MILK AND MEAT FROM MAIZE SILAGE IN AUSTRALIA

J.B. MORAN*, A.G. KAISER** and C.R. STOCKDALE*

SUMMARY

Maize silage is a basic forage in many overseas countries yet its use is still in its infancy in Australia's livestock industries. Our forage maize crops are generally higher yielding but of lower quality than those grown in Europe but are on a par with those grown in the United States. Genetic diversity of maize hybrids and the ranges in crop management and climate in Australia have produced silages with variable nutritive values. Stage of maturity at harvest is important and a milk line which marks the margin between the starch and milk phase in the grain correlates well with crop dry matter (DM) content, has been adopted in N.S.W.

Until recently, little attention has been given to the role of maize silage as a supplement to grazing animals. Research at Kyabram has quantified marginal responses to supplementation and the effect of pasture quality on milk responses to various levels of maize silage in the diets of grazing cows. During early lactation, marginal responses are approximately 1.0 1 milk/kg silage DM on grass and 1.4 1 milk/kg silage DM on higher quality clover diets. Cows grazing grass pastures (containing up to 25 g N/kg DM) can consume up to 40% of their diet as maize silage before requiring additional protein supplements whereas cows grazing clover pastures (with 35 g N/kg DM) can show milk responses with up to 60% maize silage in their diet DM. The potential for maize silage in beef production has been shown at Wagga Wagga where growth rates of over 1 kg/day were achieved in young steers fed entirely on maize silage plus minerals plus urea.

The integration of clover pastures and conserved forage crops should lead to large productivity gains which on irrigated dairy farms in northern Victoria, could amount to over 80% above current levels. Maize silage can constitute over 75% of the diet of intensively fed beef cattle in the U.K. Because of its unequalled capacity to produce utilized metabolizable energy for livestock and a better infrastructure for silage making (machinery, contractors, off-farm maize growers), maize silage should become an important source of quality forage for dairy and beef cattle throughout Australia.

(Key Words: Forage maize, maize silage, meat, beef, milk, dairy)

INTRODUCTION

The ensiling of forage maize for winter feeding of livestock has been practised in Europe and the U.S. for over 100 years. Growing maize for silage in Australia was first mentioned in the late 1800's (Anon. 1890) while O'Callaghan in his 1912 textbook "Dairying in Australasia", considered that "no dairy farm was complete without an ensilage pit or stack". Recent advances in plant breeding and crop mechanisation, have generated considerable worldwide interest in maize silage over the last 30 years. Plant breeders are still able to develop improved varieties as maize yields in the U.S. show little evidence of plateauing. Nearly three million ha of maize are grown each year for silage in the U.S. while annual forage maize plantings increased fivefold in Europe between 1965 and 1983 when they totalled 2.8 million ha (including 1.4 million ha in France and 0.8 million ha in Germany). The rate of adoption of this technology has been much slower in Australia probably because of our low cost, pasture-based livestock systems. Nevertheless, there

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* Kyabram Research Institute, Kyabram, Vic., 3620
** Agricultural Research Institute, Wagga Wagga, N.S.W., 2650

are certain areas where maize plantings have dramatically increased, for example, on the N.S.W. north coast (130 ha in 1978 to 525 ha in 1983) and irrigated northern Victoria (10 ha in 1983 to over 700 ha in 1988).

Despite its importance in overseas dairy **and** beef production, little attention has been given to maize silage in grazing systems. The majority of cattle in the U.S. are lotfed while in Europe, silage is fed to housed cattle in winter, although conserved forages are now being used to supplement grazing cattle in autumn (Phillips 1988). In Australia, hay has been the traditional supplement for dairy cows although concentrates are fed on dairy farms with milk quotas. Even in seasonal calving areas such as Victoria, farmers now feed concentrates to overcome pasture deficiencies. Complementary forage crops for grazing in *situ* are grown in certain dairying areas, but forage maize has rarely been considered among these crops, presumably because it requires harvesting prior to feeding. This review will present recent information on the nutritive value of, and animal responses to, the feeding of maize silage in Australia. These data will update that published in the proceedings of the national workshop on silage technology that washeldin Armidale in 1984 (Kempton et *al.* 1984).

THE NUTRITIVE VALUE OF AUSTRALIAN MAIZE SILAGES

Forage maize combines the desirable attributes of high dry matter (DM) yields and high feed quality, making it the elite forage crop for animal production. Agronomic studies in Australia have confirmed the hi& productive potential of the crop, with yields equal to or better than those reported in many overseas countries. In northern Victoria, average yields of 20-25 tonne DM/ha are commonwithirrigated crops, while in coastal N.S.W, dryland crop yields have averaged 18 tonne DM/ha in fieldtrials, However the nutritive value, particularly with dryland crops, has been variable.

