provide a barrier against air and water penetration. At least 30 cm of soil should cover the plastic. A cheaper, lower-quality plastic, such as builder's black plastic, although not recommended for above-ground silos or bunkers, may be used if the covering soil is not a porous sand or a cracking clay.

Although it is never recommended that soil be placed directly onto the silage, if plastic is not used then at least 50 cm of soil on top of the forage is required for long-term storage. The soil must not be porous or a cracking clay.

The level of maintenance required depends on how often the pits are used and refilled. Some 'clean-up' prior to refilling may be required to remove any soil that has fallen in or to re-level the base of the pit.

Safety must be considered at all times. The risks of walls collapsing and cave-ins will increase with the depth of the pit. Construction of very deep-sided pits may raise occupational health and safety issues and may involve regulations concerning depth of excavations, fencing off dangerous areas, specifying and erecting formwork, retaining walls and other potentially dangerous situations. Refer to the websites mentioned in Section 9.0 or contact local State authorities for detailed information.

There are numerous variations on types of in-ground storage, but they can be categorised as underground pits, hillside pits or bunkers, or the less-common trenches.

In-ground pits

Advantages	Disadvantages
• Inexpensive to construct. • Ideal for long-term drought storage.	• Not recommended for short-term storage. • Not suitable for areas with a high water table. • Cannot be used during wet weather. • Unstable walls can be a safety issue.

In-ground pits

Underground pits are dug into flat ground with the silage stored completely below ground level or mounded. The soil removed from the hole should be mounded over the top of the pit to shed water. If the stack shrinks below ground level then more soil should be added.

They are usually used for long-term or drought storage and are only recommended for drier areas. Feeding out from the pits should take place during dry weather. If the pits are open during wet weather they will fill with water, making it impossible to remove the silage and causing large losses.

Underground pits should not be constructed in areas where a high water table allows water to seep into the pit, resulting in losses of DM and quality.

Plate 9.3

Hillside pits or bunkers can be effective, low-cost storage systems.

Photograph: M. Martin

Hillside pits

Advantages	Disadvantages
• Suitable for long and short-term storage. • Reduced plastic costs per tonne of ensiled forage. • Can be used for self-feeding if the base of the pit is solid and dry, and can be scraped clean. • Good compaction, reducing losses. • Much lower risk of water entry compared to in-ground pits.	• Usually low cost, but can be expensive to construct if rocks or loose soil are encountered. • Need constant attention if walls become unstable, can be a safety issue. • Earthen floors can become untrafficable in wet weather. • Risk of water infiltration if location is not well planned.

Hillside pits or bunkers

Hillside pits are constructed into the sides or tops of hills, or high embankments (see Plate 9.3), the surrounding earth providing the walls of the structure. In some cases the wall height or pit length can be extended using soil excavated from the pit.

Trench silos

Advantages	Disadvantages
• Can be constructed quickly and inexpensively, with little preparation. • Plastic costs are lower than for buns. • Can be used for long-term storage if covered with soil. • Shed rainwater well because they are higher than surrounding ground level.	• Losses can be high. • The above ground wall portion is often unstable and may cave in. • The earthen floor is often not trafficable during wet weather. • Not suitable for long-term storage unless the plastic is protected from sunlight.

Trench silos

Trenches are usually a compromise construction between pits and above-ground walled bunkers, where the silage is stored partly above and partly below ground.

The trench silo is a popular method of storage, particularly for producers making silage for the first time. A low-cost, unlined silo can be made with a tractor and blade. It can be built as a temporary silo and lined at a later date. They are quick to construct and repairs are limited to smoothing the walls and base.

Trench silos can be formed with dirt carted from elsewhere and may require only one wall to be constructed, usually from soil.

If trenches are excavated to form relatively low banks (1-1.5 m), rolling a stack above this height must be done carefully. The soil moved from the trench is usually placed and rolled along the trench sides to form the walls.

Banks constructed from loose soil should be battered (sloped) to reduce the risk of collapse. A slope of 1:8 to 1:10 is desirable (i.e. 1 horizontal to 8-10 vertical). If the soil is very loose and it is not possible to build walls any steeper than 1:3, there are likely to be better storage options. Table 9.1 shows guidelines of preferred slopes for various silo constructions. Professional advice should be obtained for individual circumstances.

Table 9.1

Gradients of floors and walls in various silo constructions.

Structure	
Floor type:	**Suggested slope (horizontal to vertical):**
Earthen floor – mechanical feedout	50:1 to 60:1
Earthen floor – self-feeding feedout	Up to 30:1
Cement floor – mechanical feedout	80:1 to 100:1
Wall type:	**Wall slope:**
Earthen walls – dry clay	1:6 to 1:8
Earthen walls – loose soils	1:3 (consider a concrete wall)
Cement walls	1:8 to vertical

9.1.5

Stretchable bag system

The stretchable bag system (e.g. German Eberhardt® silopress, American Ag Bag®) is a temporary storage system (1-3 years) suitable for chopped, wilted forage (30-50% DM), maize silage (33-38% DM) or high-moisture grain (68-72% DM). Although mostly used for chopped forage, bags can be used for round bales if an alternative filling mechanism is adopted (see Plate 9.4 a & b and Section 9.5.1).

The heavyweight plastic bags are 2.44-3.64 m in diameter and 50-150 m long, with a range of storage capacities. The chopped forage is compacted as it is forced into the bag, which is then tied off.

The level of storage loss with this system depends largely on the density and moisture level of the ensiled material and the amount of compaction developed by the machine. Rodents, particularly rats, can be a problem, chewing holes in the plastic near the ground and inhabiting the bags. Producers should implement some control measures if rodents are expected to be a problem.

Plate 9.4a

Stretchable bag system.

Photograph: K. Kerr

Plate 9.4b

The stretchable bag system is a convenient storage system for chopped or baled silage and requires no capital investment in storage facilities.

Photograph: K. Kerr

Stretchable Bag System

Advantages	Disadvantages
• Flexibility with storage siting. • Stronger plastic. • Relatively small exposed face at feeding • Ability to store different batches separately. • Can be used for chopped or baled fodder.	• Specialised packing machine required; contractor probably needed. • Bags more expensive than other plastics. • Not suitable for long-term storage (>3 years).

Tower silos

Advantages	Disadvantages
• Losses during storage are very low, particularly with sealed systems. • Capable of storing a large quantity of material in a limited area.	• Increased field and harvesting losses due to extended wilting; with direct cut crops, later harvest to achieve high DM may reduce forage quality. • Expensive to construct and maintain.

Plate 9.5

Tower silo (Harvestore® System).

Photograph: M. Martin

9.1.6

Tower silos

Tower silos are permanent, above-ground structures constructed from metal (e.g. the Harvestore®, see Plate 9.5) or concrete (either concrete staves or poured on site). Although popular in the United States, very few have been built in Australia.

There are two main types of tower silos – those hermetically sealed by closing a filling hatch at the top and unsealed silos in which the surface of the silage is sealed with an impervious sheet.

Sealed silos have two-way relief valves in the roof to prevent a build-up or reduction in pressure that can occur with changes in ambient temperature. In some makes, the valve connects the atmosphere to a large bag in the roof so that any airflow to and from the silo is isolated from the silage.

Tower silos are built on concrete foundations. A drain should be provided on the inside, near the base of the wall, to prevent hydraulic (fluid) pressures developing. The drain outlet should be resealable to stop air entering the silo.

With the Harvestore® system, the forage must have a DM content of 45-55% DM, and is referred to as 'Haylage'. Ensiling material below the recommended DM content increases the risk of fluid pressure developing and of structural damage to the tower.

Lower DM forages will produce more acid during fermentation. This can corrode the silo and feed out equipment. However, the likelihood of wastage in towers is less than in other types of silos, although well-compacted and sealed stacks can be nearly as efficient.

Section 9.2

Designing bunkers and pits

The design of bunkers and pits must ensure:

- sufficient slope to allow water and effluent to flow out of, off and away from the storage area;
- location of the structure to avoid water tables or seepage;
- location of the structure to avoid accessibility problems;
- structural soundness; and
- dimensions to match your feedout system.

Although these points are particularly relevant for ensiling chopped forage, many of the issues covered are pertinent for baled silage. Many also have relevance for portable clamp structures.

The following sections cover the basic principles that must be considered when designing bunkers and pits. Poor design has the potential to be expensive in the long-term (short life and high maintenance costs), difficult to use and dangerous. Potential problems can be avoided by seeking engineering advice before construction begins.

9.2.1

Location

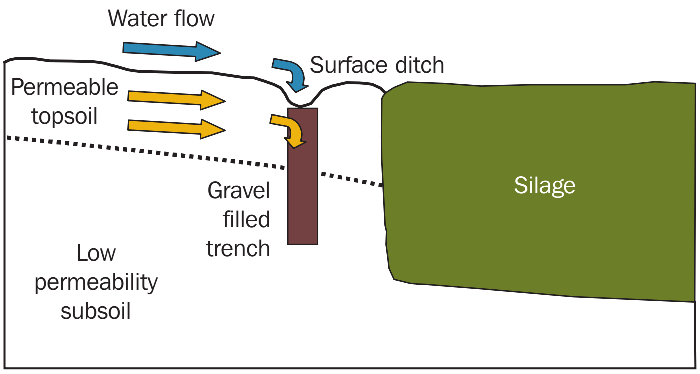
The site of the silage storage facility is important. Unlike a number of other silage systems, these structures are permanent and cannot be moved from season to season. The following factors need be considered when deciding on location:

- Distance and time to travel to and from the site during feedout will usually be greater than at harvest. The bunkers should be located close to where the silage will be fed out. Alternatively, if the silage will be fed at various places around the farm, the bunkers should either be at a convenient central location or at a number of sites. The latter is the only option if using a forage wagon to harvest.
- If silage odour is likely to become a problem to neighbours – particularly if sites are near towns and/or easily viewed by the public – consider siting the storage to minimise 'smell drift' disputes.
- Avoid low-lying areas, which may become flooded or difficult to reach in wet weather.
- Access must be easy for machinery and vehicles at harvest and feeding out. Fences around the storage area should be constructed to allow this.
- Locate away from streams and waterways to avoid any risk of silage effluent or runoff contamination (see Chapter 2, Section 2.1.1).
- Avoid overhead power and telephone lines and any below-ground obstacles such as water lines, gas pipes and fibre-optic cables. Also be aware of hazards such as steep slopes to/from the stack.
- Locate clear of trees.

- Avoid sites where soil water seepage will enter hillside pits or pits. If this is unavoidable, Figure 9.2 shows some options to limit water entry. Water can be intercepted and redirected away from the stack, often by a slotted corrugated plastic pipe. If water entry via the soil profile is not a problem, then a small earthen bank uphill from the stack will divert the surface water.

Figure 9.2

Side view of silage hillside bunker or pit, showing techniques to avoid water entry into the pit.



9.2.2

Dimensions and storage capacity

The dimensions of the bunkers and pits will affect feedout rate, the cost per tonne of silage and accessibility for machinery during storage and feedout.

- Aerobic spoilage will increase if the area of the bunker face is too large, resulting in an insufficient feedout rate (see Chapter 2, Section 2.5.3). The factors affecting feedout rate and calculations for determining pit dimensions for optimum rates are in Chapter 10, Section 10.2.1.
- Unnecessary costs result if the silage face is too small, the pit is too narrow or the walls are not high enough because of:
  - increased construction costs – longer walls;
  - increased sealing costs – plastic, labour to weight down the plastic;
  - increased wear and tear on equipment, pit floor, strain on the operator, and time taken to feedout because of the longer distance between the silage face and the feedout equipment;
- For chopped silage, the bunker must be at least 1.8 times the width of the tractor used to roll the silage to ensure the stack centre is compacted.
- A higher-walled bunker will ensure greater compaction of chopped silage, particularly at the base of the stack. It also reduces the cost of plastic and storage area required, and the amount of surface waste for each tonne of forage ensiled. However, if animals are to self-feed at the bunker, the silage should not be more than 1.5 times the height of the animals (see Chapter 10, Section 10.3.1).

Table 9.2

Dry matter contents and densities of maize and haycrop silages in Wisconsin, United States.

Characteristic	Haycrop* silages (87 silos)		Maize silages (81 silos)	
	Average	Range	Average	Range
DM content (%)	42	24-67	34	25-46
Wet density (kg/m^3)	590	210-980	690	370-960
DM density(kg/m^3)	237	106-434	232	125-378
Average particle size (mm)	11.7	6.9-31.2	10.9	7.1-17.3

* *Most hay crops were lucerne crops.*

Source: Muck and Holmes (1999)

Estimating storage capacity

Calculation of the silage storage capacity is sometimes necessary to:

- estimate available stored silage reserves; and
- determine the dimensions needed to store the required amount of silage.

In a well-compacted pit or bunker, silage density should exceed 225 kg DM/cubic metre, but can be extremely variable (see Table 9.2).

The DM content and chop length of the silage and the effectiveness of rolling (compaction) must be taken into account when estimating the density of silage in storage, after settling. Silage depth is also a consideration. Density will be greatest at the bottom of the silo.

The calculation is sometimes based on the amount of silage stored on a fresh weight basis. This is then calculated back to quantity of stored DM. Table 9.3 gives the storage capacity for bunkers or pits with different dimensions, where the silage has a density of 650 kg fresh silage per cubic metre. An equation that can be used to calculate the density of fresh silage is in Chapter 8, Section 8.3.1.

Table 9.3

Silo capacity (tonnes/linear m) at 650 kg fresh silage/m^3.

Average silo width (m)	Silo depth (m)		
	2	2.5	3
3	3.9	4.9	5.9
4	5.2	6.5	7.8
5	6.5	8.1	9.8
6	7.8	9.8	11.7
7	9.1	11.4	13.7
8	10.4	13.0	15.6
9	11.7	14.6	17.6
10	13.0	16.3	19.5

9.2.3

Construction

There are a number of points to consider when constructing walled silage bunkers or pits:

- The floor should slope towards the open end (or ends) to allow rainfall or effluent to drain away. The recommended slope for various floor types is given in Table 9.1.
- Concreting the floor will provide all-weather access, and reduce contamination of the silage with mud. The concrete should be strong enough to cope with the weight of machinery and silage. A cement apron at the end of the storage area, upon which chopped forage can be dumped prior to spreading, will reduce contamination with soil and mud.
- Sloping the walls so that the width at the base of the pit or bunker is narrower than at the top will:
  - allow easier consolidation of the forage at the edges;
  - ensures that as the silage settles, contact with the walls is maintained;
  - increases compaction of the silage at the base of the pit.

  Table 9.1 gives recommended wall slopes.
- It is advisable to have safety rails along the tops of portable clamps and bunkers to avoid tractor wheels dropping off the stack edge.

Plate 9.6

Guard rails are strongly recommended on the walls of above-ground bunkers and portable clamps to reduce the risk of tractors slipping over the edge of the wall when rolling silage. *Photograph: R. Morris*

There are a number of materials and construction methods used for building above ground bunkers. Walls can be constructed of various materials – they can be earthen, or made from concrete, steel mesh, thick plywood or sleepers on their edge. The wall can be reinforced or supported by posts made of metal or timber. Some materials, such as mesh, are porous and need to be lined with plastic sheet to obtain an airtight seal. Others may need sealing to protect them from corrosion by silage acids. Construction details will not be discussed in this publication.

It is recommended that anyone intending to build such structures seek engineering advice. It is important that the correct materials be used – strength and resistance to silage acids must be considered. The design of the structure must ensure that the base and walls are able to withstand the pressure of the compacted silage and the machinery operating during silage making and feedout.

Construction of several smaller pits rather than one large and/or long pit can increase the flexibility of silage storage substantially:

- different forages can be separated, e.g. maize and lucerne silage;
- forages of different quality can be stored separately, e.g. early versus late cut pasture;
- avoids the need to reseal large pits or bunkers if only feeding for a short time;
- can feed animals with different feed requirements from different silages.

Section 9.3

Filling and compacting silage in bunkers, pits and buns

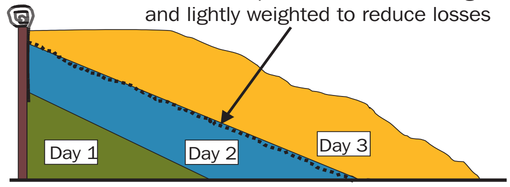
Filling and compaction should be continuous throughout the silage-making period (not more than three days for each storage unit).

At the end of each day's harvesting, cover the stack with a lightly weighted plastic seal to limit respiration losses.

- Begin filling against the back wall of a pit or one-ended bunker. In the case of open-ended bunkers and buns, filling can be from one end or spread along the area if using a forage wagon which unloads as it travels. Figures 9.3, 9.4 and 9.5 show three alternative methods of filling – two variations on the progressive or Dorset wedge and the top-up method.
- If the forage is too dry and difficult to compact, alternate with loads of freshly cut or partially wilted forage.
- Evenly spread each load to <30 cm thick – tractor wheels will have minimal compression effect below this depth.
- Compaction will be less effective if the chopped forage is delivered to the bunker at a high rate. Under these circumstances, the forage should be spread more thinly (15 cm) to improve compaction. Rolling with a heavy-wheeled tractor (preferably 4WD) achieves better compaction than tracked vehicles, although they are satisfactory if very heavy. Roll slowly to allow the tractor weight to compress the forage. Continue rolling after the last load is delivered until there is little impression left by the tractor wheels.

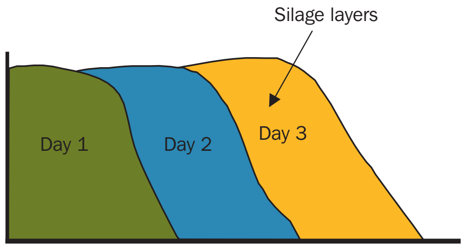
The version of the progressive or Dorset wedge shown Figure 9.3 is the preferred technique, having shown slightly lower losses than the other two systems (see Figures 9.4 and 9.5).

Figure 9.3



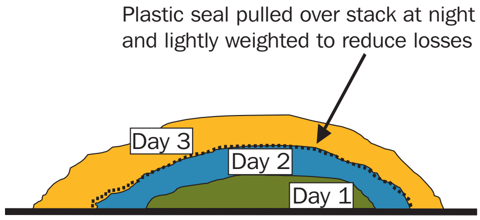
Single Dorset wedge technique for filling of pit over three days.

Figure 9.4



Variation on the single Dorset wedge. This is the technique for filling a silo over three days to the full height before increasing the length.

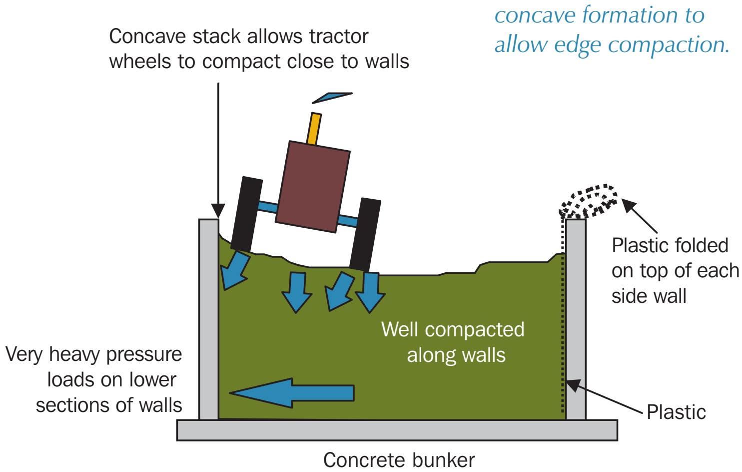
Figure 9.5



The top-up method. This is the technique for filling over three days to the full length of the bun/stack before increasing the height.

With walled bunkers and pits, when reversing the tractor, run the front wheel along the wall to compact the edges. Be careful not to scrape the wall, which may damage the wheel and plastic sheeting (see Figure 9.6).

Figure 9.6



Bunker being filled using concave formation to allow edge compaction.

Section 9.4

Sealing bunkers, pits and buns

Effective sealing is critical to ensure the silage is successfully preserved and to minimise storage losses.

The following management procedures will ensure an airtight seal:

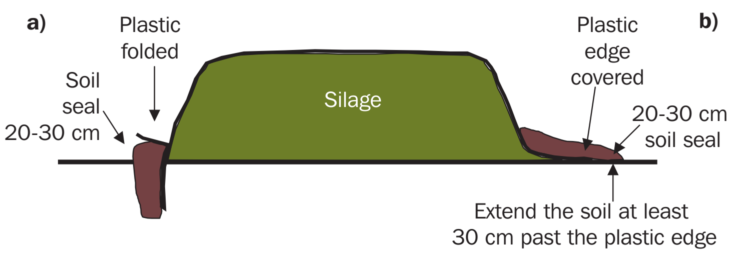
- Seal as soon as filling and compaction is completed, using plastic specifically manufactured for silage making (see Section 9.7). Overlap any joins by 50 cm and seal them with plastic adhesive tape specifically designed for silage sheeting. The plastic must be clean, dry, not hot, and allowed shrink after cutting for the tape to work effectively. Alternatively, overlap by 1 m and lay tyres or sandbags along the joins.

  If sealing is not possible on the day the stack is filled, cover with plastic and tyres overnight. Seal the next morning, but do not remove the plastic to re-roll the stack. Delayed sealing increases losses (see Chapter 2, Section 2.2.1).
- When filling, ensure the surface of the silage has enough slope to allow water to flow off the surface. Avoid forming hollows on the surface, particularly against the walls.
- Because silage settles during storage, it sinks below its original height, often leaving a depression. If the stack is not well-sealed, moisture may seep through into the silage. Avoid filling walled bunkers above the wall height – this is dangerous and should not be attempted.

  If pits are covered with soil, this can be mounded up to increase height above ground level, and shaped to assist water run-off.
- Burying the edges of the plastic in the ground is the most effective way to seal silage buns and pits. Covering the ends with 20-30 cm of soil can create a satisfactory seal (see Figure 9.7). Do not use sand as it is porous and will allow air to enter the silage. For long-term storage, cover the stack with at least 30 cm of soil if the forage is covered with plastic or 50 cm if there is

Figure 9.7

Cross-section of buns showing airtight sealing techniques. Covering the plastic with soil (b) can be unreliable. The seal will not be effective if insufficient soil depth or a porous soil is used.

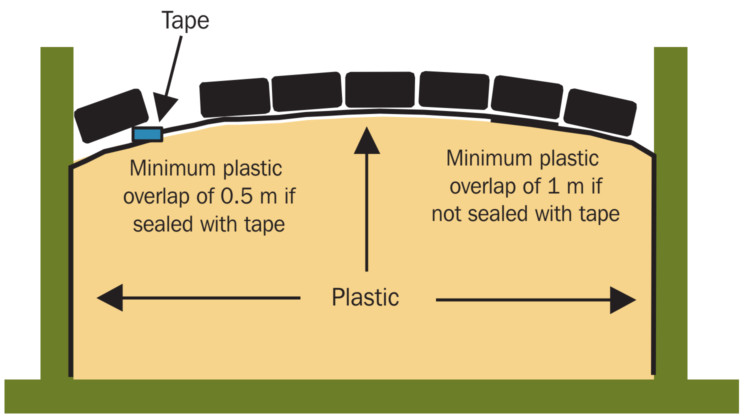


no plastic covering. Increase the depth of coverage for sandy soils or cracking clays. Note that a plastic cover is the recommended option (see Section 9.1.4).

- With walled bunkers, it is necessary to lay a shoulder sheet of plastic along the wall. This should extend down towards the floor of the silo to improve sealing. This plastic is then folded back onto the bunker and covered with a second sheet weighed down with, for example, tyres or sandbags (see Figure 9.8).
- There are various ways to seal a bunker with plastic. The final way the plastic is laid out will depend on the width of the silo and the width of the plastic sheeting. Figure 9.8 shows one method, with and without tape.
- The plastic should be weighed down well, usually with tyres and/or soil.
- In the past, several alternatives to plastic have been used to seal silage. These include mashed potato, citrus pulp and other by-products, freshly cut wet pasture or weeds, and products such as lime or cement. None of these is recommended because the integrity of the seal cannot be guaranteed, and some may have animal health implications. Plastic seals are recommended and are economical (see Section 9.7).

Figure 9.8

Examples of methods that can be used to seal a bunker. Joining plastic sheets with tape is the preferred option.



Maintenance

Fence off stacks to exclude stock. Single wire electric fencing is often not reliable.

Regularly check for holes in the plastic seal, and repair as soon as they are noticed, using tape specifically manufactured for silage sheets (see Section 9.7).

Where a layer of soil is used, regularly check that burrowing animals have not disturbed the soil seal.

Section 9.5

Storage systems for baled silage

Various systems have been developed to store forage in round and large square bales as silage (see Figure 9.1). Bales can be stored in groups under sheets of plastic, in stretchable bags or wrapped in sausage rows using stretchwrap plastic, or individually in stretchwrap plastic, or in double bale plastic bags.

9.5.1

Bulk storage above-ground

Round bales in stacks

Round baled silage can be stored on their curved sides, under sheets of polythene plastic, in single (see Figure 9.9) or double (see Figure 9.10) rows/sausages, or as triple rows, sometimes referred to as pyramid stacks (see Figure 9.11).

Because it is difficult to effectively reseal bale stacks, careful planning is essential to minimise feedout losses.

- Minimise aerobic spoilage losses at feedout by storing only enough bales in each stack, or compartment, for 7-10 days' feeding.
- Use soil or bury plastic to form airtight seals. Don't use sand or cracking clays.

Figure 9.9

Single row or sausage storage system.

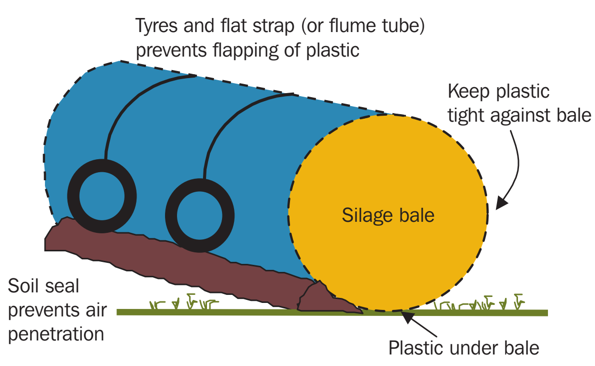


Figure 9.10

Double row or sausage storage system.

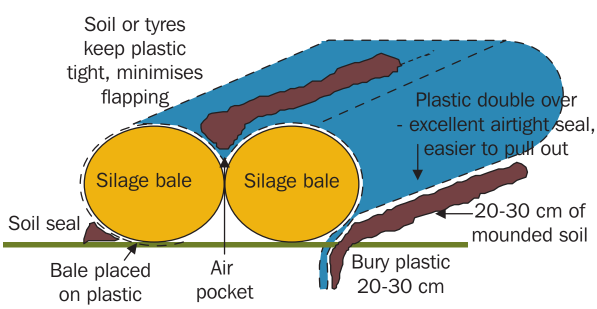


Figure 9.11

Triple row or sausage storage system.

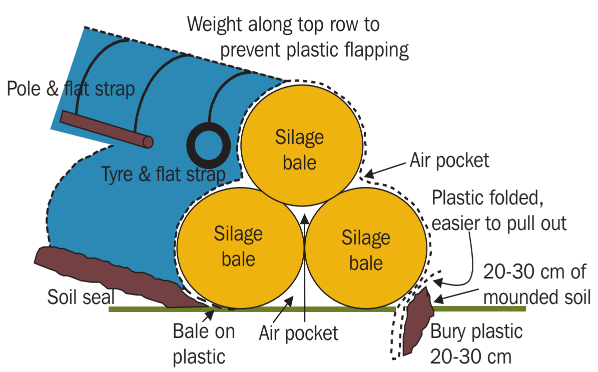
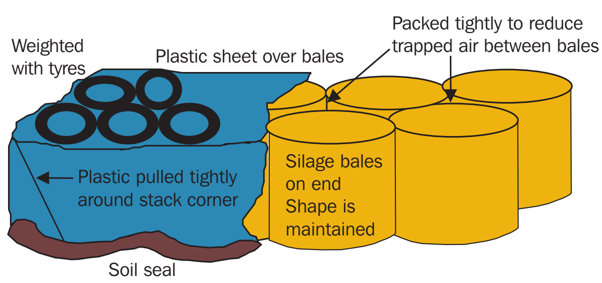


Figure 9.12

Stacks of round bales on their ends.



- For double rows, place soil or tyres between the rows before sealing to maintain plastic contact with bales.
- For triple rows, connect tyres on either side of the stack with wide straps to prevent plastic flapping and tearing.
- Immediately patch any holes with the correct tape. If possible, extract air from stack before patching to reduce amount of aerobic deterioration.

Round bales stored on their ends retain their shape and are easier to feed out (see Figure 9.12). They can be stacked 1-2 rows high depending on the DM content at baling:

- <30% DM (baled too wet), 1 row only
- >35% DM, 2 rows high.

Square bales in stacks

The shape of square bales makes them ideal for storing in stacks covered with plastic.

- Aerobic spoilage losses at feedout can be minimised by storing only enough bales in each stack, or compartment, for 2-3 weeks feeding (see Plate 9.7 a & b).
- Square bales can be stored two or three rows high (see Plate 9.7 a & b). The width of the stack (number of bales wide) is limited by the width of the plastic, as well as the anticipated rate of feedout (see Chapter 10, Section 10.2.1).
- Stack the bales starting at one corner, keeping the line of bales straight on one side. Because bales vary slightly in their width, it is difficult to not to leave gaps between the bales and the plastic. Keeping the stack straight, so there is a flat surface on one side, reduces the amount of air trapped at sealing, and the movement of air down the stack when it is opened.

Plate 9.7a

Individual stacks of big bale silage. *Photograph: M. Martin*

Plate 9.7b

Dividing a large stack into several small compartments is an alternative to making several smaller stacks. The internal sealing reduces feedout losses, there is less area covered and less perimeter to maintain.

Photograph: D. Stanley

Bulk storage of bales

Advantages	Disadvantages
• Less expensive than individually wrapped or bagged bales. • Does not require additional operator or equipment for wrapping. • Plastic sheeting used is more durable than plastic wrap, providing a storage life of up to 2-3 years.	• Losses can be high with round bales because of trapped air between and around the bales. • The whole stack will begin to deteriorate after opening. • Any small tear in the plastic will cause the whole stack to deteriorate. • Not suitable for long-term storage (>2-3 years) unless the plastic is protected from sunlight.

Stretchable bag system

Round and large square bales can be stored in plastic tubes (see Plate 9.8) as for chopped silage (see Section 9.1.5).

- Bales must be similar in size to minimise pockets of trapped air.
- Bags should last 2-3 years, if handled carefully and not damaged.
- Storage losses are low (see Section 9.8).
- Length varies from 30-45 m and diameters range from 1.2-1.5 m. They hold between 23 and 35 bales. These can be stretched approximately 15% oversize and then allowed to shrink back onto the bale.

Plate 9.8

Bales can be stored in stretchable (multi-bale) bags or socks.

Photograph: M. Martin

Stretchwrapped bales – in a line

Round and square bales may be wrapped in line as an alternative to individual wrapping. This saves about 40% in plastic compared to individual wrapping.

- Bales are laid end to end. End bales act as a 'plug' to stop air entry and must be well sealed.
- Bales should have consistent diameters to avoid air being trapped between large and small diameter bales. Over-stretching the plastic can be a problem when bales are of different diameters.
- Square bales are usually stacked two high before wrapping.
- Plastic is wrapped with 75% overlap at 55% stretch.
- Bales must be covered with at least 4 layers of plastic.
- Storage life is limited to about 12 months after which time the plastic begins to deteriorate. Covering the line of wrapped bales with an extra sheet of plastic will increase storage life.
- The line of bales can be divided into segments by placing an individually wrapped bale or sheet of plastic along the row. This will act as a secondary seal if feeding out stops before stack is completely used.

9.5.2

Individual above-ground bale storage

Single bales

Round and square bales can be individually stored in stretchwrap plastic. This is an expensive form of conservation because of high plastic and wrapping cost. However, many producers find the individual bales convenient to handle, although a storage life of only 12 months can be expected.

Individually wrapped bales are susceptible to air penetration, resulting in losses of DM and quality. This is because the surface area to volume is large – about half the silage volume is within 12 cm of the plastic film. All silage is within about 60 cm from the covering plastic.

- Forage stored in bales should be in the 35-50% DM range. Bales that are too wet are at risk of poor fermentation and greater DM losses, highlighted by the Australian data in Table 9.4.
- Wrap the bales as soon as possible after baling. The guidelines in Table 9.5 show the maximum number of hours recommended between wrapping and baling at various temperatures. The higher the temperature, the greater the respiration losses from the baled forage.
- Bales must be tight and of even shape. Plastic application follows the bale contour more effectively on convex shaped bales. Air is more easily trapped in concave shaped bales. Loose bales, conical shaped bales and uneven bales are very difficult to wrap, and will not have four layers of plastic all over without extra revolutions of the wrapper.
- Ensure the plastic wrap contains sufficient UV stabiliser (see Section 9.7). Be wary of cheap plastic that may not contain sufficient UV stabilisers for use under Australian conditions.
- It is preferable to wrap the bales at the storage site to reduce risk of damage to the plastic and movement of the plastic layers during transport. If wrapped in the paddock, bales should be moved immediately after wrapping, taking care to minimise damage to the plastic. Check bales carefully at the storage site and repair any holes with appropriate silage tape.
- Wrap bales using the 2+2 system, with 50% overlap (see Figure 9.13), ensuring there is a minimum covering of four layers of plastic over the entire bale. A 2+2 system with less than 50% overlap results in areas of the bales with only two to three layers, allowing air to enter

Table 9.5

Maximum delay (hours) recommended between baling and wrapping for a range of temperatures.

Temperature (°C)	Period after baling (hrs)
30	0-1
20	2
15	3

Table 9.4

Weights and losses from bagged and wrapped round bales of low and high DM.

	Bagged bales		Wrapped bales	
	Low DM (28.6% DM)	High DM (49.2% DM)	Low DM (31.7% DM)	High DM (44.6% DM)
Fresh weight at baling	686	514	686	540
DM weight at baling	193	249	210	240
DM weight after 4 mths	149	197	185	238
Total DM loss (kg DM)*	44	52	25	2
Total DM loss (%)	23	21	12	1

* *Includes spoilage, fermentation and effluent losses.*

Source: Adapted from Hadero-Ertiro (1987)

Individual above-ground bale storage

Advantages

- Flexible system suitable for small batches of silage.
- No construction costs for storage.
- Flexibility in locating storage site.
- Existing hay equipment may be used.
- Easy to monitor silage stocks/supply.
- Convenient to handle and feed out.
- A saleable commodity.

Disadvantages

- Not suitable for all crop types.
- High cost/t DM (wrapping and plastic).
- More susceptible to damage if handled after wrapping.
- More susceptible to bird and vermin damage.
- Short-term storage only (12 months).
- Feedout costs are high if handling large quantities.
- Plastic disposal is an issue.

the bale and resulting in aerobic spoilage, DM and nutrient loss (see Figure 9.14 and Section 9.8.2). Use six layers if the silage is being stored for more than 12 months or it is made from crops that are stalky.

➤ To ensure four layers on all parts of the bale, record the number of rotations of the turntable to cover all visible forage. At this stage, all except the last section of the bale will have two layers of cover. Add one more rotation to give a complete two layer cover. Double this number to apply four layers, and triple it for six layers, see example at left.

See Table 9.6 for recommended rotations required to apply four layers to 1.2 m x 1.2 m bales of consistent diameter and the likely numbers of bales covered per roll of film for a range of film sizes.

➤ Check that the pre-stretcher is working correctly, mark a fixed length, e.g. a match box, on the plastic roll before it passes through the pre-stretcher. Once the plastic film is applied to the bale the length should now be about 1.5 matchbox lengths, about 55% stretch.

Example

If 7 turns are needed to cover a 1.2 m x 1.2 m bale with one layer of a 750 mm wide film, then (7 + 1) x 2 = 16 rotations is required to apply 4 layers.

Figure 9.13

Bale correctly wrapped.

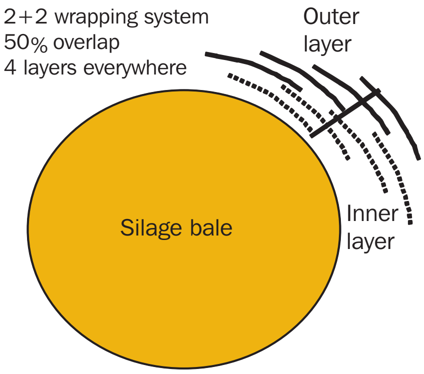


Figure 9.14

Bale incorrectly wrapped.

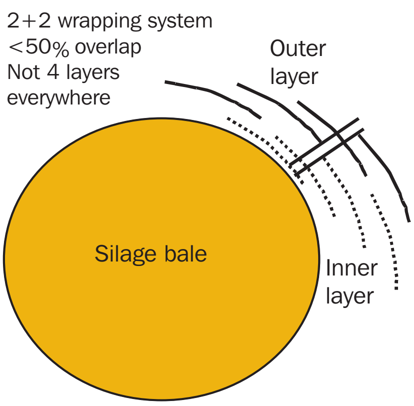


Table 9.6

Number of rotations to apply 4 layers and number of bales (1.2 m x 1.2 m) wrapped from a range of plastic sizes at 55% stretch.

Stretchwrap plastic roll size – width (mm) x length (m)	Approx. number of rotations to apply 4 layers	Approx. number of bales wrapped/roll
480 mm x 3,100 m*	24	Up to 34
500 mm x 1,500 m	24	17-18
500 mm x 1,800 m	24	21-23
600 mm x 1,500 m	20	20-22
600 mm x 1,800 m	20	25-27
730 mm x 3,100 m*	16	Up to 54
750 mm x 1,500 m	16	27-30
750 mm x 1,800 m	16	32-35

* *Pre-stretched plastic film – gearing of the wrapper will need to be altered.*

- Spikes should not be used to transport wrapped bales. It is very difficult to repair damage and prevent air penetration.
- Store round bales on the flat surface. This increases the number of layers of wrap exposed to the direct sun, and any sharp grass or twigs on the ground.

