# Maize silage for dairy cows

E.S. KOLVER[1], J.R. ROCHE[1], D. MILLER[2], and R. DENSLEY[2]
[1]*Dexcel, Private Bag 3221, Hamilton*
[2]*Genetic Technologies Ltd, P.O. Box 105 303, Auckland*
eric.kolver@dexcel.co.nz

## Abstract

This paper reviews the use of maize silage in pastoral dairying systems in New Zealand. The evolution of dairying systems to make profitable use of maize silage and other supplementary feeds has occurred during the last decade in conjunction with an increased use of maize silage. When used within recommended levels of feeding, maize silage provides a low cost source of starch and fibre which complements pasture well for much of the year. Balancing dietary deficiencies in protein, minerals, and in some cases fibre, will optimise milksolids production at high levels of maize silage supplementation. Targets for good quality maize silage include a dry matter content of 28–35%, an energy content of 10.8 MJME/kgDM, a protein content of 7–8%, and a pH of 3.8 to 4.5. Opportunities for further productivity gains exist through further intensification of dairying systems using high-yielding crops.

**Keywords:** dairy cow, feed quality, maize silage, nutrition

## Introduction

New Zealand dairy farmers are using maize silage as a low-cost source of energy to break the pasture feed barrier. Maize silage is used to increase lactation length and stocking rate, and to manage risk (Dean 1999; Macdonald 1999; Cooper & Austin 2000). The increased usage has occurred as profitable dairying systems for using maize silage have been developed by farmers (van der Poel 1996) and researchers (Macdonald 1999; Penno *et al.* 1996; Cooper & Austin 2000).

Livestock Improvement ProfitWatch data for the 1999/2000 season indicated that 47% of Waikato dairy farmers used maize silage, with the majority (56%) buying an average of 102 t DM from off the farm (C. Glassey, pers. comm.). Those that grew maize silage on-farm planted an average of 4 ha. Since the 1997/1998 season, maize silage use has increased from an average rate of 193 kg DM/cow (531 kg DM/ha), to 339 kg of DM per cow (1028 kg DM/ha) in 1999/2000.

This paper reviews how maize silage is being used to make profits in pastoral dairying systems, the nutritive characteristics of good quality silage, and the effect these characteristics have on the feeding value of silage when fed to dairy cows grazing pasture. Opportunities to further extend the feed barrier in the future are examined.

## Using maize silage in pastoral dairying systems

Farmer experience and dairying systems research have shown that profits can be made from maize silage when it is used as a supplement to, not a substitute for, pasture (Macdonald 1999; van der Poel 1996). Maize silage is most profitable when used to fill a feed deficit that either occurs naturally (summer dry) or a deficit created by extending lactation or increasing stocking rate (Deane 1999; Macdonald 1999).

Whenever maize silage is fed in a pasture-based system there will always be a degree of pasture substitution. The overall response to the maize silage will be dependent on how well the substituted pasture is utilised by the dairy cows for milksolids production or increasing body condition at a later date (Macdonald 1999; Cooper & Austin 2000). When farm pasture cover is low, pasture substitution can result in a higher post-grazing herbage mass and subsequently higher pasture growth rates.

High-producing dairying systems focus on achieving increased production per cow, primarily by increasing the number of cow milking days per ha. This can be achieved either by keeping the herd milking through a summer drought; milking the herd further into May; calving earlier; or increasing stocking rate. The profitability of any supplementary feeding system is highly sensitive to the milksolids payout, the price of the supplement, and the cost structures, especially labour, that are incurred (Deane 1999; Macdonald 1999).

Farmlet studies designed to produce 1.75 t milksolids/ha during the mid-1990s (Macdonald 1999) demonstrated how an increased stocking rate and high inputs of maize silage could be used to increase days-in-milk and per-ha milksolids production. The response of 78 g milksolids/kg DM was very close to the theoretical production response (75 g milksolids/kg supplement DM) and equated to 13–14 kg supplement DM being required to produce an extra kg of milksolids (Table 1).