Variation in nutritive value

TABLE 1 Digestibility of maize silages (measured in sheep) produced in various countries

Country	Digestibility	Level of feeding of sheep	Reference
United Kingdom	0.736 (OM) *	Restricted	W
Netherlands	0.735 (OM)	Restricted	D
Belgium	0.730 (OM)	Restricted	D
France	0.704 (OM)	*Ad libitum*	D
West Germany	0.688 (OM)	Restricted	D
Australia (Kyabram)	0.679 (OM)	Restricted	M
Australia (Wagga Wagga)	0.655 (DM)	*Ad libitum*	K
United States	0.640 (DM)	Restricted	D

* OM, organic matter; DM, dry matter.
Reference: D, Deinum and Struik (1986); K, Kaiser and Piltz (unpublished data); M, Moran (1986); W, Wainman *et al.* (1979).

When compared to European crops, Australian forage maize crops are generally higher yielding but of poorer quality (see Table 1). This could be due to climatic differences, but there is evidence that choice of maize hybrid, crop management, stage of harvest and method of assessing nutritive value are also important. Even when comparing in *vivo* digestibility data, the amount of nitrogen (N) or mineral. supplementation, level of feeding and animal species can account for up to 0.05 units of digestibility. Even after allowing for such differences, Australian maize silages have lower digestibilitiesthantheir European counterparts, but are similar to those grown in the US. Nutritive values may be even lower in tropical countries as Miller (1969) reported a value of 0.627 for OM digestibility (OMD) in maize silages from Nigeria.

When considering climatic differences, temperature appears to have the greatest influence on nutritive value and Deinum and Struik (1986) calculated that an increase in temperature of 10°C can cause OMD to drop by 0.03 units. Furthermore, high temperatures tend to stimulate plant growth and reduce digestibility more so during the vegetative growth phase, when most of the cell walls are being formed. Because environmental conditions are relatively constant within the Netherlands, a fixed value of 0.735 in *vitro* OMD (of both fresh and ensiled maize) has been proposed with corrections being made for variations in weather, hybrid selection and crop agronomy, In a recent survey involving 24 sites throughout Europe, Deinum (1988) also noted average digestibility values of 0.735 with a range of only 0.701 to 0.760 across locations when corrected for hybrid effects. Mean digestibility data for different hybrids, corrected for location, ranged from 0.699 to 0.787. This range is similar to that reported by Wainman *et al.* (1979) for 16 maize silages grown throughout the U.K. (ie, 0.701 to 0.773 *in vivo* OMD) which were fed to sheep in calorimeters. Metabolizable energy (ME) contents of these silages varied from 10.2 to 11.7, averaging 11.1 MJ/kg DM.

To date 20 maize silages from irrigated crops grown in southern N.S.W. and northern Victoria have been fed *ad libitum* to sheep at Wagga Wagga and DM digestibilities (DMD) ranged from 0.589 to 0.705 (Kaiser and Piltz, unpublished data). Schmid *et al.* (1975) reported a similar range in *in vivo* DMD (0.563 to 0.701) in 25 maize silages grown over three years in Minnesota in the U.S. To place this variability in nutritive value into context with its effect on animal performance, at 20 tonne DM/ha, increasing OMD from 0.60 to 0.70 would increase yield of ME/ha from 168 x 10^3 to 196 x 10^3 MJ, resulting in 5600 1 more milk/ha or 1320 kg more liveweight gain/ha.

Perhaps a better appreciation of variability in nutritive value can be obtained from laboratory analyses of samples taken from an even wider range of crops and silages. Three data sets from N.S.W. are presented in Table 2. They highlight the variable nature of maize silages produced within one state through the large genetic diversities of maize hybrids, crop management and environmental conditions under which they are grown.