Double bagged bales

Single bale, heavy gauge (150 micron thick) black plastic bags were originally used for bale storage. These were then replaced by double bale-sized bags to reduce storage costs.

- The first bale is usually spiked in the centre then placed at the back of the bag at the storage site. The second bale is positioned in front of the first bale.
- The bales must be of uniform size and fit snugly into the bag.
- The neck of the bale is twisted as tightly as possible and tied off. The neck is then doubled over and retied to ensure that air cannot enter the bag. Gases during early fermentation will expand the bag, but will dissipate over time. Do not puncture the bag and check for burst gussets in the corners. A small hole or poorly tied neck can result in large losses.

Bagged bale systems have been superseded by wrapping because the former system is slow, labour intensive and expensive, and losses are greater.

9.5.3

Bales stored in pits

Unwrapped round and square bales may be stored in pits or hillside bunkers. Round bales are usually of lower density and create much larger air pockets than large square bales when stored in pits. This means there is much greater risk of aerobic spoilage if the plastic seal is damaged during storage and on opening for feeding. The risk of losses can be reduced by storing the bales in compartments of 7-10 days feed supply, with plastic sheets separating each group.

Round bales will lose their shape and the feedout machinery may have difficulty handling them.

Large square bales are well suited to storage in pits, although compartments, containing enough feed for 2-3 weeks, are also recommended (see Plate 9.7b). The larger compartment size, compared to that recommended for round bales, is possible because the square bales trap considerably less air, so reducing the risk of spoilage.

After the bales are covered with plastic, placing soil over the top and particularly down the sides of the pit, will improve the seal. Figures 9.15 and 9.16 show cross-sections of bales stored in an earthen pit.

Figure 9.15

End section of round bales in a pit.

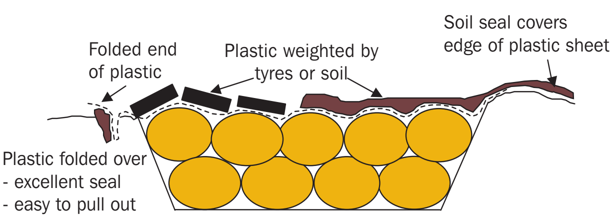
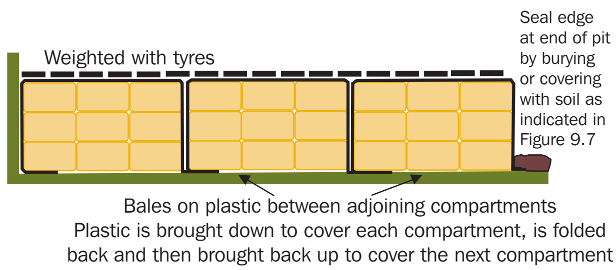


Figure 9.16

Side section of round/square bales in a pit.



Section 9.6

Location and maintenance of stored bales

A number of the issues raised in Section 9.2.1 regarding the location of pits, bunkers and buns, particularly issues of accessibility, are relevant to baled silage. Additional measures and precautions need to be taken because bales are more prone to damage from birds, rodents, foxes and livestock. Bales wrapped with thin stretchwrap plastic are even more at risk than bale stacks.

Some techniques to minimise these problems are:

- Because freshly harvested paddocks attract birds, move bales as soon as possible.
- Do not store bales under or near tree lines as they are likely to suffer damage from falling branches and birds sheltering in the trees.
- Stack bales well clear of fencing, including the permanent fence line.
- Construct solid fences in preference to single-wire electric fences, which are often unreliable. If electric fences are used, check them regularly.
- Place rodent bait in area surrounding bales, preferably not between bales as the baits are an attractant. A plastic, claimed to contain a pest repellant, was introduced onto the Australian market in 2001.
- Maintain a vegetation-free area around the site to remove cover for rodents.
- Irish research has shown that bales painted with an eye design (about 10 cm wide) suffered 70-80% less damage from birds compared to light netting stretched over tyres on top of bales, or monofilament lines at 1 m spacings and 1 m above the bales.
- Monofilament lines spaced about 0.5 m above bales and at 0.5 m spacings also greatly reduced bird damage. This spacing tends to make landing and 'taking off' very difficult for the birds.
- 'Humming wires' (plastic tape), used in orchards, set up in a diamond pattern across tops of bales catch wind from any direction (see Plate 9.9a).
- Tying silver foil or light plastic bags to single strings/wires above the row of bales.
- Tyres on bales can 'scare' some birds, who fear predators may be hidden in them.
- Similarly an artificial cat placed on bales can act as a deterrent to birds.
- Cover the bales with some form of netting.

Plate 9.9a

Humming wire deters birds from bales. *Photograph: F. Mickan*

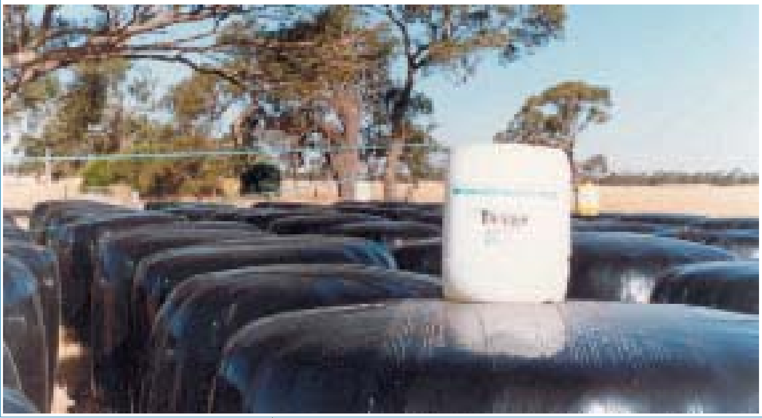


Plate 9.9b

Store bales well clear of fencelines to avoid damage from livestock. These bales are too close to the trees in the background, which may increase the risk of bird damage. *Photograph: F. Mickan*

Section 9.7

Plastics used for silage

Plastics used for silage come in thick sheet form, stretchwrap (cling wrap, shrink wrap) form, in short or long bags, or as an open-ended plastic tube. The latter is also stretchable, to a small degree, and shrinks back onto the bales.

Plastic tape specifically developed for patching holes and punctures in sheet and stretchwrap plastic is also considered briefly here.

9.7.1

Plastic sheeting

Plastic sheeting used for sealing silage is made from Low Density Polyethylene (LDPE), should contain UV stabiliser and be strong enough to prevent most puncturing and last several years. The plastics currently used are designed specifically for silage and are 150-200 microns thick.

Silage plastic should be made from 'virgin' polyethylene. Recycled plastics can have very small holes, due to impurities, that allow more air to penetrate.

Although plastic sheets were traditionally black most are now laminated (two sheets joined together) – white on one side and black on the other. Laminated plastic is much stronger than traditional black plastics of the same thickness. The white side faces the sun to reflect heat, reducing heat load and heat damage to silage at the surface.

Bird damage to the laminated plastics is claimed to be reduced because they do not like landing on the bright surface. Black plastic is more susceptible to bird damage because it 'softens' on hot days and, when a bird lands on it, is more easily punctured.

Although plastic sheets can be used for several years, it rarely lasts that long. The plastic is usually torn or punctured by machinery, animals or vermin before it deteriorates. Some farmers use old plastic to cover the new plastic, to extend the life of the new sheet to 5-7 years.

Builder's plastic should not be used on silage unless it is covered with at least 30 cm of soil. It is made from lower-quality plastic (often recycled) and will allow some transfer of air through to the silage. It will break down quickly when exposed to sunlight.

9.7.2

Stretchwrap plastic film

Stretchwrap plastic films are made from either a Low Density Polyethylene (LDPE) or a Linear Low Density Polyethylene (LLDPE) polymer or a mix of the two. Most films contain UV light inhibitor or stabiliser, colour and some form of 'tackifier.' The tackifier ensures that the layers of film 'stick' together after being applied to the bale, producing a relatively impermeable barrier to air when four layers are applied.

Most manufacturers guarantee the stretchwrap film for 12 months of silage storage. If the following points are observed, it is reasonable to expect a 12-month storage life for individually wrapped bales under Australian conditions.

High temperatures will affect the plastic's stretchability and thickness, becoming thinner as the temperature rises. The thinner the plastic, the greater the air penetration. Plastic rolls should be kept in cool locations during hot weather to avoid this problem.

- Store stretchwrap plastic rolls in shade until required.
- Avoid damaging film by allowing it to roll around in vehicles and on gravel. Avoid damage to the edges of the roll.
- Do not allow the cardboard centre roll to become wet as it may collapse.
- Light-coloured plastics tend to reflect more heat than black plastics.
- Repair holes immediately, with tape specified for silage plastic.
- Films usually have a batch number, which should be recorded in case there are quality problems.

Although stretchwrap film is 25 micron thick, it undergoes a 55% 'stretch' after it passes through a geared pre-stretcher, resulting in less than a total of 100 micron thickness for four layers. Earlier machines were set at 70% stretch. This is suitable for European conditions but is too much for Australian conditions.

After passing through the pre-stretcher mechanism the plastic will reduce in width ('neck down'), before being applied to the bale. If the film has been correctly stretched, the width of a 500 mm wide film should measure about 400 mm when measured on the flat end of the bale. A 750 mm wide film should measure about 600 mm. However, film quality, temperature and pre-stretcher unit type can all affect the final amount of 'stretch' or 'necking down'.

Stretchwrap film comes in a range of colours from white, black, grey, beige, brown and various shades of green. Some companies, using multi-layers (laminated), have produced films with a black interior but lighter colour exterior. Preferences vary widely between farmers and contractors and between regions. Film colour also has an impact on the heat generated within the wrapped bale (see Section 9.8.2).

It is important to recognise that film colour, apart from temperature effects of the darker films, is a much less important issue than the film quality. Films produced in Australia, which did not contain enough UV inhibitor, broke down within months in the field. Also some films are 'dumped' or offloaded in Australia from European countries at the end of their silage season. Some of these originate from countries requiring little or no UV inhibitor. Producers should ensure that the plastics they buy are guaranteed for use under Australian conditions.

9.7.3

Silage tapes

To minimise losses due to air penetrating the stack or bale:

- Use tape to seal joins of plastic sheeting when sealing bunkers and stacks.
- Seal any holes in the plastic as soon as they are noticed.
- Use only tape specifically manufactured for plastic sheeting or stretchwrap film. Before applying the patch ensure that the plastic is clean, dry, not hot and allow the patch to shrink after cutting to size.
- Inferior quality tapes (e.g. duct tape) may seal well initially, but cannot be guaranteed to withstand exposure to weather and sunlight. After a period of time, most will either fall off or disintegrate.

Section 9.8

Storage losses

During storage, loss of silage DM and quality can result from:

- Effluent production (avoidable).
- Respiration (unavoidable, but manageable). Prolonged respiration results in excessive heating and will reduce silage quality.
- Fermentation (unavoidable, but affected by management e.g. wilting).
- Aerobic spoilage (avoidable with good management) can account for significant losses if compaction is inadequate or if the airtight seal is damaged and air is allowed to penetrate the silo.

The extent of losses will vary with management, forage type and DM content. Some indicative levels of storage losses are given in Chapter 2, Section 2.5.2.

9.8.1

Effluent

The principles and magnitude of effluent losses are covered in Chapter 2 (Sections 2.1.1 and 2.5.2), and wilting strategies to avoid effluent production are discussed in Chapter 6.

Chopped silages tend to produce more effluent than baled silages at any given DM content because:

- fine chopping causes more damage to the plant cell, increasing the release of fluids; and
- low DM, chopped silages are more densely compacted than most bales.

In the case of wrapped or bagged bales the effluent is trapped and pools towards the base of the bale. The result is often a dark, slimy layer which may have undergone a clostridial fermentation (see Chapter 2, Section 2.2.2).

9.8.2

Respiration and aerobic spoilage

Some respiration occurs in all silages during filling or immediately after baling, and continues after sealing, while oxygen and WSCs are available (see Chapter 2, Section 2.2.1). DM and quality is lost during the respiration process (see Table 9.11). Respiration should be kept to a minimum by:

- rapid filling and efficient compaction of pits and bunkers;
- sealing of pits and bunkers immediately filling is completed; and
- wrapping bales soon after baling, with sufficient, good quality plastic.

Poor quality fermentation can occur if a significant proportion of the WSCs are lost during respiration. Forages with a low WSC content are most susceptible to poor fermentation and this problem is exacerbated by delayed sealing (see Table 9.11 and Section 9.8.3).

A prolonged aerobic respiration phase at the start of the ensiling process, due to poor compaction or sealing, allows the growth of aerobic micro-organisms including moulds, which results in visible spoilage and waste. Although moulds are more often found on the surface of the bunker or bale, they can occur in pockets throughout poorly compacted silage. These mould patches may be toxic, and are unpalatable and of almost no nutritional value (see Chapter 2, Section 2.3.4). Establishing an airtight seal quickly, and maintaining it during storage, is essential if aerobic spoilage losses are to be minimised.

The Appendices to this Chapter show likely patterns of storage losses, the possible problems and their solutions.

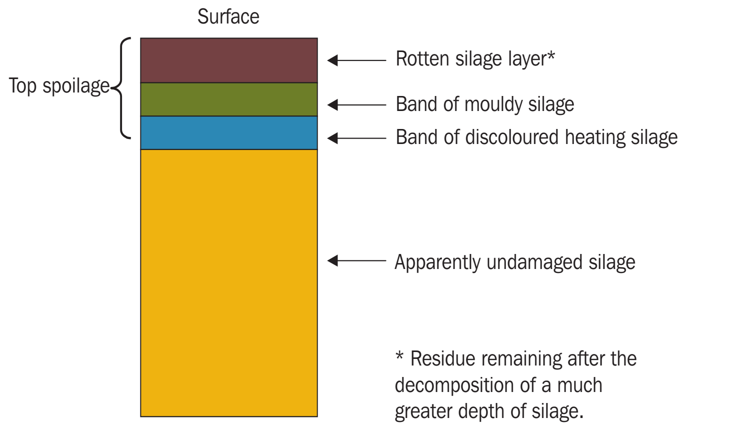
Appendix 9.A1 contains patterns relevant to pit or bunker storages and Appendix 9.A2 contains those for baled silages.

Losses in pit and bunker silage

Storage losses are minimal with good management – rapid filling, and effective compaction and sealing. However, some producers do not seal pits and bunkers of chopped silage, in the belief that the stack will seal itself, that losses are minimal, and that the cost and inconvenience of using plastic is not justified. The levels of waste may appear small because the bands of discoloured and mouldy silage are often not very thick (see Figure 9.17). However, these bands are all that remains of what was a much greater thickness of forage that is gradually decaying (see Table 9.7

Figure 9.17

Layers observed near the surface of unsealed silage.



Source: Kaiser (1997)

Table 9.7

Effect of sealing treatment and depth from original surface on DM losses for farm-scale lucerne and maize silage.

Depth from original surface (cm)	Lucerne DM losses (%)		Maize DM losses (%)	
	Covered	Uncovered	Covered	Uncovered
25	7	78	23	80
50	2	23	9	29
75	6	15	12	19

Source: Adapted from Bolsen et al. (1993)

Table 9.8

Cattle production from wilted lucerne silages stored with and without covering.

	Covered	Uncovered
Wilted to 34% DM[1]		
Liveweight gain (kg/day)	0.30	0.12
Feed efficiency (kg liveweight gain /t silage DM)	60	25
OMD% in sheep	60.3	58.2
Wilted to 43% DM[1]		
Liveweight gain (kg/day)	0.39	0.29
Feed efficiency (kg liveweight gain /t silage DM)	69	61
OMD% in sheep	60.1	57.4
Wilted to 44% DM[2]		
Liveweight gain (kg/day)	0.64	0.57
Feed efficiency (kg liveweight gain /t silage DM)	91	84

Sources:
[1] McGuffey and Owens (1979);
[2] Oelberg et al. (1983)

and Figure 9.18). The silage in the discoloured layer has also lost significant quality, even though there is no visible sign of mould.

In a study on 15 dairy farms in Gippsland, Victoria, the losses in DM for unsealed and sealed pits were measured at 15-30 cm and 1 m below the surface of the stack. Losses were greater at both depths for the unsealed silage (see Figure 9.18). Although not determined in this study, other studies have shown that associated with an increased loss of DM is an increased loss in digestibility of the silage deeper in the stack, and therefore animal production (see Table 9.8). Losses, as a proportion of ensiled forage, decline with increasing depth of the silage.

When quality decline and loss of physical DM in poorly stored silages are considered, they not only represent a significant loss of potential animal production, but also an increase in the cost per tonne of silage fed.

Where cattle production was compared on covered and uncovered silage, growth rates were low for the covered silage and lower on the uncovered silage. A similar study using high-quality silages, capable of supporting gains of 0.8-1.0 kg/day, would probably have shown a greater loss of potential animal production.

If the plastic seal on pits or bunkers is damaged aerobic spoilage may be confined to a localised area. The rate at which air can move through a pit will depend on the density of the silage (how well it is compacted) and the pressure applied to maintain contact between the plastic and the silage (number and closeness of tyres). Rain entering the silage through holes will increase losses.

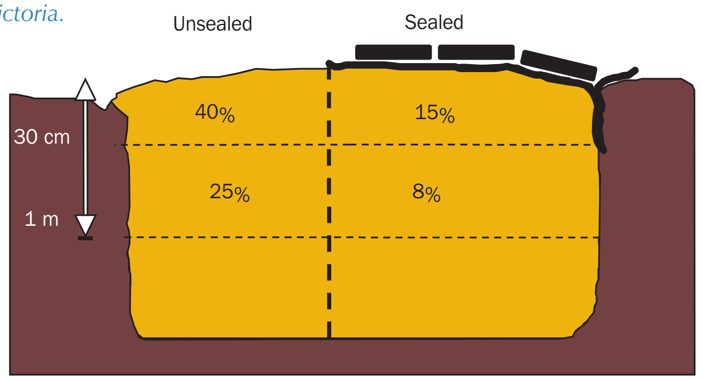
Losses in wrapped bale silage

Insufficient or poor wrapping is one of the major causes of prolonged respiration, aerobic spoilage and the resulting higher DM and quality losses in wrapped bale silage (see Table 9.9). An inadequate number of wraps or poor wrapping technique can allow air to penetrate the bale.

If the plastic seal protecting the silage is damaged at any time between sealing and feedout air will penetrate the silage and aerobic spoilage will begin. In the case of baled silages, there is little to restrict air movement around the bales, whether they are individually wrapped or stored above

Figure 9.18

Losses of DM in pit silage stored either unsealed or sealed in Gippsland, Victoria.



Source: Hadero-Ertiro (1987)

Table 9.9

Effect of bale density and number of layers of plastic film on the quality of baled silage.

		Low density			High density		
Number of layers of plastic		2	4	6	2	4	6
Mould patch (%)*	Bale end	20.4	1.3	4.7	18.5	5.5	2.6
	Bale side	32.1	1.1	2.1	32.3	3.1	2.5
Mould depth (cm)	Bale end	10.0	2.2	3.2	9.4	3.1	2.4
	Bale side	10.0	2.4	3.4	8.9	3.4	4.6
Aerobically rotted bale surface (%)*	Bale end	68	0	1	82	3	0
	Bale side	64	0	0	90	11	0
Aerobically rotted depth on bale (cm)		45	0	2	54	1	0
DM content (%)		36.8	39.6	37.7	36.8	39.0	40.7
pH		5.8	4.7	4.7	5.7	5.0	4.5
DM Digestibility (%)		68.3	70.5	72.9	71.2	73.5	71.8
Ammonia-N(% of total N)		13.6	9.6	9.9	13.4	10.9	8.9

* *% of visible surface area.*

Source: Adapted from O'Kiely et al. (2000)

ground in modules. As a result, the DM losses can be very high and, in some cases, the whole bale or stack of bales will deteriorate.

Plastic colour may also have an impact on silage losses. Bales wrapped in dark plastic become hotter near the surface than bales wrapped in light-coloured plastic. Because heat can reduce forage digestibility, it has been speculated that wrap colour may affect silage digestibility. However, results from an Irish study showed that there was no effect of bale colour on digestibility, amount of visible mould or quality of the fermentation (see Table 9.10).

The results may have been different under Australian conditions where the intensity of sunlight and heat load is greater. Producer experience and research from warmer climates has measured significantly higher temperatures under

Plate 9.10a

Plastic will break down after extended exposure to sunlight.

Photograph: F. Mickan

Plate 9.10b

If the plastic deteriorates badly the whole stack can be lost.

Photograph: K. Kerr

Table 9.10

The effect of film colour on silage composition and mould growth. There was no statistical difference between any of the treatments, i.e. colour had no effect on any aspect of composition or mould growth.

Colour	DM content (%)	DMD* (%)	pH	Crude protein (% DM)	Lactic acid (% DM)	Ammonia-N (% of total N)	Visible mould (% area)
Black	30.4	76.8	4.7	13.9	2.7	8.5	7.7
Clear	31.3	76.3	4.7	13.6	2.7	9.6	8.7
Green	31.0	76.2	4.9	13.8	2.6	9.2	9.3
Light green	31.0	77.3	4.8	13.8	2.8	8.6	5.2
White	30.8	77.2	4.7	13.9	2.8	9.0	9.0

* *DM digestibility.*

Source: Forristal et al. (1999)

black films than the lighter coloured films. There have been reports of temperatures inside bales sealed with black plastic being 10 to 30°C higher to depths of about 0.10 m. Heat-damaged silage can caramelise, resulting in some bonding of the sugars and protein components, reducing their availability to the animals (see Chapter 12, Section 12.4.4).

Plastic deterioration

Plastic deterioration can be in two forms: UV light degradation and heat breakdown. Plastic affected by UV light degradation will usually break down in 3-4 layers at the same time. Heat degredation breaks down one layer at a time, starting from the outside layer.

Although not confirmed by controlled experiments, there is anecdotal evidence that chemicals released from some silages may break down plastics. Anecdotal evidence indicates that sulphur compounds in canola silage may affect stretchwrap plastics.

Reducing storage losses

- Wilt to ensure DM is >30% to avoid effluent losses.
- Wilt quickly to the recommended target DM content (see Chapters 4, 5 and 6) to avoid a poor fermentation.
- Consider using an additive (see Chapter 7) for ‘at risk’ or problem forages (low WSC content, or unable to wilt successfully).
- Compact chopped forage well or bale at high density to minimise the amount of trapped air.
- Seal effectively, as quickly as possible after filling or baling.
- Protect buns, pits and bales from vermin and livestock damage.
- Regularly inspect storage and immediately patch any holes.

9.8.3 Fermentation

Losses during fermentation are usually small – between 2 and 4% (see Chapter 2, Sections 2.2.2 and 2.5.2). With a rapid and efficient fermentation, where WSCs are fermented primarily to lactic acid, the losses of DM are small, and the loss of energy is even less. Where WSC content is low or insufficient, the fermentation will be slower and less efficient, and fermentation losses of DM and energy will be higher (see Table 9.11). The losses will be greater when there is a delay in sealing.

Fermentation losses are affected by a number of factors and will:

- decline with increasing DM content because bacterial activity is restricted;
- lessen when homofermentative LAB dominate the fermentation;
- increase when the fermentation is slow due to low WSC content or high buffering capacity;
- increase if enterobacteria, yeasts or clostridia contribute to the fermentation.

Fermentation losses can sometimes be reduced through the use of additives (see Chapter 7).

Table 9.11

Effect of initial WSC content and delay until sealing on the fermentation quality of forage harvested ryegrass.*

	Experiment 1 (27.3% WSC content)		Experiment 2 (10.8% WSC content)	
Time to sealing (days)	0	3	0	3
pH				
near the surface	4.36	4.41	4.45	5.74
middle of the silage	4.25	4.24	4.42	5.01
Loss of DM (%)	9	22	15	20

* DM basis.

Source: Henderson and McDonald (1975)

Section 9.9

Drought (or long-term) storage

Silage has an important role as a drought reserve and has been successfully stored in underground pits for 20-40 years. Because drought reserves may need to be stored for long periods (>20 years), some additional factors need to be considered to ensure the silage remains well preserved. Take note of the guidelines for sealing in Section 9.4 and consider the following points to ensure the silage will remain preserved for long periods.

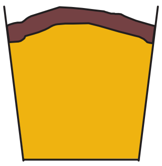
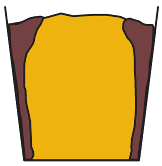
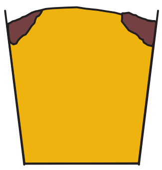
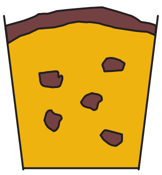
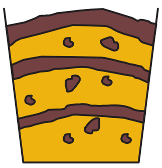
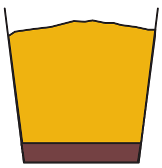
- Good site selection will minimise the risk of water entry.
- Where silage is part of the regular farming practice, the ‘drought’ supply can be part of the normal rotation. Aim to accumulate two years’ supply of silage when excess high-quality forage is available. Such a program ensures that the silage is never more than a couple of years old, and it is less likely to suffer losses due to the storage seal breaking down.
- Conserve a high-quality forage. The conservation costs per tonne of forage ensiled are about the same, regardless of quality. High-quality forage is capable of maintaining animals for longer, and allows flexibility – it may be used for production as well as maintenance (see Chapter 14, Table 14.26). Costs of pit construction per tonne of ensiled energy (ME) are reduced.
- If storage is used infrequently, the overhead costs of pit construction are spread over a lower tonnage and a longer time compared to when the pit is used often and emptied regularly.
- Drought reserves are best stored in hillside or underground pits, sealed with plastic and covered with soil. The soil acts as a protective layer for the plastic – at least 30 cm of soil is required.
- Regularly inspect the storage area for signs of damage, such as burrowing by vermin. The silage will begin to deteriorate as soon as the airtight seal is broken or water seeps into the pit.
- Keep records of when and where silage is stored to avoid ‘losing’ underground pits.

Section 9.10

Appendices

9.A1

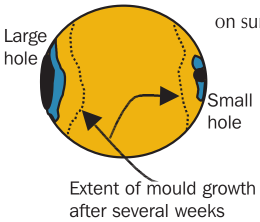
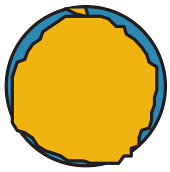
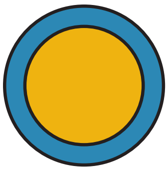
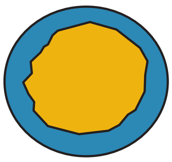
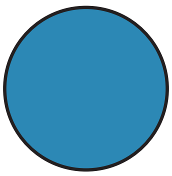
Spoilage losses with forage-harvested silages – likely causes and solutions

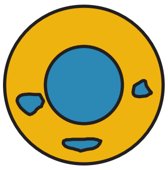
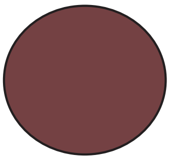
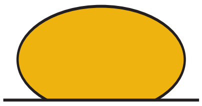
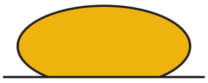
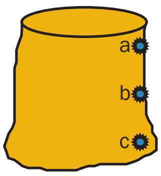
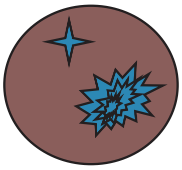
	PROBLEM	LIKELY CAUSE	SOLUTION
1. 	Top waste or crust. Actual losses are much greater than they appear.	Inadequate sealing. Final rolling insufficient and/or final load DM too high.	Adequate rolling/compaction Ensure plastic sheeting is adequately weighted, use plastic sheeting on walls of stack. Ensure seal between wall and plastic.
2. 	Side waste.	Porous walls. Inadequate seal between plastic and wall. Inadequate compaction along edges.	Apply a sealer to concrete walls or use plastic sheeting on walls of stack. Ensure edge compaction is adequate.
3. 	Shoulder waste.	Lack of consolidation, or ineffective sealing of shoulders.	Improve compaction and sealing technique. Plastic sheeting folded over from the side walls will assist. Ensure edge compaction is adequate.
4. 	Top waste and mouldy pockets throughout stack.	Inadequate consolidation of over-wilted or mature material resulting in trapped air.	Improve consolidation, seal immediately and weigh down sheet. Avoid over-wilting. Top stack with loads of moist or direct cut material. To improve compaction – spread loads evenly over area; spread loads to <30 cm depth
5. 	(a) Layers of poor-quality dark brown unpalatable silage. (b) Rotten pockets.	Frequent stops, lack of rolling and covering during extended stops. Forage too wet. Contamination by soil.	Wilt longer. If major delay occurs seal off stack as a separate batch. Avoid soil contamination.
6. 	Butyric and foul-smelling bottom layer.	(a) Crop too wet (b) Poor drainage from stack.	(a) Wilt, avoid excessive rain. (b) Improve drainage from stack.

Source: NSW Agriculture (1997)

9.A2

Spoilage losses with baled silage – likely causes and solutions

	PROBLEM	LIKELY CAUSE	SOLUTION
	Mould growth patches on surface of bale.	Air entering at site of hole.	Patch holes as soon as detected, using proper silage tape.
		Air entering hole over extended period. Much greater surface area affected. Holes not noticed or patched; if patched, incorrect tape used or incorrectly applied.	Inspect bales more frequently and carefully for signs of damage.
	Mould around bale & ~1-5cm depth.	Baler left outside of bale 'fluffy'.	Reduce excessive turning of the bale in chamber before ejecting. Use net wrap instead of twine.
		Plastic starting to break down or seal damage.	Check plastic: is it cracking/splitting off?
		Tackifier not fully effective. Layers not sticking together tightly.	Possibly faulty stretchwrapping – discuss problem with the supplier.
		Wrapper underlapping regularly or conical shaped bales cause underlapping.	Correct overlap on wrapper (50% overlap, 55% stretch). Tight, even-shaped bales, with very slight barrel shape.
	Mould around outside of bale and ~5-20+cm depth, often rotten layer on outside.	Plastic seal damaged.	Check regularly and repair holes.
		Plastic severely breaking down (UV light) or damaged in a number of places.	Ensure plastic has UV stabiliser incorporated.
		Plastic over-stretched when applied.	Check pre-stretcher – 55% stretch only.
		Not enough plastic applied.	Essential to apply 4 layers all over.
	Unpleasant odour, moisture under plastic and in outer 5-20+cm, often slimy, but warm/hot. Common in cereal bales & rank, dry pastures.	Air penetrating bale rapidly.	Bale less mature forage or at lower DM.
		Bale density too low.	Bale more tightly.
	Mould throughout most of bale. Musty odour.	Air entering the bale for extended period. Not properly sealed or seal broken early in storage period.	Avoid baling over-dry or stemmy crops. Ensure adequate bale density. Seal correctly, check regularly for holes.
		Bale stored too long, e.g. >12 months. Plastic starting to break down.	Use within 12 months, or use more layers/ or thicker wrap for longer storage period.

	PROBLEM	LIKELY CAUSE	SOLUTION
	Mould in centre of bale or rotten pockets inside bale	Air in centre of bale.	Loosely baled with early model fixed-chamber baler. Bale spiked in middle when transported.
		Soil or manure picked up at baling.	Avoid contamination.
		Dead plant material picked up at baling.	Graze or slash well ahead of harvest period.
	Dark brown coloured silage, possibly with black charring – no mould, pleasant odour.	Too much air in bale at wrapping	Avoid delayed sealing or wrapping, or wrapping too dry.
	Bale slumped, mould throughout	Baled too loosely. Bale density low.	Bale more tightly, regularly adjust bale chamber.
	Bale severely slumped, very unpleasant odour, wet, often water in bottom, no holes	Baled too wet.	Bale at 35-50% DM. Use tedder, etc, to increase drying rate.
		a) Driest part ,more pleasant & palatable. b) Very damp/wet, unpleasant odour, will be eaten. c) Possibly rotten, slimy, very strong unpleasant odour, often not eaten.	
	Plastic breaking down 1 layer at a time, from outside.	Heat degradation due to faulty manufacture.	Rewrap or protect bales from heat with a cover (be aware of rodents under covered area). Feed out before silage deterioration begins.
	Plastic breaking down 3-4 layers at a time	UV breakdown due to lack of UV light inhibitor.	Manufacturing problem. Low UV inhibitor in some imported films.

Chapter 10

Feeding silage

Chapter 10

Feeding silage

In this chapter

The authors

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The Key Issues

- Planning an efficient feeding system must take account of the farm production goals, number and class of livestock to be fed, location of the silage storage and feedout sites, current facilities and equipment, and the potential for investment in improved silage handling equipment.
- An efficient system must minimise losses caused by aerobic spoilage and wastage at feedout. Feedout losses have a major effect on the success and profitability of silage in a farming system.
- Management of the silage face will have a major impact on aerobic spoilage. Aerobic spoilage can be reduced or eliminated by:
  - removing a minimum of 15-30 cm of silage per day; and
  - minimising disturbance of the silage face, to reduce air penetration.
- Wastage at feedout can range from a negligible amount to >50%. Wastage can be minimised by:
  - using barriers to prevent animals from trampling, camping, defecating or urinating on the silage.
  - feeding regularly and only in quantities that the animals can consume within a short period.
- Feedout management aimed at reducing wastage could be the most important factor affecting silage profitability.
- Accessibility of the silage to livestock may influence intake, and therefore animal production. This may only be important in production feeding situations.

Section 10.0

Introduction

The silage-feeding process is made up of three interlinked operations:

1. Removal of silage from the pit, bunker or stack.
2. Transport of silage to the feeding site.
3. Feeding silage to the animals.

Each activity uses considerable capital and labour resources so it is important that it is done efficiently, minimising feedout losses and with a focus on the feeding cost per tonne of DM fed.

The anaerobic storage stage ends when the sealed silage is opened to begin feeding. Silage is a perishable product and aerobic spoilage begins as soon as it is exposed to air. The first sign of spoilage is heating of the silage.

The rate of spoilage depends on a range of factors, including the speed at which the silage is removed from the silage face, the equipment used to remove silage and operator technique (see Chapter 2, Sections 2.2.3 and 2.5.3). Aerobic spoilage and wastage, during removal from storage and at the feeding site, are the factors determining feedout losses.

Another important issue is the accessibility of the silage to the animals. This may be important in production feeding situations and is likely to be influenced by the type of feedout system used.

Safety first

Silage feedout involves the use of a range of machinery including tractors, shear grabs, mixer wagons and front-end loaders.

Make sure you obtain, read and fully understand any information provided by the manufacturer on the safe operation of the machinery.

There have been a number of serious accidents and fatalities in Australia when people have been feeding out silage and other feeds. Examples of the potential areas of risk with silage feedout systems are:

- Stability of baled silage. Stacks of bales have been known to collapse. Bales have fallen off the trucks and front-end loaders on which they are being transported.
- Mixer wagons pose a particular hazard. Caution is essential when working close to the augers used to mix the silage with other feed ingredients, and to deliver the silage to the animal.
- Tower silos are sealed spaces that can contain trapped gases. Care must be taken when entering these structures.

Seek advice from Workcover, or the relevant State authority, to ensure all feedout equipment and practices are safe and meet recommended guidelines, and that all necessary regulations are complied with.

Section 10.1

Planning a feeding system

As discussed in Chapter 1, long-term management goals and the role for silage on the farm must be clearly defined when planning a silage-feeding system.

It is essential to identify the number of animals that are to be fed, the likely period of feeding and the quantities of silage that need to be handled.

Deciding the type of feedout system is usually, but not always, the first step in the silage planning process. The harvesting and storage systems are then designed around it.

The design of the feedout system is dependent on the scale of silage feeding and the form of the silage. Where large quantities of silage are fed, efficient, high-throughput systems are essential. Small quantities, often fed as a supplement, only require basic facilities.

There are many feeding systems (see Section 10.3) that are often 'customised' to suit the circumstances on individual farms. Common criteria that can be used to assess a system at the individual farm level are:

- cost ($/t DM fed);
- feedout losses; and
- labour use efficiency (labour units/t DM fed).

Feeding costs for the same (or similar) system can vary considerably from farm to farm (see Chapter 11, Section 11.2.8).

Factors influencing the choice of a feeding system

- Cost is the most important consideration. Producers should assess the cost of their current system and investigate options for reducing costs (see Chapter 11). This will provide a firm basis for decisions on investing in new feeding equipment.
- Feedout losses can be due to aerobic spoilage of the silage during feeding and wastage during unloading and during feeding. Losses can vary considerably between feedout systems.
- When costing the various feedout systems, farmers must take into account the difference between the amount of silage fed and the amount actually eaten by the animals.
- The scale of the feeding operation depends on the number of animals to be fed, whether they will be fed large amounts of silage for production feeding purposes or smaller quantities as a supplement, and the time available for feeding. Consider these requirements when determining the need for capital investment.
- Producers may decide to expand the scale of an existing feedout system or change to a new system. Costs can be kept down if existing facilities can be adapted.
- The labour required to feed each tonne of silage DM is an important consideration in many feeding systems, particularly on farms where labour is a limiting resource.
- The most efficient feeding systems are usually those where the feeding site is close to the silage storage.
- Where silage is fed in the paddock, wet weather can result in extensive pugging around the feeding site(s), impair vehicular access, and increase wastage during feedout.
- If access time is at all limited or the silage is difficult for the animal to access, silage intake may suffer. This could be important in a production feeding situation, where high intake is required to sustain high levels of animal production. It will not be as important in maintenance feeding situations, where limited silage is fed.

Section 10.2

Removing silage from storage

Removing silage from storage is the first step in the feedout process. When selecting equipment, producers should not only take into account the cost and efficiency of this operation, but also the impact of management of the silage face on the silage's aerobic stability and wastage. This is particularly important with chopped silage stored in a pit or bunker, but can also be important with baled silage stored in bale stacks.