**Table 1** Summary of three farmlet systems from the 1.75 t/ha trial at Ruakura No. 2 Dairy (three-season average; Macdonald 1999).

| | Control | 200 kg N/ha | 200 kg N/ha plus maize silage |
|---|---|---|---|
| Cows/ha | 3.34 | 3.34 | 4.42 |
| Maize silage kg DM/cow | 0 | 0 | 1279 |
| Maize silage kg DM/ha | 0 | 0 | 5640 |
| Milksolids kg/cow | 311 | 362 | 364 |
| Milksolids kg/ha | 1040 | 1208 | 1606 |
| Days in milk | 253 | 266 | 277 |
| Response g MS/kg DM maize silage | | | 78 |
| Response g milksolids/MJME fed | | | 7.4 |

More recently, farm systems research at Waimate West Demonstration Farm has investigated the most profitable way of incorporating maize silage into pasture systems (Cooper & Austin 2000). Results have shown that the largest increases in profitability were gained from strategically feeding maize silage to allow for an increased stocking rate (4.65 compared to 3.78 cows/ha). Across all systems tested, increases in economic farm surplus (EFS) were greatest when maize silage was used to extend lactation length in autumn, rather than to calve earlier. Systems that calved earlier and used maize silage in the spring to fill the ensuing feed deficit were only more profitable than the optimally stocked (3.78 cows/ha) all-pasture system when stocking rate was increased (from 3.78 to 4.65 cows/ha).

## Characteristics of good quality silage

From a nutritional viewpoint, maize silage complements pasture well providing a relatively cheap source of energy. With good management, quality can be very consistent. The targets in Table 2 can be used to identify good quality maize silage (adapted from Mahanna 2000). Generally, high levels of metabolisable energy, protein, and starch are desired, with lower levels of fibre. Maize silage with a low pH and ammonia nitrogen content, and a high lactic acid content will be well preserved and have a long stack life. The nutritive characteristics of maize silage are largely determined by the cob:stover ratio.

Silage samples received in 2000 by FeedTech analytical service (n=203) indicated that on average, nutritive quality of New Zealand maize silage was very good (D. Corson, pers. comm., FeedTech Analysis, Celentis). Mean values and range were: Energy 10.6 MJME/kg DM (7.5–13.6); Crude protein 7.5% (5–15); Acid detergent fibre (ADF) 25.8% (15–38); Neutral detergent fibre (NDF) 44.6% (30–48); Soluble carbohydrate 34.4% (20–60); Fat 3.7% (2.4–4.4); pH 3.9 (3.6–4.2); Lactic acid 3.5% (<1–6.8); and ammonia nitrogen 8.4% of total N (<1–30). However, the range in quality also indicated that there were stacks of very poor, and extremely good, maize silage.

Average maize silage yields of 22 ± 3.39 tDM/ha (mean ± standard deviation; Densley *et al.* 2001) achieved on many farms in New Zealand are very high by world standards. These high yields are a result of a high grain yield per hectare.

**Table 2** Targets for good quality silage (adapted from Mahanna 2000).

| | Target |
|---|---|
| DM (%) | 28–35% |
| Energy (MJME/kg DM) | 10.8+ |
| Protein (%) | 7–8 |
| Degradable protein (% protein) | 65–70 |
| Undegradable protein (% protein) | 27–31 |
| Soluble protein (% protein) | <50 |
| Acid detergent fibre (ADF) (%) | 23–28 |
| Neutral detergent fibre (NDF) (%) | 38–45 |
| Soluble carbohydrate (%) | 38–50 |
| Fat (%) | 3–5 |
| Calcium (%) | 0.20–0.30 |
| Phosphorus (%) | 0.20–0.30 |
| Magnesium (%) | 0.15–0.20 |
| Potassium (%) | 1.0–1.30 |
| Sulphur (%) | 0.13–0.18 |
| pH | 3.8–4.5 |
| Lactic acid (%) | 4–5 |
| Ammonia nitrogen (% total N) | <5 |

## Maize silage and dairy cow nutrition

### Crop maturity and nutrient content

In New Zealand, the focus on high energy yields per ha have reduced the cost per tonne of DM harvested. As maize silage is primarily used as an energy source, any changes in the nutritive characteristics of maize that result in a reduced yield of energy per ha are not desired.