TABLE 2 Variation in nutritive value of maize crops and silages in N.S.W. (range in parenthesis)

Source of sample	No. of samples	OM digestibility	Predicted ME content (MJ/kg DM)
Farm crops and silages throughout N.S.W.*	64	0.612 (0.462 - 0.757)	9.2 (6.9 - 11.4)
Crops from Grafton at one harvest date†	57	0.693 (0.633 - 0.735)	10.5 (9.6 - 11.2)
Crops from Nowra over one harvest season†	212	0.664 (0.472 - 0.730)	10.1 (7.2 - 11.1)

* Digestibility predicted from ADF and N contents (Anon. 1983)

† *In vitro* digestibility (Kaiser and Havilah, unpublished data)

Factors influencing nutritive value

Digestibility in forage maize is closely related to the concentration and digestibility of structural carbohydrates in the cell walls of the stem and also to the grain content of the crop, High yielding forage maize crops in northern Victoria generally have higher levels of neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin than those grown in Europe (Wilkinson 1978), presumably because of the need for greater stalk strength. Pinter (1986) noted a close relationship between stalk strength and content of lignin (rather than cellulose or hemicellulose) and concluded that high stalk strength was not desirable in silage maize hybrids. In the U.S. study of Schmid *et al.* (1975), ADF content was the best single predictor of *in vivo* DMD of 25 maize silages. From our sheep studies at Kyabram, we have noted a close relationship between NDF content and OMD in 11 silages made from six consecutive maize crops (Moran, unpublished data). These data, together with mean values from the U.S., U.K. and Holland (H) are presented in Fig. 1 and the plotted line (from Kyabram data only) is:

$$OMD = 0.897 - 0.00041\ NDF \quad (r = 0.87, \ RSD = 0.111)$$

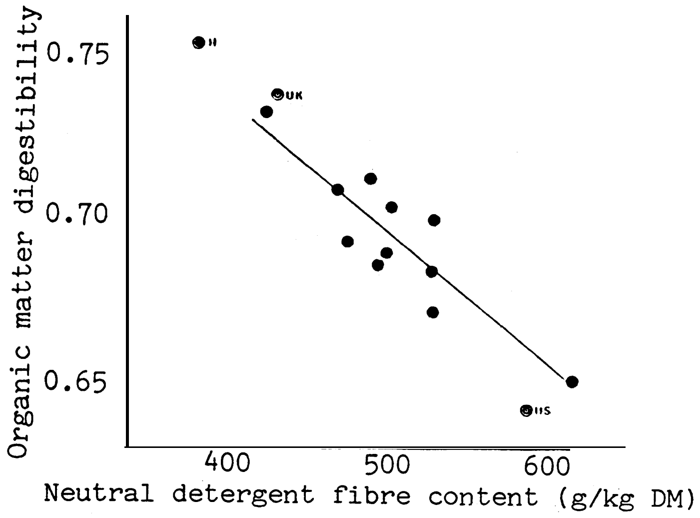


Fig. 1 The relationship between organic matter digestibility and neutra detergent fibre content in maize silages fed to sheep at Kyabram between 198 and 1986 (Moran, unpublished data)

Deinum (1988), on the other hand, considered the genetic variation in nutritive value of maize crops in Europe when harvested at silage maturity was mainly due to genetic variation in cell wall digestibility rather than wall production and composition.

With regards grain content of the crop at ensiling, the situation is n clear. Nutritive value improves with more grain in the silage up to a point, 300 g grain/kg stover as suggested by Pinter (1986). Thereafter, lignif cation of the stem during grain fill can reduce any nutritional benefits f increasing grain content. Consequently in certain trials, digestibility and animal performance have improved through feeding silages containing more grain, whereas in other trials, little effect of grain content has been observed (Wilkinson 1978). Results from these trials are often confounded by the feeding of-silages differing in both stage of maturity and grain fill

Grain content can be influenced by stage of maturity at harvest, plant population or variety. With regards stage of maturity, Kaiser and Havilah (unpublished data) measured reduced *in vitro* DMD within 17 maize hybrids grown at Nowra, with advancing maturity (from 0.68 to 0.63). When comparing four maturity groups taking 116, 125, 133 and 148 days to reach the same stage of maturity, they recorded *in vitro* DMD of 0.685, 0.667, 0.655 and 0.622 respectively. Barriere and Traineau (1986) compared yield and nutritive value of seven maize hybrids in France, finding the later maturing varieties to be higher yielding but to have less grain. They noted little effect of variety on feed intake in sheep although the earlier maturing varieties had the higher nutritive values. However the later maturing varieties far outyielded the earlier maturing ones in yield of digestible OM/ha. Deinum and Struik (1986) also reported a slight negative correlation between crop yield and silage digestibility.

In summary, nutritive value can be improved by early harvesting but maybe at the expense of yield. Stalk strength, an attribute for producing grain, is a liability for forage maize but may be associated with the later maturing varieties grown in Australia. The best hybrid for maize grain production may then not be the best for forage maize. However the ideal forage maize variety should be one producing the maximum yield of digestible OM per ha (above a critical OMD) under the existing environmental conditions and the optimum agronomic practices for each particular area. There are no comprehensive data available on digestibility of the stover fraction of the maize hybrids best suited to Australian conditions and this needs to be collected (preferably with low cost rapid screening methods such as near infra-red reflectance spectroscopy) to allow maize breeders to incorporate nutritive value in their hybrid selection criteria. Deinum (1988) believes that digestibilities of forage maizes grown in Europe could be increased to 0.80 through breeding for better digestible cell walls in the stover.

