Chapter 7

Silage additives

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In this chapter

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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.

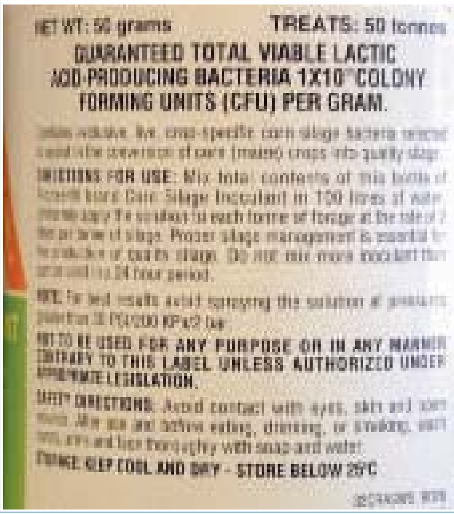
There has been some interest in the use of heterofermentative LAB and propionic acid bacteria to improve aerobic stability of silages (see Section 7.7.2).

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:

1×10^5 (100,000) colony forming units (cfu) per gram of fresh forage

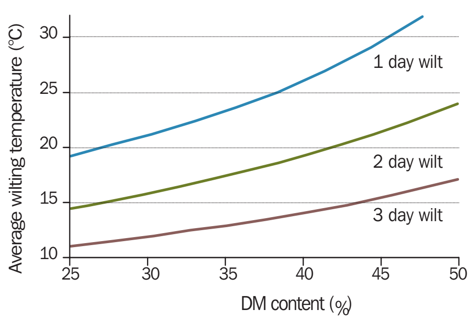
Crop DM and WSC content: Inoculant response is influenced by the WSC and DM content of the forage. Responses to inoculants may not occur with low-WSC content and high-buffering capacity legumes unless the forage is wilted rapidly, to a DM content of at least 30%. Where it is not possible to achieve this 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		Formic acid treated	
	No supplement	Barley supplement	No supplement	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.*