In general, plant maturity at harvest drives many of the nutrient characteristics of maize silage (Table 3). The DM content of the plant can be used to indicate maturity, with more mature plants having a higher DM content. Although the fibre and lignin content of the stover increases with age, the increased grain fill with age means that fibre levels of the whole plant are reduced as the plant matures (Bal *et al.* 1997). These changes occur in concert with an increase in energy content until DM content is approximately 35%, a dramatic increase in starch content, and a small reduction in protein. When maize silage of different maturities were fed as part if a total mixed ration to dairy cows, milk yield was highest for the silage with a DM content of 35% (Bal *et al.* 1997). DM intake was similar across treatments. These changes in nutrient content and resultant yield of energy per ha are the basis for the recommendation to harvest at between 30–35% DM.

**Table 3** The effect of maturity (expressed as the dry matter content of the silage) on the quality of maize silage and milk production response to total mixed ration containing similar proportions of maize silage DM (Bal *et al.* 1997).

| | Dry matter content of maize silage (%) | | | |
|---|---|---|---|---|
| | 31 | 32 | 35 | 42 |
| ADF (%) | 32.0 | 27.1 | 23.9 | 24.2 |
| Starch (%) | 18.2 | 28.7 | 37.2 | 37.4 |
| Energy (MJME/kg DM) | 9.2 | 10.1 | 10.6 | 10.5 |
| Protein (%) | 7.5 | 7.3 | 7.1 | 7.0 |
| Milk (kg/d) | 32.4 | 32.6 | 33.5 | 32.8 |
| DM intake (kg/d) | 25.6 | 25.7 | 25.8 | 25.4 |

## Level of maize silage

In periods of energy deficiency, cows will give the best milksolids response to maize silage when the feeding level does not exceed the guidelines shown in Table 4. These guidelines recognise that energy is the most limiting nutrient on most dairy farms in New Zealand (Kolver 2000) and are based on previous research that identified optimal inclusion rates of maize silage (Stockdale 1995). When feeding levels are greater that than these guidelines, nutrients other than energy will likely limit the milksolids response, and must be supplied to optimise the response to maize silage. In most cases a shortage of protein will limit further milksolids yields. At high feeding levels, possible mineral deficiencies are likely to occur.

If other starchy feeds (grains, concentrates) are being fed in conjunction with high levels of maize silage, starch should not exceed 30% of dietary DM, and NDF should not be less than 30% of the diet, to avoid problems with rumen and hoof health (Kolver 2000). Fibre may further be described as being "effective" at stimulating rumination, saliva production, and subsequent buffering of the rumen. Effective fibre levels for pasture-based diets with more than 25% of the diet fed as supplement should exceed 20% (of DM). Although not easily measured in pasture, it is estimated that 40% of the NDF in fresh pasture is "effective", although this can vary depending on pasture quality (De Veth & Kolver 2001). Estimates of effective fibre for other supplements are given by Kolver (2000).

**Table 4** Feeding guidelines for recommended maximum inclusion of maize silage in pasture diets (for a 450–500 kg cow).

| | Proportion of total diet DM (%) | Approximate intake (kg DM/cow/day) |
|---|---|---|
| Early lactation | 20–35 | 3.5–6.5 |
| Late lactation | 30–40 | 5.0–6.5 |
| Dry period | 60–70 | 5.5–6.5 |

## Spring pasture with 20% or 50% of the diet as maize silage

A 500-kg cow grazing 14.4 kg DM of spring pasture (11.5 MJME/kg DM, 25% crude protein, 42% NDF) and fed 3.6 kg DM of maize silage (10.5 MJME/kg DM, 7.5% protein, 49% NDF), will be consuming enough energy to produce 2.1 kg milksolids/day. At this level of maize silage (20% of DM intake), the cow's protein requirements will be more than met (21.5% of DM), there will be sufficient effective fibre (24.6% of DM) to promote chewing and maintain rumen health, and starch levels will not be excessive (8.5% of DM).

