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The role of silage inoculants

Introduction

Silage is an important feed supplement to New Zealand pastoral systems, with the FAR AIMI report (2015) stating a total of around 1.4 million tDM harvested in 2015. Maize silage alone represents about 6% of the total feed energy supplied to New Zealand dairy cows (Kleinmans et al. 2016). Good harvest and stack management are the key factors for quality silage production. Inoculants can be used to help promote effective and rapid fermentation, and to protect against degradation of nutrients and dry matter during the fermentation process and after the silage stack is opened. This Update outlines the silage fermentation process and some of the factors to consider when deciding whether or not to use a silage inoculant.

Silage production

Silage and baleage are produced via fermentation, a process where microorganisms convert the sugars in green forage into acids in the absence of air (anaerobic conditions). Both beneficial and antagonistic microorganisms occur naturally on the forage. Depending on circumstances, these may be supplemented with silage inoculant products which contain specific, more efficient bacteria selected to dominate the fermentation of crops in the stack.

The most effective silage fermentation is performed by bacteria which convert sugars into lactic acid. This process lowers the silage pH quickly and reduces the potential effects of undesired microorganisms that compete with lactic acid bacteria. Undesirable fermentations from microorganisms such as enterobacteria and clostridia, can dominate if the pH does not drop rapidly. Clostridia are a particular risk factor in grass and lucerne silages that are harvested at low dry matters and can cause significant quality losses.

The ability to ferment differs between forage types, depending on sugar levels, dry matter content etc. Maize and cereals are examples of easily fermentable crops because they provide high levels of water soluble carbohydrates (mainly sugars) and a low buffering capacity, i.e. enough substrate to allow high levels of lactic acid production and little “resistance” from the “buffering capacity” of the crop, which is the ability of the forage to resist a drop in pH. However they are also prone to aerobic spoilage (heating and fungal infections leading to mould) at the pit face and at feed out.

Lucerne and grass silages are the reverse of maize silage where up front fermentation is harder and slower and less susceptible to heating at feed out and pit face.

The DairyNZ Forage Value Index – Handbook puts the cost of purchased maize silage at 30.5 cents per kg DM, and the cost of harvesting and ensiling grass produced on a farmer’s property at 15.7 c/kg DM. At a current cost of 0.7 - 1.5 c/kg DM, inoculants can help protect this investment.

Key points

- Silage inoculants provide insurance against less than ideal forage or stack management by reducing the risk of dry matter and quality losses by:
  - Improving the fermentation, particularly when used on lower dry matter forages or legumes.
  - Reducing quality losses from the stack once opened.
- To be effective, inoculants should be applied at greater than 100,000 viable colony forming units per gram of fresh forage.
- A wide range of inoculants are available. Select those that have been found to be effective in independent and statistically analysed trials.

Factors affecting silage losses

Harvest management

Harvesting crops at the proper dry matter percentages with high sugar contents is key to ensuring good fermentations. Wilting crops efficiently without losing too much sugar is critical for forages like grasses, clover and lucerne. This is because they are cut at a low dry matter level and wilting increases the dry matter before ensiling, which increases their ability to ferment well. However, crops such as maize and cereal silage can be directly harvested without wilting when the whole crop reaches an ideal dry matter content (generally 32-40% DM). Crops that are too wet when they go in the stack will not ferment well because the water dilutes the sugar and increases the risk of Clostridia fermentation, resulting in high losses and low quality. Harvesting crops when they are too dry tends to make ensiling difficult due to inadequate moisture, and because the crop becomes too springy to compact, leaving air in the stack which can hinder fermentation and lead to increased aerobic losses after stack opening.

Stack management

Fermentation takes place in the absence of air, so creating a well compressed stack with a good oxygen barrier seal is essential. Preventing air from entering the silage once the stack is open can be more difficult but is key to preserving dry matter and quality of the feed. Even with good fermentation, dry matter losses are inevitable, but minimising damage at the face of the stack helps to reduce air penetration into the stack. In extreme conditions dry matter losses can reach 30% over a 10 day period (Honig & Woolford, 1980). When feeding out, remove at least 20 cm each day from the stack face to ensure fresh unspoiled silage is fed every day.

Effluent

Ensiling crops below 28% dry matter releases liquid (effluent). The rate of effluent loss is determined by the DM content, chop length of the ensiled forage and by silage density in the stack. While effluent represents a loss of nutrients in the silage, the risk it poses for water pollution is probably of greater concern. Low dry matter silages are more likely to have higher effluent losses.