More specialised equipment is required to remove silage from pits and bunkers while producers feeding out baled silage can often use the same equipment that is used to load the bales into the bale stack at the time of ensiling.

What does it mean?

Aerobic spoilage – the loss of DM and nutrients that occurs during prolonged exposure to air, not only during feedout, but also during storage if the silage is sealed inadequately or the seal is damaged. Heating is the first sign of aerobic spoilage.

Aerobic stability – term given for the time taken for the silage to begin heating on exposure to air.

The stability of the silage after opening will be influenced by the crop type, DM content, silage density, type of fermentation, quantity of residual spores of spoilage organisms present from the initial aerobic phase (e.g. yeasts and moulds), ambient temperature during feeding, rate of feedout and removal technique.

Feedout rate – the speed at which silage is removed from the feeding face, for example, 15-30 cm/day, or the number of days to remove one layer of bales from a bale stack.

10.2.1

Reducing aerobic spoilage

Aerobic spoilage at feedout begins when silage is opened and exposed to air. Losses can be significant under warm Australian conditions, particularly for silages prone to aerobic spoilage, such as maize, sorghum, whole crop cereal or wilted temperate grass silages.

The first obvious sign of this process is heating at the silage face or in the feed trough. The silage's inherent susceptibility to aerobic spoilage, and how quickly it develops, is influenced by both silage characteristics and the conditions prevailing during feedout. The influence of these factors on aerobic spoilage is discussed in Chapter 2 (Sections 2.2.3 and 2.5.3).

If the silage is unstable, aerobic spoilage can significantly increase feedout losses (DM losses can be as high as 30%), lower nutritive value (lower ME and heat damage to protein) and reduce palatability, resulting in a reduction in intake. There are management steps that can eliminate or reduce an aerobic spoilage problem:

- Good management during silage making – including rapid filling, good compaction and effective sealing for bunker or pit silage (see Chapter 2, Section 2.2.1). In baled silage this includes high bale density and rapid and effective sealing.
- Use a silage additive specifically developed to improve silage stability where aerobic spoilage is a potential problem (see Chapter 7, Section 7.7).
- Ensure good silage management during feedout. The two important principles here are a sufficiently high feedout rate, to avoid heating at the silage face, and minimum disturbance of the feeding face, to minimise air penetration.

Feedout rate

The rate of silage feedout determines the time the silage at and near the feeding face is exposed to air. It also determines the extent of aerobic spoilage losses.

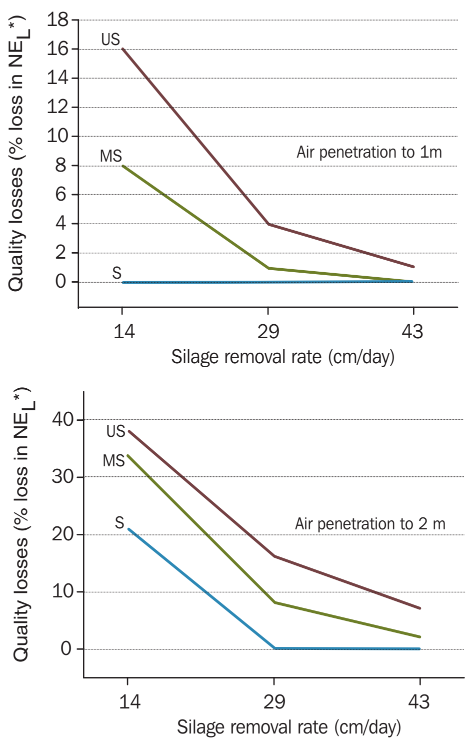
A German study investigated the effects of rate of feedout and silage porosity on the loss of nutrients from silages of varying susceptibility to aerobic spoilage (see Figure 10.1). DM losses and losses in nutritive value (the loss in net energy for lactation, MJ/kg DM in this case) were combined to calculate the total loss in nutrients (%) due to aerobic spoilage. Nutrient losses calculated in this way were 40-70% higher than the DM losses. The silage temperature results for this study are given in Chapter 2 (see Figure 2.10). Both temperature and nutrient losses increased as air penetration increased and when feedout rate was slower.

Where significant heating of the silage occurs, DM and quality losses can be high (see Figures 10.1 and 10.2). In both European and American studies, DM losses of up to 3.5-4.0% per day have been observed. Studies on dairy farms in the United States have confirmed that losses are higher when feedout rate is slow.

With good silage management during filling and removal, a feedout rate of at least 15 cm/day will usually minimise aerobic spoilage losses in bunkers and pits. However, a rate of at least 30 cm/day is recommended with unstable silages, such as maize. This may need to be increased during warmer weather. This higher rate is certainly justified by the results in Figure 10.1.

The surface area of the feeding face required to achieve the target feedout rate can be calculated from the quantity of silage fed per day and the density of silage in the bunker or pit. For baled silage stored in stacks, producer experience indicates that the removal of one layer of bales from

Figure 10.1



Effects of air penetration and rate of silage removal on nutrient losses from silages varying in aerobic stability, under German conditions.

* *NE_L is the net energy available for lactation.*

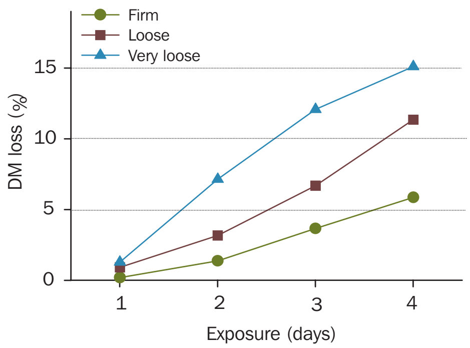
US: Unstable – stable for only 1 day.

MS: Moderate – stable for 3 days.

S: Stable – stable for 7 days.

Source: Honig et al. (1999)

Figure 10.2



Effects of management of the silage face and duration of exposure to air on the DM losses during the feeding of maize silages stored in bunkers.

Source: Roth and Undersander (1995) citing the results of Zublena et al. (1987)

Silage stability and recommended minimum feedout rate for chopped silage.

		Feedout rate (cm/day)
Unstable	Stable for 1 day	>30
Moderately stable	Stable for 3 days	25
Stable	Stable for 5 days	20
Very stable	Stable for >7days	15

Plate 10.1a

Poor management of the silage face. Disturbance of the face and buildup of loose silage at the base of the pit. *Photograph: F. Mickan*

Plate 10.1b

Good management of the silage face. Silage removed cleanly without disturbance. *Photograph: F. Mickan*

the feeding face over two days will usually minimise aerobic spoilage. Calculations that can be used to determine the dimensions of the feeding face are given below.

Disturbance of the silage face

Minimising disturbance of the silage face during feedout will reduce air infiltration into the silage stack and keep aerobic spoilage losses down. The level of disturbance of the silage face is affected by the equipment used to remove the silage and the operator's skill, as well as the type of forage ensiled, its DM content, the chop length and degree of compaction. All these factors affect the handling properties and porosity of the silage.

The results in Figures 10.1 and 10.2 show that aerobic spoilage losses are significantly increased where poor management allows significant air penetration into the silage face. This has been confirmed by on-farm studies in the United States, which have shown that where the silage face was poorly managed and significant loose silage was allowed to accumulate at the floor of the silo, aerobic spoilage and DM losses increased, and silage quality decreased.

Calculating the maximum surface area of the feeding face to minimise aerobic spoilage losses

$$\text{Area of feeding face [width x height, m}^2\text{]} = \frac{\text{Quantity of silage fed per day (kg fresh weight)}}{\text{Silage density (kg/m}^3\text{) x Rate of removal (m/day)}}$$

- ➤ The target rate of removal should be at least 0.15 m/day, rising to at least 0.30 m/day with unstable silages.
- ➤ Silage density is kg fresh silage/m^3. Silage densities can be highly variable, so it is best to use actual densities measured on-farm for the appropriate type of silage. For wilted pasture and maize silages, typical average densities are 575 and 650 kg/m^3, respectively. (Chapter 8, Section 8.3.1, contains an equation to calculate the density of fresh silage.)
- ➤ The calculated result is the maximum area of the silage face that will allow the silage to be fed out at the desired rate. If the area of the feeding face is greater, the feedout rate will be too slow. The appropriate width and height of the silage face can be estimated from the area.

Example: 250 cows are fed 6.5 kg DM/day of a maize silage with a 37% DM content. To minimise aerobic spoilage losses, the desired rate of removal from the whole face is 0.30 m/day. Assumed density is 650 kg fresh silage/m^3.

Silage removed/day (kg fresh weight) = (250 x 6.5) x (100 ÷ 37) = 4,392 kg/day

Required area of feeding face (m^2) = 4,392 ÷ (650 x 0.30) = 22.52 m^2

The area should be no more than 22.52 m^2. If the height of the silage is 2.5 m, the maximum width of the bunker would be: 22.52 m^2 ÷ 2.5m = 9.0 m.

The best implements for removing silage – including shear grabs, block cutters or similar machinery – leave a firm face and minimise wastage. A front-end loader with bucket can remove silage with minimum disturbance of the face if it is operated carefully. Use the edge of the bucket to pull the silage down the face. The silage can then be scooped from the floor and loaded into the feedout wagon or cart. A variation of this procedure is to first remove a section at the base of the face, then pull down sections above it, making it easier to scoop up and load silage from the floor of the silo.

Although it is tempting to drive the bucket into the silage face and lift up to remove the silage, it is not advisable. This action opens fissures in the silage face and allows a large amount of silage to loosen. This, in turn, allows air to penetrate deep into the silage face.

Aerobic spoilage after the silage has been removed from storage

Moderately unstable silage may not heat while it remains in storage during the feedout period, but may heat once removed from storage. This situation often arises where silages are processed before feeding. Processing by machines such as mixer wagons, feedout carts or bale choppers usually results in significant aeration of the silage.

While good management during silo filling and during removal of the silage from storage, and more frequent feeding will help alleviate this problem, unstable silages can still heat in the feed trough or feeder. In these circumstances, silage additives applied at the time of ensiling and designed to inhibit aerobic spoilage can be useful (see Chapter 7, Section 7.7). Additives can also be added at the time of feeding to overcome an aerobic spoilage (as in the study shown in Table 10.1).

Although this strategy was successful in this example, it needs further evaluation. Applying an aerobic deterioration inhibitor at the time of ensiling would be a more practical approach.

Management of plastic cover

When feeding silage from a bunker or pit, or from a stack of baled silage, the plastic top cover should be rolled back just far enough to expose an area that will meet the silage requirements for the next 2-3 days. The rest of the top cover should remain firmly anchored to the top surface of the silage.

Under most circumstances, it is recommended that the top cover should be pulled back over the exposed face after removing each day's silage requirement.

It has been argued that this can create a hot, humid microenvironment between the top cover and the silage face during warm weather, and that this may increase aerobic spoilage in some silages. In these circumstances, it may be better to leave the face exposed, unless a strong wind is blowing directly into the face. There are insufficient research results to resolve this issue.

Resealing will be necessary if feeding is stopped. It is important to trim back the face so that it sufficiently even to maintain good contact between the plastic cover and the silage face. Effective sealing is essential to minimise losses.

Table 10.1

*Effect of a sulphite additive applied at the time of feeding on aerobic stability and milk production from a total mixed ration (TMR).**

	Untreated	Treated
Silage temperature (° C)	22.2	13.0
DM intake (kg/day)	20.4	21.4
Milk production (kg/day)	26.9	28.0
Milk protein content (%)	3.56	3.68
Milk fat content (%)	4.56	4.83

* *TMR (DM basis): maize silage 50%, grass silage 13%, cracked wheat 21%, molasses 5%, concentrates 21%.*

Source: R.H. Phipps (personal communication)

10.2.2

Equipment for removing silage from bunkers or pits

Tractors with hydraulically powered front-end loaders are commonly used to empty pits/bunkers. Attachments vary in complexity from a fork with a set of horizontal tynes that are forced into the heap and raised to tear out the silage, through to loaders with some form of cutting mechanism (e.g. shear grab or block cutter).

Front-end loaders fitted with a fork or bucket tend to leave a disturbed silage face, and require careful operation to minimise air penetration. Table 10.2 gives the results of a comparison of alternative equipment for removing a lucerne/pasture silage (30-150 mm chop length) from a silage pit with face dimensions of 12 m wide by 2.5 m high. This study confirmed that estimated losses were lower with the equipment that cut silage from the face, and left it relatively undisturbed. Further studies, covering a range of silages and weather conditions, are required to more accurately quantify losses for various silage removal methods.

Plate 10.2

A tractor-mounted shear grab, used correctly, will leave the silage face relatively undisturbed.

Photograph: D. Stanley

Tractor-mounted shear grabs and block cutters are efficient implements for removing silage and leave a relatively undisturbed face. Shear grabs are the cheaper option and provide satisfactory work rates, influenced by the grab's capacity and the distance from the stack to the feeding site (see Figure 10.3).

Block cutters can be front- or rear-mounted. They have a set of tynes that are driven into the silage and knives, either reciprocating or on a continuous chain, cut vertically down the surface removing a block of silage.

The weight of the block removed varies from 300 to 1000 kg, depending on the type of machine used. Some block cutters have guards to prevent the silage from spilling in transit, while others have clamps that hold the block firmly to the

Table 10.2

A comparison of alternative tractor-mounted equipment for removing lucerne/pasture silage from a silage pit.

	Bucket	Silage grab	Shear grab	Block cutter (horizontal)	Block cutter (vertical)
Capacity (m^3)	0.4	0.6	0.95	2.5	1.5
Attachment*	F	F	F	T	T
Maximum operational height (m)	4	4	4	3	2.3
Operation time (seconds for each load)	10	10	15	90	90
Face condition	loose & uneven	loose & uneven	uneven	firm & even	firm & even
Estimated losses, aerobic spoilage + wastage (%)	10-20	10-15	0-5	0	0
Temperature 15 cm behind the face after 6 days (°C)**	38	38	17-38	14	14
Approximate price (1994)	$1,200	$2,700	$5,700	$13,000	$11,800

** F = front-end loader; T = three point linkage.*

*** Ambient temperature 14°C.*

Source: Anon (1994)

tynes. Because the blocks are, in effect, an undisturbed part of the stack, air penetration is minimal and the block tends to remain aerobically stable well into feedout.

More sophisticated pit/bunker unloaders, with rotating cutters, are available for operations that handle large quantities of silage. The silage is transferred into a wagon or truck for feedout.

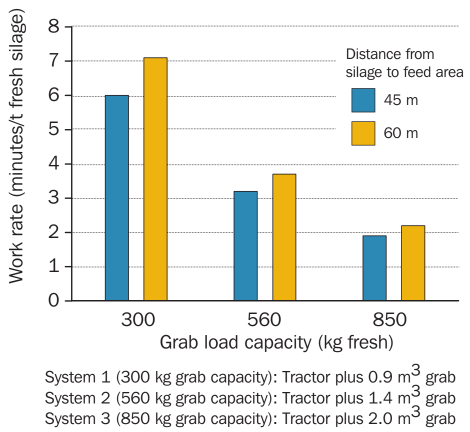
A rotating drum cutter is a common design, which has a rotating drum, about 30 cm in diameter, fitted with small knives (see Plate 10.3). The drum is carried on a boom attached to a tractor. The drum can swing in an arc up and down the face, the silage falls onto a conveyor belt and is delivered into a wagon or truck. This type of unit shaves the silage off the face, leaving it relatively undisturbed. Care must be taken to ensure the unloader is moved sideways regularly so the silage face does not become irregular.

The Australian market for silage-handling equipment is expanding rapidly as the amount of silage produced increases. Producers intending to buy equipment should seek information on the machinery that is available, and the work rates of various machines, from machinery dealers.

Any capital investment in equipment and facilities should be based on sound business principles, i.e. careful consideration of the costs and benefits.

Figure 10.3

Effect of shear grab capacity and distance from the silage to feedout on work rates.



Source: Forristal (2000)

Plate 10.3

Maize silage being removed from a bunker using a rotating drum cutter.

Photograph: N. Griffiths

Section 10.3

Delivering silage to the animal

10.3.1

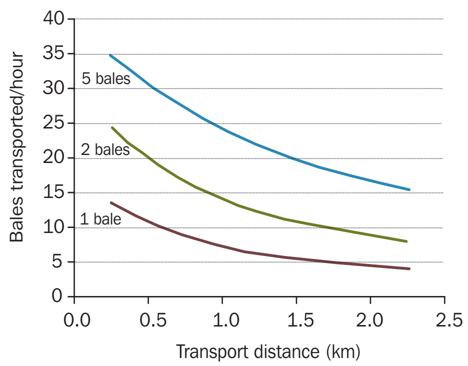
Feedout systems available

Feedout systems can be very basic and low cost, from self-feeding from a pit (with no transport component), feeding whole bales in the paddock, through to expensive integrated systems used on large feedlots or dairy enterprises.

Advantages and disadvantages of the more common feeding options are presented on pages 265 to 267.

Figure 10.4

Difference in number of bales transported per hour either by tractor (1 or 2 bales) or trailer (5 bales) for a range of distances.



Source: Adapted from Forristal (2000)

Transporting the silage to the animals

Baled silage

Baled silage is usually removed from the storage site using forks or a spike mounted on the front of a tractor (front-end loader) or to the three-point linkage. One or two round bales can be carried at any time with these attachments. If there is a reasonable distance between storage and feedout, using a truck or trailer to increase the number of bales carried will substantially improve the work rate. This will save time, particularly when a large number of bales need to be fed, in several paddocks.

The relatively large farm sizes in Australia make efficient delivery systems essential, particularly if silage is being fed to several groups of animals.

An Irish study compared transporting one or two bales with a tractor or five bales on a self-loading trailer to find the number of bales that could be transported in an hour. Figure 10.4 shows the work rate benefit from the increased transport capacity and

Comparing Feeding Systems

Feeding system	Capital investment*	Labour efficiency*	Feeding losses	Accessibility to the animal
Chopped silage in a pit or bunker:				
A1. Self-feeding	Low	High	High	Restricted
A2. Fed on the ground in a paddock	Medium	Medium	High	Easy
A3. Fed on the ground under an electric wire	Medium	Medium	Medium	Easy
A4. Fed in a paddock in a trough, self-feeder or off trailer	Medium	Medium	Low/medium	Easy
A5. Fed in a specialised feeding area (feedlot, feed pad)	High	High	Low	Easy
Baled silage:				
B1. Fed out as a whole bale on the ground in a paddock	Low	Low	High	Restricted
B2. Unrolled or fed as biscuits on the ground in a paddock	Low/medium	Low	High	Easy
B3. Chopped and fed out on the ground in a paddock	Medium	Medium	High	Easy
B4. As for B2 but under an electric wire	Low/medium	Low	Medium	Easy
B5. As for B3 but under an electric wire	Medium	Medium	Medium	Easy
B6. Whole bale fed in the paddock in a self-feeder or off a trailer	Medium	Low	Medium/low	Restricted
B7. Chopped and fed out as for B6	Medium/high	Medium	Low/medium	Easy
B8. Chopped and fed out in a specialised feeding area (feedlot, feed pad)	High	High	Low	Easy
B9. Whole bale fed out on a feed pad	High	Medium	Low/medium	Restricted

* *Within a system, differences in the equipment used, the numbers of animals fed and the distance travelled will influence the ratings for capital investment and labour efficiency (labour units/t DM fed).*

For more detailed information on various feeding options, *see pages 13-15.*

the penalties associated with increasing transporting distance. While trucks and trailers can be used to efficiently transport bales, they have the disadvantage that separate equipment is needed to feed out the bales once they are delivered to the feed site.

There is equipment available that is specifically designed to chop round and square bales at the time of feedout. The chopped silage is then delivered into a windrow, trough, pad or bale feeder.

The advantage of this system is the reduced particle length and increased accessibility (feeding space). Chopping aims to increase animal production by increasing intake. However, because the chop length is still relatively long (similar to that produced by a forage wagon) any advantage is likely to be greater for cattle than for sheep. Any improvement in sheep production will probably be due to increased accessibility. The effect of chop length on sheep intake and production is discussed in Chapter 15, Section 15.2.5.

Anecdotal evidence from studies at Cowra, NSW, suggests that baled silage, chopped just before feeding may be less aerobically stable than unchopped bales or fine chop silage produced from the same material. The most likely reason is the increased rate of aerobic spoilage caused by vigorous aeration of the silage during chopping. More details on factors affecting aerobic stability are covered in Chapter 2, Section 2.2.3, and Section 10.2.1.

Chopped silage

Silage removed with a shear grab or block cutter holds together as a block and it can either be fed out whole, similar to a large square bale, or fed out through a mixer wagon or forage wagon.

Forage wagons or feed carts are used for feeding out chopped silage. They have moving floors and convey the forage to one end where the silage can then be fed out in a windrow or into a trough through a side delivery chute. They are not designed for feeding mixed rations.

Feed mixer wagons are used when mixed forage-based diets are fed. There are essentially two designs:

- horizontal mixer wagons – these are usually V-shaped and have three or four augers running the length of the body in banks of one or two, and
- vertical mixer wagons – usually conical shaped with a single auger.

Plate 10.4

Forage wagon used for feedout. Photograph: K. Kerr

Plate 10.5

Mixer wagon being loaded by a front-end loader. Photograph: M. Martin

Mixer wagons vary in capacity and handle chopped silage from pits, bunkers and tower silos. They can be mounted on either a tractor-drawn trailer or a truck. Some models contain a series of blades along one or more of the augers that are capable of chopping baled silage and hay. The augers mix the roughage with the other feed ingredients, usually concentrates. Mixer wagons can be fitted with load cells so that the correct quantity of different feeds can be monitored. The silage or mixed ration is then delivered into a trough or windrow.

In highly mechanised and intensive feeding systems, the transport of silage from the storage to troughs or feedbunks can be fully mechanised. A series of augers transport the silage or mixed ration, unloading at the appropriate location. These systems combine well with tower silos where the silage is mechanically removed from the bottom of the silo.

Plate 10.6

Internal auger system of a mixer wagon. *Photograph: M. Martin*

Feeding options

There are a number of ways that baled and chopped silage can be presented to the animals. In many cases, the feeding option is only limited by the imagination of the producer and available material. The advantages, disadvantages and management strategies for a range of feeding options are given on the following pages.

Self-feeding from the silage face

Plate 10.7

Cows feeding from the silage face, with electric wire limiting access.

Photograph: F. Mickan

Suitable for chopped pit and bunker silage. Not recommended for baled silage because wastage is high.

Requires a barrier or electric wire to keep animals off the silage.

Pros

- No machinery or labour required to remove the silage from the pit or bunker and deliver it to the animals.
- Low capital cost to construct barrier.

Cons

- Number of animals that can feed is limited by face width.
- Wastage can be high in wet weather, unless the floor is made of concrete and well sloped.
- Floor needs to be scraped clean regularly to remove faeces and waste silage.
- Barrier needs to be moved regularly to ensure continuous access.
- Depth (height) of the silage face needs to be restricted to suit animal type.
- It can be difficult for stock to extract long silage particles, particularly if it is very well compacted.

Management tips

- Most suitable when the chop length is uniform and about 50 mm or less.
- Silage should not be more than 1.5 times the height of the animal so the silage is not eaten out underneath, collapsing onto animals and the barrier.
  The major risk is that collapsing silage can kill smaller livestock, in particular sheep. Face depth should be no more than about 2 m high for mature cattle, 1.5 m for weaner cattle and 1.2 m for grown sheep. With deeper bunkers, the silage can be cut out and thrown to the stock but this is very labour intensive.
- If the silage is very densely compacted the animals will have difficulty removing the silage. The silage will be more tightly packed at the bottom of the face.
- Fences need to be secure to ensure that animals cannot get on top of the pit and damage the plastic.
- Regularly clean the floor of the bunker at the silage face to minimise ‘bogging’ and wastage.

Self-feeding from flat-top trailer

Plate 10.8

Cows feeding from flat-top trailers.

Photograph: A. Kaiser

Can be used for chopped and baled silage. Trailer design will vary with silage type and the class of livestock to be fed.

Pros

- Trailers are relatively inexpensive to construct and maintain.
- Able to transport silage in bulk for several groups of animals, simply hook up the trailers and drop them off into the appropriate paddocks.
- Can move feedout point regularly to reduce damage to surrounding pasture/soil.
- Can be used for pit or baled silage.

Cons

- Tall or wide trailers are unsuitable for smaller stock, such as sheep.

Management tips

- Trailer size needs to vary to reflect animal sizes.
- Accessibility will depend on the number of trailers.
- Monitor silage wastage, ensuring animals do not drag much from the trailer. It may be necessary to install feeding barriers to minimise wastage.

Windrow on ground in paddock

Plate 10.9

Square baled silage being chopped and trailed out in a windrow.

Photograph: J. Piltz

Suitable for fine chop and chopped bale silage, round bale silage that has been unrolled, or square bale silage fed in biscuits.

Pros

- Requires no expenditure on feed troughs or pads.
- Feeding sites are well-distributed – little damage to pastures/soil.
- Good accessibility.

Cons

- Will need specialised equipment to make a silage windrow.
- Wastage can be very high if animals trample, camp, urinate and defecate on the silage.
- Uneaten silage will be contaminated by soil, particularly in wet weather.

Management tips

- Running a single or double electric wire along the top of the windrow can reduce wastage due to trampling and fouling.
- Avoid overfeeding to reduce wastage. It is better to feed less silage more frequently.

Bale silage fed whole in the paddock

Plate 10.10

Baled silage fed whole in the paddock – low cost, high wastage.

Photograph: K. Kerr

Suitable for round and large square bales.

Pros

- Little capital cost.
- Feedout location can be varied to reduce pugging and damage to surrounding pasture.

Cons

- Wastage is high due to camping, trampling and fouling by animals. Under most circumstances this method of feeding will result in the greatest amount of wastage.
- Competition for access may limit intake.

Management tips

- Avoid overfeeding to reduce wastage. It is better to feed less silage more frequently. This is sometimes a compromise between providing enough bales to allow reasonable access for a number of animals – may need to provide 2-3 days silage at a time to ensure intake is not limited. Silage may then become unstable (heat) over time, increasing wastage and reducing intake.

Bale silage fed whole in a feeder

Plate 10.11

A bale feeder will reduce the amount of wastage caused by trampling and fouling.

Photograph: R. Inglis

Suitable for round and large square bales, and chopped silage.

Pros

- Very small capital cost.
- Eliminate wastage due to trampling and fouling by animals.
- Feedout location can be varied to reduce pugging and damage to surrounding pasture.

Cons

- Competition for access may limit intake.

Management tips

- Will require different feeders for different classes of livestock – sheep are unable to use some feeders designed for cattle, and weaner cattle may not be able to reach the centre of the bale. With sheep a circle of mesh may be a better option – as the bale is eaten, the sheep can push the circle of mesh around to get at the remaining silage.

Feed trough

Plate 10.12

Feed troughs should be deep enough to avoid spillage. *Photograph: J. Piltz*

Appropriate for fine chop or chopped bale silage. Can vary from inexpensive homemade troughs to permanent concrete feed bunks.

Pros

- Reduces wastage during feedout because – the silage is kept off the ground, preventing contamination by dust and mud, and – animals are not able to trample, urinate or defecate on the silage unless they stand or jump in the trough.
- Suitable for a range of feeds – silage and mixed rations (including dry rations).
- Portable units can be moved to reduce paddock damage.

Cons

- Any aerobically spoiled or uneaten silage must be cleaned out to prevent contamination of fresh silage.
- May need expensive equipment to deliver silage to the trough.

Management tips

- Avoid overfeeding to reduce the need to clean out troughs.
- A bar or cable over the top of the trough will prevent animals from standing in the silage.
- Permanent troughs are more common on dairy farms, feedlots and some beef properties. They should be located near the silage storage site to reduce transport time and must be easily accessed by machinery for feeding and cleaning surrounding area.

Feed pads

Plate 10.13

Feed pads are permanent feeding stations commonly used on dairy farms. *Photograph: M. Martin*

Permanent feeding stations, usually associated with dairy farms and beef feedlots. Feed pads can vary enormously in cost of construction, depending on size, roofing, etc. May be used for feeding for a limited time (e.g. after milking) or allow access throughout the day.

Pros

- Reduces wastage during feedout because
  – the silage is kept off the ground, preventing contamination by dust and mud, and
  – animals are not able to trample, urinate or defecate on the silage.
- Suitable for a range of feeds – silage and mixed rations.
- Allows cattle to be fed in a relatively clean environment, irrespective of weather conditions.

Cons

- Any aerobically spoiled or uneaten silage needs to be cleaned out to prevent contamination of fresh silage.
- Expensive to construct.
- Requires expensive equipment to deliver silage to the pads.

Management tips

- Avoid overfeeding to reduce the need to clean pads.
- A physical barrier, usually an iron bar or cable, is used to keep cattle from getting into the feed.
- Feed pads should be centrally located, e.g. next to the dairy and the silage storage site, to reduce feeding time.
- Should be designed to allow for easy machinery access at feeding and for cleaning surrounding area.

10.3.2

Accessibility

Accessibility refers to how easily the silage can be reached or approached (available feeding space) as well as how easily it can be removed and eaten (depends on the physical form of the feed).

In most Australian systems, silage will be fed either as a supplement to pasture or as part of a ration in a full feeding situation, such as a feedlot. It may be fed separately or mixed with other feeds such as grain.

Animal production is usually highest when DM intake (consumption) is not limited by the amount of feed provided or by the animal's ability to access that feed. Depending on the production system, most producers will want to maximise an animal's silage intake over a day or achieve a target intake within a set period. The two major factors that can restrict silage intake are:

- the ability of the animal to physically access the feed; and
- the physical form of the feed.

Factors affecting animals' space requirements at the silage

Animal factors that affect space requirements at the silage are:

- Type of animal.
- Pregnancy or lactation status.
- Age and size.
- Dominance ranking or hierarchy within the herd.

Management factors that affect space requirements are:

- Amount of time that the animals have to access the silage. Restricting time will effectively reduce the space available for each animal.
- Quantity of silage available – fed *ad lib* or as supplement.
- When fed as a supplement, usually to grazed pasture, the quantity and quality of other feed available will influence an animal's requirement for silage.
- Accessibility – baled or loose; long or short chop.

There is little information available on how various feedout systems and the physical form of the silage affect accessibility. In a number of cases the information is for hay, but the principles should be similar even if the expected level of production is different. Species (sheep versus cattle), age, stage of lactation and quality of the silage are also likely to affect accessibility.

Physical access to the silage

Physical access refers to the space available for the animals to position themselves to consume the feed offered (in this case silage or diets containing silage). In the simplest terms, the greatest access is when an animal can stand and feed from a trough, windrow or bale, *when they want to and without any disruption*. This depends on available space per animal.

Space available for each animal is calculated by dividing the length of windrow or feed trough, or the circumference of a bale, by the number of animals (see Example 1 on the next page). If there is a barrier, which is divided into sections, between the silage and the animal, the number of sections and the size of the animal will determine how many animals can feed at any one time (see Example 2).

Ad lib feeding is when animals have continuous access to silage throughout the day. The number of animals eating at any one time under *ad lib* feeding systems is usually 20-40%. The animals rest and ruminate for the remainder of the day.

Using horizontal barriers with sheep can reduce backjumping and aggressive behaviour compared to vertical divisions (tombstone barrier type). The horizontal barriers allow the sheep to move sideways to accommodate other animals.

Guidelines for feeding space needed for animals to access silage from a pit or feed trough

Dairy cows

- *Ad lib* feeding – 24 hr access – 15-23 cm per cow.
- Limited access (controlled feeding) – 30-45 cm per cow when access is restricted to a period after milking. Can increase to 80 cm per cow if all animals are to be fed at once.

Beef cattle

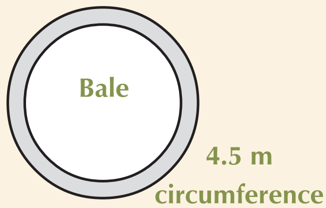
- *Ad lib* feeding – 24 hour access – 15 cm for young stock, increasing to 20 cm for mature cattle. May need to be increased where silage or a mixed silage diet forms more than 75% of the ration. The space allocation may need to be increased, even doubled, for these animals when being introduced to this type of feeding regime.
- Limited access (controlled feeding) – 25-40 cm for young animals, increasing to 30-50 cm for mature stock.

Sheep

- 9 to 11 cm per mature sheep for *ad lib* feeding.
- Increase to 15 cm for lambs or pregnant ewes.

Note: There are so many variables that affect accessibility, it is impossible to make blanket recommendations.

Example 1: Calculating available space per animal



Assuming 25 steers have access to the silage:

Trough or windrow (feeding from 1 side)

6 m row ÷ 25 steers ≈ 0.25 m per steer (25 cm per steer)

Trough or windrow (feeding from 2 sides)

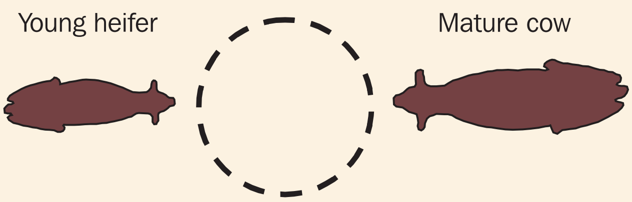
6 m row x 2 ÷ 25 steers ≈ 0.5 m per steer (50 cm per steer)

Round bale (access all around bale)

4.5 m circumference ÷ 25 steers = 0.18 m per steer (18 cm per steer)

Note: The total number of feeding positions that are available on a round bale ring feeder will determine the available access space.

Example 2: Calculating the number of animals that can consume silage at the same time, when the barrier is divided into sections.



Round bale ring feeder with spaces for 14 animals.

Young heifer: Room for one heifer per feeding spot – can fit 14 heifers at one time

Mature cow: Only room for one cow every two places – can fit only 5 to 6 cows

Where cattle are allowed to self-feed from the silage face, an electric wire can be used to prevent animals trampling the silage. They are not as cumbersome to move as solid barriers. However, in order to maintain high intakes, animals must be able to reach the silage without making contact with the wire. This may mean moving the wire more than once daily, which may not be practical.

A barrier must also take account of access by horned sheep or cattle, and the risk of animals being trapped.

Four studies of dairy heifers in the UK showed that restricting access to maize silage directly reduced intake (see Figure 10.5). In these experiments, heifers self-fed from the silage face with either a tombstone barrier or electric wire used to control wastage.

The different restrictions in access were achieved by either limiting the time the heifers were allowed to feed or limiting available space for each animal. (Limiting space effectively limits time available for each animal to feed.) Behavioural interactions between the heifers were observed in two of the studies.

The following observations were made:

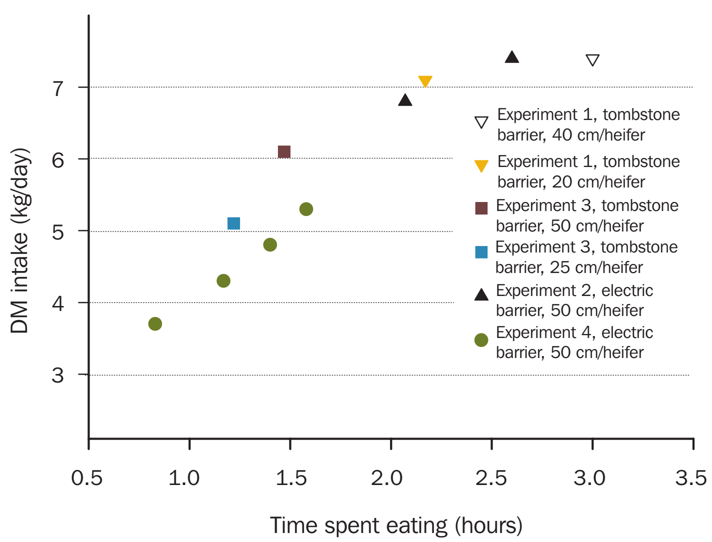
- Reducing access time reduced the amount of time individual heifers spent eating.
- Reducing time spent eating reduced DM intake.
- Heifers increased the rate at which they ate when access to the silage was reduced. Therefore the drop in DM intake was not proportional to the reduction in time spent eating.
- Dominant (top-ranked) heifers ate 11% more silage than bottom-ranked heifers, even though bottom-ranked heifers spent more time at the silage face.
- Bottom-ranked heifers had less visits to the silage, but these were longer, and they consumed silage more slowly.

Physical form of the feed

Physical form refers to the way the silage is delivered (loose or in a bale) as well as the length of the silage (long versus short chopped). The potential impact of chop length on animal production is covered in Chapters 13, 14 and 15. The various physical forms in which silage is delivered to animals are shown in Figure 10.6.

Figure 10.5

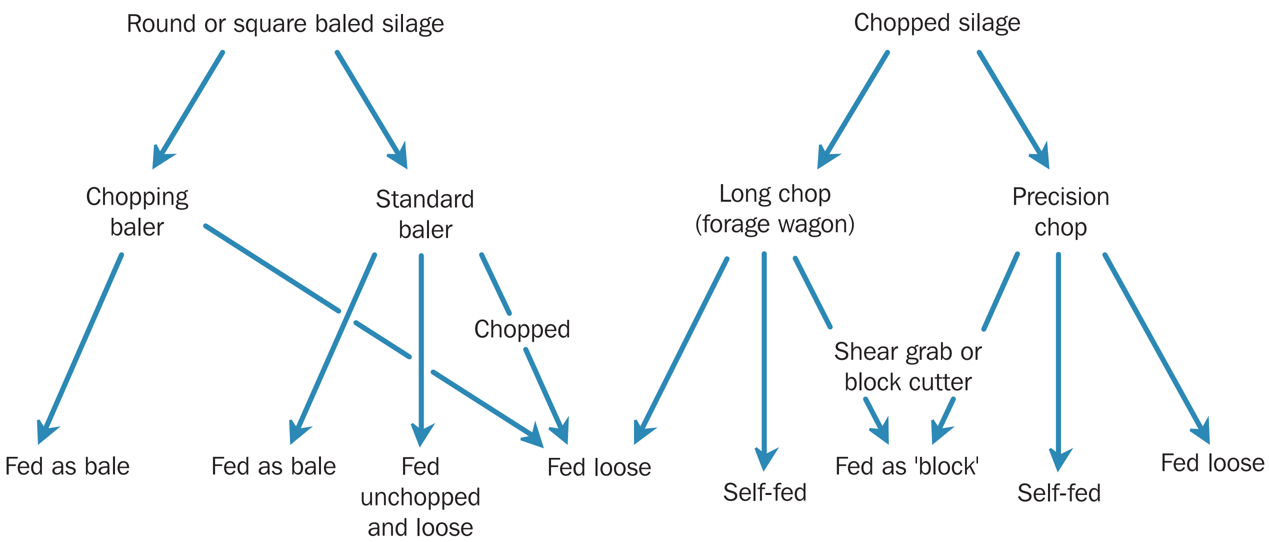
Effect of time spent eating on DM intake of maize silage by heifers self-feeding from the silage face, using either tombstone barriers or electric wire. Heifers also received 0.9 kg of a 18% crude protein supplement.