If maize silage supplied 50% of the diet (9 kg DM/cow/day), protein will become limiting (16.3% supplied vs. 18% required by the cow). Even though the cow is consuming enough energy to produce 2.1 kg milksolids/day, the protein limitation will reduce milk production.

## Summer pasture with 20% or 50% of the diet as maize silage

The same cow in mid-late lactation grazing 12.8 kg DM of poorer quality summer pasture (10 MJME/kg DM, 16% protein, 50% NDF) and fed 20% maize silage (3.2 kg DM) will consume enough energy to produce 1.5 kg milksolids/day. Although total dietary protein is less than in spring (14.3% of DM), the cow requires less protein in late lactation (14% of DM) and so should be able to produce the potential 1.5 kg milksolids/day on this diet.

If maize silage supplied 50% of the diet (8 kg DM/cow/day), protein will be in short supply (11.8% of DM) and 1.5 kg milksolids/day will not be achieved. In this 50% maize silage diet, the content of effective fibre (40% of DM) will be more than enough and starch content (19% of DM) will not be excessive.

## Protein

Cows require approximately 18% dietary protein in early lactation, 16% protein in mid lactation, and 14% in late lactation when supplemented with maize silage (Kolver 2000; NRC 1989). Dietary protein deficiencies can occur when maize silage is fed at rates higher than recommended, or if pasture has a low protein content. This can often occur during dry summers when pasture supply is limited and quality is poor (protein content 12–15%).

Although a number of protein sources are available in New Zealand (Table 5), many will not be profitable, except in years of high milk payout. The most accessible and probably the least expensive is high quality pasture silage or lucerne, brewers grains if available, or soybean meal depending on the price. In the previous example of a 50:50 maize silage:summer pasture diet, half of the maize silage (4 kg DM/cow/day) could have been replaced with high quality grass silage to boost dietary protein and milksolids production (to the potential 1.5 kg milksolids/day). Generally, the cheaper that the main energy supplement (maize silage) can be purchased for, the more options are available for purchasing protein supplements.

**Table 5** Protein sources to complement maize silage.

| | ME (MJME/kg DM) | Protein (%) | $/t DM | $/kg protein |
|---|---|---|---|---|
| Grass silage | 10.5–11.5 | 17 | 200 | 1.20 |
| Lucerne silage | 10 | 20 | 300 | 1.50 |
| Copra | 14 | 20 | 350 | 1.75 |
| Brewers grains | 10 | 23 | 180 | 0.80 |
| Whole cottonseed | 16 | 23 | 450 | 2.00 |
| Soybean meal | 12.9 | 50 | 700 | 1.40 |
| Fishmeal | 11.7 | 67 | 1200 | 1.80 |
| Urea | 0 | 281 | 480 | 0.17 |

The cost of the protein in the supplement (Table 5) needs to be considered when balancing maize silage, as well as recognising that some protein supplements will provide more energy than others, e.g., cottonseed contains 16 MJME/kg DM, whereas fishmeal contains only 11.7 MJME/kg DM.

The use of urea as an inexpensive nitrogen source for rumen microbes is widely practised overseas. However, the milksolids response to urea can be variable, especially if energy supply limits the rumen microbes' ability to convert the urea into protein. An additional carbohydrate source may be required if feeding urea with high levels of maize silage and poor pasture. In addition, rumen microbes require a 2–4-week adjustment period when urea is fed (Dairy Reference Manual 1995). Urea can be a worthwhile option for increasing the protein content of the diet by 2–3 percentage units, but thorough mixing with water and then with maize silage must be guaranteed to avoid ammonia toxicity and dead cows.