Silage inoculants

A better understanding of silage microbiology has led to the development of silage inoculants. Generally, bacteria in inoculants act in one of two ways, improving either fermentation efficiency or aerobic stability, which is the maintenance of quality once silage has been exposed to air after stack opening.

Specifically selected strains of lactic acid bacteria can convert plant sugars more efficiently and are more competitive than bacteria and yeasts already present on the plant. These are homofermentative strains, often from the species *Lactobacillus plantarum*. They form the basis of silage inoculants that can improve fermentation efficiency.

In the 1990s the use of heterofermentative strains of *Lactobacillus buchneri* was found to produce less heating of maize silage once it was exposed to air after opening. These strains are used in silage inoculants, and produce lactic acid, as well as other acids, such as acetic or propionic acid, and can improve aerobic stability.

Some silage inoculants contain enzymes, which are claimed to unlock insoluble carbohydrates (sugars) in the plant cell wall to feed the bacteria to grow, multiply and produce more acid to improve the speed of the fermentation.

Research has linked the use of some silage inoculants with increased milk or meat production. Scientists believe that in some cases this is a result of improved silage fermentation leading to higher silage feed value and animal intake, and in others, a result of interactions between the silage inoculant and microflora in the animal rumen.

Depending on their effects, the use of silage inoculants can be very profitable. Combination effects i.e. improved silage quality plus animal performance will bring the highest return.

Things to consider when selecting silage inoculants

Research

An effective silage inoculant will have independent and statistically analysed published data supporting its use for the purpose planned.

Type of bacteria and targeted effects

Some bacteria strains have shown their effect in improving silage fermentation and sometimes animal performance. If improved aerobic stability is required, look for a product with *L. buchneri*.

Application rate

The international industry standard for application rates is a minimum of 100,000 viable colony forming units per gram of forage. A good inoculant product will have its guaranteed bacteria number printed on the label.

Service
The inoculant should be supplied by a company with competent service that will support customers to make the right decisions selecting a product and provide on-going support and advice as required.

Price
Price alone should not be the driving factor for choosing an inoculant.

Factors influencing silage inoculant effectiveness

Silage inoculants do not always work, and there are many different possible reasons why:

Active ingredients
Some products fail to provide information about active ingredients. Unless the mentioned technology has been proven scientifically it can't be considered an effective ingredient.

Product handling and quality control
Silage inoculants are live organisms, and production quality control and proper product storage handling are fundamental steps in supplying and maintaining a product that supplies the guaranteed number of colony forming units on the label to the forage harvested.

Product form and application
Considering all of these issues, products applied wet generally have an edge over dry products. Two potential issues may affect the viability of inoculant bacteria when mixed with water:

1. Chlorine - if the water source is chlorinated and contains more than 1ppm chlorine you should look for an inoculant that has compounds which react with the chlorine so it doesn't kill the live bacteria.
2. Temperature - inoculant viability is best below 40° C.

Forage type
If the carbohydrate content of the forage is too low it may be difficult to ensile, because silage inoculant bacteria need sugar to convert into lactic acid. Conversely, a maize crop may already show a rapid pH drop without any silage inoculant applied and an improvement in pH drop might not be possible.

The main silage inoculant products in the New Zealand market

A survey of marketing literature in October 2016 found 19 products sold by six companies in New Zealand (Table 1 over page).

Some products contain the same species (e.g. *Lactobacillus plantarum*); but many contain different strains of the species. Different claims are made on product benefits; and some are advertised with data supporting their claims.

References

FAR (Foundation for Arable Research) and AIMI (Arable Industry Marketing Initiative) (2015) *Summary Survey Of Maize Areas And Volumes – June 1, 2015*. Available from: https://www.far.org.nz/assets/files/editable//e9f8c956-a2a2-4fcb-8608-7d11fff8ceed.pdf (Accessed 16 April 2016).

Honig, H. & Woolford, M.K. (1980) Changes in silage on exposure to air. *Forage conservation in the 80's (ed. C. Thomas), Occasional Symposium No.11, British Grassland Society, Brighton. 76–87*.

Kleinmans, J.J., Densley, R.J., Hurley, T. & Williams, I.D. (2016) *BRIEF COMMUNICATION: Feed value of maize silage in New Zealand - a review. Proceedings of the New Zealand Society of Animal Production. 76*.