Source: Adapted from Leaver and Yarrow (1977); Dominance effects reported in Leaver and Yarrow (1980)

Figure 10.6

Various forms in which silage may be presented to animals.



The relative intakes and potential animal production of the various systems, for silage produced in Australia, is not known.

The two extreme forms, in terms of ease of access, are likely to be:

- baled silage made without chopping; and
- fine chop silage fed in a trough.

Long chopped forage and chopped bales are essentially the same physical form and likely to support the same level of animal production. Intake of the silage made with a chopping baler may be higher than the unchopped bale because animals are able to remove the material from the bale more easily.

In a study of dairy cows and heifers in Queensland, soybean silage was fed in a round bale ring feeder either as whole bales or after chopping to 15 cm using a bale chopper. As Table 10.3 shows, the cows receiving the chopped silage consumed more, although the difference was not statistically significant. Several overseas studies have shown improved intakes when silage is available in an 'easy-feed' system. An easy-feed system is one where the silage is in the loose form.

Table 10.3

Effect of chopping baled soybean silage before feeding on the intake of silage by dairy cows.

Treatment	Silage DM content (%)	Stem length (cm)	Proportion rejected (%)	Silage intake (kg DM/day)
Unchopped	47	56	20	9.6
Chopped	52	14	14	12.5

Source: Ehrlich and Casey (1998)

Table 10.4

Intake and change in body condition score of pregnant mature ewes and hoggets fed baled or double-chop silage.

Source: Grennan (2000)

	Baled silage		Double chop silage	
	DM intake (g/day)	Condition score change	DM intake (g/day)	Condition score change
Mature ewes	1,051	-0.22	904	-0.45
Hoggets	882	-0.06	684	-0.42

It is possible that even when good-quality, baled silage is fed *ad lib*, in self-feeders, growth rates may be disappointing due to low intake as a result of:

- competition for space; and
- animals having to work harder, compared to loose silage, to remove the silage from the bale.

The impact of competition for space is likely to be greater for bale feeding compared to loose silage because animals are less able to adjust feeding time or eating rate. Research is required to clarify this.

In a number of overseas studies, the production from sheep fed long chopped silage has been inferior to that of sheep fed short chopped silage. In these studies, the silages were fed loosely, in feed troughs, and intake of the shorter chopped silage was higher. As a result, the general recommendation has been to provide short material to sheep (and young cattle) to improve intake and production.

In studies at Cowra, NSW, the growth rate of lambs fed round bale silage was the same as when fed precision chopped silage, produced from the same forage (see Chapter 15, Section 15.2.5).

The results seen at Cowra need follow-up research to understand why the response was different to the overseas experiences. Some possible explanations include:

- Sheep are able to ‘graze’ bales, in a manner similar to pasture and they are able to reduce the length of the silage as it is bitten off.
- Sheep are able to selectively ‘graze’ the higher quality leaf fraction of baled silage. Selection is more difficult with very finely chopped silage.

This conjecture is supported by a five-year study in Ireland, shown in Table 10.4, where pregnant mature ewes and hoggets were fed either baled or double-chopped silage. Double-chopped silage still has relatively long particles, longer than precision-chopped silage. The baled silage supported higher growth rates and better animal production than the double-chopped silage.

Further research is needed on the impact of access and the form in which silage is delivered to the animal.

10.3.3

Wastage

There is very little information available to quantify feedout losses (wastage) under different practices; most that is available relates to hay. Wastage at feedout can be due to:

- aerobic spoilage;
- wastage due to animals trampling, camping, urinating or defecating on the silage; and
- silage which the animals refuse to eat.

Losses caused by aerobic spoilage are discussed in Section 10.2. Aerobic spoilage during feedout may have begun at the storage site. Silages that have started to heat before feedout will be less stable and need to be fed regularly to avoid wastage due to increasing unpalatability.

Baled silage

Losses are likely to be greatest with baled silage. Bales are usually consumed over two or more days. The longer bales are left uneaten, the greater the losses due to trampling, fouling and aerobic spoilage. The longer fibre in the bales means that more material is dropped and remains uneaten. This is subsequently trampled and spoilt. In wet weather, losses increase when the silage becomes caked in mud and it is more easily trampled into the ground.

In a Western Australian study of weaner steers and heifers grazing dry, low-quality summer pastures, the animals were supplemented with hay, fed either on the ground or in a ring feeder. A visual assessment of the amount of waste hay was 15% for that fed on the ground compared to 5% in a ring feeder. Table 10.5 gives the hay consumption and liveweight responses in this study. The total amount of hay offered was 16% less for the ring feeder, which suggests that the animals with access to hay in a ring feeder actually consumed 6% less hay.

Plate 10.14

Excessive wastage will occur if stock are allowed unrestricted access to whole bales fed in the paddock.

Photograph: K. Kerr

Table 10.5

Effect of supplement type and method of feeding on cattle production.

	Hay (on ground)	Hay ('Waste-not' ring feeder)
Number of animals	34	31
Final liveweight (kg)	283	301
Liveweight gain (kg)	38.5	57.4
Supplement (kg/head)	350	295
Supplement costs ($/head)	35.00	29.50
Costs/gain (¢/kg liveweight gain)	91	51

Source: Tudor et al. (1994)

Table 10.6

Wastage and intake of hay fed to beef cows either in racks or on the ground.

Source: Adapted from Parsons et al. (1978)

	Hay fed in racks	Hay fed on the ground			
Amount of hay offered per cow at each feeding (kg)	–	9	18	36	72
Wastage (%)	4.7	10.9	24.9	31.0	34.3
Relative amount of hay fed (%)	100	112	133	145	152

The hay fed in a feeder produced high liveweight responses. When the increased gain and the lower supplement costs are considered, there was a substantial economic advantage in using the feeder. Losses due to trampling also increased substantially after rain for the hay fed on the ground, but not the hay fed in a feeder.

Plate 10.15

Electric wires will reduce wastage when silage is fed onto the ground in windrows.

Photograph: A. Kaiser

In a study in the United States, round bale hay was fed to beef cows either in hay racks or on the ground. The cows fed on the ground were offered 9, 18, 36 or 72 kg at each feed. Additional hay was provided once the cows had consumed all of the available hay that they would eat. The rejected hay was wasted. As Table 10.6 shows, wastage was less for hay fed in racks. When hay was fed on the ground the level of wastage increased with the amount of hay fed at each time.

Although these studies were not conducted with silage, the message is quite clear and likely to be directly applicable to baled silage systems.

Chopped silage

There have been no studies quantifying the levels of wastage Australian producers are likely to experience when feeding chopped silage. Much of the chopped silage fed overseas is to sheep and cattle that are housed indoors. In these situations, the silage is presented to the animals either in a trough or on a feed pad. The animals are kept separate from the silage to prevent trampling and contamination from faeces and urine. Silage is fed at regular intervals and the amount offered can be accurately controlled to ensure all the silage is consumed before the next feeding. In these systems, wastage should be negligible, and consist mainly of mouldy pieces that animals will not eat.

When silage is fed outdoors, which is usually the case in Australia, wastage would be higher, particularly if fed on the ground and animals are allowed to trample and camp on it. The factors that influence the level of waste are likely to be the same as for baled silage, although the levels of wastage may differ. Management considerations to reduce wastage include:

- Prevent animals trampling and camping, and defecating and urinating on the silage.
- Quantity and regularity of feeding:

  – When silage is fed loose, on the ground and unprotected from trampling and fouling, wastage will be greater if more silage is provided than can be consumed in a short time. Wastage will increase as feeding interval increases, for example, when more than one day's silage ration is provided at a time.

  – If the silage is aerobically unstable, wastage will increase when silage is not provided fresh at regular intervals, due to spoilage and increasing unpalatability.
- Wastage increases in wet weather if silage is fed on the ground and as a result of water-logging if it is fed in undrained troughs.
- If the silage is aerobically unstable spoilage increases with ambient temperature.

The potential wastage during feedout of silage can range from almost negligible amounts for well-managed systems, using troughs or feed pads, through to >50% for silage fed on the ground in poorly managed systems. The results of the New Zealand study in Table 10.7 clearly demonstrated this. When pasture silage was fed in troughs, wastage was 6%, compared to 23% when fed on the ground.

Further research is needed to quantify actual losses for a range of systems under Australian conditions. Improved feedout management to reduce wastage will significantly affect the profitability of silage feeding.

Table 10.7

Effect of feedout system on the wastage (% DM) of pasture silage offered to dairy cows.

Silage fed on the ground (in paddock)	Silage fed in a trough (in a yard)
23.0	6.1

Source: Wallace and Parker (1966)

Chapter 11

Assessing the economics of silage production

Chapter 11

Assessing the economics of silage production

In this chapter

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Key Issues ... see Page 278

The Key Issues

- The cheapest forage is usually grazed in the paddock. Conserved forage is often only valuable when there is a feed gap that cannot be filled by producing pasture or a forage crop.
- To justify conserving forage, it must either be cheaper to make than growing additional forage to graze or buying an alternative feed, or there must be other benefits to outweigh the additional costs. Investment in fodder conservation equipment must also provide a reasonable return on the capital.
- While there are substantial differences in the costs and benefits of the various forage production systems, there can also be large differences in similar operations.
- The whole farm benefits of forage conservation need to be considered. Benefits include:
  - forage conservation can be a good pasture management tool, resulting in improved quality of pasture regrowth;
  - forage reserves can justify higher stocking rates and improve pasture utilisation; and
  - forage conservation can reduce costs such as slashing and weed control.
- The benefits of the regrowth following the making of an early silage crop are generally under-valued.
- Machinery costs, especially overhead costs, can be high and throughput needs to be sufficiently high to justify ownership of expensive equipment. Contractors are usually a cheaper option on smaller holdings.
- All labour, including family labour, should be costed. The labour requirements of some feedout systems are very high, making them uneconomic. Investment in more efficient feedout equipment will often be the most cost-effective forage conservation investment that a farmer can make.
- The economics is greatly influenced by the quality of feed produced. It is usually more profitable to harvest earlier and produce a higher-quality forage than to wait for maximum yield. Costing of forage should be on the basis of what is most limiting. For example, if energy is required it should be costed on an energy (MJ) rather than on a weight basis. If protein is the limiting factor, forage costs should be compared on a per unit of protein basis.
- Minimise losses. Losses in the forage-making process occur at harvest, transport to storage, in storage and during the feedout phase. Total losses can exceed 30% and add considerably to the 'as fed' costs of any forage.
- Contract growing of forage by a neighbour may become more common, especially in areas where transport costs for alternative feeds are high.
- Many of the principles considered in this chapter apply equally to silage and hay production.
- A computer-based decision aid has been developed to help dairy, beef and prime lamb producers compare the economic merits of forage conservation systems. The *Forage Systems Model* compares the present system with the proposed system and calculates the return on capital likely from the additional machinery investment.

Section 11.0

Introduction

A 'whole farm' approach is needed to properly assess the economics of forage production.

The process of forage production affects other things on the farm. For example, one of the benefits may be a higher stocking rate and better pasture utilisation.

After taking into account any indirect consequences – both positive and negative – the economics of forage production could be justified when:

- the cost of the forage is less than alternative feed sources on an energy or protein basis, and
- the net result (income from feeding the forage minus all the costs of producing it) provides a satisfactory return on the additional capital required.

This chapter:

- outlines the potential economic benefits from forage production and the costs involved (see Sections 11.1 and 11.2);
- discusses strategies to reduce costs;
- emphasises the importance of striving for quality (see Section 11.3);
- examines some of the risk issues from an economic perspective; and
- highlights the substantial variations between forage production systems (for an example, see Appendix 11.A2).

There can also be large variations in the benefits and costs when similar production systems are compared. Producers should use their own cost and production figures to realistically assess the impact of a forage production system.

While the focus in this chapter is on silage production, the principles apply equally to hay production.

To help producers with their calculations, a computer-based decision aid has been developed by this author. The use of the *Forage Systems Model* (a costing analysis of forage conservation systems) will assist the dairy, beef and lamb producers or their advisers assess the benefits and costs of forage production. Section 11.5 contains information on how to access a copy of this model.

Plate 11.1

Harvesting surplus pasture can be a cheap source of feed and can be a valuable pasture management tool.

Photograph: F. Mickan

Section 11.1

Benefits of silage production

The likely financial benefits of a forage production system will vary between animal production enterprises and include:

- Increased stocking rates.
- Forage can be transferred from a time or place where it can be grown cheaply to replace more expensive feed when there is a feed shortage.
- It can be the cheapest supplementary feed source to fill feed gaps and balance rations.
- Pasture management benefits may lead to improved pasture utilisation, production and quality, resulting in greater milk or meat production.
- A wider range of enterprise choices may be available, allowing producers to:
  - reach production targets faster;
  - access new markets; and
  - cash-in on periods of premium prices or production bonuses.
- Savings in slashing or weed control costs.

The value of the forage

The forage's value can be estimated by:

1. The cost of the equivalent purchased feed (opportunity-cost method).
2. The net income received from meat or milk produced as a result of feeding that forage (value-added method).

Method 1 should be used where purchased forage can profitably do the same job as conserved forage. Use Method 2 when purchased feed is too expensive and cost outweighs the production advantage or where there is no infrastructure to handle purchased feed.

The main sources of raw material for forage conservation are surplus pasture, crops grown specifically for forage production and off-farm by-products.

Each source can provide cheap feed. However, the forage crop growing costs must be included when calculating the cost of feed. Crop costs are discussed further in Section 11.2.5; Appendix 11.A1 gives an example of maize growing costs.

Section 11.2.6 covers the opportunity cost of lost grazing due to closing a paddock for forage conservation. This cost is usually minimal because the only paddocks that are used for forage conservation are those that are surplus to grazing requirements. The exception may be where large quantities of forage are needed for feeding outside of the growing season: some supplementation can be justified during the forage conservation period to release the required quantity for conservation.

Potential advantages

Increased stocking rates: Once forage has been made and stored, farmers have access to a buffer of feed, which may allow increasing stocking rates. This can improve pasture management, resulting in improvements of both quality and quantity of feed (see Chapter 3).

Increased pasture utilisation: Controlling the pastures in periods of rapid pasture growth can increase pasture utilisation. By maintaining pastures in a vegetative phase as long as possible, greater overall production and improved pasture quality can result (see Chapter 4). Silage or hay making can mean that pasture growth is better controlled and utilisation increased .

Savings in slashing, weed control costs: The timely harvest of surplus growth for silage production can prevent pastures becoming rank and so avoids the expense of slashing or mulching and the additional penalty of slow pasture growth because of slashed material covering the pasture.

Silage making can also prevent weeds setting seed. The ensiling process usually renders weed seeds non-viable and can reduce the bank of weed seeds in the soil (see Chapter 3, Section 3.3).

Section 11.2

Costs of forage conservation

It is important to consider all the costs involved in forage conservation. Besides machinery and labour, there are pasture or crop growing costs, the opportunity cost of lost grazing when paddocks are closed up, harvesting costs, storage costs and feedout costs.

Losses can vary greatly between systems and between farms, so it is important to identify and minimise wastage. This will, in turn, reduce the cost of silage on a fed basis.

Cost calculations are on a fed basis ($/t DM fed) – on the quantity and quality of product that is actually consumed by the animals (see Section 11.2.4).

11.2.1

Machinery costs

Machinery costs incurred in forage conservation can be calculated by substituting your own figures into the examples provided in Appendix 11.A2.

The traditional method is to include the variable costs (e.g. fuel, oil, repairs, tyres) for machinery that is already owned and used outside the forage conservation system.

For specialist machinery, and any purchases required as a result of changes to the forage conservation system, both variable and overhead costs should be included.

It can be argued that if a change in a system causes additional usage for a machine that is also used for other purposes (e.g. tractor), some of the depreciation will be due to the additional usage. The *Forage Systems Model* allows for the option of allocating a portion of the overhead costs for dual purpose machinery towards the forage conservation costs.

Fixed or overhead costs

Fixed costs, or ownership costs, do not vary with usage. You pay these costs every year, regardless of whether you use your machine for 10 hours or 1,000 hours. Owning expensive forage conservation equipment can only be justified if there is adequate throughput to spread the overhead costs. Where possible, the harvest period should be extended by having a range of crops or pastures with a range of maturities.

Insurance, shedding, workshop and registration are among the fixed costs, but the two major costs are depreciation and interest.

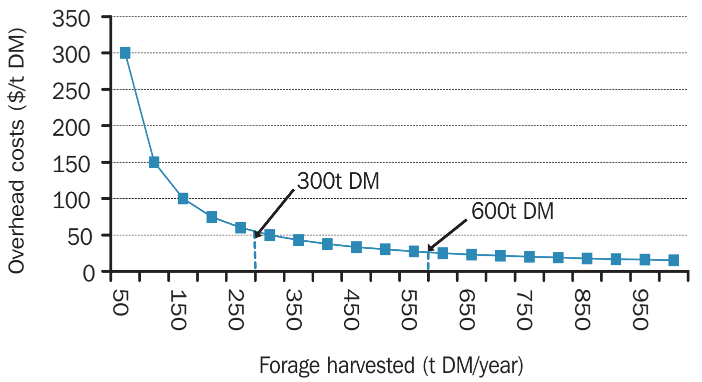
Depreciation

A straight-line depreciation method is the simplest way to estimate machinery depreciation. Take the price of the new machine (ignoring trade-in effects), subtract the estimated trade-in value you expect to get when you think you will sell it and divide by the number of years.

Depreciation cost/year =
(purchase price – trade-in value)
÷ number of years used

Figure 11.1

Effect of usage on overhead costs of forage conservation machinery.



Interest

Interest (or opportunity cost) is the cost of using money. If you had invested your money instead of using it to buy the machine, it would have generated income at the rate earned on the investment. If you need to borrow to buy the machine, the rate will be the borrowing rate.

Interest cost =
average value x interest rate

Average value =
(purchase price + trade-in value) ÷ 2

Where machinery is used in activities other than forage conservation, estimate the proportion of the machinery use for forage conservation to work out the proportion of the overhead costs.

The effect of machinery usage on interest and depreciation costs

Figure 11.1 shows the effects of annual forage production on overhead costs and the costs per tonne of forage conservation for machinery worth $100,000, with a life of 10 years and an interest rate of 10%.

Based on these assumptions, Figure 11.1 clearly shows that more than 300 tonnes of DM a year needs to be made before overhead costs fall to $50/t DM. Doubling the quantity harvested to 600 t of DM halves the overhead costs to $25/t DM.

Although smaller farms may be able to operate with less equipment and the machinery may last for more than 10 years, the shape of the graph is still the same and there will be significant cost reductions on a per tonne basis if the quantity harvested can be increased.

In many regions, there are a number of ways to increase machinery use:

- use pastures and forage crops with varying maturity dates and staggered closure to spread the harvest period;
- use lucerne, maize or other summer species to provide a harvest outside the main spring season;
- contract, especially in other districts where the harvest season is earlier or later than your season;
- harvest a greater area;
- ensure there is sufficient labour available at harvest to operate machinery to full capacity;
- ensure that machines are given a thorough check prior to harvest to minimise the risk of breakdowns;
- hold key spare parts; and
- form a syndicate to share the machinery among a number of farmers.

Where usage is still low, farmers should consider using a contractor (see Section 11.2.3).

Plate 11.2

Machinery such as this can save time but the usage must be high to spread the overhead costs.

Photograph: K. Kerr

Timeliness costs

A timeliness cost is a reduction in returns (or an increase in costs) caused by an operation not being completed within the optimal time.

The quality of forage deteriorates if harvesting is delayed past the optimal time. It can be a large cost to silage production. If there are excessive delays between harvest and sealing, there can be additional losses. These factors are covered in detail in Chapters 2, 6, 8 and 9. The economic consequences of timeliness, in relation to quality losses, are discussed in Section 11.3.

Although timeliness costs are more likely to occur because a contractor could not arrive on time, they can also occur when the farmer's own equipment is used. The machinery capacity may be insufficient, there may be a machine breakdown at a critical time or other priorities may delay forage conservation. Losses due to timeliness will vary depending on the circumstances and are difficult to forecast.

Variable costs

Variable (or operating) costs are those costs that vary in proportion to machinery use.

The main variable costs for tractors and other engine-powered machines include fuel, oil, filters, tyres, tubes, batteries and repairs. For implements and other non-engine operated machinery, variable costs can be repair and maintenance costs plus twine and plastic costs in the case of baled silage.

A rule of thumb is to allow 3% of a new tractor's cost per 1,000 hours of operation for repairs and maintenance and 4% per 1,000 hours for tyres, tubes and batteries. For non-powered machinery, a figure of 5% of new cost per 1,000 hours is suggested. Fuel costs can be calculated from the rated litres per hour by the price of diesel per litre, after rebates. Oils and filters are generally costed at 10-15% of the fuel price.

Machinery work rates

Machinery work rates are important because, along with hourly costs of operating the machine, they determine the machinery variable costs.

Work rates are also important in calculating labour costs (see Section 11.2.2).

Machinery work rates can be determined by the formulae:

$$\text{Work rate (ha/hr)} = \frac{\text{width (m)} \times \text{speed (km/hr)} \times \text{an efficiency factor}}{10}$$

$$\text{Work rate (hr/ha)} = 1 \div \text{workrate (ha/hr)}$$

The efficiency factor is included because the machine is only working for a portion of the time. There are repairs, maintenance and stoppages to consider. Efficiency for most operations is likely to be around 80%.

For example, if a 3 m mower-conditioner operates at 9 km/hr and has an 80% field efficiency, the work rate is:

$$\frac{3\ \text{(m)} \times 9\ \text{(km/hr)} \times 0.8}{10} = 2.16\ \text{ha/hr}$$

$$\text{Work rate per ha} = 1 \div 2.16 = 0.463\ \text{hr/ha}$$

Syndication

Syndication in silage production involves sharing machinery or labour to reduce costs. This allows overhead costs of machinery to be reduced, with a higher throughput and a larger source of labour used to keep the machinery operating. Often only one key machine, such as a baler, is syndicated.

There are a number of important guidelines to running a successful syndicate. The areas to get right include adequate communication between members, fair sharing rules and operating the machine under sound business management principles.

If circumstances change, syndicate members must have sufficient business knowledge and rules to be able to fairly adjust the membership or cease operation so that all members are treated equitably.

11.2.2

Labour costs

Family labour costs should be included in calculations at award wage rates. A higher rate can be justified for the farm manager. It is important to account for family labour as it can always be used productively for other activities, either on or off the farm.

The value of employed labour should be included at the relevant hourly rate, including costs of workers' compensation and any other compulsory costs. Allow 20-25% on top of the wage for these.

Labour costs depend on the type of labour used – casual, permanent or the farmers themselves. Casual labour costs are quoted on a 'per hour' basis.

Although permanent or family labour is often not costed as a variable cost, it should be included. The hourly cost is the value of the labour if it were spent on the most profitable alternative operation or the value you place on your leisure time.

Due to factors such as downtime in machinery maintenance and setting up, the labour required is often 20-30% more than the actual machinery operation time.

11.2.3

Contracting costs

It is often impossible to justify ownership of all of the machinery required for a forage conservation operation. This is especially the case in smaller operations where limited usage results in high overhead cost per bale, per hour or per tonne (see Section 11.2.1).

Table 11.1 gives a range of contractor prices for key operations. These are indicative rates only; costs will be influenced greatly by factors such as the local competition between contractors, prevailing fuel prices, the size of the equipment, the carting distance from paddock to storage site, the size of the job and the proximity to the contractor's base.

The contract prices used in this chapter will date quickly. Local rates should be used, with quotes from several contractors to ensure the quotes are competitive. Some of the major rural newspapers publish sample contract rates on an annual basis. Contact with other farmers who use contracting services is another way to establish the market rate.

Table 11.1

Examples of contract rates for various operations required in the silage-making process.

Operation	Example rates for 2001 (GST inclusive)
Mowing	$39.50/m of width/hr, $47/ha
Mower-conditioning	$43/m of width/hr or $60.85/ha
Raking	$22/m of width/hr or $35.70/ha
Tedding	$17-$22/m of width/hr or $35.70/ha
Baling large squares (hay)	$11-$24.55/bale depending on size (raking extra)
Baling large squares (silage)	$12-$18 depending on size (raking extra)
Round bale (hay)	$8.50-$16 depending on size (raking extra)
Round bale (silage)	$9-$11.30 depending on size and location (raking, net wrap extra)
Wrapping round bales	$6.05 + plastic
Wrapping large square bales	$7.90 + plastic
Self-loading forage wagon	$170-$190/hr
Tractor hire (including driver)	$0.80/hp/hr
Precision chop silage	$6-$10/tonne wet
Truck hire for carting silage (including driver)	$55-$60/hr

Source: Various; including Weekly Times 31 October 2001, p81; NSW Agriculture, Department of Agriculture WA

Plate 11.3

Contractors may be the only economical solution for some operations, especially when the scale of operation is small. *Photograph: N. Griffiths*

When quoted a rate, check whether it includes GST. Get the quote in writing and check that it clearly states the unit price on which it is based. For example, is it per bale, per tonne (wet weight), per hectare or per hour.

Table 11.1 includes example contract rates based on published material, mainly obtained in 2001. Because rates can vary, these rates should only be used as a guide for preliminary budgeting purposes. If preliminary budgeting indicates that contractors may have a place in your system, actual quotes should then be obtained.

Appendix 11.A3 contains a list of contacts for contract rates.

Ownership versus contract

Harvesting is the most common contracting operation. This section discusses the costs of machinery ownership, and the advantages and disadvantages of contractors.

To illustrate the effect of scale of operation on various forage conservation options, the Kondinin Group compared ownership and contractor costs and owner-operator labour costs for making 50 t DM, 250 t DM and 500 t DM of forage (see Table 11.2). Ownership options (darker shaded rows) in the range of case studies were more expensive at low production levels (50 t DM). At 250 t DM, contract round bale hay and contract wrapped silage were more expensive, but similar for the self-loading forage wagon.

This analysis is on the basis of cost per tonne DM, with no reference to silage quality. Forage quality is very important to the economics and delays in silage making can significantly lower silage quality (see Section 11.3).

Advantages of contracting include:

- no capital tied up in harvest machinery and so may be available for, e.g., a more efficient feedout system;
- less labour to organise;
- costs are running costs and therefore are fully tax deductible;
- contractors often have better machinery that can do the job more quickly or increase wilting rates.

Table 11.2

Effect of scale of operation on total costs ($/t DM) of making forage excluding owner operator labour (ownership options shaded).

	50 t DM	250 t DM	500 t DM
Round bale hay	95	30	19
Contract round bale hay	75	39	31
Wrapped silage	175	56	40
Contract wrapped silage	135	100	95
Self-loading forage wagon	142	35	20
Contract self-loading forage wagon	80	33	27
Contract precision chop	84	38	37

Source: Evans (1997b)

- some contractors have a good knowledge of silage-making principles and good machinery-operating skills that may result in a better quality product; and
- the farmer can concentrate on animal, crop and pasture management.

Disadvantages include:

- some contractors often book far more than they can comfortably handle and may be delayed;
- a crop may be harvested either under- or over-wilted;
- the contractor may have inadequate training in silage-making and storage principles;
- new labour often has to be trained at the start of the season;
- breakdowns or bad weather at a number of sites can extend delays;
- costs are likely to increase if access to paddocks and storage sites is restricted, e.g. narrow gateways;
- if not supervised, the contractor may make forage in unsuitable weather conditions; and
- there is a bill to pay.

Organising the contractor

Good planning and communication is essential.

The farmer should:

- Book the contractor early, giving an accurate indication of the area to be harvested. Give an approximate harvest date and ask about other bookings in that period. If bookings appear heavy, consider another contractor.
- Notify the contractor when you intend to start mowing and check when they can arrive.
- Make sure the paddock is clear of obstacles or notify the contractor of their location, e.g. burrows, wombat holes, rocks or tree stumps.
- If harvesting is the only job contracted, ensure the mowing and raking equipment is in good order to minimise the chance of breakdowns that will delay the contractor.
- Ensure the rake is well set up and suited to the job. A common complaint by contractors is 'ropey' windrows that cause blockages, slow throughput and may lead to breakdowns.

Get it in writing

Having a written contract helps safeguard against legal conflict. Considerations for each party to formally agree on include:

- Who pays for what if damage occurs, e.g. machinery hitting obstacles.
- The charging rate and acceptable measures, e.g. $/t DM, $/bale (light or heavy bales), or $/ha (light or heavy crops); the rate may also vary depending on the ease of doing the job, e.g. small versus large paddocks.
- The course of action if rain falls at various stages of the harvest;
- Who supplies the string, stretchwrap or sheet plastic.
- How long rolling of a pit may occur after harvest is completed.
- How long after baling storage and sealing will occur.
- Penalties for lapses in the agreement may be worth including.

There is often conflict between farmers requiring high-quality silage and the contractor who needs high yields to cover his costs, the greatest of which is machinery replacement.

11.2.4

Effect of losses on forage costs

Losses can occur at harvesting, storage and feedout. Depending on the standard of management, the combined losses can easily total more than 20% of the original parent forage. Losses occur in two ways:

- physical losses, when a portion of the original material is lost and is not available for consumption by the animal, i.e. DM losses; and
- losses because of a decline in quality.

If a feed that is cut for forage conservation is 11MJ/kg DM and falls to 10MJ/kg DM at feeding, there is a 9% loss in ME. The cause and likely extent of these losses is discussed in Chapters 2 and 8-10.

Storage losses vary with bunker size due to surface to volume ratio. Studies have shown that storage losses in feed bunkers in the United States dropped by 6-7 percentage units as storage capacity increased.

Table 11.3 provides a record of experimental results of losses that, even under good management conditions, can be significant. Losses under poor management can be much higher. Table 11.4 shows the final cost of the forage taking into account field, storage and feedout losses. Feedout losses have not been included in Tables 11.3, but will be very dependent on the system.

Losses could vary from as little as 1-2% when fed into troughs or onto pads, but are usually much higher when fed into paddocks. Attention to ways of reducing losses (see Chapters 2, 6 and 8-10) is vital to produce an economical feed supplement. When costing alternative feeds ensure that their losses are also accounted for.

Plate 11.4

Losses such as this can dramatically increase the costs of forage conservation.

Photograph: N. Griffiths

Table 11.3

Forage conservation losses (% DM) under conditions of good management.

Source of loss	Low DM silage (DM = 15-20%)	High DM silage (DM = 35-45%)	Hay (DM = 80-85%)
Field	2.8	6.7	18.9
Storage	16.5	6.3	4.2
Total	19.3	13.0	23.1

Source: Various sources -see Chapter 2, Section 2.5. The hay loss data have been derived from the same sources.

Table 11.4

Effect of DM losses on 'as fed cost of forage.'

Cost of making forage including storing & feeding* $/t DM	% losses in making, storing and feeding forage: 10	20	30	40	50
	As fed cost of forage (i.e. after losses) $/t DM				
$50	56	63	71	83	100
$75	83	94	107	125	150
$100	111	125	143	166	200
$125	139	156	179	208	250
$150	167	188	214	250	300

** This cost should also include the cost of the parent forage, as discussed in Section 11.1.*

11.2.5

Forage growing costs

The costs of growing a specialist crop must be included as a cost of the forage conservation system.

These costs include ground preparation, seed, fertiliser, herbicides, insecticides and irrigation. An example set of growing costs for a maize crop is provided in Appendix 11.A1. Farmers should complete their own cost estimates from previous records or seek advice from other farmers or advisers.

If extra costs are incurred when growing a pasture specifically for forage production, such as higher fertiliser inputs, these should be included as a cost of the forage system.

11.2.6

Opportunity costs of pasture set aside for forage conservation

Grazing opportunities may be sacrificed when a special crop is grown for fodder conservation or a paddock of pasture is closed up for several weeks before harvest. Lost grazing can have a cost. If, as a result of closing the paddock up, the cost of feeding the stock increases, or there are losses in the quantity of milk or meat produced, these costs need to be included.

Examples relevant to this scenario occur in dairying enterprises in the south-west of Western Australia, where the growing season is very short and roughage is required as part of the diet for the rest of the year. Where roughage of satisfactory quality can't be economically obtained off-farm, there may be a case to conserve forage, although the grazing animals will then require extra supplementation when paddocks are closed. In these circumstances, it is important to include the cost of the additional supplementation in the calculations.

However, as is often the case during spring, there is surplus pasture and production is not affected if some of the grazing area is withdrawn. Withdrawing an area for forage conservation can have benefits, rather than costs, such as improved production, with greater pasture utilisation or reduced slashing expenses.

11.2.7

Purchased feed costs

Purchased feed is a major cost in many high-production enterprises. Additional forage conservation may be carried out to reduce dependence on purchased feed while maintaining, or even improving, production levels. However, particularly in many dairy and beef finishing systems, the requirement for purchased feed may still be high.

A feed budgeting model is recommended to ensure accurate estimates of purchased feed costs are made and to help identify feed gaps and opportunities to conserve forage (see Chaper 1, Section 1.4.1).

Plate 11.5

Feedout costs can be very high. Highly mechanised systems can be justified if they save a lot of time and usage is high. *Photograph: N. Griffiths*

11.2.8

Feedout costs

Although feedout costs are made up of machinery and labour costs (see Sections 11.2.1 and 11.2.2), they are a very significant cost in most systems and justify special mention. Farmer research by Kondinin Group (see Table 11.6) demonstrated that the cost of feeding out hay and silage in 1997 was on average $34/t DM, with labour making up more than 52% of the total feedout costs.

The most efficient system will depend on the scale of operation. A farm making large quantities of forage can justify spending more on machinery to speed up the delivery. Smaller operations may not be able to justify the capital-intensive, labour-saving devices.

Other factors to be taken into account are the losses likely from each system and if there is more production from using one system compared to another. Work in field testing the *Forage Systems Model* indicated that many farmers spend a considerable amount of time feeding out forage. In a number of cases, systems that significantly reduced this time were justified if the farmer costed their labour at market rates.

Economics of the location of forage storage

The decision on where to locate pits or stacks of forage should take into account the total feedout cost. This is not only the cost of getting harvested forage to the stack, but also the cost of feeding out, which can be high.

The filling operation can often be completed relatively efficiently but feedout is carried out over a much longer period and often with smaller equipment moving small quantities, so any inefficiencies can be costly.

Initially, it may be less costly to fill a pit that is close to the harvest site, but this site may 'cost' a lot more time at feedout. Some case studies testing the *Forage Systems Model* indicated that when machinery costs and labour costs are considered, feedout could be very expensive. Any modifications that could improve the efficiency of this process will result in a cheaper system.

11.2.9

Infrastructure costs

In analysing the use of forage as a means of increasing production, other costs involved with the expansion will have to be considered.

The implications of introducing forage conservation to the whole farm situation needs to be examined. For example, in a dairy situation, if more cows are milked, interest on the capital cost of the additional cows is a legitimate expense to include. Similarly, if extra vat or milking capacity is required, interest and depreciation on this additional equipment should be included.

In a situation where additional forage is to be used as a substitute for purchased feed, there may be no additional infrastructure to consider other than those costs directly spent on forage machinery.

11.2.10

Effect of bale weights and DM content on cost per tonne

Producers paying a contractor on a per bale or wet tonne basis should be converting the costs to a cost per tonne DM basis. To do this, the farmer must know the DM content and have weighed a sample of bales to know the wet weight of the bales.

Table 11.5 demonstrates the effect of DM content on bale costs. On a cost basis, dry bales are cheaper, but if quality is considered (MJ/kg DM) they may not be good value (see Section 11.3.5). There is the added disadvantage of potentially high field and storage losses when forage is ensiled at high DM levels.

Table 11.5

Effect of DM content and bale-making cost on cost/tonne DM ($/t DM).

Bale* cost	DM content of bale (%)		
($/t DM)	35	45	55
20	82	63	52
25	102	79	65
30	122	95	78

* Bale weight = 700 kg wet weight.

11.2.11

Comparing costs of forage systems

There are significant differences between the costs of various forage conservation systems. Costs of any system are influenced significantly by the economies of scale, with costs decreasing as the amount of forage conserved increases. Research by the Kondinin Group (see Table 11.6) compared the costs of forage conservation systems on dairy farms. Costs for each system are averages of the individual conservation systems surveyed from mowing through to feeding out.

Note that besides cost/t DM, other factors need to be included in any final evaluation of systems. As discussed in Section 11.3, the quality of the forage produced is very important, and although the convenience of different systems is very difficult to value, convenience is also important.

From the limited sample, direct chopped crops were the cheapest system to use, costing an average $52.28/t DM, from chopping to feedout.

Forms of precision-chopped silage were less than half the price of other systems, costing an average $66.50 to $76/t DM to mow, chop, cart, roll, store and feedout.

The most expensive system was round bales of individually wrapped silage, costing an average $138/t DM.

The lowest cost for an individual system was $19/t DM for a precision chopped silage system, and the highest cost was $210/t DM for round bales of wrapped silage.

The high average cost of feedout for the self-loading forage wagon systems may be due to the small sample. A larger sample size is needed before conclusions can be made.