What is the milksolids response to extra protein? A study by Macdonald *et al.* (1998) demonstrated that including 0.7 kg of protein in a 50:50 diet of maize silage and summer/autumn pasture increased the protein content of the diet from 11.8% (deficient) to 16.8%. Milksolids production was increased by 115 to 165 g milksolids/cow/day when soybean and fishmeal were fed, respectively (Table 6). The soybean response is equivalent to a response of 165 g milksolids/kg protein. We can calculate the return as the income from the extra milksolids plus the cost of the maize silage replaced by the protein supplement, minus the cost of the protein supplement. No response was obtained to urea, and feeding soybean almost broke even. Fishmeal gave the greatest milksolids response, but the high cost of fishmeal resulted in a financial loss. In this experiment, soybean feeding would have broken even if the price of soybean was $600/t DM instead of $700/t DM, or if the milksolids price was $5.73/kg milksolids.

These are the immediate responses to protein. Less clear is the size of the carry-over response. For soybean to be profitable, a carry-over response (as a result of more days in milk, or sustained higher milk production) of 31 g milksolids/cow/day or more would be required. This carry-over response may occur if a more persistent lactation results from meeting protein requirements. If high quality grass silage had been used in this experiment, and we assume a response of 100 g milksolids/0.7 kg protein, then this would have generated a 37 cent/cow/day profit (Table 6).

**Table 6** Milksolids response and return to supplementing a 50:50 maize silage:pasture diet during summer and autumn with protein (calculated from Macdonald *et al.* 1998).

| Protein supplement | Milksolids response (g MS/0.7 kg protein) | Return[1] $/cow/day |
|---|---|---|
| Urea | 0 | -$0.05 |
| Soybean | 115 | -$0.14 |
| Fishmeal | 165 | -$0.24 |
| High quality grass silage[2] | 100 | +$0.37 |

[1]Using a payout of $4.50/kg MS.
[2]Likely response and returns if grass silage had been used as a protein supplement in this experiment.

## Minerals

Maize silage has low concentrations of calcium, magnesium, sodium, and phosphorus. Feeding maize silage can exacerbate mineral deficiencies such as magnesium and calcium already present in pasture diets. As a general rule, if maize silage makes up 25% or more of a lactating cow diet, mineral supplementation is recommended (Table 7). Depending on the individual farm, phosphorus supplementation may also be required.

Requirements for trace minerals are similar when feeding maize silage or grazing pasture. A trace element supplementation or animal treatment programme should be routine 1 month before calving and 4 months after calving. Supplying the cow's copper, selenium, cobalt, iodine, and zinc requirements will cost approximately 4 cents per cow per day.

**Table 7** Mineral supplementation guidelines when more than 25% of the diet DM is maize silage.

| | ---------------------- g/cow/day ---------------------- | | |
|---|---|---|---|
| | Limeflour (Ca) | Causmag (Mg) | Agsalt (Na) |
| Pre-calving | 0 | 40 | 0 |
| Early | 60–100 | 40–70 | 15–30 |
| Mid | 0–60 | 40 | 15–30 |
| Late | 0–60 | 40–60 | 20–50 |

**Fibre and starch**

Maize silage contains sufficient concentrations of effective fibre (eNDF) and most pasture/maize silage diets will not be deficient in fibre (see the spring and summer maize silage examples discussed earlier). Stockdale (1995) reported that fibre in maize silage was very effective at maintaining milkfat percentage in mid- and late-lactation, with no decline in milkfat yield up to 12 kg DM of maize silage. However, high levels of maize silage feeding (>50–70% of the diet), in conjunction with other supplements high in soluble carbohydrates such as grain or vegetable and fruit by-products, can result in diets requiring additional fibre. The decision to include additional fibre should be based on results from a feed analysis. If the NDF content of the total diet is less than 30%, and ADF is less than 19%, inclusion of an additional fibre source may increase milksolids production (Kolver 2000). This scenario is more likely with crops that have a high cob:stover ratio.

