Chapter 13

Feeding silage to dairy cows

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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.

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.

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*

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.

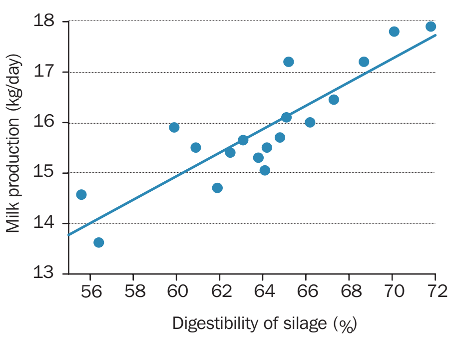
This principle is demonstrated in Table 13.5 for a mixed silage and concentrate diet. The high-digestibility silage system (3 cuts per season) supported higher levels of milk production per cow, and allowed a similar level of milk production at a low level of concentrate input to that obtained on the 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)

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.

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 to full 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)

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.

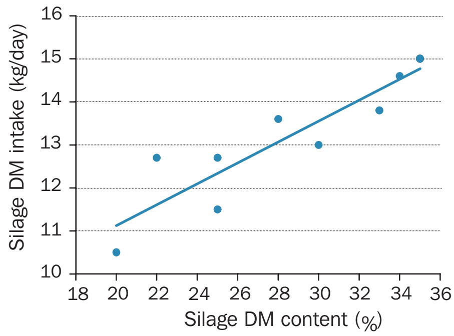
Preservation of control silage	Unwilted silage DM content (%)	Unwilted silage Ammonia-N (% total N)	Wilted DM content (%)	Response to wilting DM intake (kg/day)	Response to wilting Milk production (kg/day)
Good	26.0	7.5	38.8	0.31	-1.24
Bad	23.4	21.7	37.9	1.39	0.65

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.

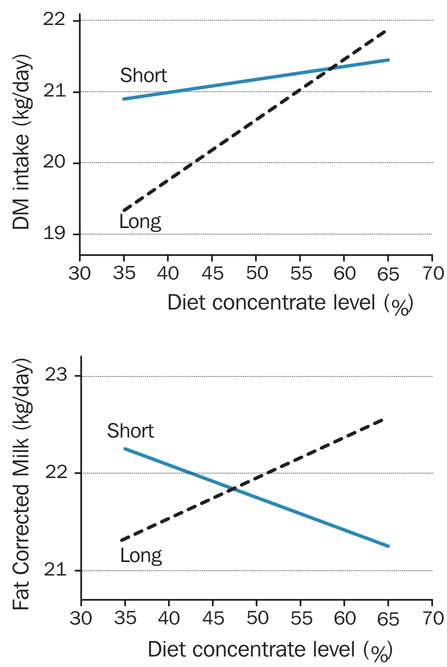
In summary, shorter chop lengths will often improve the silage fermentation, allow greater compaction (reducing storage and feedout losses) and, in some cases, increase intake and milk production. Therefore, finer chopping is usually the recommended option.

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.

Source: Adapted from Murphy (1983)

	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

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.

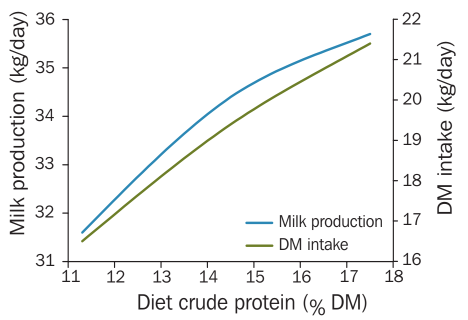
If adequate protein is provided by other components of the diet, e.g. pasture, and the level of silage supplementation is low, protein supply is likely to be adequate. However, at higher levels of supplementation with low-protein silage, milk production will fall if supplementary protein is not provided, 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)