High-cost systems are generally associated with low throughput. In these situations contractors should be considered to undertake harvesting.

Table 11.6

Range in costs of forage conservation systems ($/t DM).

System	Low	Average (incl. feedout)	High	Average harvest cost	Average feedout cost
Small square bales of hay	60	92	119	69	23
Round bale hay	23	82	167	48	34
Direct chop silage	19	52	122	22	30
Pick-up precision chopped silage	38	67	121	34	33
Self-loading forage wagon	37	109	173	47	62
Wrapped round bales of silage*	82	138	210	105	33

* *With increased bale dimensions and the option to bulk wrap, bale silage costs have probably reduced since this survey was taken.*

Source: Evans (1997a)

Section 11.3

Quality versus quantity – the effect on economics

11.3.1

Dairy example

The computer program, RUMNUT, was used in Chapter 13, Section 13.2.1, to generate milk production responses when a dairy herd was supplemented with either good-quality silage or lower-quality silage. All other components of the diet were kept constant. Table 11.7 gives a summary of the results. Depending on the stage of lactation, milk production increased by 2.7 to 3.3 kg/day when the higher-quality silage was used as a supplement compared to lower-quality silage.

This example demonstrates that milk production can be increased by moderate improvement in silage quality. If milk is valued at 30¢/L (equivalent to 30.9¢/kg), the value of the additional milk produced from each tonne (DM) of the higher quality silage is about $85.

Work in the UK examined financial performance of 2,000 farms to judge the relationship between margins and silage quality and quantity. Margins per cow and per hectare increased as quality of silage increased (see Table 11.8).

Table 11.8 clearly demonstrates that the farmers who made high-quality silage had the highest margin per hectare. In this study, delaying silage harvest was also associated with reduced silage quality. Chapter 13, Table 13.10, gives details of this work.

While there are dangers in extrapolating data from Britain to Australia, the principles are the same and they clearly demonstrate that it is more profitable to produce quality silage by harvesting early.

Table 11.7

Milk production response in early lactation dairy cows supplemented with silages at two levels of quality. Cows received 30 kg of silage/day (fresh weight).

Lower-quality silage supplement		Good-quality silage supplement		Additional milk production from high-quality silage*
ME (MJ/kg DM)	Crude protein (% DM)	ME (MJ/kg DM)	Crude protein (% DM)	(kg/day)
9.0	14	10.0	17	+2.7

* Dietary and milk production data is provided in Chapter 13, Table 13.6.

Table 11.8

Effect of quality of silage on margin per cow and per hectare based on British data for 1987-88.

Quality of silage (MJ/kg DM)	% of herds	Margin over feed and fertiliser £/cow	($A/cow)	£/ha	($A/ha)
9.0-9.5	2	600	(1,714)	1242	(3,549)
9.5-10.0	17	637	(1,820)	1407	(4,020)
10.0-10.5	54	656	(1,874)	1496	(4,274)
10.5-11.0	25	682	(1,949)	1575	(4,500)
>11.0	2	719	(2,054)	1712	(4,891)

Conversion at £1 = $A2.85

Source: Poole (1989)

11.3.2

Beef example

Table 11.9 shows the effect of harvest delays on silage quality and cattle production. Liveweight gain (kg/ha) and silage quality declined significantly when harvest was delayed.

When liveweight gain was valued at $1.50/kg there was an additional $674/ha worth of beef produced on the early-harvest pasture. Potential net gain could be even higher, given that per hectare costs of silage production are likely to be lower because there is less quantity to harvest. The higher-quality silage that can be produced from the early harvest could also result in higher cattle prices (¢/kg) with potential for a higher proportion of the cattle meeting premium market specifications.

As well as affecting weight gains, feeding the lower-quality, late-cut silage is likely to limit the final market options that a producer may have and reduce the price/kg received for the end product.

11.3.3

Quality and machinery capacity

As discussed in Chapters 4 to 6, the growth stage of the parent forage at harvest and minimising delays during harvest are very important in the production of quality silage. There is likely to be a trade-off when using smaller equipment. Machinery overhead costs will be lower, but because harvest is slower, less optimum quality silage will be made. This is called a timeliness cost.

As a rule of thumb, a one-week delay in harvest decreases quality by 0.25-0.6 MJ/kg DM. This can, in turn, drop dairy cow milk production by up to 1.5 kg/cow/day. Conversely, an increase of one percentage unit in the digestibility of silage can increase milk production in dairy cows by approximately 0.35 kg/day or an additional 45 g/day liveweight gain in beef cattle.

Table 11.9

Effect of time of cut on silage quality and cattle production on perennial ryegrass silage.

	Relative growth stage at harvest		
	Early	Medium	Late
Days from 1st cut	–	9	17
Silage digestibility (DOMD%)	71.3	67.2	64.2
Silage intake (kg DM/day)	7.2	7.0	6.7
Liveweight gain (kg/day)	0.92	0.78	0.6
Feed efficency (kg liveweight gain/t silage DM)	129	112	90
Total forage yield (t DM/ha/year)	12.9	12.8	13.5
Liveweight gain (kg/ha)	1,664	1,434	1,215
Break-even yield for equal liveweight gain/ha	–	14.9	18.5
$ value of gain @ $1.50/kg ($/ha)	$2,496	$2,151	$1,822
Additional value compared to late cut ($/ha)	$674	$329	–

Source: Adapted from Steen (1992)

11.3.4

Quality and contractors

The use of a contractor can also incur timeliness costs. A contractor is likely to be interested in taking on a lot of work to help pay for the equipment and reduce the overhead costs per hour. Weather delays or equipment failure may mean that a contractor will not complete all contracted work at the optimal time. However, the high costs of machinery ownership can make this risk worth taking.

There are ways to reduce risks of delay when using contractors:

- establish a long-term relationship with a contractor so that you are likely to be given some priority;
- if possible, choose a contractor who will place you at the start of their run;
- some local farmers may have machinery and be interested in some contract work to supplement the work they do on their own farms; this can be an advantage, especially if your farm is ready for forage conservation a little earlier than the farm where the machinery is from;
- consider offering some labour and machinery to help a nearby farmer/ contractor finish the work faster on their own farm and then be available for yours; and
- consider carrying out forage conservation on some portion of the farm earlier than normal. For example, an area could be set aside early for baled silage.

11.3.5

Effect of quality on feed costs per unit of energy

There is a temptation to delay harvesting silage to increase forage yield, and so increase throughput and reduce unit costs. But, is it really worth it? Contractors may charge less per tonne or bale if harvesting is delayed to increase the bulk. When the rate is on a wet basis, the drier material will be cheaper on a $/t DM basis. However, a feed can be cheaper on a DM basis, but dearer on an energy basis (see Table 11.10).

Although Feed 1 is considerably dearer than Feed 2 on a DM basis, Feed 1 is cheaper when MJ levels (MJ/t DM) are taken into account. This principle is highlighted in Chapter 14, Table 14.26.

If Feed 1 was a silage made early and Feed 2 made later, Feed 1 is also likely to have a higher protein level. If so, this energy cost comparison does not show the extra savings with Feed 1 by reducing the requirement for protein supplements, nor does it reflect the greater animal production achievable using the higher energy feed.

The effect of ME content (MJ/kg DM) on intake should be noted. At low ME levels, DM intake is reduced and production potential is lessened because animals cannot achieve reasonable DM intakes.

In some situations, fibre or protein may be the limiting factor. For example, in Western Australia grain is often the cheapest source of energy on a ¢/MJ basis but silage still forms part of the diet because it provides the fibre missing from a grain ration. The cheapest protein or fibre source can be calculated in a similar way to that used for energy in Table 11.10.

Table 11.10

Comparing costs of two feeds on a DM basis and a per MJ basis.

	Feed 1	Feed 2
Cost of feed ($/t DM)	$120	$95
MJ/kg DM	11	8.0
MJ/t DM	11,000	8,000
Cost of feed per MJ	1.09¢/MJ	1.19¢/MJ

11.3.6

Effect of time and length of closure

The pasture management benefits of forage conservation are discussed in Chapter 3. However, Table 11.11 clearly demonstrates the economic benefits of making silage early.

Although less silage is made with an early harvest, it is of higher digestibility and there is additional high-quality regrowth compared to a situation where silage is made at a later date. The total DM production from the pasture is also higher.

The milk, beef and sheep production benefits of harvesting at an early growth stage are discussed in Chapter 13, Section 13.2.1; Chapter 14, Section 14.2.1, and Chapter 15, Section 15.2.1, respectively.

However, in areas with a high chance of weather damage or poor wilting conditions early in the silage-making season, the high risk may limit this option.

Plate 11.6

Maize silage offers a large bulk of forage, with high energy but low protein content. Per hectare costs of growing maize are considerable.

Photographer: K. Kerr

Table 11.11

Effect of closure time and harvest time after closure on silage yield and total pasture production. Results from perennial ryegrass/ white clover pasture, Ellinbank, Victoria.

Source: Rogers and Robinson (1981)

Closure length	Silage yield (kg DM/ha)	DM digestibility (%)	Forage yield (kg DM/ha) Yield 23 Sep to closure	Regrowth from cutting to 16 Dec	Total to 16 Dec
Early closure 23 September:					
Silage made 4 wks later	2,435	73.5	0	4,129	6,564
Silage made 6 wks later	3,373	71.6	0	1,949	5,322
Late closure 13 October:					
Silage made 4 wks later	1,625	69.2	1,826	806	4,257
Silage made 6 wks later	2,000	66.1	1,940	400	4,340

Section 11.4

Valuing a silage crop

11.4.1

Valuing maize silage from the maize grower's point of view

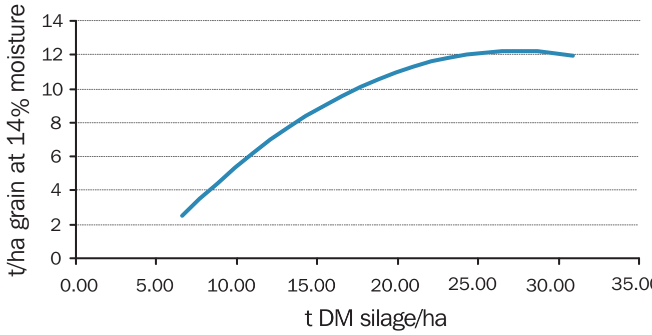
An increasing number of producers are choosing to buy maize silage from a nearby farm in an effort to decrease feed costs and increase feed supply without buying extra land. From the maize grower's point of view, the return from the silage crop should at least equal the return from the grain crop, or an alternative use of the land, after taking into account differences in harvesting and other costs of the two options. The example at right uses the following rules of thumb:

- The relationship between grain yield and silage yield has been taken from US information (see Figure 11.2). For maize crops, final grain yield at 14% moisture is approximately 55% of the DM yield of silage.
- The positives in making silage – having a clean paddock, getting the money early and having a paddock available earlier for another enterprise – is balanced out by the negative of losing most of the organic matter from the paddock.

The break-even price is the minimum price required for silage to match the returns expected from taking the maize crop through to grain harvest.

Figure 11.2

Relation between maize forage yield and grain yield.



Source: Adapted from Lauer (1999)

Calculating the break-even price (maize grower's view)

To calculate the break-even price for silage from the maize grower's point of view use the formulae:

Tonnes of grain equivalent =
Estimated wet yield of silage (t) x DM % of silage x grain as a % of DM (or read from graph in Figure 11.2)

Value of grain =
tonnes of grain equivalent x (grain price – grain harvest cost)

Harvest cost of silage =
estimated wet yield of silage (t) x harvest costs borne by grain farmer

Break-even price silage $/t wet =
(value of grain + harvest cost of silage) ÷ estimated wet yield

Example:

Estimated wet yield = 60 t/ha

DM% = 35% (DM yield = 21 t)

Estimated grain yield at 14% moisture (from Figure 11.2) =11.3 t

Maize price = $160 on farm

Grain harvest cost = $18/t

Harvest cost borne by farmer = $12/t wet for harvest and cartage.

(Harvest costs may be borne by the buyer. If so, the harvest cost borne by the farmer will be zero.)

If the grain option is chosen, the value of the organic matter in the crop residue (stover) is assumed to be equal to the cost of having the land tied up for longer plus the cost of slashing the stubble.

Calculations:

Tonnes of grain equivalent = 11.3 t

Value of grain = 11.3 x (160-18) = $1,605

Harvest cost of silage = 60 x 12 = $720

Break-even price silage ($/t wet) = (1,605 + 720) ÷ 60 = $38.75

Based on the assumptions listed, the grain farmer would have to receive at least $38.75 for every tonne of silage (35%DM) delivered to the pit to make it a better proposition than grain.

11.4.2

Valuing maize silage from the buyer's point of view

The maximum that a buyer should pay for silage is based on the feed value compared to the cheapest alternative feed source. Maize silage may be the preferred option for a number of reasons besides supplying energy. For example, silage may be sought for fibre or in the situation where cattle are grazing high protein pasture, access to maize silage may help balance the nitrogen in the diet. In situations where factors other than energy are important, the supplementary feed, which you are comparing it to, should have similar attributes. For the comparison to be accurate, it may have to be made to a mix of feedstuffs.

The maximum price payable (the maize buyer's view)

The following formulae are used to work out the maximum price payable:

Tonnes of silage required to match a tonne of alternative (TSR) =

$$\frac{\text{MJ/t wet of alternative (allowing for losses)}}{\text{MJ/t wet of silage (allowing for losses)}}$$

Maximum price to pay (MP) =

$$\frac{\text{Price per tonne fed alternative}}{\text{TSR}} - \text{cost of feeding silage}$$

Example:

Best alternative = barley

MJ/kg DM barley = 12

DM barley = 90%

Feedout losses for barley 3% – or 97% fed
(Feedot losses include spillage losses in processing, transport or feed left by cows)

MJ/kg DM silage = 10.5

DM = 35%

Additional losses in silage (storage and feedout) 10% – or 90% fed

Cost of barley ($160 on farm + $15/t to feed and process) = $175

Cost of feeding silage = $12/t wet

Calculations:

MJ/tonne barley = 12 x 1,000 kg x 0.90 x 0.97= 10,476 MJ

MJ/tonne fed silage = 10.5 x 1,000kg x 0.35 x 0.90 = 3,307 MJ

Tonnes of wet silage required to match 1 t of barley (TSR) = 10,476 ÷ 3,307 = 3.17 t

Maximum price = ($175 ÷ 3.17) - $12 = $43.20

The maximum value that the farmer should pay in this case is calculated at $43.20. The final price would be negotiable and in this case if the grain farmer and the dairy farmer had done their calculations, the final price should fall between $38.75 (from the previous page) and $43.20/t.

In some circumstances the maximum the purchaser is prepared to pay is less than the minimum the farmer is prepared to accept. In this case, the farmer would let their crop go through to grain and the potential purchaser would choose the alternative feed.

11.4.3

Valuing a pasture for silage from the forage owner's point of view

A method of valuing standing feed is as follows:

The pasture could be compared to the value of the hay that could be made minus the value of any additional grazing from regrowth. The value of any regrowth is important because it is likely to be very palatable and is capable of producing high liveweight gain or milk production.

The following estimates are required:

- estimated quantity of silage likely, in bales or tonnes;
- estimated quantity of hay that could be made, in bales or tonnes;
- estimated on-farm value of the hay;
- estimated costs of making the silage;
- estimated value of the additional grazing. (As a guide good quality feed will produce 0.13 to 0.14 kg liveweight gain per kg of DM. A spring pasture is likely to produce around 1 tonne of good quality feed between silage making and the time when it could have been harvested as hay. If there were alternative pastures that could be grazed, the appropriate value to include would be an estimate of the additional value of meat or milk produced because of the higher weight gains achieved.)

The value of pasture for silage (the grower's view)

The formulae to make the calculation are:

Net value of hay =

quantity of hay made on farm x on-farm value of hay – cost of hay making.

Break-even value of silage =

$$\frac{\text{net value of hay - value of additional grazing + silage-making costs}}{\text{quantity of silage.}}$$

Example:

Size of paddock = 10 ha

Estimated quantity of silage = 35 t DM

Estimated quantity of hay = 42 t DM

Estimated on-farm value of hay = $110/t

Estimated costs of making hay = $1,800

Estimated cost of making silage = $0 (costs born by purchaser)

Value of additional grazing to the owner of the paddock = $1,000

Calculations:

Net value of hay = (42 x 110) - $1,800 = $2,820

Break-even value of silage = ($2,820 – $1,000 + $0) ÷ 35
= $1,820 ÷ 35 = $52/t DM.

That is, the owner of the feed would need to be paid at least $52/t DM, otherwise it would be better to leave it for hay.

If a per bale rate is required, you must know the number of bales to produce a tonne of DM. If each bale contains 200 kg of DM there are

1,000 ÷ 200 = 5 bales/t of DM.

The amount the purchaser would have to pay would be at least

$52 ÷ 5 = $10.40/bale.

If a paddock charge is desired, the amount required by the paddock owner would be at least $1,820.

11.4.4

Valuing a pasture for silage from a buyer's point of view

The value to the buyer is either the value of the cheapest alternative feed, or in a situation where there are no alternative feeds that are economic it is the value of the additional milk or meat less the costs.

Valuing pasture forage compared to the cheapest alternative feed (buyer's view)

The following estimates are required:

- value of the alternative feed per tonne DM, including feeding costs. A mix may be required to supply levels of protein and energy.
- the harvesting, transport and feedout cost per tonne of the silage.

Example:

Value of alternative feed is barley at $190/t DM on farm

Feeding costs is an additional $15/t = $205/tDM. (The additional protein in the silage is surplus to requirements in this case and a protein additive is not costed into the mix)

The harvesting, transport and feedout cost of silage is $110/t DM

The maximum the purchaser could pay in this case is $95/t DM (i.e. $205 – $110).

In this situation, the $95 value to the potential purchaser is well above the $52 (from previous page) required by the feed owner, so there is plenty of room for negotiation.

Valuing pasture forage where there are no alternative feeds

The estimates required to make this calculation are:

- expected extra production from using the silage;
- net value of that extra production;
- harvesting, transport and feedout cost of the silage.

Example:

The meat produced from each tonne DM of silage is estimated to be 135 kg.

The 35 tonne of silage is estimated to produce an additional 4,725 kg (i.e. 35 t x 135 kg/t) of meat, with a net value of $1.40/kg. Value of meat = $6,615 (i.e. $4,725 x 1.40)

Cost of making, harvesting, transporting and feeding the silage is $110/t DM.

Total cost is 35 x $110 = $3,850

Net gain = $6,615 – $3,850 = $2,765

The maximum price that could be paid is less than $2,765 or $79/t DM (i.e. $2,765 ÷ 35).

In this example, the break-even price is greater than $52 (from Section 11.4.3) required by the fodder owner, so an agreement can be negotiated.

Section 11.5

The *Forage Systems Model* – a costing analysis of forage conservation systems

This *Forage Systems Model* is a decision aid tool to help evaluate alternatives.

To access a copy of this model and to download the software go to <www.topfodder.com.au> on the Internet and follow the menu options: 'Silage Resources' and 'Decision Making Tools' . The model requires Excel 97, or later, to run and has been designed to lead the user through a series of worksheets.

From time to time an updated version of this software will be placed on the web. A check at the web address will reveal the version number.

The model uses a partial budget approach, which means that it only considers the effect of changes. It requires present production information as well as projections of production that will result from the intended change. The additional net income expected and the return on additional capital resulting from change is calculated on the analysis worksheet.

If projected returns on additional capital are inadequate, then it is pointless in proceeding further. If however, returns are attractive, it may be worthwhile following up with income and costs projections in a cash flow budget to assess the cash flow consequences of making a change.

The model is divided into a number of inter-related worksheets. Once you have entered all the necessary information on one sheet, click onto the next worksheet at the top of the screen to proceed.

Relevant data is automatically transferred between worksheets. If you need to change data already entered, go back to the relevant sheet, make the change and proceed.

First, enter data about the present situation. If it is going to take, for example, two years for the proposed system under consideration to get to full production, the figures for the present situation should be the projections of where the present system would be in two years' time. The model worksheets are as follows:

Present system

Crop Information: Details of the fodder production levels from the present system on an area basis.

Hours & Costs: Details of machinery hours spent on fodder conservation in each area and details of hourly running costs to determine the variable costs of machinery.

Overhead Costs: Calculations of machinery and labour costs.

Income: Milk and/or stock sales and prices are estimated and estimated net income is calculated.

Proposed system

An identical set of worksheets have to be filled in to get a picture of the proposed system.

Analysis

The Analysis worksheet contains a summary of the additional income and costs expected as a result of a system change, as well as an economic analysis.

It is recommended that a feed budgeting model is used in conjunction with the *Forage Systems Model* to ensure that feed cost and cow number estimates are achievable. There are a number of feed budgeting products available, or in development, that may have more information on pasture growth rates for a particular locality. Your adviser will be able to recommend the most suitable feed budgeting model for your area.

Section 11.6

Recommended procedure to evaluate a new forage conservation system

It is recommended that the following steps are carried out to properly evaluate whether a change in fodder production is warranted. Below is a summary of the steps required to accurately evaluate any proposed silage system or changes to an existing system:

1. A feed budget detailing production and consumption of the present pastures and fodder supplies should be undertaken. A similar feed budget should be prepared for the proposed situation.
2. Check the present budget to ensure it approximates what is currently happening on the farm. If there are significant differences an effort must be made to get it right. If the base production level is out, how can any projection possibly be accurate?
3. Detail the machinery and other resources required for the proposed situation.
4. Decide which equipment can be sold and what equipment has to be purchased. The cost of silage bunkers should be included here.
5. Estimate the changes in costs and income that occur as a result of the change. Costs include depreciation and interest costs, forage crop and pasture costs, animal costs and marketing costs.
6. Calculate the net returns (additional income less changes in costs).
7. Prepare a partial budget that calculates percentage return on the extra capital.
8. Decide if the return is attractive enough.
9. If return is attractive, prepare a cash flow budget to detail the adoption of the change.
10. If the cash flow budget looks acceptable, adopt the change.

The *Forage Systems Model* (see Section 11.5) is set up to take you through these steps.

Section 11.7

Appendices

11.A1

Maize pit silage example costs – dryland system

Calendar of operations

Operation	Month	Machinery hrs/ha	Machinery Cost $/hour	Machinery Total $/ha	Inputs Rate/ha	Inputs Cost $	Inputs Total $/ha	Total Cost $/ha
Slash	Oct	0.42	20.70	8.69				8.69
Cultivate – chisel	Oct	0.58	18.45	10.70				10.70
Cultivate – scarifier	Oct	0.42	16.60	6.97				6.97
Sow with planter	Nov	0.29	24.87	7.21				7.21
Seed	Nov	with above			20 kg	5.00	100.00	100.00
Fertiliser – Grower 11	Nov	with above			300 kg	0.56	168.00	168.00
Insecticide	Nov	with above			2.50 L	18.50	46.25	46.25
Herbicide – Primextra	Nov	0.10	18.20	1.82	5.30 L	9.85	52.21	54.03
Side dress urea	Dec	0.10	15.20	1.52	360 kg	0.44 kg	158.40	159.92
Inter-row cultivate	Dec	0.42	16.60	6.97				6.97
Harvest – contract	Apr		45.00 /t DM			(18 t DM)		810.00

Variable cost summary

Ground preparation and seed	141
Fertiliser	328
Herbicide	54
Insecticide	46
Irrigation	0
Harvest – contract	810
Levies	0
Total variable costs $/ha:	**1,379**
Cost $/t DM = $1,379 ÷ 18 = $76.60	

Note: cartage costs, pit costs and feedout costs not included.

11.A2

*Costing forage conservation systems**

As examples of costings of fodder conservation systems, three separate systems have been considered. These are:

- round bale hay;
- silage made in a pit with self-feeding or mechanised feeding; and
- round bale silage wrapped in plastic.

The round bale hay and silage systems have been considered on an owner/operator basis or with some or all of the operations done by contractors.

Assumptions

In costing these systems, the following assumptions have been made:

- 3.7 t hay/ha, 10 bales hay/ha, 9 bales silage/ha
- 150 t hay (85% DM); 127.5 t of DM
- 364 t wilted double-chopped pit silage (35% DM); 127.5 t of DM
- 255 t wilted round bale silage (50% DM); 127.5 t of DM
- area cut for fodder – 40.5 ha
- bales (1.5 m diam x 1.2 m wide) weigh 370 kg as hay and 700 kg as wilted silage
- density of wilted pit silage 700 kg/m^3

Losses assumed (at harvest, ensiling & feedout)

Hay 15%, round bale silage 8%, self-feeding pit silage 20%, mechanically fed pit silage 8%

MJ of final product

Hay 8.3 MJ/kg DM

Round bale and pit silage mechanically fed 10.5 MJ/kg DM

Pit silage – self-feeding 10.0 MJ/kg DM

Machinery costs	$
Tractors:	
40 kW	50,000
50 kW	65,000
70 kW	85,000
Disc mower	12,000
Rotary rake	12,000
Round baler	35,000
Front-end loader	12,000
Round bale feeder	9,000
Double-chop forage harvester	22,000
Hay trailer	6,000
Silage trailer	3,000
Silage feedout trailer	25,000

Hay shed cost	
8,500 conventional bales (405 round)	20,000

Silage pit cost	
Excavation costs – (two pits) each 260 m^3 (10.5 m x 2.5 m) i.e. to excavate a total of 260 m^3 and heap soil along sides to double capacity. Total cost	850
Labour cost	15/hr

Annual overheads	
Machinery	
Depreciation	10% of new price
Interest	6% of new price
Insurance/housing	1% of new price
Storage	
Depreciation (over 30 yrs)	3.3%
Interest	6%

* *Adapted from Valentine and Cochrane (1996)*

Tractor running costs	$
40 kW	
Fuel (10.7 L/hr @ 45¢/L after rebates)	4.82
Oil & filters (15% of fuel)	0.72
Repairs & maintenance (3% of 50,000 per 1,000 hrs)	1.50
Tyres & batteries (4% of 50,000 per 1,000 hrs)	2.00
Total	**9.04/hr**
50 kW	
Fuel (12.1 L/hr)	5.45
Oil & filters	0.82
Repairs & maintenance (3% of 65,000 per 1,000 hrs)	1.94
Tyres & batteries (4% of 65,000 per 1,000 hrs)	2.60
Total	**10.81**
70 kW	
Fuel (16.0 L/hr)	7.20
Oil & filters	1.08
Repairs & maintenance (3% of 85,000 per 1000 hrs)	2.55
Tyres & batteries (4% of 85,000 per 1000 hrs)	3.40
Total	**14.23**
Repairs and maintenance on non-powered machinery 5% of capital cost per 1,000 hours	

ROUND BALE HAY (OWNER/OPERATOR)

Machinery	$
Tractor (50 kW) (20% usage x $65,000)	13,000
Mower	12,000
Rake	12,000
Round baler	35,000
Front-end loader (40% usage x $12,000)	4,800
Trailer	6,000
Round bale feeder	9,000
Total	**91,800**

Annual overheads	
Machinery (17% x 91,800)	15,606
Storage (9.3% x 20,000)	1,860
Total	**17,466**

Operating costs (50 kW tractor)	
Mowing (0.54 hr/ha x 10.81 hr x 40.5 ha)	236
Raking (0.63 hr/ha x 10.81 hr x 40.5 ha)	276
Baling (0.45 hr/ha x 10.81 hr x 40.5 ha)	197
Carting (0.42 hr/ha x 10.81 hr x 40.5 ha)	184
Feeding (3 hr/ha x 10.81 hr x 40.5 ha)	1,314
Total	**2,207**

Labour	
5.04 hr/ha x $15/hr x 40.5 ha	**3,062**

Twine	
50 ¢/bale x 405 bales	**203**

Repairs & maintenance on non-powered machinery	
Mowing (5% x 12,000 x 40.5 x 0.54 hr/ha) ÷ 1,000	13
Raking (5% x 12,000 x 40.5 x 0.63hr/ha) ÷ 1,000	15
Baling (5% x 35,000 x 40.5 x 0.45 hr/ha) ÷ 1,000	32
Carting (5% x 6,000 x 40.5 x 0.42 hr/ha) ÷ 1,000	5
Feeding (5% x (13,800)* x 40.5 x 3 hr/ha) ÷ 1,000	84
Total	**149**

Summary	
Total cost	**23,087**
Cost/t of hay = 23,087 ÷ 150	154
Cost/tDM = 23,087 ÷ 127.5	181
Cost /t DM consumed allowing 15% losses	213
Cost ¢/MJ consumed @ 8.3 MJ/kg DM = 21,300 ÷ 8,300	2.57
* Front-end loader + Round bale feeder	

ROUND BALE HAY (CONTRACT BALING)

Machinery cost	$55,500
(18% usage of 50 kW tractor, baler not required)	

Annual overheads	$
Machinery (17% x 55,500)	9,435
Storage (9.3% x 20,000)	1,860
Total	**11,295**

Operating costs (50 kW tractor)	
Mowing	236
Raking	276
Carting	184
Feeding	1,314
Total	**2,010**

Labour	
4.59 hr/ha x $15/hr x 40.5	**2,788**

Repairs & maintenance on non-powered machinery	
Mowing	13
Raking	15
Carting	5
Feeding	84
Total	**117**

Contract baling	
405 bales x $11/bale	**4,455**

Summary	
Total cost	**20,665**
Cost/t of hay = 20,665 ÷ 150	138
Cost/t DM = 20,665 ÷ 127.5	162
Cost/t DM consumed (15% losses)	191
Cost ¢/MJ consumed @ 8.3 MJ/kg DM	2.3

ROUND BALE HAY (CONTRACT MAKING)

Machinery cost	$28,250
(13% usage of 50 kW tractor, mower, rake & baler not required)	

Annual overheads	$
Machinery (17% x 28,250)	4,803
Storage (9.3% x 20,000)	1,860
Total	**6,663**

Operating costs (50 kW tractor)	
Carting	184
Feeding	1,314
Total	**1,498**

Labour	
3.42 hr/ha x $15/hr x 40.5 ha	**2,077**

Repairs & maintenance on non-powered machinery	
Carting	5
Feeding	84
Total	**89**

Contract mowing raking	
Mowing (40.5 ha x $44/ha)	1,782
Raking (40.5 ha x $31/ha)	1,256
Baling (405 bales x $11/bale)	4,455
Total	**7,493**

Summary	
Total cost	**17,820**
Cost/t of hay = 17,820 ÷ 150	118.80
Cost/t DM = 17,820 ÷ 127.5	139.76
Cost/t DM consumed (15% losses)	164.43
Cost ¢/MJ consumed @ 8.3 MJ/kg	1.98

PIT SILAGE – SELF FEEDING (OWNER/OPERATOR)

Machinery	$
Tractor (70 kW) (20% usage x $85,000)	17,000
Tractor (40 kW) (10% usage x $50,000)	5,000
Mower	12,000
Rake	12,000
Forage harvester	22,000
Trailer (x 2)	6,000
Total	74,000
Annual overheads	
Machinery (17% x 74,000)	12,580
Storage (9.3% x 850)	79
Total	**12,659**
Operating costs (40 kW tractors)	
Mowing (0.54 hr/ha x 9.04 hr x 40.5 ha)	198
Raking (0.63 hr/ha x 9.04 hr x 40.5 ha)	231
Carting (0.5 hr/ha x 9.04 hr x 40.5 ha)	183
Forage harvesting (70 kW tractor) (0.52 hr/ha x 14.23/hr x 40.5 ha)	300
Total	**912**
Labour	
2.19 hr/ha x $15/hr x 40.5 ha	**1,330**
Plastic	
21 m long x 6 m wide x 200 cm ($100) x 2 pits	**200**
Hire tractor with front-end loader	
(for pit maintenance) $50/hr x 30 hrs (including driver)	**1,500**
Aggregate	
Base of pit (10.5 m x 10 m x 0.3 m) x 2 pits = 63m^3	
Feeding pad (10 m x 6 m x 0.3 m) = 18 m^3	
Total = 49.5 m^3 x 2 pits = 99 m^3 x $20 ÷ 1.8 m^3/t = 1,100	
Annual cost = 1,100 x 10%/year = 110	**110**
Repairs & maintenance on non-powered machinery	
Mowing (5% x $12,000 x 40.5 x 0.54 hr/ha) ÷ 1,000	13
Raking (5% x $12,000 x 40.5 x 0.63 hr/ha) ÷ 1,000	15
Carting (5% x $6,000 x 40.5 x 0.50 hr/ha) ÷ 1,000	6
Forage (5% x 22000 x 40.5 x 0.52 hr/ha) ÷ 1,000	23
Total	**57**
Summary	
Total cost	**16,768**
Cost/t silage = 16,768 ÷ 364	46.07
Cost/t DM = 16,768 ÷ 127.5	131.52
Cost/t DM consumed (25% losses)	173.35
Cost/MJ consumed @ 10MJ/kg DM	1.75

PIT SILAGE – MECHANICAL FEEDING

Mechanical feeding requires the purchase of a front-end loader with a silage grab and a 9 m^3 silage feedout wagon which will replace one silage trailer.

Additional costs	$
Machinery overheads	
17% x $(25,000 + 12,000 – 3,000) = 17% of $34,000	5,780
Operating costs (70 kW tractor)	
Loading & feeding out silage (1hr x ha x $14.23/hr x 40.5ha)	576
Labour	
1 hr x ha x $15 x 40.5 ha	608
Repairs & maintenance on non-powered machinery	
Feeding (5% x $3400 x 1hr/ha x 40.5ha) ÷ 1,000	69
Total additional costs	**7,033**
Subtract annual cost of aggregate for feed pad which is no longer required	-72
Summary	
Total additional net cost	**6,961**
Cost/t silage = (16,768 + 6,961) ÷364	65.19
Cost/t DM = 23,729 ÷ 127.5	186.11
Cost/t DM consumed (15% losses)	218.95
Cost ¢/MJ consumed @ 10.5 MJ/kg DM	2.09

Note: This system is expensive because there is not enough throughput to justify the high capital outlays. A larger quantity of silage made per year would reduce costs.

PLASTIC WRAPPED ROUND BALE SILAGE (CONTRACT WRAPPING)

Machinery	$
Tractor (50 kW) (25% usage x $65,000)	16,250
Tractor (40 kW) (10% usage x $50,000)	5,000
Mower	12,000
Rake	12,000
Round baler	35,000
Front-end loader (50% usage x $12,000)	6,000
Trailer	6,000
Round bale feeder	9,000
Total	101,250

Annual overheads	
Machinery (17% x 101,250)	**17,213**

Operating costs (50 kW tractors)	
Mowing (0.54 hr/ha x 10.81 hr x 40.5ha)	236
Raking (0.63 hr/ha x 10.81 hr x 40.5ha)	276
Baling (0.74 hr/ha x 10.81 hr x 40.5ha)	324
Carting & wrapping (0.5 hr/ha x 10.81 hr x 40.5 ha)	219
Feeding (4 hr/ha x 10.81/hr x 40.5 ha)	1,752
Total	**2,807**

Labour	
(6.41 hr/ha x $15/hr x 40.5 ha)	**3,894**

Twine	
(50¢/bale x 365 bales)	**183**

Plastic	
($6/bale x 365 bales)	**2,190**

Repairs & maintenance on non-powered machinery	
Mowing (5% x 12,000 x 40.5 x 0.5 hr/ha) ÷1,000	12
Raking (5% x 12,000 x 40.5 x 0.63 hr/ha) ÷ 1,000	15
Baling (5% x 35,000 x 40.5 x 0.50 hr/ha) ÷ 1,000	35
Carting (5% x 6,000 x 40.5 x 0.50 hr/ha) ÷ 1,000	6
Feeding (5% x (15,000)* x 40.5 x 2.5hr/ha) ÷ 1,000 * Front-end loader + Round bale feeder	76
Total	**144**

Hire wrapping machine	
$3/bale x 364 bales	**1,095**

Summary	
Total cost	**27,526**
Cost/t silage = 27,526 ÷ 255	107.95
Cost/t DM = 27,526 ÷ 127.5	215.89
Cost/t DM consumed (8% losses)	234.66
Cost ¢/MJ consumed @ 10.5 MJ/kg DM	2.23

ROUND BALE SILAGE (CONTRACT BALING)

Machinery

Cost $58,000

(20% usage of 50 kW tractor; 40 kW tractor and baler not required)

Annual overheads	$
Machinery (17% x 58000)	**9,860**

Operating costs (50 kW tractor)	
Mowing	236
Raking	276
Carting	219
Feeding	1,752
Total	**2,483**

Labour	
(5.67 hr/ha x $15/hr x 40.5 ha)	**3,445**

Repairs & maintenance on non-powered machinery	
Mowing	12
Raking	15
Carting	6
Feeding	76
Total	**109**

Contract baling & wrapping	
(365 bales x $20/bale)	**7,300**

Summary	
Total cost	**23,197**
Cost/t silage = 23,197 ÷ 255	90.97
Cost/t DM = 23,197 ÷ 127.5	181.93
Cost/t DM consumed (8% losses)	197.75
Cost ¢/MJ consumed @ 10.5 MJ/kg DM	1.88

ROUND BALE SILAGE (CONTRACT MAKING)

Machinery

Cost $30,750 (15% usage of 50 kW tractor; mower, rake, baler and 40 kW tractor not required)

Annual overheads	$
Machinery (17% x 30,750)	**5,228**

Operating costs	
Carting (0.5 hr/ha x 10.82 hr x 40.5 ha)	219
Feeding (4 hr/ha x 10.82/hr x 40.5 ha)	1,752
Total	**1,971**

Labour	
(4.5 hr/ha x $15/hr x 40.5 ha)	**2,734**

Repairs & maintenance on non-powered machinery	
Carting	6
Feeding	76
Total	**82**

Contract mowing, raking & baling	
Mowing (40.5 ha x $44/ha)	1,782
Raking (40.5 ha x $31/ha)	1,256
Baling & wrapping ($20/bale x 365 bales)	7,300
Total	**10,338**

Summary	
Total cost	**20,353**
Cost/t silage = 20,353 ÷ 255	79.82
Cost/t DM = 20,353 ÷ 127.5	159.63
Cost/t DM consumed (8% losses)	173.51
Cost/MJ consumed @ 10.5 MJ/kg DM	1.65

Conclusion

There are obviously large differences between the systems in costs per tonne of DM conserved. However, the relative costs can be altered significantly by changes in scale and assumptions of work rates, the feed quality and the losses involved. These costings provide a template of how to use your own figures to arrive at a cost.