The effective fibre content of maize silage is influenced by the level of grain and the chop length. The effective fibre content of maize silage in New Zealand is approximately 80–90% (i.e., 80–90% of the NDF is effective at stimulating rumination and salivation; Table 8). In comparison, only 40% of the fibre in high-quality pasture in spring and autumn is considered to be "effective" (Kolver 2000; de Veth & Kolver 2001). Effective fibre is important for buffering ruminal pH to maintain optimal digestion and to avoid ruminal acidosis. The relationship between effective fibre and ruminal pH has been described by the equation pH = 5.425 + 0.04229 × eNDF (%DM) (Fox *et al.* 1999). The data in Table 8 from the United States show that most of the fibre in maize silage is effective at stimulating chewing and rumination, with a reduction in the level of effective fibre when grain content is high or chop length short (Fox *et al.* 1999).

The level of effective fibre is calculated from the distribution of particle sizes determined by sieving devices such as the Penn State Forage Separator. This method was used to calculate the effective fibre content of maize silage samples from 26 farms in the North Island of New Zealand in 1997 (Table 8). The effective fibre content was 87% (i.e., 87% of the NDF was effective at stimulating chewing, and maintaining milkfat content). In 1997 when these measurements were made, crop processing (rolling/crushing during harvest) was not common. Maize silage currently made in New Zealand is generally harvested at a chop length of 10–15 mm, and will be processed in some way. While crop processing will increase starch and energy availability (by approximately 10%), processing will also increase the level of effective fibre as cows are more likely to eat the high-fibre cobs.

Processing maize silage at harvest increases DM intake and milk production. The study by Jirovec *et al.* (1998) compared processed (rolled) and unprocessed maize silage with a theoretical length of cut of 9.5 mm. When incorporated into a total mixed ration, the processed maize silage resulted in a small increase in DM intake (25.8 vs. 25.1 kg/d) and 1.1 kg more milk (46.3 vs. 44.7 kg/d) than unprocessed maize silage.

**Table 8** Estimates of effective fibre content (% of NDF) of maize silage at different grain contents and chop lengths (Fox *et al.* 1999; R. Densley, unpublished data).

| | ------------ Grain content (%) ------------ | | | |
|---|---|---|---|---|
| | 30 | 40 | 50 | New Zealand |
| Chop length (mm) | | | | |
| 6.3 | 71 | 71 | 61 | |
| 12.5 | 81 | 81 | 71 | |
| 10–15 | | | | 87 |

**Dairy cow response**

The response of the dairy cows is the ultimate measure of the feeding value of maize silage. High genetic merit cows, and cows in early lactation will partition more energy towards milk production. Protein content of the diet can also affect energy partitioning via the growth hormone/IGF axis (Bauman *et al.* 1995). A high energy/low protein diet of maize silage and pasture, as may occur in summer, will result in more energy deposited as fat. This can be used to advantage when the aim is to increase cow body condition. Including more protein in a protein-deficient diet will generally result in more energy partitioned towards milk production.

Maize silage will have a different metabolisable energy content depending on the combination of other feeds it is fed with. The synergistic effect of feed combination was examined using a model of digestion and absorption (the Cornell Net Carbohydrate and

Protein System model; Fox *et al.* 1999). For a cow consuming 18 kg of a good quality pasture-based diet, including 25 or 50% of the diet as maize silage increased the metabolisable energy content of the grass from 11.6 to 11.7 MJME/kg DM. When the total diet consisted of maize silage, less nutrients were digested because the supply of nitrogen to rumen microbes was deficient. As more pasture was included in the diet, more protein became ruminally available and microbes were able to digest more of the maize silage.

## Intensification of New Zealand dairying

It has long been realised that almost complete reliance on ryegrass and white clover would set a limit to animal production (Campbell & Bryant 1978). Campbell & Bryant (1978) stated that "for future progress, we must turn our attention to high yielding crops, with all the economic constraints which they will inevitably impose".

While these observations are as applicable today as in 1978, much has changed in the dairying environment during the last 20 years. If supplement availability and cost, and milksolids payout remain similar to current costs and prices, further intensification of dairying is likely in New Zealand. Different dairying systems ranging from low-cost systems, to high-feed input systems with seasonal calving, and non-seasonal intensive systems might be expected in different regions of New Zealand (Penno & Kolver 2000). Driving this diversity will be the greater use of supplementary feeds, the development of feeding systems that allow the profitable use of supplementary feeds, and the evolution of non-seasonal dairying systems that will occur in response to clearer seasonal price signals. These changes are already being seen in New Zealand, with farm systems ranging from the traditional pastoral system to intensive feedlot dairying systems. With positive prospects for milksolids payout, and the availability of reasonably priced supplementary feed, the stepwise progression in use of maize silage and other supplements (Densley *et al.* 2001) is likely to continue.