As maize grain can constitute 50% of the total crop DM, its degree of processing during harvesting could influence digestibility of the silage. For example, Stockdale (unpublished data) observed faecal grain excretion in dairy cows to increase from 7 to 16% (of total faecal DM) as maize silage intake increased from 3 to 12 kg DM/cow/day. Because of this possible loss in nutrients, a trial was conducted to compare cow performance when fed maize silage of three different chop lengths. Silages were prepared from a maize crop harvested at physiological maturity and chopped to three nominal lengths of 4 (fine), 8 (medium) and 13 (coarse) mm. These were fed to cows, in conjunction with pasture, in metabolism cages. There was no treatment effect on digestibility, milk yield or maize grain excretion in the faeces (Stockdale and Beavis 1988b). However there were differences in fuel usage during harvesting in that the medium chop silage required 12% and the fine chopped silage required 40% more fuel than the coarse chopped silage.

Assessing stage of maturity - the milk line score

Definitions of the physiological stage of development of the maize crop have generally been based on subjective descriptions of grain development or a measure of whole crop DM content. The former method, using such descriptions as milk, dough and dent, lacks precision, is subject to different interpretations by various observers and, in any event, not all maize varieties dent during grain filling. Content of DM, while useful for researchers, is not appropriate for accurate assessment in the field. Kojic and Stojsin (1986) and Havilah and Kaiser (unpublished) have adopted a milk line scoring system as a visual maturity indicator. The milk line is the border between the solid (starch) and liquid phase of kernel (grain) contents and moves down the kernel as the crop matures. In N.S.W., a 5 point scoring system has been adopted with the score 0 at the top of the kernel and a score 5 when the milk line reaches the base of the kernel at "black layer" physiological maturity. The milk line is closely correlated to whole crop DM content and typical data are presented in Table 3.

TABLE 3 Changes in composition of the maize hybrid XL82 (harvested at Nowra in 1988) with advancing maturity (Havilah and Kaiser, unpublished data)

Date	Milk line score	DM content (g/kg)	Grain content (g/kg DM)
March 22	0.5	248	326
29	0.8	285	363
April 13	2.5	328	461
20	3.3	369	474
May 5	4.9	403	497

Forage maize will make good quality silage over the DM range 300 to 350 g/kg, therefore the optimum time to harvest this crop would be between milk line score 1.5 and 3.0. This would extend the range of suitable harvest dates over 17 days (from April 2 to 18) during which time grain content would increase from 400 to 450 g/kg DM. More data are required to establish relationships between milk line score and crop DM and between crop yield and nutritive value for a range of hybrids over a number of seasons.

MILK FROM MAIZE

Initial studies at Kyabram assessed the role of maize silage in feedlot diets (Moran and Trigg 1989). These plus a more recent unpublished study showed the potential of such nutritionally balanced, complete diets (containing 40% rolledwheat inearlylactationand 20% rolledwheat in mid andlatelactation) to produce 7000 1 milk, 290 kg milk fat and 200 kg milk protein in Australian Friesian cows over a full lactation, During the last four years, maize silage has also supplemented pasture-fed cows. In 14 trials, 197 cows were handfedmaize silage in pens or metabolism cages in conjunction with varying levels of pasture to delineate responses to supplementation in terms of appetite, milk production and rumen digestion. A further 175 cows in five trials were supplemented with silage while grazing different allocations of pasture, These trials were conducted over spring and autumn, with cows in different stages of lactation and involved both clover and grass-based pastures. Grazed pasture intakes were measured in each trial which allowed the determination of milk responses from the maize silage portion of the diet.

Responses in early and late lactation

In several indoor experiments cows were fed different levels of grass-based pasture and supplemented with amounts of maize silage ranging from none *to ad libitum*. During early lactation, the marginal response was approx 1.0 1 milk/kg maize silage DM before yield plateaued between 30 and 50% silage of the total DM intake. Marginal responses during late lactation were only 0.4 1 milk/kg maize silage DM but there was no plateau in milk yields up to 60% silage of the total DM intake. Responses in milk yield in early lactation ceasedwhen dietary protein levels dropped to 13% while inlatelactation, yields were unaffected by dietary protein contents as low as 10% (Stockdale, unpublished data). These minimum protein levels are considerably lower than reported values of 16% for early and 13% for late lactation (National Research Council 1978).