11.A3

Contacts for contract rates

Australian Fodder Industry Association <http:// www.afia.org.au>

South Gippsland Ag Contractors Association

West Gippsland Fodder and General Contractors Association Inc.

Victorian Western Districts Agricultural Contractors Association

Big Square Baling Contractor's Association (WA)

Western Australian rates can be found on the web at <http://budget.farmline.com.au>

A broad guide to contract rates is often published in the major rural newspapers. The *Weekly Times* publishes rates at the beginning of each silage-making season.

Chapter 12

Feed testing: assessing silage quality

Chapter 12

Feed testing: assessing silage quality

In this chapter

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The Key Issues

- Feed testing is an essential tool in a feeding program, providing important information on the nutritive value of silages.
- The success of a silage-making operation can be assessed by monitoring quality changes during the ensiling process. This can be achieved by comparing the parent forage and the resulting silage.
- Sampling procedure is critical. It is important to obtain a representative sample of the silage and ensure that it does not deteriorate during transport to the laboratory.
- A preliminary, but subjective, evaluation of silage quality can be made in the field by assessing silage colour and aroma. This should be followed up with a laboratory test.
- The laboratory test should include DM content, digestibility or ME content, crude protein content and silage fermentation quality. Ammonia-N content and silage pH can be used as a guide to silage fermentation quality.
- Silages are fermented feeds and contain volatile compounds that are lost if the sample is dried for analysis. This will affect the results. Check whether your feed-testing laboratory has taken this into account when calculating the results.

Section 12.0

Introduction

Feed testing is an integral part of a well-managed forage conservation program. It establishes the quality of a silage and the success of the ensiling process, and can be a useful way to determine if quality and wilting targets have been met.

'Quality' – encompassing all the attributes that influence a silage's nutritive value – determines the potential animal production per tonne of silage and so is an important indicator of whether producing the silage has been profitable.

Perhaps the most important use of feed tests is in the formulation of diets. The ME and crude protein content of a silage determine whether it will supply adequate nutrients for animal production. The feed test provides information that can be used to answer key feed management questions:

- Is the silage suitable for the intended animal production target?
- What production response can be expected?
- If used as a component of a diet, how much silage will need to be fed?
- Will other supplements be required? If so, what quantity?

An early feed test, well before the silage is to be used, can provide valuable information to assist with budgeting and formulation of diets.

If the feed test indicates that the silage quality is below the level required for the animal production targets, there is time to source alternative supplements.

The results of feed tests may be used as an objective basis for costing silage, for trading crops and pastures for silage production, and for trading silage.

The trading of baled silage is becoming more popular. Hay prices are often used as a reference point, with adjustments for differences in DM content, possible differences in quality and conservation costs.

Information on the nutritive value of Australian hays and silages (see Appendix 12.A1) shows that silages, on average, have a higher crude protein and ME content than hays in each forage class. The large range in crude protein, DM digestibilities and ME values for the silages highlight the potential quality many producers are losing due to poor silage-making practices. The hay data indicates a similar situation with hay-making practices.

Section 12.1

Testing the parent forage

The quality of the parent forage is a key factor influencing the quality of the resulting silage. Testing the parent forage will provide a guide to the *potential* quality of the silage.

In a well-managed system, where losses are low, the silage DM content, digestibility and ME content will be similar or slightly lower, and crude protein content similar or slightly higher, than that in the parent forage.

However, if there have been significant quality losses during wilting, harvesting or storage, the parent forage will no longer accurately indicate silage quality. There can be quite significant reductions in digestibility (and ME content) and crude protein content. In cases of overheating or poor silage fermentation, the availability of crude protein may also be reduced.

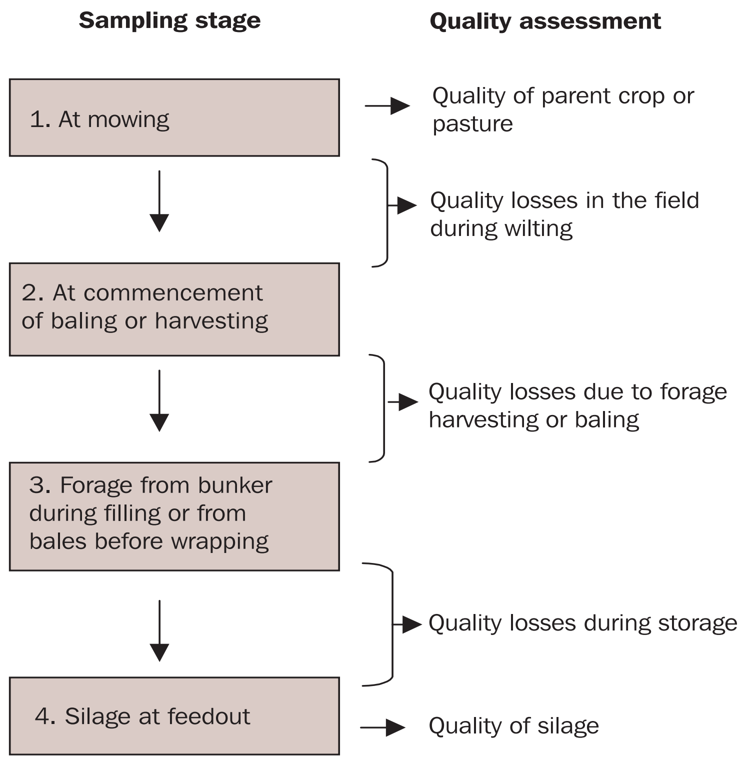
Researchers and some producers monitor the quality losses during various stages of the ensiling process to identify problem areas that need to be targeted with improved management.

The time of sampling is important; it determines which categories of loss contribute to any differences between parent forage and silage ME content (see Figure 12.1).

Obtaining a complete inventory of where quality losses occur may only be realistic in research programs. However, producers who have had difficulties producing higher-quality silage may find it useful to compare the quality of the parent forage with that of the resulting silage to help diagnose the problem. The best time to sample the parent forage is at mowing. Samples at a later stage will not account for all the losses that can occur during the ensiling process (see Figure 12.1).

Figure 12.1

Using feed tests to track changes in quality during the silage-making process.



*Note: This sampling regime (representative samples are essential at each stage) uses laboratory tests to monitor changes in forage/silage **quality**. There will also be losses in the **quantity** of forage (DM losses) during various stages of the ensiling process (see Chapter 2). These losses are usually only determined in research studies and are difficult to determine under farm conditions.*

Diagnosing quality problems

Diagnosing quality problems using feed test analyses of parent forage and the resulting silage

- If the ME content of the parent forage is low, the crop or pasture has been cut too late.
- If the ME content of the parent forage is considerably higher (>0.5 MJ/kg DM) than the silage, there have been significant losses during silage making or storage (see Chapters 2, 6, 8 and 9).
- If parent forage and silage ME content are similar, conservation losses have been minimal.
- The silage ME cannot be significantly higher than the parent forage ME. Such a result indicates a technical problem – a laboratory error or, more likely, a sampling problem.

The sampling method is important if a representative sample of parent forage is to be collected. When sampling mown forage in the paddock, a series of small 'grab' samples (minimum of 12) should be collected across the whole paddock. Each 'grab' should sample the full depth of the swath or windrow.

As soon as sampling has been completed, bulk and *thoroughly mix* the sample. Make sure the mixing surface is clean to avoid contamination. If you have collected more forage than the laboratory requires, take a sub-sample by splitting the sample two or four ways and retaining a half or a quarter.

The method for sampling wilted forage before baling is the same as for freshly mown material.

If sampling forage that is to be chopped by a forage harvester, a representative sample can be collected either from the windrow at mowing or prior to harvest, or from several loads as they are delivered to the pit or bunker. Note the difference that the stage where the samples are collected has on interpretation of quality changes (see Figure 12.1).

Each forage-harvested sample collected over a day should be put into a plastic bag, sealed and kept in a refrigerator or insulated cooler (e.g. an Esky®) with freezer bricks. It is best not to use ice in the cooler in case water from the melting ice contaminates the sample. When all samples are collected they can then be bulked together, mixed and sub-sampled in a similar manner to that described earlier.

Once bulked, mixed and sub-sampled, place the sample for analysis in a plastic bag, squeeze to remove air, seal the bag immediately and store in a freezer. It is important to minimise the interval from sampling to freezing, as fresh forage samples deteriorate quickly. Plant sugars, for example, can be lost quickly via respiration (see Chapter 2, Section 2.2.1).

Once frozen, the sample will remain stable and can be forwarded to the feed testing laboratory. An overnight courier service is the most reliable means of getting the sample to the laboratory in good condition. The sample should be well wrapped in newspaper, to minimise thawing, and sent early in the week so that it can be received and processed before the next weekend. If the sample thaws, it can deteriorate.

Microwave drying is an alternative method of preparing parent forage samples (see Chapter 6, Section 6.4.2) and is advisable where an overnight courier service is not available for frozen samples. However, care should be taken to ensure the sample is not charred or heat damaged during the drying process.

12.2
Collecting silage samples

12.2.1
Corers

Core sampling tubes are the most acceptable tools for obtaining representative silage or hay samples. They are commercially available or can be made on-farm (see Figure 12.2).

A common construction material is stainless steel dairy air-line. This material is resistant to corrosion and the smooth surface creates little friction during sampling.

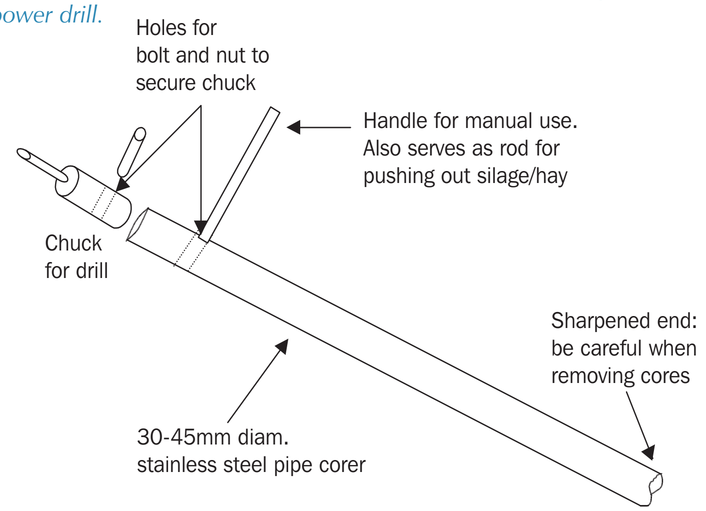
More sophisticated corers have a removable cutting head, but home-made corers simply rely on scalloping one end of the tube and sharpening with an angle grinder. It is important to keep the cutting surfaces sharp for efficient sampling.

Corers can be manually operated or fitted with an attachment for use with a power drill. With a manually operated corer, a hole is drilled through one end of the pipe so that a lever/handle can be inserted. If using an electric drill, a variable speed unit is preferable so that slow speeds can be used to reduce heating at the tip.

The silage core can be pushed out of the corer using a length of wooden dowel.

Figure 12.2

Construction of a silage corer that can be used either manually or with a power drill.



Source: F. Mickan

Plate 12.1

Using a corer like these is the most practical way of obtaining representative samples from bales of silage or hay.

Photograph: F. Mickan

12.2.2

Collecting a representative sample

Sampling technique can have an enormous effect on the value of silage feed test results. If it is not a representative sample, the results will not reflect the average composition of the silage 'batch' and can be misleading.

There can be considerable variation in the composition of silage within a pit or between bales produced from a single 'batch' of silage. The sample for feed testing must represent the average for the whole batch. Each batch should contain only forage mown and harvested from the same paddock, ideally within a 2-3 day period. Separate samples should be taken for each batch.

Silage sampling should be delayed for at least six and preferably 12 weeks to ensure that the fermentation is complete. The fermentation in a well-preserved silage is usually completed in less than six weeks. However, with less efficient preservation, the fermentation proceeds more slowly.

Sampling methods need to be varied according to the method of storage

Bunker or pit silage: During feeding, collect at least 12 samples across a freshly cut silage face (to avoid silage that has deteriorated due to prolonged exposure to air). A silage face represents only a small proportion of the silage in the bunker, so the value of test results from such samples will depend on how much variation in quality there is along the bunker or pit.

If bunkers are unopened, the plastic sheeting will need to be cut to collect a sample. Avoid places where rainwater collects on the sheet or near any holes. Samples, collected by using a corer or auger, should be taken from several locations along the length of the pit or stack to gain a representative sample. Avoid sampling from only the top 50 cm of the stack because this material may have been affected by exposure to air and may be of lower quality than the main body of silage.

Baled silage: Samples should be collected from a number of bales (at least 10-12) randomly selected from the total for that batch. The bales are cored from the middle of the curved surface of a round bale or from the end of a square bale. The corer should be taken through to the middle of the bale.

Tower silos: Tower silos are not common in Australia. Their design means sampling is only possible during feedout. To obtain a representative sample of the silage, daily samples need to be collected over the course of 7-10 days. These are frozen and then bulked for analysis.

Resealing bunkers, pits and bales after sampling

Plastic sheeting or plastic wrap should be resealed immediately, using commercially available tape or a patch especially designed for use with silage plastic.

Inferior plastic tapes, particularly those sensitive to UV light, should be avoided – they will deteriorate or fall off over time.

Make sure the silage plastic is clean and dry before applying a patch or tape. Chapter 9, Section 9, gives more information on the correct use of silage tapes.

12.2.3

Sample storage, packaging and delivery to the laboratory

After collecting the samples, thoroughly mix the bulk sample, take a sub-sample of the quantity required, place it in a plastic bag, remove the air by squeezing the bag, and seal it immediately.

For added security, double seal the sample inside a second plastic bag. This is especially important if the silage contains stalky material, such as unchopped lucerne or cereals, which may puncture the plastic.

Never leave samples in vehicles, particularly on a hot day. They will deteriorate quickly if allowed to heat during storage and transport.

It is recommended that silage samples be frozen before sending to a feed testing laboratory. Frozen samples should be well wrapped in newspaper and packed in an insulated cooler containing a freezer brick during warm months. Testing laboratories may have guidelines on the best way to ensure samples arrive in good condition for analysis.

Important steps in collecting a silage sample

- Ensure that the sample is representative of the whole batch.
- When the sample is collected during storage, ensure that the bunker or bales are effectively resealed.
- Do not leave the sample in a vehicle – it will deteriorate if it is not sealed in a plastic bag and stored in a cool place (e.g. an insulated cooler) immediately.
- Freeze the sample as soon as possible.
- If poor sampling and handling procedures are used, the feed test results will be of little value.

Section 12.3

Subjective appraisal of silage in the field

While laboratory testing provides an objective assessment of silage quality, a preliminary appraisal can be made in the field using simple subjective criteria such as colour and aroma.

It must be stressed that observations based on colour and aroma are subjective, but they can provide useful support to a laboratory feed test when diagnosing problems. Tasting is not recommended as poorly preserved silages may contain undesirable bacteria, yeasts and moulds, and it is unlikely to provide additional information beyond that provided by colour and aroma.

Mouldy or rotten silage indicates inadequate compaction or air penetration during storage, see Chapter 9, Section 9.8.2. and Appendices 9.A1 and 9.A2.

Colour	Silage characteristics and interpretation
Very dark olive green	Weather damaged and/or very wet silage with a poor fermentation. Usually occurs with high legume content or immature grass that may have been fertilised with a high rate of nitrogen. Sour or putrid aroma.
Dark olive green/brown	Normal colour for wilted legumes, which usually produce a darker-coloured silage than grasses.
Light green to green/brown	Normal colour range for grass, cereal and maize silages.
Pale green/straw yellow	Normal colour range for wilted grass silages. Tendency for heavily wilted silages with restricted fermentation to be greener.
Light amber brown	Typical colour for more mature grasses and cereals. Sometimes seen with low DM silages, and weather-damaged grass silages. Bottom layer of wet silage can be yellow with fruity or sour aroma.
Brown	Some heating has occurred during storage or due to aerobic spoilage during feedout. Some loss in digestibility and heat damage of protein. More common with wilted silages.
Dark brown	More extensive heating. May also be some black patches of silage on the surface. Significant loss in digestibility and high proportion of protein is heat damaged and unavailable to the animal. Due to inadequate compaction, delayed sealing or poor air exclusion. Usually accompanied by significant proportion of waste (mouldy) silage.

Aroma	Silage characteristics and interpretation
Mild, pleasantly acidic, sour milk or natural yogurt smell	Normal lactic acid fermentation – desirable.
Very little smell, but slightly sweet aroma	Heavily wilted silage with little fermentation, especially from crops with low sugar content. Stronger aroma as DM content falls.
Sweet, fruity alcoholic aroma	Yeasts have played an active role in the fermentation. Ethanol levels high. These silages are often unstable during feedout.
Sour vinegar smell	Poor fermentation dominated by bacteria producing acetic acid. Common with low DM, low-sugar forages. Intake likely to be depressed.
Rancid butter, putrid aroma	Poor fermentation dominated by clostridia bacteria that produce high levels of butyric acid. Silage wet and sometimes slimy. Rub silage between fingers, warm the hand for a few seconds and then smell. The presence of butyric acid is easily detected. Intake likely to be depressed. Not a common problem in Australia.
Strong tobacco or caramel smell with flavour of burnt sugar	Heat-damaged silage, dark brown in colour. Often palatable to stock but the nutritive value is very low.
Musty or mouldy aroma with only mild fermentation aroma	Mouldy silage due to poor compaction and sealing. Also evident in aerobically spoiled silage, which can be warm and have a compost aroma. Intake likely to be low; some silages may be rejected.

Section 12.4

Using and interpreting silage quality analyses

Silage differs from other ruminant feeds because it is a fermented product. The type of fermentation will influence silage quality, voluntary intake (and palatability), and the utilisation of the silage nitrogen by animals. As a result, the potential high level of animal production possible from a silage with a high ME and high protein content may not be realised if there has been a poor fermentation. Therefore, the conventional quality measures (digestibility and ME, and protein) used for other ruminant feeds are not sufficient for silage samples – some measure of *fermentation quality* is also needed. Ammonia-N and silage pH can be used as a guide to silage fermentation quality.

A sample feed analysis sheet for a silage, and guidelines on how to interpret these results, are given in Figure 12.3.

When interpreting laboratory feed test results the following points need to be considered:

1. The estimated digestibility and ME provided are usually predicted *in vivo* values (i.e. digestibility in the animal). Therefore, laboratories need standards of known digestibilities to calibrate their results.
2. Ideally, laboratories should indicate what methods they have used to estimate digestibility and ME.

Appendix 12.A2 provides examples of feed analysis results for problem silages.

Figure 12.3

How to interpret the information from a feed test.

'TopFodder' Feed Testing Service

Client Name and Address:

Type of Sample: Baled ryegrass silage
Your Sample Identification: Creek paddock, 14 October 2002
Laboratory No.: S230
Sample No.: 11353

Order No.: P0074752
Date Collected: 2 March 2003
Date Received: 3 March 2003
Date Reported: 10 March 2003

Results of Analyses

Test	Units	Result
Oven dry matter (DM)	% fresh	35.0
True dry matter (TDM)	% fresh	36.9
Crude protein (CP = N x 6.25)	% DM	15.9
Acid detergent insoluble nitrogen (ADIN)	% DM	0.18
	% total N	7.1
Acid detergent fibre (ADF)	% DM	35.8
Neutral detergent fibre (NDF)	% DM	60.5
Digestibility of DM	% DM	68.7
Metabolisable energy (ME)	MJ/kg DM	10.3
pH	–	4.9
Ammonia nitrogen	% total N	10.8

Comments: Silage ME is good, but silage fermentation quality could be improved, as ammonia-N content should be below 10%.

Because silage contains volatile compounds that are lost when samples are oven dried, true DM will be higher than oven DM. Some laboratories use prediction equations to calculate true DM.

If it is suspected that overheating has occurred during the ensiling process, an ADIN test will assess if the protein has been heat damaged. ADIN should be <12% of total N.

If the silage fermentation quality is poor, intake will be depressed and the animal response to silage feeding poor. Ammonia-N is the best simple test of silage fermentation quality and should be ≤10% total N.

Livestock obtain their nutrients from the DM component of the silage. Feed composition and dietary requirements are presented on a DM basis. DM content indicates if the forage has been wilted to the target DM range (see Chapters 2, 4 and 5).

CP content is used to formulate diets to meet dietary requirements. If the silage has a low CP, and other components of the diet cannot compensate, a protein supplement may be required.

These measures are all related. As fibre content increases, digestibility decreases and ME decreases. ME is calculated from fibre or digestibility. ME is the most important measure of feed quality and is usually the first limiting nutrient in most ruminant diets (see Section 12.4.2).

For silages with a DM content ≤35%, silage pH can be used as a guide to silage fermentation quality (see Table 12.3).

Notes: (1) Laboratories need to allow for the loss of volatile compounds from silage during oven drying of samples, otherwise digestibility, ME and crude protein content will be under-estimated;
(2) Tests available vary between laboratories;
(3) For examples of feed analyses for problem silages see Appendix 12.A2.

12.4.1

Silage DM content

Both DM and moisture content are used when describing the composition of a silage or its parent forage. Although one can easily be derived from the other, it does cause confusion (see Figure 12.4).

It is recommended that DM content (DM as a % of fresh weight) be used because:

- The costs of alternative feeds are compared on a DM basis and silages should be traded on a DM basis.
- Laboratories express the composition of feeds (e.g. crude protein and ME) on a DM basis.
- Diets for animals are formulated on a DM basis.

Knowing the DM content of a silage is important as it indicates the adequacy of wilting.

Forages ensiled below 30% DM will produce effluent, which can result in a significant loss of nutrients. These forages are also at risk of a poor fermentation, particularly if sugar levels are also low.

When forages are too dry (DM >50-55%) it is difficult to achieve anaerobic conditions and the silage will be more susceptible to heating and mould growth (see Chapter 2, Section 2.1.1).

The effect of volatile fermentation products on DM estimates

Because silage contains volatile fermentation products that are lost during conventional oven drying (volatile fatty acids, alcohols and some nitrogenous compounds), true DM content will be under-estimated. Lower DM silages usually undergo a more extensive fermentation and therefore contain more volatile products.

In the study illustrated in Figure 12.5, true DM content was determined by a method that directly measures water content. As DM content increases, the proportion of volatile products declines and the error due to volatile losses falls.

At an oven-dried DM content of 50% the error was only about one percentage unit (i.e. true DM content = 51%), indicating that there would be little difference between true DM and oven DM for oven DM levels >50%.

It is unlikely that commercial feed testing services will directly measure true DM content for silages. However, the prediction equation on the next page, based on the results in Figure 12.5, can be used to estimate true DM content from oven DM content, when samples are dried

Figure 12.4

Equivalent DM and moisture contents in forages.

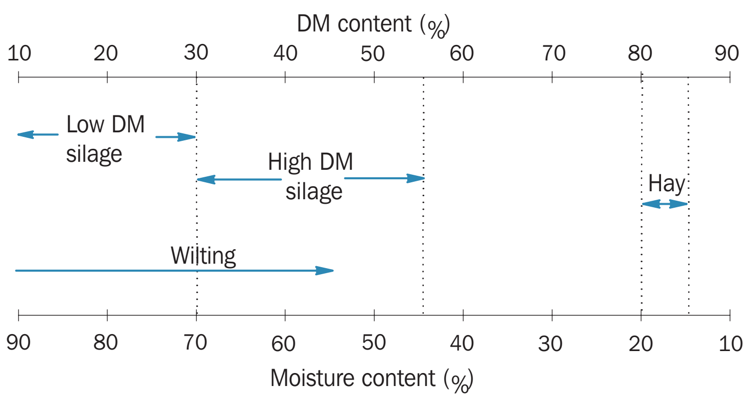
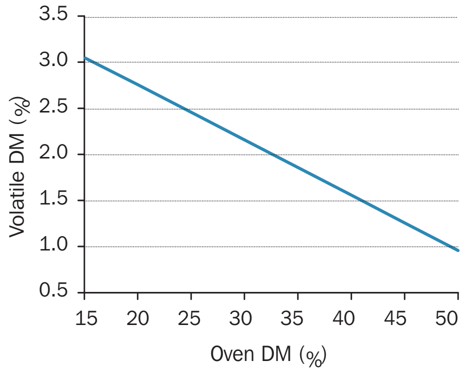


Figure 12.5

Loss of volatile compounds during the oven drying of silage samples (at 80°C).



Source: Kaiser et al. (1995)

Note: oven DM + volatile DM = true DM.

Estimating True DM content

To estimate the true DM content of silage from an oven DM use the following prediction equation:

True DM % = 3.96 + (0.94 x oven % DM) (Eqn 1)

Example:

If the oven DM of the silage = 33%

True DM % = 3.96 + (0.94 x 33) = 34.98%

This equation should not be used with aerobically spoiled silages (see Chapter 2, Section 2.2.3, and Chapter 10, Section 10.2). The heating that occurs in these silages will drive off silage volatile compounds. As a result, there may be little difference between oven DM and true DM of aerobically spoiled silages.

As some feed testing laboratories in Australia may already be using this correction, check that the laboratory has not already made the correction before adjusting your results.

at 80°C. This equation is based on (and should only be used for) silages with oven DM in the range 15-50%. Further research is planned to increase the number, and range, of silages used to develop this calculation.

Failure to take account of the volatile losses during oven drying has important implications in a number of areas:

- Laboratory analyses for fibre and mineral content, expressed on an oven DM basis, will be over-estimated, although in most cases the error will not be large;
- Digestibility and ME content will be under-estimated;
- Protein content will be under-estimated because of volatile losses of some nitrogen compounds;
- DM intake by animals consuming silage will be under-estimated.

The microwave drying method can be used on-farm to determine the oven DM content of the parent forage or silage (see Chapter 6, Section 6.4.2). If done correctly, this oven DM can be used in conjunction with Equation 1 to estimate true DM of silages (see example at left).

12.4.2

Energy value and digestibility

The metabolisable energy system is used in Australia, i.e. the energy value of a feed is expressed as megajoules (MJ) of ME per kg of DM. The ME is that component of the feed energy available to the animal for heat production, maintenance and production (see Figure 12.6).

In balanced diets, feed intake and animal production increase with increasing ME content or digestibility of the diet (see Chapters 13 to 15). This impact on feed intake and production is the reason that 'quality' should always be the focus in any silage program.

Dietary ME content is usually the most important component when appraising feed 'quality' – and the first limiting factor in most ruminant diets. However, other 'quality' components, such as nitrogen content and fermentation quality, are also important (see Sections 12.4.4 and 12.4.5).

Few directly measured ME values are available for sheep or cattle feeds. Measuring ME is an expensive process, using specialised equipment (a respiration chamber). More often, digestibility of the DM, organic matter (OM) or energy is determined, then prediction equations are used to estimate ME content from digestibility.

The general procedure for estimating the ME content of a feed is outlined in Figure 12.7. Note that net energy (NE) rather than ME is the feeding standard used in the United States.

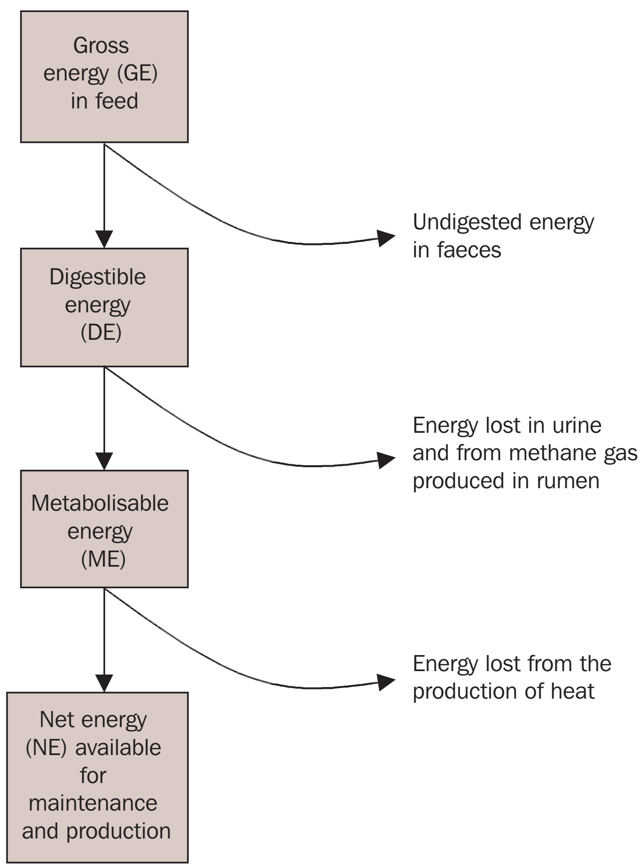
It is also expensive to measure the digestibility of a feed in cattle or sheep. Various laboratory methods have been developed to estimate digestibility, allowing large numbers of samples to be routinely processed through feed testing laboratories.

In practice, the fibre content of a feed determines the extent to which it is digested (high fibre = low digestibility), which, in turn, determines its ME content. So, estimates of ME can be calculated in various ways (see Figure 12.7):

1. Digestibility is estimated from one of a number of fibre analyses that have been calibrated against samples of known digestibility – where digestibility has been determined in sheep and/or cattle. ME is then estimated from digestibility using a prediction equation derived from studies with animals where the ME was determined in a respiration chamber.
2. Digestibility is estimated using an *in vitro* digestibility procedure, based on the use of rumen fluid (obtained from sheep or cattle) or various enzymes.

Figure 12.6

Energy digestion and metabolism in ruminants.



The metabolisable energy (ME) content of silages

- ME is the component of the feed energy that is available to the animal for heat production, maintenance and for production. It is measured as megajoules per kg of dry feed (MJ/kg DM).
- ME is usually the first limiting nutrient in most ruminant diets.
- It is closely related to the fibre content and digestibility of a feed, so that:
  High fibre = low digestibility = low ME
  Low fibre = high digestibility = high ME
  (see Table 12.1).
- Feed testing laboratories calculate ME from the fibre content or the digestibility of the feed.
- ME (and digestibility) will be under-estimated if the laboratory does not take account of the volatile compounds in silage lost during oven drying.
- Potential ME values achievable from various pastures and crops are provided in Chapters 4 and 5. Producers should set silage ME targets of ≥10.0 for temperate forages, 10.5 for maize and >9.5 MJ/kg DM for tropical pastures and forage crops respectively.

Figure 12.7

Laboratory-based methods for estimating the energy value of feeds.

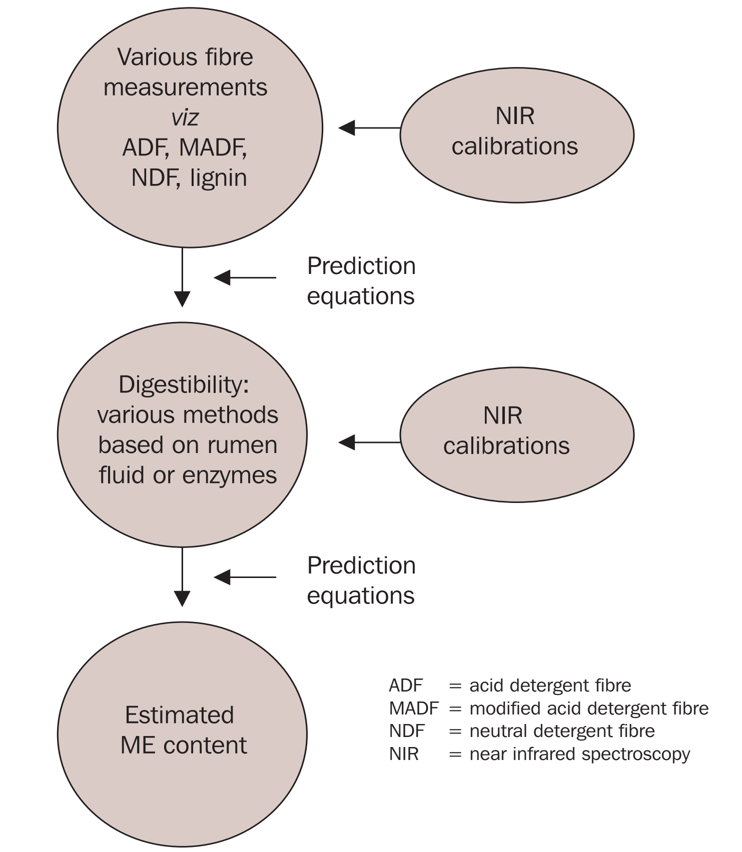


Plate 12.2

NIR machines are used in laboratories to simplify and speed up feed testing procedures estimating fibre components and ME. *Photograph: K. Kerr*

These methods have also been calibrated against samples of known digestibility in animals. ME is then estimated from digestibility in the same way as in point 1.

3. ME can be *directly* estimated from a laboratory measure of fibre or *in vitro* digestibility, using prediction equations that have been calibrated against samples (ME standards) of known ME in animals. However, as indicated earlier, there are relatively few measures of the ME of silages in animals.

The first two are the most commonly used procedures, with the second tending to be more accurate for forages. Near Infrared Spectroscopy (NIR) is now being used extensively in feed testing laboratories to replace these slower and more expensive 'wet chemistry' methods. Various NIR calibrations are available in Australia for estimating fibre components and digestibility. NIR has been successfully used overseas to directly predict the digestibility of silages in animals. It is important that the digestibility standards used for calibration purposes include feeds that are used in Australia and are relevant to the feeds being tested.

Calculating digestibility

Digestibility can be expressed in three ways – dry matter digestibility (DMD), organic matter digestibility (OMD) or digestible organic matter in the DM (DOMD). DOMD is the digestibility estimate most widely used in Europe and is sometimes referred to as the 'D value'.

The DM of all feeds is composed of organic matter and ash. Ash content comprises the minerals present in a feed and is determined by burning a sample in a furnace at a very high temperature for several hours and measuring the weight of residue remaining.

DM = Organic matter + ash

For laboratory estimates of DM digestibility, the quantity digested is the difference between the initial sample dry weight and dry weight of residue remaining after the *in vitro* digestion process. The quantity digested is divided by the initial sample dry weight to calculate digestibility. Some laboratories determine DOMD directly, while others use prediction equations to estimate DOMD from DMD as follows:

DOMD % = (0.95 x DMD %) – 0.9 (Eqn 2)

If ash content information is available to calculate OMD, then DOMD can be calculated without the use of this prediction equation.

Equation 2 should only be used for feeds with ash contents in the range 9-12 % of the DM. Higher ash contents may be due to soil contamination.

Some silages, such as maize silage have low ash contents (5.0 to 6.5 % ash). In this case, the above equations will under-estimate DOMD %.

Alternatively, an equation developed at Wagga Wagga, NSW, from cattle digestibility studies, could be used to estimate DOMD from DMD for maize silages:

DOMD % =
(0.887 x DMD %) + 5.60 (Eqn 3)

This equation may also be appropriate for use with other low ash content silages.

Calculating ME content

Estimating the ME content of a feed involves the use of a prediction equation to estimate ME from DOMD. The following equations, which can be applied to most forages, are commonly used:

ME (MJ/kg DM) =
(0.18 x DOMD %) – 1.8 (Eqn 4)

Equation 4 has been recommended by the Standing Committee on Agriculture, in Australia, and is used by some feed testing laboratories.

ME (MJ/kg DM) =
0.157 x DOMD % (Eqn 5)

Equation 5 has been more recently recommended by the Agricultural and Food Research Council (AFRC) in the UK.

Other ways to calculate digestibility

The total DM of a feed can be divided into two fractions – the organic matter (usually 85-95% of the DM) that is combusted when the feed is placed in a furnace, and the ash or residue remaining after combustion (usually 5-15%).

Dry matter digestibility (DMD), % =

$$\frac{\text{Feed DM consumed} - \text{Faeces DM}}{\text{Feed DM consumed}} \times 100$$

Organic matter digestibility (OMD), % =

$$\frac{\text{Feed OM consumed} - \text{Faeces OM}}{\text{Feed OM consumed}} \times 100$$

Digestible organic matter in the dry matter (DOMD)*, % =

$$\frac{\text{Feed OM consumed} - \text{Faeces OM}}{\text{Feed DM consumed}} \times 100$$

** Referred to as 'D value' in the UK.*

It is has the advantage of being based on direct measurements of ME in animals for a large and very diverse range of forages.

It is recommended that the following equation, which has been derived by AFRC *specifically for silages* (using DOMD corrected for volatile compounds), be used in Australia:

ME (MJ/kg DM) =
0.16 x DOMD % (Eqn 6)

Example for a silage with a 62% DOMD:

ME (MJ/kg DM) = 0.16 x 62
= 9.9 MJ/kg DM

Corrections for the volatile content of silages

As indicated earlier, the loss of volatile compounds during oven drying can result in the digestibility and ME content of silages being under-estimated. The volatiles lost are all organic compounds, have a high energy content and are considered to be completely digestible. In this case, DM and OM are the same (for volatile compounds). As more laboratories take volatile losses into account, the estimated ME values reported for silages have increased and are more accurate.

Correction for the loss of volatile compounds can have a significant impact on the estimated ME value for low DM silages (<30%) – the adjustment can be as great as 0.8-1.0 MJ/kg DM. However, with higher DM silages (e.g. 50%) the correction is much smaller and of the order of 0.1-0.2 MJ/kg DM.

Check if feed test results have been corrected for volatile losses. If not, seek the advice of a nutritionist.