What is the potential DM (energy) production per ha in New Zealand if we are not limited to ryegrass–white clover systems? Cereals such as maize, oats, barley, wheat and triticale are all likely candidates for high yield systems, and all can be either harvested as high-quality, energy-dense grains or ensiled as forage cereal crops in some regions of New Zealand. Likewise, the accessibility of protein supplements such as lucerne, copra or soybean, allow more flexibility in the types of diets that can now be used on-farm.

Maize, harvested as silage, is probably the most suitable energy foodstuff in many regions of New Zealand as it produces substantially more energy per hectare than other cereal silages or cereal grains. Yields of 20–25 t DM/ha are now common (Densley *et al.* 2001) and with crop breeding continuing to increase dry matter yields per hectare it is conceivable that average yields in excess of 25–30 t DM/ha may be achieved in the future. The growth pattern of maize, being planted in early November and harvested in late March, also allows the planting of a second crop, such as oats for silage during the same year (double cropping) (Clark *et al.* 2001). This may further increase production potential to approximately 35–40 t DM/ha. Following harvesting of the oats, land can be sown down to maize once more.

One possible scenario to push the feed barrier out to 35 t DM/ha would be to double-crop the whole farm in maize and oats and purchase soybeans as a protein source for the cows' diet. A number of simple diets were investigated using the Cornell model (Fox *et al.* 1999) to utilise maize and oat silage while meeting protein requirements (18% of DM in early lactation). An annual intake of 5500 kg DM/cow/yr was targeted, and milk production was estimated based on peak milk production and an assumed 2% decline in milksolids per month. The protein supplements were bought in from off-farm. It was assumed that the whole farm would be producing maize and oat silage, and cows would be confined to a feedlot. Of the diets investigated, the most simple in terms of the number of dietary components, and low-cost, was a diet consisting of 80% maize and oats silages (70:30 maize silage:oat silage) and 20% soybean (Table 9). This

**Table 9** Breaking the feed barrier: Simple feedlot system based on growing 35 t DM/ha using double-cropping[1].

| Milksolids payout | SR cows/ha | Milksolids[2] kg/ha | Milk income $/ha | Feed costs[3] $/ha | Margin[4] $/ha |
|---|---|---|---|---|---|
| $4/kg milksolids | 6.36 | 4135 | 16540 | 8400 | 8140 |
| $5/kg milksolids | 6.36 | 4135 | 20675 | 8400 | 12277 |

[1]Diet contains 80% maize and oat silage and 20% soybean meal.
[2]Milksolids production based on predicted peak milk production and a 2% decline per month in milksolids yield.
[3]Cost of feed and fertiliser.
[4]Margin is milk income less feed costs.

diet met the protein requirements and allowed a stocking rate of 6.4 cows/ha. If an irrigated all-pasture system is capable of a maximum of 1500 kg milksolids/ha, a feedlot system would result in increased per cow milk production in mid- and late-lactation (150 kg milksolids/cow/year increase) and increased per ha production (2635 kg milksolids/ha/year increase) due to increased feed availability and increased stocking rate. The cost of feed and fertiliser would account for approximately 50% of milk income.

## Conclusions

Maize silage provides a low cost source of energy in the form of starch and fibre which complements pasture well for much of the year. During the last decade, farmers and researchers have developed dairying systems that continue to break the feed barrier and allow the profitable use of reasonably priced supplements such as maize silage. Further opportunities exist for overcoming the feed barrier. These will be dependent on milksolids payout, the continuing availability of reasonably priced supplements, and an improved understanding of dairy cow nutrition.