Full Report

A copy of the full report *A review of silage inoculants in the New Zealand market* is available on the FAR website.

Table 1. Overview of silage inoculant products in NZ market* (alphabetical order distributor) as advertised in October 2016. 2x indicates there are two separate strains of the species present.**

Company	Product	Manufacturers' claims	Active ingredients	Product form
BioStart[1]	Silage King	Better fermentation and better palatability in cereal and pasture silage	Fermentation extracts. Not technically a silage inoculant, as they contain no live bacteria.	Granular & soluble
	Maize King	Better fermentation, palatability and aerobic stability in maize silage		Granular & soluble
	Hay King	Inhibits moulds in bales, reduced losses and better palatability		Granular & soluble
Donaghys[2]	Ecosyl 100	Better fermentation, higher animal performance	*L. plantarum*	Soluble
Grevillia-Ag[3]	Si-Lac	Improved fermentation, reduced losses	*L. plantarum, E. faecium*	Soluble
	Si-Lac Extra	Improved fermentation and aerobic stability of silage, earlage, high moisture hay and high moisture grain	*L. plantarum, E. faecium, L. buchneri*	Soluble
Nutritech[4]	BioSil	Better fermentation, reduced losses, more palatable and nutritious silage for all types of silage	*Enterococcus faecium,* 2x *L. plantarum,* 2x *P. pentosaceus, Lactobacillus lactis plus enzymes*	Granular & soluble
	BioSil Maize	Improved aerobic stability in maize and whole crop cereal silage, improved animal performance	*E. faecium,* 2x *L. plantarum,* 2x *P. pentosaceus, Lactobacillus lactis, L. buchneri*	Granular & soluble
	BioSil Hay	Allows harvest of hay at 5-8% lower moisture, reduce heating, more palatable, inhibit mould and yeasts	*E. faecium,* 2x *L. plantarum,* 2x *P. pentosaceus, Lactobacillus lactis, L. buchneri*	Soluble & granular
	Sil-All 4x4	Faster fermentation, reduced losses, higher digestibility and higher milk yield in wide range of forages	*L. plantarum, Pediococcus acidilactici, P. pentosaceus, Propionibacteria acidipropionici, enzymes*	Granular & soluble
	Sil-All LV	Faster fermentation, reduced losses, higher digestibility and higher milk yield in wide range of forages	*L. plantarum, Pediococcus acidilactici, P. pentosaceus, Propionibacteria acidipropionici, enzymes*	Granular & soluble
	Sil-All Stability	Better fermentation, reduced losses, improved feed value, improved aerobic stability of maize and whole crop silages	*P. pentosaceus, L. buchneri, enzymes*	Soluble & granular
Pioneer® brand products[5]	1174	Improves fermentation, feed value and animal performance in different crops	*L. plantarum, E. faecium*	Soluble
	1127	Improves fermentation, feed value and animal performance in pasture silage	*L. plantarum, E. faecium*	Soluble
	11H50	Improves fermentation and feed value in lucerne silage	*L. plantarum*	Soluble
	1132	Improves fermentation, feed value and animal performance in maize silage	*L. plantarum, E. faecium*	Soluble
	11C33	Improves fermentation, aerobic stability and feed value in maize silage	*L. plantarum, E. faecium, L. buchneri*	Soluble
	11CFT	Improves fermentation, aerobic stability and feed value and neutral detergent fibre digestibility in maize silage	*L. casei, L. buchneri*	Soluble
PPP Industries Ltd[6]	Bio Power Gold	All-purpose silage inoculant	*L. plantarum, B. subtilis, L. casei, E faecium, L. buchneri, Aspergillus oryzae, A. niger*	Soluble

* Best efforts were made to list all who actively advertise, but possibly not all have been captured.

** This table contains manufacturer's claims, and should not be considered an endorsement by FAR.

1 http://www.biostart.co.nz/products/single-preservatives/silage-king/
2 https://www.donaghys.com/search/results/11bfb4402dd4df03467cf831c1fd88c2
3 http://www.grevilliaag.com.au/silageInoculants.aspx
4 http://www.nutritech.co.nz/product-category/forage/
5 http://www.pioneer.co.nz/inoculants/
6 PPP Probiotics, www.abtusa.com

PO Box 23133, Templeton, Christchurch 8445, New Zealand
Phone: +64 3 345 5783 • Fax: +64 3 341 7061 • Email: far@far.org.nz • www.far.org.nz