12.4.3 *Fibre analyses*

In general, increased fibre content of a forage is associated with decreased digestibility and intake, and subsequently lower animal production. As a result, fibre content has been used as an indicator of feed quality and digestibility for various classes of feeds, including silage (see Figure 12.8). Table 12.1 summarises the ranges in digestibility, ME and fibre content that are likely to be seen in Australian silages.

The fibre fraction contains a range of compounds that are linked in various combinations to form the wall of individual plant cells in the forage. Individual fibre fractions can be identified using a series of chemical analyses according to the Van Soest classification system (see Figure 12.8).

Neutral Detergent Fibre (NDF)

The NDF content provides an estimate of the total cell wall content of forage. It consists of hemicellulose and the remaining fibre included in the acid detergent fibre (ADF) fraction (cellulose and lignin). Hemicellulose is partially digested by ruminants. There is evidence from some studies that feed intake in ruminants declines with increasing NDF in the forage, although results have been variable.

Acid Detergent Fibre (ADF)

The ADF fraction consists of cellulose and lignin. Cellulose is partially digested by ruminants while lignin is effectively indigestible. Lignin also forms protective barriers around the cellulose and hemicellulose components reducing their digestion. The ADF fraction also contains some unavailable (bound) nitrogen.

Digestibility of feeds declines with increasing ADF. Hence, a number of prediction equations have been developed to estimate the digestibility of forages from ADF content (often in combination with other chemical components). These are routinely used in the United States.

A modified ADF method (MADF) is often used in Europe. This method removes most of the bound nitrogen and has been reported to improve the accuracy of the relationship between fibre content and digestibility.

There is no need to measure ADF (or MADF) when *in vitro* digestibility is determined. *In vitro* digestibility is generally a more accurate predictor of the digestibility of forages in animals than ADF.

While increasing fibre content leads to a reduction in animal production, ruminants require some dietary fibre for normal rumen function (see Chapter 13, Section 13.4.2). To avoid a depression in milk fat content, minimum fibre requirements have been set for dairy cows:

	ADF in diet %	NDF in diet %
First 3 weeks of lactation	21	28
Peak milk production	19	25

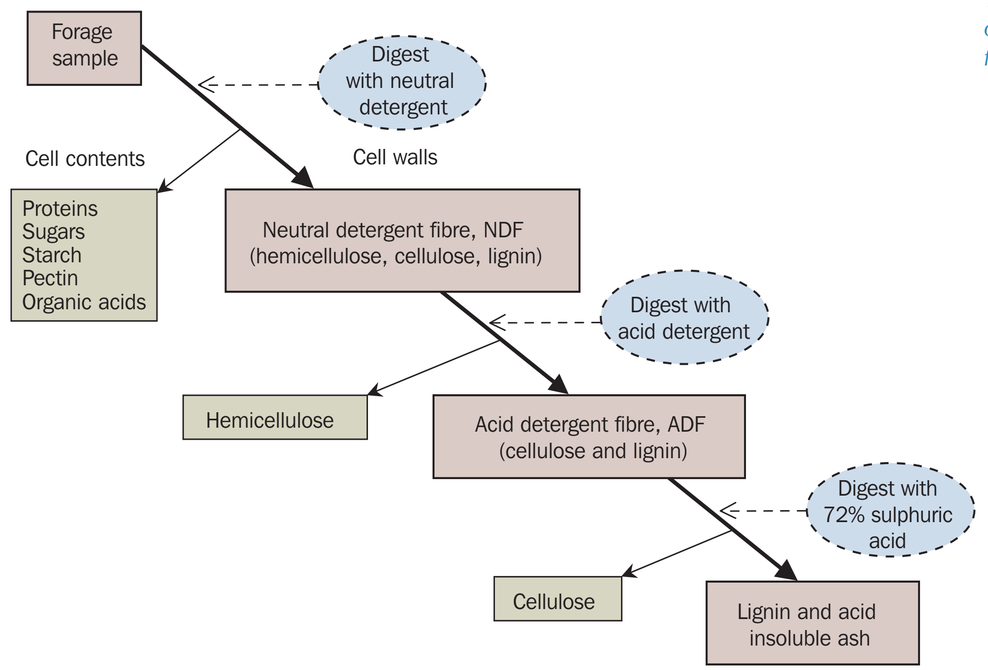
These levels, which are based on American feeding standards from the National Research Council, can be increased as lactation progresses to avoid depression of milk fat. Seventy-five per cent (75%) of the NDF in the diet should be supplied from forages. The reader is referred to a dairy nutrition publication for a more detailed coverage of this topic.

Table 12.1

The range of ME content, digestibility and fibre contents (NDF and ADF) seen in Australian silages.

Quality measure	Quality Range Low	Quality Range High
ME (MJ/kg DM)	6.7	11.3
Digestibility (DOMD), %	42	72
Neutral detergent fibre (NDF), %	72	32
Acid detergent fibre (ADF), %	47	25

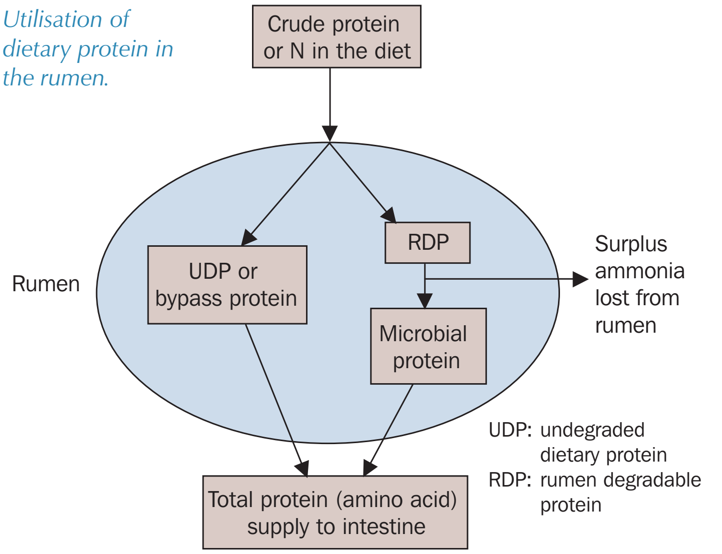
Figure 12.8



The Van Soest classification of the fibre fraction of feeds.

Figure12.9

Utilisation of dietary protein in the rumen.



The total nitrogen or crude protein content of a diet does not indicate the degradability of the protein or the extent to which it is utilised by the animal.

12.4.4

Protein analyses

Although ME, rather than protein, is usually the first limiting nutrient in forage-based diets for ruminants, inadequate protein levels can limit animal production. For sound nutritional management, it is important to know the protein content of each component of the diet. Feed testing laboratories determine the total nitrogen (N) content of silages and other feeds and estimate crude protein (CP) content by multiplying by 6.25:

CP % = N % x 6.25

The crude protein (CP) content of silage

- Although not usually the first limiting nutrient in most ruminant diets, inadequate crude protein (CP) levels will limit animal production.
- The protein in silage usually has a high rumen degradability.
- Some of the nitrogenous compounds in silage are volatile and are lost if the sample is oven dried, so silage CP content will be under-estimated. Check whether your feed testing laboratory conducts their silage analyses on fresh or oven dried samples.
- If it is suspected that the silage may have suffered heat damage during the ensiling process (see Chapter 2), this can be assessed by an analysis of the acid detergent insoluble nitrogen (ADIN) content of the silage.

A large proportion of the crude protein, often 90% or more for silages, is degraded in the rumen. This fraction is referred to as rumen degradable protein (RDP) (see Figure 12.9). Ruminants need adequate RDP in the diet to sustain normal microbial activity and digestive function in the rumen. How much RDP is needed is directly related to the quantity of fermentable ME supplied to the rumen by the diet.

As feed is digested in the rumen by the action of rumen microbes, the dietary RDP is utilised by the microbes and converted to microbial protein. This is subsequently digested in the intestine, and supplies a substantial component of the animal's protein requirement. A balanced supply of energy and RDP in the rumen improves the efficiency of microbial protein production. Inadequate RDP will result in a reduced rate of digestion in the rumen. A surplus (even a temporary one) of RDP, although not harmful, may result in less efficient utilisation of nitrogen with the surplus being wasted and excreted by the animal (see Figure 12.9).

The remaining proportion of dietary protein that escapes digestion in the rumen is known as undegraded dietary protein (UDP) or bypass protein. This protein, together with the microbial protein, is digested in the intestine to meet the animal's protein requirements. Production in lactating and young, rapidly growing ruminants can be limited if they have to rely almost entirely on the microbial protein produced from RDP to meet their protein requirements. In these cases protein supplements providing sources of UDP (e.g. cottonseed meal) can increase production.

Few laboratories currently provide estimates of RDP and UDP for feed samples, and nutritional advisers usually rely on 'book' values for various feed categories when formulating diets.

Effect of the loss of volatile compounds on the accuracy of crude protein analyses

As indicated earlier, the oven drying of silages will result in the loss of some of the volatile nitrogen compounds in the silage, so that nitrogen or crude protein content will be under-estimated. A study with 10 silages at NSW Agriculture's Feed Evaluation Service in 1993 showed that the under-estimation of the true crude protein analysis varied from 0.2 to 2.2 percentage units.

Similar results were obtained in a UK study with five low DM (16-20%) ryegrass silages (see Table 12.2). In this study, volatile nitrogen losses also occurred in freeze-dried samples.

The size of the error will vary from silage to silage. It is likely to be greater when the silage protein content is high, and when silage DM content is low and the silage is poorly preserved (has a higher pH).

The under-estimation of the crude protein content of silages can be a significant problem for livestock producers who rely on feed tests to determine whether they need to buy protein supplements. The cost of purchased protein meal needed to raise the crude protein content of a silage-based diet by 1% unit is presented in the example at right.

Clearly, producers need an accurate assessment of silage crude protein content when formulating diets. This will be achieved when crude protein analyses are conducted on fresh silage samples. Producers should ask their feed testing laboratory whether the crude protein analyses reported are based on a fresh or an oven-dried sample. Research is in progress to determine if a correction equation can be developed to account for these losses.

Where analyses are based on dried samples, some allowance has to be made for the loss of nitrogen. In production feeding situations where the crude protein content of the diet appears to be borderline, and the silage comprises a significant proportion of the diet, it is recommended that producers seek nutritional advice on the need for protein supplementation.

The cost of boosting crude protein content

To calculate the cost of raising the crude protein (CP) content of a silage-based diet by 1% unit:

Silage CP content = 11% (DM basis)

Target CP content = 12% (DM basis)

Cottonseed meal CP content = 40% (DM basis)

Cottonseed meal required:

35 kg (DM basis) for each tonne of silage DM

DM content of cottonseed meal = 90%

Therefore, 39 kg cottonseed meal required (as fed basis) (35 x 100/90)

- Cottonseed meal @ $470 /tonne
- Cost of raising CP content of each tonne silage DM by 1% unit

$$= 470 \times \frac{39}{1,000}$$

= $18.33

Table 12.2

Effect of sample preparation method on the estimated crude protein content (% DM) of five ryegrass silages.

Silage	pH	Estimated crude protein (% DM) Fresh sample	Oven dried	Freeze dried
1	4.2	14.1	12.4	13.3
2	5.4	13.5	13.5	12.4
3	3.6	14.0	13.7	13.4
4	5.6	21.4	16.5	16.4
5	5.2	19.0	12.8	11.8
Mean		16.4	13.8	13.4

Source: Based on Wilkins (1974)

Using acid detergent insoluble nitrogen (ADIN) to assess heat damage

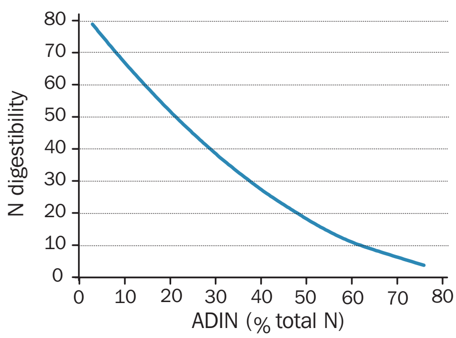
A small proportion of the nitrogen in forages is naturally bound (in the ADF fraction) and will be unavailable to the animal. This can be measured in the laboratory as ADIN. It may also be expressed as acid detergent insoluble protein (ADIP):

ADIP % = ADIN % x 6.25

When heating occurs during the ensiling or hay-making process, heat damage to the protein increases the level of bound nitrogen, and results in a significant increase in ADIN. The risk of heat damage is greatest when forage DM >50% and compaction is poor. Heating results in a significant reduction in digestibility, particularly nitrogen digestibility, which declines markedly with increasing ADIN content (see Figure 12.10). Despite this reduction in digestibility, heated silages are often quite palatable to ruminant livestock.

Figure 12.10

Effect of increasing acid detergent insoluble nitrogen (ADIN) content due to heat damage on the digestibility of nitrogen (N) in lucerne silages and hays fed to sheep.



Source: Yu and Thomas (1976)

The ADIN content of silage can be used as a guide to the extent of heat damage. For well-preserved silages the ADIN content is usually in the range 0.10-0.25% of DM. In the United States, the ADIN content of hays and silages is sometimes expressed as a % of total nitrogen to give an estimate of the % of nitrogen (or crude protein) that is 'bound':

% of total N (or CP) 'bound'	Heat damage
<12%	Little or none
12-15%	Some heating
>15%	Extensive heating

In the case of silages with low crude protein (e.g. maize and some cereals) the calculation of % 'bound' may give higher values, and it is unclear whether the above guidelines are appropriate for these crops.

12.4.5

Silage fermentation quality

The type of silage fermentation influences the losses during fermentation and the intake of the silage by livestock (see Chapter 2, Section 2.2.2). A poor silage fermentation produces an unpalatable silage and, irrespective of its ME and crude protein content, DM intake and utilisation of silage nitrogen by the animal will be reduced.

For silage intake to be similar to that of the parent forage, the following characteristics should apply:

- ammonia-N: ≤5% of total N;
- acetic acid: ≤2.5% of DM; and
- other volatile fatty acids: approximately nil.

Ammonia-N is widely recognised as a key indicator of silage fermentation quality.

For a comprehensive appraisal of the fermentation quality, a full analysis of the silage fermentation products – lactic acid, volatile fatty acids, alcohols and ammonia nitrogen – will be needed. Such analyses are currently too expensive to justify their routine use in a feed testing laboratory in Australia and are usually confined to research samples. However, these more detailed analyses are available to European farmers with the use of NIR technology. Future development of the local calibrations may allow this information to become routinely available to Australian famers. In the meantime, feed testing laboratories can provide silage pH and ammonia-N, which are useful indicators of silage fermentation quality.

Silage pH

Silage pH is a measure of silage acidity and hence the extent of the fermentation (see Chapter 2, Section 2.2.2). Silage pH is influenced by:

- DM content of the forage ensiled. As DM content increases bacterial growth is restricted and less acid is produced, so wilted silages have higher pH values.
- Sugar content of the forage ensiled. At any given DM content, silage bacteria can produce more acid if sugar content is high. Therefore, forages with a high sugar content produce silages with a lower pH.
- The type of silage fermentation. The preferred lactic acid fermentation will produce silage with a lower pH.

Silage fermentation quality

- After ME content, silage fermentation quality is probably the most important measure of silage quality influencing animal production.
- A poor silage fermentation (see Chapter 2) will result in an unpalatable silage, and even if ME and crude protein content are high, intake and animal production will be low on these silages.
- The protein fraction is extensively degraded in a poorly preserved silage, so high ammonia-N (as a % of total nitrogen) in a silage indicates a poor fermentation. Ammonia-N is an excellent guide to silage fermentation quality, with levels ≤10% of total nitrogen indicating a good silage fermentation.
- Silage pH can also provide a guide to silage fermentation quality for silages with a DM content ≤35%.
- The risk of a poor silage fermentation can be minimised by good silage management (see Chapters 2, 6 and 7).

Table 12.3

Use of silage pH as a guide to silage fermentation quality.

Silage DM content (%)	High probability of poor fermentation if pH exceeds: Grasses	Legumes*
15	4.10	4.20
20	4.20	4.30
25	4.35	4.50
30	4.50	4.70
35	4.65	4.80

* *Tropical grasses with low sugar content, such as kikuyu grass, can be included in this category (see Chapter 2).*

DM content should be considered when using silage pH as a guide to silage fermentation quality. When DM is low, pH values of well-preserved silages are usually in the range 3.5-4.2. Table 12.3 gives guidelines on upper limits for pH in silages of different DM contents. If silage pH exceeds these limits there is a high probability that the silage has been poorly preserved. For silages with DM contents of >35%, pH is not considered to be a useful guide to fermentation quality.

Table 12.4

Use of silage ammonia nitrogen content as a guide to silage fermentation quality.

Ammonia-N (% total silage N)	Silage fermentation quality
<5	Excellent
5-10	Good
10-15	Moderate
>15	Poor

Source: Wilkinson (1990)

Ammonia nitrogen

Ammonia-N, expressed as a percentage of the total nitrogen in the silage, is an excellent guide to silage fermentation quality. High ammonia-N is seen in poorly preserved silages and indicates extensive degradation of the forage protein during the ensiling process (see Chapter 2). Feed testing laboratories in Europe and the UK routinely provide ammonia-N values to producers.

Silage intake by ruminants declines with increasing ammonia-N content. In addition, the animals' utilisation of the silage nitrogen/protein is poor due to the rapid degradation of nitrogen in the rumen.

Table 12.4 shows how ammonia-N can be used as a guide to silage fermentation quality. In well-preserved silages, with an ammonia-N of ≤5% of total nitrogen, the intake of the silage is likely to be similar to that of the parent forage. In poorly preserved silages, ammonia-N can be as high as 50% of the total nitrogen.

While most emphasis has been placed on ammonia-N content as the most extensively degraded component of the silage N, there has been some focus on the importance of other N components in silage. It is widely accepted that, in well-preserved silages, the proportion of protein N should be high (soluble N <50% of total N). Recent research indicates that the degree of protein degradation during the ensiling process may explain the difference in animal production between apparently well-preserved silages with low ammonia-N content (see Chapter 7, Section 7.4.3; Chapter 13, Section 13.4.1; and Chapters 13 and 14). Improved liveweight gain has been observed in silages with lower levels of free amino acids. If further experiments confirm these results, free amino acids may be included in feed test analyses on silages.

12.5

Appendices

12.A1

Composition of Australian hays and silages

Table 12A.1

Composition (mean and range) of Australian hays and silages analysed by a feed testing laboratory over a five-year period, 1996/97 to 2000/01.

Forage type	No. of samples	Crude protein (% DM)		DM digestibility (%)		Estimated ME (MJ/kg DM)	
Hays							
Legume	3,496	18.2	(6.1–30.7)	64.9	(39.1–79.9)	9.2	(5.0–11.7)
Legume/grass (legume dominant)	2,238	14.8	(4.1–25.4)	62.5	(39.0–77.3)	8.9	(5.2–11.2)
Grass/legume (grass dominant)	3,365	11.2	(2.9–24.5)	61.1	(45.0–77.4)	8.6	(5.7–11.2)
Grass	260	8.5	(1.4–17.7)	58.9	(45.2–69.9)	8.3	(6.2–9.9)
Cereal	4,741	7.3	(1.2–13.4)	60.0	(32.9–76.6)	8.4	(4.2–9.7)
Cereal/legume	707	10.1	(3.5–23.0)	61.6	(40.9–75.2)	8.7	(5.5–10.8)
Silages							
Legume	258	18.8	(6.3–27.2)	66.7	(46.1–76.3)	9.5	(5.8–11.2)
Legume/grass (legume dominant)	710	16.2	(8.6–24.7)	66.3	(42.9–77.1)	9.5	(5.9–11.1)
Grass/legume (grass dominant)	3,124	14.4	(5.2–27.3)	66.1	(39.9–80.2)	9.4	(4.8–11.6)
Grass	321	13.3	(5.2–25.1)	64.9	(48.0–76.7)	9.3	(6.7–11.1)
Cereal	467	10.3	(3.2–24.0)	62.4	(43.8–76.7)	8.8	(5.5–11.2)
Cereal/legume	189	11.8	(5.5–20.8)	62.9	(43.3–74.8)	8.9	(5.4–10.9)
Maize	531	7.8	(3.3–16.5)	69.1	(50.6–78.0)	10.5	(7.2–12.4)

Source: FEEDTEST Service, Victorian Department of Primary Industries

12.A2

Interpreting feed analysis results for problem silages

Silages 1 to 3

Test	1: Lucerne		2: Maize		3: Phalaris-dominant pasture	
	Test results	Target	Test results	Target	Test results	Target
Oven DM (% fresh)	55.0	35-50	46.0	33-38	41.2	Acceptable
True DM (% fresh)	55.7	35-50	47.2	33-38	42.7	Acceptable
Crude protein (% DM)	16.5	18-24	5.8	Acceptable	8.7	12-16
Digestibility of DM (%)	58.8	60-67	62.0	64-71	54.9	63-70
Estimated ME (MJ/kg DM)	8.8	9-10	9.7	10-11	8.2	9.5-10.5
pH	5.7	Acceptable	3.9	Acceptable	4.3	Acceptable
Ammonia-N (% total N)	9.1	Acceptable	8.5	Acceptable	8.7	Acceptable

Areas where the test results indicate silage quality is less than ideal

Preferred ranges for this silage if well managed

Interpretation:

Silage 1. A baled lucerne silage harvested at the late bud stage. It has been overwilted, as indicated by the high DM content, and this has resulted in increased field losses. Hence the ME and crude protein content are lower than expected.

Silage 2. A direct cut maize crop that has been harvested with a forage harvester, at a milk line score (MLS) of 4. The high DM content indicates that this maize crop has been harvested too late. ME content is low because of the late harvest. Difficulty in compacting the drier forage could also have led to higher in-silo losses and a further reduction in ME. (Note: Compared to other silages here, a different calculation method has been used to estimate the ME content of maize silage from DM digestibility.)

Silage 3. A baled phalaris silage cut when in head. This pasture has been cut too late and as a result both ME and crude protein are low.

Silages 4 to 6

Test	4 – Clover dominant pasture		5 – Ryegrass/ white clover		6 – Kikuyu grass	
	Test results	Target	Test results	Target	Test results	Target
Oven DM (% fresh)	19.0	35-40	22.0	30-40	28.0	35-40
True DM (% fresh)	21.8	35-40	24.6	30-40	30.3	35-40
Crude protein (% DM)	17.2	Acceptable	16.5	Acceptable	16.2	Acceptable
Digestibility of DM (%)	72.7	Acceptable	74.6	Acceptable	64.8	Acceptable
Estimated ME (MJ/kg DM)	10.9	Acceptable	11.2	Acceptable	9.7	Acceptable
pH	5.2	<4.3	4.0	Acceptable	5.2	<4.5
Ammonia-N (% total N)	18.2	<10	9.2	Acceptable	22.3	<10

Areas where the test results indicate silage quality is less than ideal

Preferred ranges for this silage if well managed

Interpretation:

Silage 4. Clover silage harvested with a precision chop forage harvester in early spring. This silage has not been adequately wilted, as indicated by the low DM level. This has resulted in poor fermentation quality, as indicated by the high ammonia-N and pH (see Table 12.3). Effluent losses would be high from this silage.

Silage 5. A ryegrass/white clover silage harvested before ear emergence in the ryegrass, using a precision chop forage harvester. Although this precision chopped silage has not been adequately wilted, the silage fermentation quality has not suffered. However, there would be significant effluent losses.

Silage 6. This precision chopped kikuyu silage was produced from 28-day regrowth pasture. The kikuyu was wilted slowly over two days under difficult wilting conditions. The ME and crude protein contents are within the normal range for kikuyu grass cut at the correct stage of growth. However, the DM content is lower than the target of 35%. Silage fermentation quality has suffered (high ammonia-N and pH) as a result of the slow rate of wilt.

Chapter 13

Feeding silage to dairy cows

Chapter 13

Feeding silage to dairy cows

In this chapter

The authors

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The Key Issues

- When assessing the role for silage on a dairy farm, it is important to have clear management goals and to consider wider productivity issues such as whole farm productivity, overhead costs and costs/litre milk produced (see Chapters 1 and 11).
- High-quality silage can be produced from a range of crops and pastures. Silage production can also be a valuable pasture management tool (see Chapter 3).
- The digestibility or ME content of a silage is the most important factor influencing the milk production response to silage. Producers should aim at an ME content of 10 MJ/kg DM, or better.
- Good preservation is required if silage intake is to reach its potential. If wilting is required to improve the silage preservation, it must be a rapid wilt or potential milk production improvements may not be achieved.
- Shorter chop lengths will improve silage preservation, allow better compaction, reduce fermentation and storage losses, and will sometimes directly improve milk production.
- Additives can improve silage fermentation and milk production per tonne of silage in some instances.
- When silage is a major component of the diet, insufficient access time or available space during feedout can reduce intake. Accessibility could be important in all systems, particularly baled silage systems.
- Supplementation of grazing cows with silage needs to minimise any substitution of silage for pasture, which will reduce the response to silage and result in under-utilisation of available pasture.
- When formulating silage-based diets, the provision of adequate protein, fibre and minerals should be monitored.

Section 13.0

Introduction

The emphasis in previous chapters has been on good silage conservation practices to ensure the production of high-quality silage, with minimal losses during field wilting, storage and feeding. (Quality is a generic term used here to encompass all the attributes of a silage that determine its nutritive value for animals.) This chapter focuses on the role for silage in dairy cow diets and its impact on milk production.

More detailed information on dairy cow nutrition is available from other publications, however, examples of the nutrient requirements of various classes of dairy livestock are provided in Appendix 13.A1. Information on basic feed evaluation and the assessment of the nutritive value of silages is provided in Chapter 12.

Before deciding how silage will be integrated into their production system, producers need to clearly define their production and management goals. The various roles for silage on dairy farms, and the possible effect of silage on whole farm productivity are covered in greater detail in Chapters 1 and 11.

Plate 13.1

Silage has an important role on dairy farms as a pasture management tool, even on the tropical pasture shown here. There are significant opportunities to improve the utilisation of pasture grown and to improve milk production (see Chapter 4, Section 4.9). *Photograph: M. Martin*

On most farms, the two main roles for silage are to:

- improve the feed supply, allowing increased supplementary feeding, and/or carrying capacity; and
- improve the management and utilisation of pastures and forage crops.

The value of silage in a dairy farm system is very much dependent on its quality, as this determines the potential milk production per tonne silage DM, and subsequently profitability (see Chapter 11, Section 11.3.1).

Silage and other dietary components should be tested to ensure that nutritional requirements are met. It is important that the feed testing be done well before each feed is given to the animals so that the necessary adjustments can be made to the ration. This is particularly important if the quality of the feed is lower than expected and additional supplements have to be purchased. Late identification of quality problems not only means production may be lost, it means there is less opportunity to source cheap supplements.

Section 13.1

Milk production potential of silage

Silage is usually included in the diet with other feeds and, because of interactions between various dietary components, it is not always easy to accurately estimate its contribution. However, in the studies summarised in Table 13.1, cows were given silage as the sole feed. The high-quality ryegrass silages had an estimated mean ME content close to 11 MJ/kg DM, and sustained a milk production of 1,284 kg/t silage DM or 1.28 kg/kg silage DM.

Higher milk production levels can be sustained when cows are fed mixed silage/concentrate diets. In the study in Table 13.2, cows were given 7.6 kg concentrate pellets/cow/day, and fed ryegrass silages harvested after regrowth intervals of either 5, 7 or 9 weeks. All diets supported high levels of milk production, although production declined and liveweight loss increased when cows were fed the later-cut, lower-quality silage.

Silages can be made from a wide range of pastures and crops in Australia (see Chapters 4 and 5). In many cases, with good management, it is possible to produce silages with a ME content of 10 MJ/kg DM, or higher. When supplements are used to remove differences in silage protein content, it is essentially the ME content of the silage, rather than the type of crop or pasture from which it is made, that drives milk production.

Few studies have compared milk production when silages made from a diverse range of crops were fed to cows. In one such American study (see Table 13.3), various mixtures of silage were fed to mid-lactation cows with 36% concentrates in the diet. Each combination sustained good levels of milk production. The higher digestibility of the pea/triticale and maize silage diet supported higher milk production, milk fat content and milk fat production. The lower milk protein content and the weight loss on the pearl millet/lucerne silage diet was probably related to the lower intake.

Table 13.1

Milk production from cows given high-digestibility ryegrass pasture silage as the sole dietary component.

	Mean (8 silages)	Range
Silage DM content (%)	26.7	23.2-31.6
Digestibility of OM in the DM (DOMD, %)	70.2	68.3-71.2
Silage pH	3.96	3.79-4.24
Silage DM intake (kg/day)	11.3	10.4-12.8
(% live weight)	2.41	2.28-2.58
Milk production (kg/day)	14.4	13.3-16.0
(kg/t silage DM)	1,284	1,154-1,452
Milk fat (kg/day)	0.61	0.56-0.65
Milk protein (kg/day)	0.44	0.39-0.52

Source: Castle (1982)

Table 13.2

Milk production from cows given ryegrass silages, harvested after various regrowth intervals, and concentrates.

	Regrowth interval (weeks) 5	7	9
Silage composition:			
DM content (%)	22.4	25.7	22.8
pH	3.9	3.8	3.9
Ammonia-N (% total N)	7.4	8.5	10.3
Estimated ME (MJ/kg DM)	11.4	10.9	9.7
Intake:			
Silage (kg DM/day)	10.7	10.0	8.1
Concentrate (kg DM/day)	7.6	7.6	7.6
Total (kg DM/day)	18.3	17.6	15.7
Animal production:			
Milk production (kg/day)	28.3	28.3	26.4
Liveweight change (kg/day)	-0.10	-0.15	-0.24

Source: Adapted from Gordon (1980)

Table 13.3

Milk production from mid-lactation cows given diets based on various silages. Each diet contained 36% concentrates.

	Field pea/triticale (50%) + Maize (15%)	Pearl millet (48%) + lucerne (13%)	Lucerne (34%) + maize (33%)
Diet DM digestibility (%)	71.1	66.8	66.9
DM intake (kg/day)	22.6	19.5	23.8
Milk production (kg/day)	25.2	23.2	24.5
Milk fat (kg/day)	1.15	0.84	0.82
Milk protein (kg/day)	0.85	0.75	0.84
Liveweight change (kg/day)	+0.40	-0.04	+0.78

Source: Messman et al. (1992)

Section 13.2

Factors affecting milk production from silage

Over a range of studies, the value of a 1% unit increase in digestibility appears to be about 0.35 kg milk/cow/day, or approximately 1.1 kg milk/cow/day for each 0.5 MJ/kg DM increase in silage ME content.

To ensure good milk production responses from silage, producers need to aim at a ME content of ≥10 MJ/kg DM.

13.2.1

Silage digestibility or ME content

Effects on milk production

The digestibility or ME content of a silage is the most important factor influencing the milk production response to it. An increase in silage digestibility will increase milk production (see Figure 13.1) by improving intake and the utilisation of nutrients in the silage (see Table 13.4).

The size of the increase in Figure 13.1 and Table 13.4 was an additional 0.24 or 0.37 kg milk/cow/day respectively, for each one percentage unit increase in digestibility (digestibility of organic matter in the dry matter [DOMD], see Chapter 12, Section 12.4.2). Other reviews have shown mean responses to vary between 0.23 and 0.39 kg milk/cow/day, and individual experiments have shown responses up to 0.7 kg milk/cow/day. In some studies the response to increasing digestibility has been small, but this has usually occurred where silages have been poorly preserved, with the poor fermentation quality masking the effect of digestibility.

In mixed dairy diets, the benefits of higher silage digestibility can be increased milk production, a reduction in the quantity of concentrates fed, or a combination of the two, all improving management flexibility.

The reduction in concentrate use can be quite significant. The mean results from six studies (see Table 13.4) indicate a possible reduction of 0.67 kg concentrate/cow/day for each percentage unit increase in silage digestibility, or approximately 2.1 kg concentrate/cow/day for each 0.5 MJ/kg DM increase in ME content.

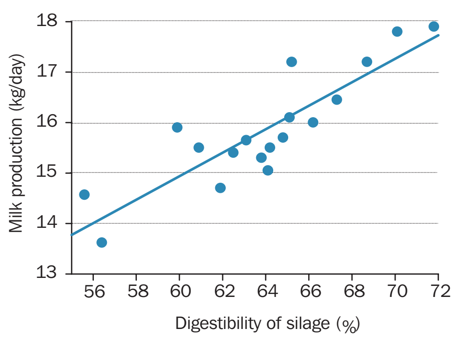
This principle is demonstrated in Table 13.5 for a mixed silage and concentrate diet. The high-digestibility silage system (3 cuts per season) supported higher levels of milk production per cow, and allowed a similar level of milk production at a low level of concentrate input to that obtained on the low-digestibility silage at a high level of concentrate input. However, in this study total forage yield over the whole season was higher for the low-digestibility system (2 cuts per season). The total milk output needs to be weighed against the cost of production to determine the most profitable option (possibly the lower-quality silage in this example).

Heavy concentrate feeding can compensate for lower silage digestibility to some extent, but at a cost. Ultimately economic factors, including milk price and the relative costs of silage and concentrates, will determine the most profitable system.

The computer program RUMNUT has been used to estimate the impact of silage ME content on milk production in an Australian pasture-based dairy system.

Figure 13.1

Relationship between silage digestibility (in vitro digestibility of organic matter in the DM) and milk production for cows given grass silages with concentrates.



Source: Castle (1982)

Table 13.4

Effects of each 1% unit increase in the digestibility of ryegrass silage on intake, milk production and the requirement for concentrate supplements.

Increase in intake (kg DM/cow/day)	0.16
Increase in milk production (kg/cow/day)	0.37
Reduction in concentrate use possible when maintaining constant milk production (kg DM/cow/day)	0.67

Source: Gordon (1989)

Table 13.5

Milk production from cows given high or low-digestibility ryegrass silages with high or low levels of concentrate supplementation.

	High-digestibility silage		Low-digestibility silage	
	High concentrate	Low concentrate	High concentrate	Low concentrate
Total forage yield (t DM/ha)	9.4		11.3	
Mean digestibility of organic matter (% DM)	69.0		62.1	
Silage intake (kg DM/day)	8.62	10.83	8.47	10.3
Concentrate intake (kg DM/day)	8.32	4.19	8.34	4.23
Milk production (kg/day)	21.6	19.6	19.5	16.2
Liveweight change (kg/day)	0.47	0.32	0.40	0.20

Source: Moisey and Leaver (1980)

Two scenarios were tested. In the first, cows were in early lactation and grazing perennial pastures in spring; in the second, cows were in mid-lactation and grazing annual pastures in autumn. In each case, cows were fed either a good-quality silage (DM 30%; ME 10 MJ/kg DM; crude protein 17%) or a lower-quality silage (DM 30%; ME 9 MJ/kg DM; crude protein 14%). The estimated milk production (see Table 13.6) clearly demonstrates the significant advantage in favour of the higher ME silage.

The huge range in quality of the silages being produced is identified in Chapter 12, Appendix 12.A1. This range highlights the production potential many producers are losing because of poor silage-making practices.

Three key factors influence silage digestibility:

- the pasture or crop species used for silage production;
- the stage of growth at cutting; and
- losses that occur during the conservation process.

The potential ME content that can be achieved for the diverse range of pastures and crops grown in Australia, and their optimum stage of growth for cutting for silage, are discussed in Chapters 4 and 5.

The losses in nutritive value during the conservation process can be minimised by good management. This is covered in more detail in Chapters 2, and 6 to 10.

Table 13.6

Milk production predictions using the program RUMNUT showing the effect of silage quality on estimated milk production from dairy cows in a pasture-based grazing system.*

	Fresh feed intake (kg/day)	DM intake (kg/day)	Diet ME (MJ/kg DM)	Diet crude protein (% DM)	Milk production (kg/day)
Early lactation cows grazing restricted perennial pastures (30 kg fresh/day) in spring, and receiving 5 kg crushed triticale and 30 kg fresh silage/day:					
Poor-quality silage*	65	18.0	10.8	15.4	27.2
Good-quality silage**	65	18.0	11.3	16.9	29.8
Mid-lactation cows grazing limited annual pastures (15 kg fresh/day) in autumn, and receiving 5 kg crushed triticale and 40 kg fresh silage/day:					
Poor-quality silage*	60	18.9	10.1	14.1	22.3
Good-quality silage**	60	18.9	10.7	16.1	25.6

Note: A summary of the analyses of the silages is in the text above.

** Poor-quality silage: ME 9 MJ/kg DM.*

*** Good-quality silage: ME 10 MJ/kg DM.*

** RUMNUT program: Chamberlain and Wilkinson (1996)*

Table 13.7

Effect of time and length of closure of perennial ryegrass/white clover pasture on silage quality, intake, milk production and liveweight change.

Date of closure	Early (23 Sep)		Late (13 Oct)	
Duration of closure (weeks)	4	6	4	6
Silage DM content (%)	39	35	43	51
Silage DM digestibility (%)	73.5	71.6	69.2	66.1
DM intake (kg/day)	15.3	14.1	15.6	14.2
Digestible DM intake (kg/day)	11.2	10.1	10.5	9.6
FCM* (kg/day)	12.2	11.3	11.2	10.0
Liveweight change (kg/day)	1.2	0.9	1.4	0.7

** Fat Corrected Milk.*

Source: Rogers (1984)

Importance of stage of growth at harvest

The importance of cutting at an early growth stage, or after a short pasture regrowth interval, to produce a high-quality silage, has been highlighted in Chapters 4 and 5, and earlier in this chapter for ryegrass-based silages (see Tables 13.2 and 13.5). It is the primary factor governing an increase in milk production from silage.

Table 13.8

Effect of stage of maturity at cutting on relative milk production (early flower = 100%) from lucerne hays and silages.

Level of concentrate in diet (% of DM intake)	Stage of maturity at cutting: Bud	Early flower	Mid flower tofull bloom
Low (20-30%)	109	100 (26.3)*	81
High (37-54%)	105	100 (30.3)*	91

** Mean milk production (kg/cow/day).*

Source: Adapted from review by Kaiser et al. (1993)

Table 13.9

Milk production from wilted wheat silage harvested either at flowering or at the milk stage of growth.