### REFERENCES


Bal, M.A.; Coors, J.G.; Shaver, R.D. 1997. Impact of the maturity of corn for use as silage in the diets of dairy cows on intake, digestion, and milk production. *Journal of Dairy Science 80*: 2497–2503.

Bauman, D.E.; Harrell, R.J.; McGuire, M.A. 1995. Nutritional modulation of the IGF system. *Proceedings of the Cornell Nutrition Conference for Feed Manufacturers 57*: 198–206.

Campbell, A.G.; Bryant, A.M. 1978. Pasture constraints on dairy production. *Proceedings of the Agronomy Society of New Zealand 8*: 115–118.

Cooper, C.; Austin, G. 2000. Using maize silage to increase economic farm surplus. *Dairying Research Corporation Field Day*: 10–12.

Dairy Reference Manual. 1995. Third edition. Northeast Regional Agricultural Engineering Service, Cooperative Extension, Cornell University, Ithaca, New York.

Deane, T. 1999. The profitable use of supplementary feeds in pasture based dairy farm systems. *Proceedings of the Ruakura Farmers' Conference 51*: 64–77.

Densley, R.; Miller, D.; Kolver, E.S. 2001. Breaking the feed barrier using maize silage. *Proceedings of the New Zealand Grassland Association 63*: 289-293.

De Veth, M.J.; Kolver, E.S. 2001. Prediction of ruminal pH of dairy cows fed pasture. *Journal of Dairy Science* (In Press).

Clark, D.A.; Matthew, C.; Crush, J.R. 2001. More feed for New Zealand dairy systems. *Proceedings of the New Zealand Grassland Association 63*: 283–288.

Fox, D.G.; Tylutki, T.P.; Pell, A.N.; Van Amburgh, M.E.; Chase, L.E.; Pitt, R.E.; Rasmussed, C.N.; Tedeschi, L.O.; Durbal, V.J. 1999. The net carbohydrate and protein system for evaluating herd nutrition and nutrient excretion. pp. 1–82. *In:* Model documentation, Cornell University, Ithaca, New York.

Jirovec, A.G.; Shinners, K.J.; Shaver, R.D.; Bal, M.; Straub, R.J.; Koegel, R.G. 1998. Physical properties of wilted alfalfa and whole-plant corn silages processed with crop processing rolls. ASAE paper no. 981119. American Society of Agricultural Engineering, St Joseph, Michigan.

Kolver, E.S. 2000. Nutritional guidelines for the high producing dairy cow. *Proceedings of the Ruakura Farmers' Conference 52*: 17–28.

Macdonald, K.A. 1999. Determining how to make inputs increase your economic farm surplus. *Proceedings of the Ruakura Farmers' Conference 51*: 78–87.

Macdonald, K.M.; Penno, J.W.; Kolver, E.S.; Carter, W.A.; Lancaster, J.A. 1998. Balancing pasture and maize silage diets for dairy cows using urea, soybean meal or fishmeal. *Proceedings of the New Zealand Society of Animal Production 58*: 102–105.

Mahanna, B. 2000. Corn silage: managing and feeding the "TMR Plant". *In:* Crop Management Research and Technology, Pioneer Hi-Bred International, Inc.

Miller, D. 2000. The role and changes in the perception of maize silage in New Zealand pastoral dairy systems. *Proceedings of the New Zealand Maize Conference*: 51–55.

National Research Council, 1989. Nutrient requirements of dairy cows. Sixth revised edition. National Academy of Science, Washington, DC.

Penno, J.W.; Macdonald, K.A.; Bryant, A.M. 1996. The economics of No 2 Dairy Systems. *Proceedings of the Ruakura Farmers' Conference 48*: 11–19.

Penno, J.W.; Kolver, E.S. 2000. Future farm systems. *Proceedings of the Ruakura Farmers' Conference 52*: 3–13.

Stockdale, C.R. 1995. Maize silage as a supplement for pasture-fed dairy cows in early and late lactation. *Australian Journal of Experimental Agriculture 35*: 19–26.

Van der Poel, J. 1996. Going for high production. *Proceedings of the Ruakura Farmers' Conference 48*: 5–10.


■