	Stage of growth at harvest: Flowering	Milk
Silage composition:		
DM content (%)	30.1	37.9
Crude protein (% DM)	6.5	6.4
In vitro digestibility (% DM)	60.9	58.1
Animal production:		
Milk production (kg/day)	36.0	32.8
Milk fat content (%)	2.45	2.79
Milk protein content (%)	2.97	2.98

Source: Arieli and Adin (1994)

A study at Ellinbank (Victoria), compared the milk production from four silage-cutting strategies using perennial ryegrass/ white clover pasture (see Table 13.7). The silages were cut after being closed either early or late, with closure periods of either four or six weeks. The silages were wilted and harvested with a precision chop forage harvester, and fed to mid-lactation cows with a freshly cut pasture (of 71% DM digestibility) providing 25% of the diet. Early closure and short lock-up increased DM intake, milk production and liveweight gain. The improvement in animal production was related to an increased intake of digestible DM.

Studies in the United States have shown that time of cut is also important with lucerne silage and hay, with early cutting at the bud stage supporting higher levels of milk production than cutting after flowering (see Table 13.8).

Earlier cutting of a wheat crop at the flowering stage, compared to the milk stage (11 days later), was also shown to increase milk production in an Israeli study (see Table 13.9). In this study the wheat silage made up approximately 32% of the diet.

The trade-off between yield and quality is a key issue when considering cutting strategies within a whole farm context. When deciding on the optimum time of cut, producers need to consider:

- The yield and quality of the silage harvested.
- The wider whole farm impact on the production and utilisation of forage (grazed + ensiled) on both the cut and uncut areas, and over the whole season/ year (see Chapter 3).
- The requirement for purchased supplementary feeds.
- The impact on total milk output from the farm. This then needs to be compared with the cost of production to identify the most profitable production strategy (see Chapter 11).

The economic importance of silage quality on a dairy farm, highlighted in Chapter 11, Section 11.3, has a significant influence on profitability. Using the data from Table 13.6, the higher-quality silage would produce an estimated $85 more in milk per tonne DM.

Few studies have investigated the whole farm implications of varying cutting time. However, a large dairy farm survey (2000 herds) in the UK showed that the margin over feed and fertiliser costs, on both a per cow and per hectare basis, increased with an increase in silage ME (see Chapter 11, Table 11.8), and when silage was cut earlier in the season (see Table 13.10). This valuable study demonstrates clearly that aiming for high quality by cutting earlier can have an impact on profitability at the whole farm level.

While earlier cutting for silage can often produce a lower silage yield, this is usually offset by a larger amount of regrowth available for grazing following an earlier cut, prolonging the vegetative growth stage of the pasture/forage crop and increasing utilisation of the forage grown.

Under Australian conditions the benefits of silage as a pasture management tool are likely to be greater with earlier cutting (see Chapter 3).

Choice of cutting date needs to take account of a number of management factors, with the effect on profitability best evaluated using an economic model or decision aid (see Chapter 11, Sections 11.5 and 11.6).

Table 13.10

Effect of date of first cut on margin per cow and margin per ha on dairy farms in the UK.

Date of first cut	% of herds	Margin over feed and fertiliser	
		£/cow ($A/cow)	£/ha ($A/ha)
Early cut*	2	692 (1,972)	1,688 (4,811)
Cut up to 7 days later	14	674 (1,921)	1,537 (4,380)
Cut 8-14 days later	29	660 (1,881)	1,511 (4,306)
Cut 15-21 days later	33	659 (1,878)	1,523 (4,341)
Cut 22-28 days later	18	648 (1,847)	1,439 (4,101)
Cut more than 28 days later	4	618 (1,761)	1,273 (3,628)

** Cut before 10 May (spring in the UK).*

Conversion at £1=$A2.85.

Source: Poole (1989)

13.2.2

Silage fermentation quality

Poorly preserved silages are unpalatable to animals and depress intake (see Chapter 2, Section 2.2.2). Silages with poor fermentation quality have high ammonia-N contents, high pH and may have a lower digestibility (see Chapter 12, Section 12.4.5). Cows given free access to these silages have been observed to have a lower intake, with fewer feeds/day and less time feeding on each occasion.

Adding to the problem of depressed intake of poorly fermented silages is the extensive degradation of the protein in these silages. This results in poor utilisation of silage nitrogen.

When ensiling 'at risk' pastures or forage crops (forage that is likely to undergo a poor fermentation), producers can use either wilting or silage additives to improve preservation. In the examples in Table 13.11, silage preservation was improved through the use of a formic acid additive which, in turn, resulted in an increase in intake and milk production (see also Chapter 7, Table 7.13).

Table 13.11

Effect of silage fermentation quality on milk production from silage/concentrate diets. Silage preservation was improved by the addition of formic acid.

	Poor	Good (+ formic acid)
Study 1 (two comparisons):		
DM content (%)	19.3	21.5
pH	4.8	4.0
Volatile N (% total N)*	24.7	9.7
Silage DM intake (% liveweight)	1.62	1.80
Milk production (kg/day)	17.2	18.9
Study 2 (five comparisons):		
DM content (%)	21.6	22.5
pH	4.8	4.1
Digestibility (% DOMD)	62.5	65.6
Silage DM intake (kg/day)	7.7	8.5
Milk production (kg/day)	15.3	16.3

** Available from one experiment only.*

Source: Study 1 – Murphy (1983); Study 2 – Castle (1975)

13.2.3

Wilting and silage DM content

A number of studies have investigated the effect of wilting on silage DM intake and milk production. In most studies, DM intake of wilted silages was higher than that of unwilted silages produced from the same forage. However, the effect of wilting on milk production has varied, and a number of studies have shown no benefit. Chapter 6, Section 6.5.2, contains further information on the intake and milk production response to wilting. As discussed in Chapter 6, any intake and milk production benefit from wilting will depend on the efficacy of the wilt (the rate of wilting and the DM content achieved), and the fermentation quality of the unwilted silage.

Determining the effect of wilting is difficult in many dairy experiments because:

1. The silages are often fed with concentrates, which can mask any differences between the unwilted and wilted silages.
2. Additives are often applied to the unwilted control silages to improve preservation. If the unwilted control silage is well preserved there is less likely to be an intake or production benefit from wilting.

Increased DM content of the silage and improved fermentation quality can both increase intake, but it is difficult to separate these two effects of wilting. Figure 13.2 is based on several studies with maize silage and shows that silage DM intake by dairy cows increases with the silage's DM content. Studies with grass silages also showed silage intake increased with silage DM content (see Chapter 6, Figure 6.7 and Chapter 14, Figure 14.4).

Table 13.12

The effect of wilting on silage fermentation and intake and milk production by dairy cows.

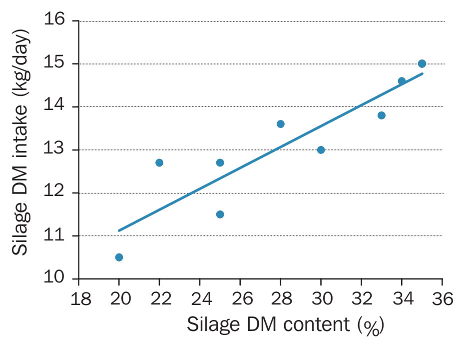
Preservation of control silage	Unwilted silage DM content (%)	Unwilted silage Ammonia-N (% total N)	Wilted DM content (%)	Response to wilting DM intake (kg/day)	Response to wilting Milk production (kg/day)
Good	26.0	7.5	38.8	0.31	-1.24
Bad	23.4	21.7	37.9	1.39	0.65

Source: Adapted from Flynn (1988) using various sources

Table 13.12 summarises the results of a number of studies where unwilted and wilted silages were compared. Where the unwilted control was well preserved, the increase in intake was small and there was often a decline in milk production. However, when compared with poorly preserved, unwilted silages, wilted silages increased both intake and milk production. In this case, the improvement in animal production on the wilted silages compared to the unwilted silages would be mainly due to an improvement in fermentation quality rather than an increase in silage DM content.

In an Australian study, perennial ryegrass/white clover pasture was ensiled after a 24-hour wilt at DM contents of either 28 or 44%. (The heavy wilt was achieved in the same amount of time by tedding the forage.) Both silages were well preserved with ammonia-N contents of 7 and 5% for the lightly and heavily wilted silages, respectively. As can be seen in Table 13.13, intake and milk production was higher on the more heavily and rapidly wilted silages.

Figure 13.2



Effect of maize silage DM content on intake by dairy cows.

Source: Phipps (1990)

Table 13.13

Effect of degree of wilting on milk production from pasture silages stored in bunkers.

	Moderate wilt	Heavy wilt
Forage composition at ensiling:		
DM content (%)	28	44
DM digestibility (%)	67.0	68.0
Crude protein (% DM)	15.6	15.6
WSC (% DM)	4.5	6.9
Animal production:		
Silage DM intake (kg/day)*	9.8	10.0
Milk production (kg/day)	10.6	11.3

* *Cows were allowed to graze restricted pasture and were supplemented with 10 kg silage DM/day.*

Source: Hadero-Ertiro et al. (1990)

13.2.4

Silage additives

There are three main scenarios where silage additives will be used on dairy farms:

1. To improve the preservation of low DM forages, where adverse weather conditions make rapid and effective wilting impossible, and where there is a significant risk of poor preservation without an additive. Various additives can be used in this situation.
2. In situations where good preservation is likely to be achieved without an additive, but the use of a silage inoculant may improve the intake and utilisation of nutrients from the silage, and subsequently milk production.
3. To improve silage stability if there is an aerobic spoilage problem during silage feedout.

Because effective wilting is usually possible under Australian conditions, the first scenario is not common. However, there is a role for additives on forages with a low WSC content (e.g. legumes and tropical grasses) in high-rainfall environments where poor wilting conditions are more common (see Chapter 7, Section 7.1).

There is growing interest in the use of silage inoculants (scenario 2). When inoculant-treated silages are fed to responsive animals, such as high-yielding dairy cows, there is significant scope for an economic response, through increased animal production and reduced in-silo losses. This is supported by the results of an Irish study summarised in Table 13.14. In this study grass silages were produced on eight occasions in the one season. On each occasion the grass was ensiled, unwilted and wilted, either with or without one of four LAB inoculants.

The role of inoculants in improving milk production from silage is discussed in more detail in Chapter 7, Section 7.4.3.

Aerobic spoilage is a significant problem under warm Australian conditions, particularly with maize, which is an important silage in the dairy industry. So there is a role for additives (scenario 3) to improve silage stability (see Chapter 7, Section 7.7).

Table 13.14

Effects of wilting and a lactic acid bacterial inoculant on silage intake and milk production.

	Unwilted (18% DM content)		Wilted (32% DM content)	
	Untreated control	Inoculant	Untreated control	Inoculant
Silage DM intake (kg/day)	10.4	10.7	12.6	12.7
Milk production (kg/day)	21.6	22.1	22.2	22.7
Milk fat production (kg/day)	0.97	0.99	1.02	1.04
Milk protein production (kg/day)	0.70	0.71	0.73	0.75

The cows received, on average, a concentrate supplement of 5.4 kg/day.

Results are the mean of 8 cuts, with 4 inoculants tested on each occasion.

Source: Adapted from Patterson et al. (1998)

A possible solution to this problem has been the development of inoculants containing the heterofermentative LAB, *Lactobacillus buchneri*. The acetic acid produced by these bacteria improves aerobic stability.

At this stage, few animal production studies have been conducted and even fewer studies have shown a positive animal production benefit. However, a significant response in lamb growth was observed in one study with an unstable maize silage (see Chapter 15, Table 15.12), and in a study with lucerne silage incorporated in a total mixed ration for dairy cows (Table 13.15). In this latter study, the lucerne silage was stable, and while the inoculant improved the stability of the total mixed ration (68 versus 100 hours) both could be considered to be moderately stable.

Other dairy studies have shown no effect of *L. buchneri* on either intake or milk production. One of the problems here (and with other additives applied to improve aerobic stability) is that a response might not be observed unless the study is conducted with an aerobically unstable silage. Further research is required.

One interesting observation with *L. buchneri* is that although it causes the acetic acid content of the silage to increase, this has not resulted in a reduction in silage intake. This is surprising because it is generally accepted that intake is depressed on poorly preserved silages, where there has been extensive degradation of the protein fraction and where the content of volatile fatty acids, including acetic acid, is high (see Chapter 2, Section 2.2.2, and Chapter 12, Section 12.4.5). Clearly, silages treated with *L. buchneri* do not fall into this category.

Table 13.15

The effects of the application of an inoculant containing Lactobacillus buchneri to wilted lucerne on silage composition, the aerobic stability of a total mixed ration containing these silages, and milk production.

	Untreated	Inoculated
Silage composition:		
DM content (%)	43.4	41.5
pH	4.36	4.66
Lactic acid (% DM)	4.4	3.5
Acetic acid (% DM)	3.4	5.7
Ammonia-N (% DM)	0.17	0.21
Aerobic stability of total mixed ration (hours before temperature increased more than 2°C)*	68	100
Animal production:		
Intake (kg DM/day)	25.1	25.4
Milk production (kg/day)	39.9	40.7
3.5% fat corrected milk production (kg/day)	38.9	40.0
Milk fat content (%)	3.37	3.43
Milk protein content (%)	3.07	3.27

* *The two silages alone remained stable throughout the test period.*

Source: Kung et al. (2003)

13.2.5

Chop length

Reducing chop length can increase intake either directly, by reducing eating and ruminating time, or indirectly by improving the silage fermentation (see Chapter 2, Section 2.4). However, the effect of chop length on intake and milk production has been variable, with increased milk production in response to finer chopping seen in about half the studies. The response to finer chopping may be less than expected where the silage has been fed with high levels of concentrates, or where silage is fed as a supplement to grazing cows or to cows in late lactation.

Silage additives can also mask the response to finer chopping by improving the fermentation quality of the longer chopped control silage.

In a Canadian study, grass-based pasture was ensiled at four chop lengths. The silage was fed to early lactation cows with a barley and protein supplement that made up more than 40% of the diet. As can be seen in Table 13.16, chop length of the forage at ensiling did not affect intake or milk production.

Reducing the silage chop length is more likely to lead to an increase in intake when silage is the major component of the diet. In a British study, early lactation cows were offered low DM (22%) grass silage at three chop lengths with a protein supplement. Table 13.17 shows that intake and milk production increased with decreasing chop length.

It has been suggested that a longer chop length may be an advantage in some dairy cow diets because it will increase the amount of effective fibre in the diet. However, in Australia, a shortage of dietary fibre is only likely to occur in diets containing a high proportion of concentrates or on very lush pastures for short periods of the year.

Table 13.16

Effect of chop length of grass silage (27% DM) on intake and milk production by dairy cows.

	Theoretical length of chop (mm)			
	6.3	12.7	25.4	38.1
Actual chop length (mm)	10.7	21.0	37.1	46.8
DM intake (kg/day)	16.4	16.3	16.1	16.2
Milk production (kg/day)	24.2	23.7	23.6	23.6
Milk fat content (%)	3.69	3.70	3.82	3.79
Milk protein content (%)	3.03	3.06	3.08	3.04
Liveweight change (kg/day)	0.26	0.21	0	0.31

Diets contained 58% silage, 34% high-moisture barley, 9% protein supplement plus minerals.
Results are the mean for two experiments.

Source: Adapted from Savoie et al. (1992)

Table 13.17

Effect of chop length on the production of dairy cows fed perennial ryegrass silage.

	Actual chop length		
	Short (9.4 mm)	Medium (17.4 mm)	Long (72.0 mm)
Silage DM intake (kg/day)	9.28	8.53	8.13
Milk production (kg/day)	13.5	13.3	12.9
Milk fat content (%)	4.05	4.10	4.10
Milk protein content (%)	3.05	2.95	2.99
Liveweight change (kg/day)	-0.22	-0.13	-0.48

Cows given 2 kg/day of protein supplement. Results are the mean of the high and low-protein content supplement.

Source: Adapted from Castle et al. (1979)

Results from a Canadian study with wilted lucerne silage (see Figure 13.3), showed that reducing chop length (from 10 to 5 mm theoretical length of chop) will increase intake and milk production on a low-concentrate (35%) diet. However, it was the longer chop length that had the highest intake and milk production on a high-concentrate (65%) diet. The high-concentrate diet in this study was extreme and the results indicated there was likely to be little effect of chop length on intake and milk production for diets containing 50-55% concentrates.

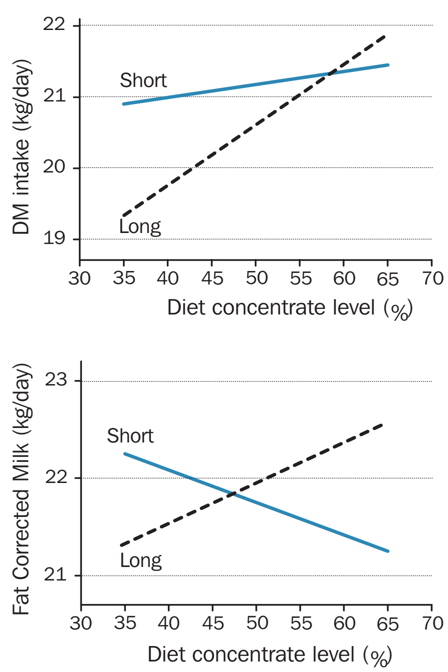
In summary, shorter chop lengths will often improve the silage fermentation, allow greater compaction (reducing storage and feedout losses) and, in some cases, increase intake and milk production. Therefore, finer chopping is usually the recommended option.

The situation concerning particle length in baled silage is unclear, as there have been few studies where it comprised a major component of the diet. Method of baled silage feeding could be important (see Section 13.2.6) as this may influence silage intake. If the balers are fitted with chopping knives, or the bales are chopped in a feedout wagon prior to feeding, this silage is more likely to produce animal production similar to silage harvested with a forage harvester.

With maize, the use of grain processors to physically damage the grain at harvest has sometimes been recommended to maximise utilisation of the grain component by cattle. Studies in Australia and overseas have shown that utilisation of the grain component is high with finely chopped maize. However, this may not be the case with sorghum, which has smaller grain, much of which escapes damage even with very fine chopping. The use of grain processors is discussed in more detail in Chapter 5, Section 5.2.4; Chapter 8, Section 8.2.1; and Chapter 14, Section 14.2.5.

Figure 13.3

Effect of silage chop length on feed intake and milk production on high and low-concentrate diets.



Note: The theoretical length of chop was 5 mm and 100 mm for the short and long silage, respectively.

Source: Beauchemin et al. (1994)

13.2.6

Feedout system

The choice of the most appropriate feedout system depends on a number of individual farm factors. Costs are a major consideration and an efficient system can significantly increase profitability per tonne of silage fed (see Chapter 10, Section 10.1).

If silage is a major component of the diet, or the time allocated to consume the daily silage supplement is limited, it is important to ensure that the silage is readily accessible to the cows. Accessibility refers to how easily the silage can be reached or approached (the available feeding space) as well as how easily the silage can be removed and eaten (the physical form of the feed). It is discussed in detail in Chapter 10, Section 10.3.2.

Table 13.18 gives results from an Irish study that looked at the effect of accessibility on milk production. Silages were produced with a forage wagon (long chop) or with a precision chop forage harvester (short chop), and fed to cows from a bunker (self-fed) system or from a trough (easy-fed) system.

These results indicate that feedout management can affect milk production, and that this effect is influenced by silage chop length. The shorter-chopped silage in both feeding systems and the longer-chop silage fed using the easy feeding system were more easily and quickly consumed and supported higher levels of milk production than the self-fed, long-chop silage. It is unclear whether milk production would have improved if the cows self-fed the long silage were given more feeding space.

Plate 13.2

A good feedout system such as this one allows cows to access silage easily and minimises wastage. *Photograph: M. Martin*

Table 13.18

Milk production (kg/day) by cows fed either forage wagon or precision chop silages both self-fed and easy-fed. The cows received 7.25 kg concentrate/day.

	Forage wagon (231 mm)		Precision chop (52 mm)	
	Self-fed	Easy-fed	Self-fed	Easy-fed
Experiment 1:				
Space allocated per cow (cm)	30	61	30	61
Milk production (kg/day)	17.5	18.9	18.6	18.3
Experiment 2:				
Space allocated per cow (cm)	18	61	18	61
Milk production (kg/day)	18.9	21.2	21.7	20.9

Source: Adapted from Murphy (1983)

Section 13.3

Response by grazing cows to silage supplements

Silage and/or hay can play an important role in complementing pasture in pasture-based dairy systems. The main uses for silage supplements are:

- *Buffer feeding.* Silage can be used to meet deficits in pasture availability during periods of low pasture growth. This is a major role for silage on dairy farms over autumn and winter in southern Australia. Silage is also used during very wet conditions when grazing has to be restricted to avoid damaging pastures.
- *Low pasture quality.* High-quality silages can be used to supply additional energy and protein to cows grazing poor-quality pastures.
- *Maintaining intake during heat stress conditions.* During hot and humid conditions, the intake of lactating cows can fall markedly. Feeding good-quality silage/grain mixes on shaded feed pads maintains intake and cow production.

When assessing the role of silage as a supplement to pasture it is important to focus on the milk production response/cow and the response/ha. The response/ha, and the stocking rate flexibility that it allows, means that silage supplementation can have a major impact on profitability.

13.3.1

Factors affecting milk responses to silage supplements

Unfortunately, most of the Australian and New Zealand research assessing milk responses to pasture silage in grazing cows has been conducted with lower-yielding cows in mid to late lactation. This has probably limited the milk response per kg silage DM in these studies. However, the results from these and other studies indicate that the response to silage supplements is influenced by the quantity and quality of pasture on offer, and the quantity and quality of the silage supplement fed.

When silage is fed to cows with unrestricted access to pasture, cows substitute silage for pasture (see Table 13.19). This results in little change in total feed intake and no change or even a negative effect on milk production. Where pasture supply is limited, the substitution of silage for pasture will be greatly reduced, and silage supplementation will increase total feed intake and milk production.

Table 13.19

The effects of pasture availability and silage quality on the response by grazing dairy cows to pasture silage.

	Unrestricted pasture		Restricted pasture	
	Low*	High*	Low*	High*
Reduction in pasture intake (kg) for each kg silage supplement (DM basis)	1.13		0.28	
Milk production response to silage feeding (kg/cow/day)	-1.7	+0.2	+1.2	+2.8

** Silage DM digestibility – Low <70%; High ≥70%.*

Source: Adapted from Phillips (1988)

Table 13.20

Response by grazing dairy cows to pasture silage supplements during various stages of the lactation.

	Silage quality		
	High	Medium	Low
Silage composition:			
Crude protein (% DM)	17.6	15.1	11.8
Digestibility (% DM)	67.5	61.1	52.3
Estimated ME (MJ/kg DM)	10.4	9.4	8.3
Animal production:			
Winter			
Liveweight change (kg/day)	0.84	0.40	0.62
Spring			
Milk production (kg/day)	18.4	17.9	17.2
Milk solids (kg/day)	1.78	1.67	1.57
Summer			
Milk production (kg/day)	12.3	11.5	10.9
Milk solids (kg/day)	1.28	1.17	1.09
Autumn			
Milk production (kg/day)	6.9	6.1	5.9
Milk solids (kg/day)	0.89	0.77	0.63

The cows were provided with sufficient pasture to provide an intake of 10 kg DM/cow/day during lactation and 5 kg DM /cow/day during the dry period. Silage offered at 5 kg DM/cow/day during lactation and 3 kg DM /cow/day during the dry period.

Source: MacDonald et al. (2000)

Plate 13.3

Maize silage is an excellent, high-quality supplement for grazing dairy cows.

Photograph: M. Martin

The effect of silage quality on milk production has been discussed earlier in this chapter (see Section 13.2). The increase in milk production observed on higher quality silages (digestibility or ME content) is also observed when silage is used as a supplement to pasture. This is demonstrated in Tables 13.6 and 13.19 and in a New Zealand study where silages of varying quality were fed to cows at various stages of lactation (see Table 13.20).

The higher-quality silage supported high production of milk and milk solids at each stage of lactation, and higher liveweight gain when cows were dry.

13.3.2

Maize silage for grazing cows

Maize silage is an excellent high-energy supplement for grazing dairy cows. Table 13.21 summarises the results from several Australian studies investigating the milk production (kg/day) of cows grazing a range of pastures and supplemented with maize silage. Typical responses of 0.9 and 0.6 kg extra milk/kg silage DM have been observed in early and late lactation, respectively, in those studies where cows had limited access to pasture.

The low protein content of maize silage needs to be considered when using maize silage as a supplement. Protein supplementation may be necessary, particularly where maize silage is a significant component of the diet (see Table 13.21).

Combining maize silage with a high-protein legume pasture can sustain high levels of milk production, with responses as high as 1.3 to 1.4 kg extra milk/kg silage DM observed in these situations. Maize silage is also effective in maintaining milk fat levels, even when fed at rates of up to 12 kg DM/cow/day.

Table 13.21

Milk production (kg/day) from dairy cattle given pasture with maize silage supplements.

Reference	Pasture type	Pasture crude protein (% DM)	Level of supplementation* Low	Medium	High
Davison *et al.* (1982)	Guinea grass/glycine	16	14.3	15.3	–
	+ protein supplement**		15.0	16.6	–
Stockdale and Beavis (1988)	Perennial ryegrass/white clover#	16	18	19	20
	Persian clover#	21	20	22	24
Hamilton (1991a)	Kikuyu	–			
	+ grain		15.6	–	–
	+ grain + protein supplement**		17.1	–	–
Hamilton (1991b)	Perennial ryegrass	–			
	+ grain		19.2	–	–
	+ grain + protein supplement**		20.0	–	–
Stockdale (1991)	Persian clover	21	26.7	26.4	26.3
Stockdale (1995)	Perennial ryegrass/white clover#	16	17.5	–	–
		20	–	21.0	–
		15	10.8	–	–
Moran and Stockdale (1992)	Paspalum/perennial ryegrass/white clover	15	19.8	–	18.5
	+ protein supplement**		19.7	–	20.1
Moran and Jones (1992)	Subclover/Wimmera ryegrass	21	–	20.0	–
	White clover/perennial ryegrass	20	–	22.7	–
Moran (1992)	Perennial ryegrass/white clover	13		14.0	
Moran and Wamungai (1992)	Red clover#	21	–	22.2	19.3
	Subclover/Wimmera ryegrass	23	–	–	20.9

* *Quantity of maize silage fed – Low = 3-5, Medium = 6-8, and High = >8 kg DM /cow/day respectively.*

** *Protein supplement provided with maize silage.*

Animal house experiment.

Section 13.4

Nutritional considerations when feeding silage

From a nutritional point of view, high-quality, well-preserved silage and high-quality pasture are essentially interchangeable. The main differences are that:

- intake may be lower if the silage has a low DM; and
- the degradability of protein is usually generally high in most silages. However, the degradability of nitrogen in lush, high-digestibility pasture is also high.

Research in Europe has shown that silage intake by sheep and cattle is similar to that of the parent forage, if

- Ammonia-N (% total N) ≤5
- Acetic acid (% DM) ≤2.5
- Other volatile fatty acids (% DM) are approximately nil.

With good silage management, these conditions can be met in well-preserved silages (see Chapter 2), and there will be little or no change in digestibility due to ensiling.

13.4.1

Protein

Utilisation of protein

During the ensiling process, WSCs are fermented to organic acids, reducing the proportion of silage ME that is fermentable in the rumen. This, together with the high degradability of silage nitrogen, can lower the efficiency of nitrogen utilisation within the rumen. The nitrogen not utilised is excreted by the animal. These effects are taken into account in current feeding standards using the metabolisable protein system and, in some cases, protein supplementation (with bypass protein) may be necessary. However, in many dairy cow diets, feeding concentrates will usually provide sufficient readily fermentable energy in the rumen to improve the utilisation of degradable nitrogen from silage and other sources (see Chapter 12, Section 12.4.4).

When feeding silages, animal production and the utilisation of silage nitrogen will improve if the silages have been well-managed to ensure good preservation. Apart from the quality benchmarks for high-intake silages (high ME and good fermentation quality), it has also been suggested that no more than 50% of the total nitrogen should be soluble if the silage is to sustain animal production levels similar to those on the parent forage.

Under Australian conditions rapidly wilted, high-digestibility pasture silage will produce the best animal responses. The restricted fermentation and higher DM content of these silages will sustain high intake, minimise DM and quality losses during conservation (unless the forage is over-wilted), and will usually leave more readily fermentable energy (as WSC) for fermentation in the rumen. Recent research has shown that wilting (and silage additives) can also improve protein utilisation by reducing the degradability of nitrogen, thereby increasing the supply of amino acids to the intestine.

Low-protein silages

If silages of low-protein content make up a significant proportion of the diet, the protein content of the diet may be inadequate for milk production. Maize, grain sorghum, sweet sorghum and some whole crop winter cereals all fall into the low-protein category. The typical crude protein content of various crops is provided in Chapter 4, Table 4.1, and Chapter 5, Table 5.2.

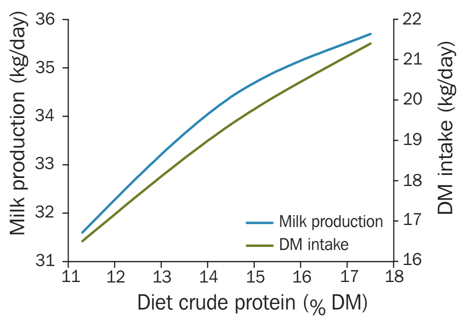
If adequate protein is provided by other components of the diet, e.g. pasture, and the level of silage supplementation is low, protein supply is likely to be adequate. However, at higher levels of supplementation with low-protein silage, milk production will fall if supplementary protein is not provided, as demonstrated in Table 13.21 (see also Section 13.3.2). In these studies the mean responses to protein supplementation were a 4.6% and 8.6% increase in milk production when cows were given <5 kg or >7 kg maize silage DM/cow/day respectively.

The level of protein in the diet is also important in more intensive production systems where low-protein silages, such as maize silage, are a major dietary component. In an American study with high-producing dairy cows and a maize silage-based diet, intake and milk production increased as the crude protein content of the diet was increased (see Figure 13.4).

Where cows are fed diets containing low-protein silages, supplementation can take the form of non-protein N (e.g. urea) or protein N (e.g. protein meal), legume silage or a combination of all three. High-yielding dairy cows have a high protein requirement and diets need to contain sufficient rumen degradable and metabolisable protein to meet their requirements. Dairy nutrition publications provide details on protein requirements.

Figure 13.4

Effect of dietary crude protein content on intake and milk production by dairy cows.



Diets contained 40% maize silage (DM basis).

Source: Kung and Huber (1983)

13.4.2

Fibre

Fibre is required in dairy diets to maintain normal rumen function and help prevent the depression of milk fat percentage. It is the subject of ongoing research and is covered only briefly here. For a more detailed coverage, refer to publications on dairy cow nutrition.

Feeding standards used in the United States indicate that if neutral detergent fibre (NDF) content of the whole diet falls below 30% and acid detergent fibre (ADF) is below 19%, additional fibre may be required in the diet to maintain milk fat content (see Chapter 12, Section 12.4.3). These recommendations are for total mixed rations and are likely to vary with the type of grain in the diet.

The NDF must be 'effective' in stimulating rumination, saliva production and hence buffering of the rumen, to prevent a fall in rumen pH and the development of acidosis. The effectiveness of the fibre is related to the chewing time per unit of NDF intake, which can be estimated from the particle size distribution in a forage (determined using a sieving device). Based on this system, only 40-50% of the fibre in high-digestibility pasture may be 'effective', while 70-80% of that in maize silage is 'effective'. Indicative fibre requirements on pasture-based diets are provided in Table 13.22. Where supplements (concentrates) comprise >25% of the diet DM, the requirement is likely to be met with most grazed pasture + maize silage diets. However, once maize silage becomes the major forage component of a high-concentrate diet, supplementary fibre may be required.

An important consideration when feeding maize silage is the total starch content of the diet, which should not exceed 30% of the dietary DM in dairy cow diets. The starch content of maize silages used in feeding experiments at Wagga Wagga, NSW, varied from 19 to 39% DM, with a mean value of 29% DM.

The issue of insufficient effective fibre is likely to arise in other situations where high levels of concentrates are fed in combination with high-digestibility, short-chopped silages. The effective fibre content has been shown to decline with finer chopping. In Australia, this scenario could arise where cows are fed a total mixed ration, under feedlot conditions.

It has been argued that increasing the chop length of forage-harvested silages on high-concentrate diets would be desirable to meet effective fibre requirements. With maize, this would necessitate the use of a grain processor in the forage harvester to ensure adequate grain damage for digestion. As has been discussed earlier, longer chop lengths, with maize or any high-DM, wilted silages, are not consistent with good silage-making practices (see Chapter 2, Section 2.4). We strongly recommend against the use of this strategy to increase the effective fibre content of the diet. Other strategies, such as feeding high-quality baled silage or hay to provide long forage, can be used to increase the effective NDF content during periods when levels are inadequate.

Table 13.22

Recommended minimum fibre requirements for dairy cows on pasture in New Zealand.

	% in diet DM
Good quality all-pasture diets:	
Minimum NDF	35
Minimum effective fibre*	17
Pasture + supplement:**	
Minimum NDF	27-33
Minimum effective fibre*	20
Minimum ADF	19-21

* *Fibre that is most effective at promoting chewing and saliva production.*

** *Supplements were >25% high starch concentrates.*

Source: Kolver (2000)

13.4.3

Minerals

Some silages contain low levels of specific minerals, and unless these are provided by other components of the diet, supplementation will be necessary, especially if the silage comprises a significant proportion of the diet. The reader is referred to feeding standards or a nutrition publication for the mineral requirements of dairy cows.

Guidelines on the mineral and protein status of the silages that may require supplementation are provided in Table 13.23. Other silages will usually supply adequate minerals and some, for example most legumes, are rich sources of a range of minerals, especially calcium. Because the mineral content of a silage can be influenced by soil type and fertiliser application, the information in Table 13.23 should only be used as a guide. Local advice should be sought to avoid mineral deficiencies, and where information is not available a mineral analysis is recommended.

Note that if silage additives containing sulphur are used, this may reduce the availability of copper to animals (e.g. sulphuric acid – Section 7.5; sulphites – Chapter 7, Section 7.7.1). Supplementary copper may be required in the diet if this has not already been added to the additive by the manufacturer.

Table 13.23

Silages containing low levels of either protein or minerals. Supplementation may be required if these silages make up a major proportion of the diet.

Crop or pasture silage	Protein content*	Mineral content
Maize	Low	Low in calcium, sodium and copper. Phosphorus, zinc and potassium may also be low in some crops
Whole crop cereal	Low when crops are cut late, or when paddock fertility is low	May sometimes be low in calcium, phosphorus and sodium
Grain sorghum	Low	Low in sodium and sulphur
Sweet sorghum	Low	Low in sodium and sulphur
Forage sorghum	Usually only low when cut late and grown on a low fertility paddock	Low in sodium and sulphur
Lucerne	High	Low in sodium
Tropical grasses including kikuyu grass	Generally satisfactory when cut early	Often low in sodium, and can be low in phosphorus

** See also Chapter 4, Table 4.1, and Chapter 5, Table 5.2.*

Section 13.5

Silage and milk composition and quality

For information on the influence of dietary factors – especially dietary ME, protein and fibre – on milk composition, the reader is referred to dairy nutrition publications. The principles are generic and apply equally to silage-based diets.

Silage and other dietary components should be tested to ensure that nutritional requirements are met.

There are other possible effects of silage feeding on milk quality:

- Feeding legume silages, particularly red clover, may increase the polyunsaturated fat content of milk, enhancing its health properties for the consumer (see Table 13.24). Further research is required to explore this opportunity for enhancing milk composition.
- Clostridial fermentations can increase the risk of clostridial spores contaminating cheese, adversely affecting the manufacturing process. Good management to avoid a clostridial fermentation will overcome this problem (see Chapter 2).
- The cheese-making properties of milk may be adversely affected when cows are fed aerobically spoiled maize silage. Further research is required to confirm this observation.

Table 13.24

The effect of feeding legume silages on the polyunsaturated fatty acid content (% of total fatty acids) of milk.

	Silage type and level of concentrate feeding (kg/cow/day)							
	Grass		Red clover		White clover		Lucerne	
	4	8	4	8	4	8	4	8
Experiment 1:								
Milk production (kg/day)	–	24.9	–	28.1	–	31.5	–	27.7
Linoleic acid (C18:2)	–	1.44	–	1.82	–	1.74	–	1.51
Linolenic acid (C18:3)	–	0.43	–	0.84	–	1.04	–	0.57
Experiment 2:								
Milk production (kg/day)	23.5	27.5	25.6	30.2	–	33.2	–	–
Linoleic acid (C18:2)	0.90	1.05	1.47	1.58	–	1.54	–	–
Conjugated linoleic acid (C18:2)	0.37	0.36	0.42	0.41	–	0.34	–	–
Linolenic acid (C18:3)	0.48	0.40	1.51	1.28	–	0.96	–	–

Source: Dewhurst et al. (2002)

Section 13.6

Appendix

13.A1

Nutrient requirements for different classes of dairy cattle

Class of dairy animal	Energy requirement (MJ/day)	Feed intake (kg DM/day)	Content required in feed			
			Energy (MJ/kg DM)	Protein (%DM)	Calcium (%DM)	Phosphorus (%DM)
600 kg cow producing 35 L/day (0.5 kg/day wt loss, non-pregnant)	231	21	11	17	0.6	0.4
500 kg cow producing 20 L/day (zero wt gain, 3 mth pregnant)	160	16	10	14	0.6	0.4
500 kg cow, non-lactating and 8 mth pregnant	117	13	9	12	0.4	0.2
400 kg heifer growing at 0.7 kg/day (2 mth pregnant)	80	8	10	12	0.3	0.2

Source: National Research Council (1989)