Effect of pasture quality

Feeding clover rather than grass-based pastures overcomes protein limitations to milk responses, particularly during early lactation.

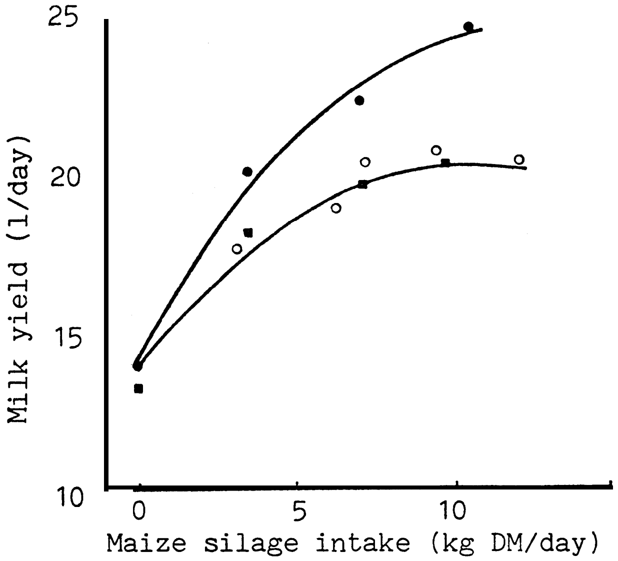


Fig. 2 Milk responses from cows in early lactation fed 7.5 kg DM/day of ryegrass/white clover (○ ■) or Persian clover (●) and supplemented with increasing amounts of maize silage (Stockdale and Beavis 1988a)

The data in Fig. 2 originated from trials in which cows were handfed 7.5 kg DM/day of perennial grass-based pasture (26 g N/kg DM, 0.67 *in vitro* DMD) or the same amount of Persian clover (34 g N/kg DM, 0.76 DMD) together with various levels of maize silage (13 g N/kg DM, 0.67 DMD) ranging from 0 to 11 kg DM/day. For grass-fed cows, milk yields peaked at 20 l/day when silage constituted 40% of the diet but with clover-fed cows, a milk yield of 24 l/day was achieved at maximum silage intake of 60% of the total DM with no indication of a plateau in milk yield (Stockdale and Beavis 1988a). Furthermore, the marginal response to the first 5 kg silage DM was 0.9 l/kg DM for grass and 1.4 l/kg DM for clover. This response for maize silage supplementing the legume can only be explained through associative effects of digestion which improved the utilization of one or both of these feeds. In a further trial, dairy cows in metabolism cages were fed at two levels of clover (34 g N/kg DM, 0.75 DMD) either 5.1 or 9.1 kg DM/day with *ad libitum* maize silage (10 g N/kg DM, 0.68 DMD) to assess therelativeimportance of changes involuntary feed intake and digestibility on milk responses. Milk yields were significantly higher on the high clover diet (22.2 v 19.3 l/day), as were total DM intakes (15.3 v 13.3 kg/day) but OMD did not differ (Moran, unpublished data).

Bryant and Donnelly (1974) and Rogers *et al.* (1979) reported improvements in utilization of digested energy and nitrogen respectively of pasture in dairy cows following supplementation with maize silage. With growing cattle, Thompson (1978) reported a higher efficiency of utilization of ME for liveweight gain when fed maize grain plus clover compared to maize plus grass, barley plus clover or barley plus grass, despite similar metabolizabilities of the four diets. Furthermore, Hvelplund *et al.* (1987) noted that efficiency of microbial protein synthesis in cattle was higher on diets incorporating maize silage plus legumes compared with maize silage without legumes. This could partly explain the better utilization of maize silage/clover silage diets, compared to maize silage/grain/urea diets, recently reported in dairy cows in France (Hoden *et al.* 1988). Further studies on interactions betweenmaize silage-starch and clover-nitrogen are currently being undertaken with sheep in calorimeters at CSIRO Prospect (in conjunction with N. McC. Graham) and with dairy cattle in metabolism cages at Kyabram (by C. Lemerle and colleagues).

Responses in grazing cows

A summary of four grazing trials is presented in Table 4. Milk yields of 21 to 22 l/day were sustained in early lactation by feeding up to 10 kg DM/day of maize silage, ie. up to 56% total DM. Hutton and Douglas (1975) in New Zealand recommended that it should not exceed a third of the total DM in grazing cows whereas Phipps (unpulished data) in England noted milk responses with up to 75% maize silage in the diets of grass silage-fed cows.

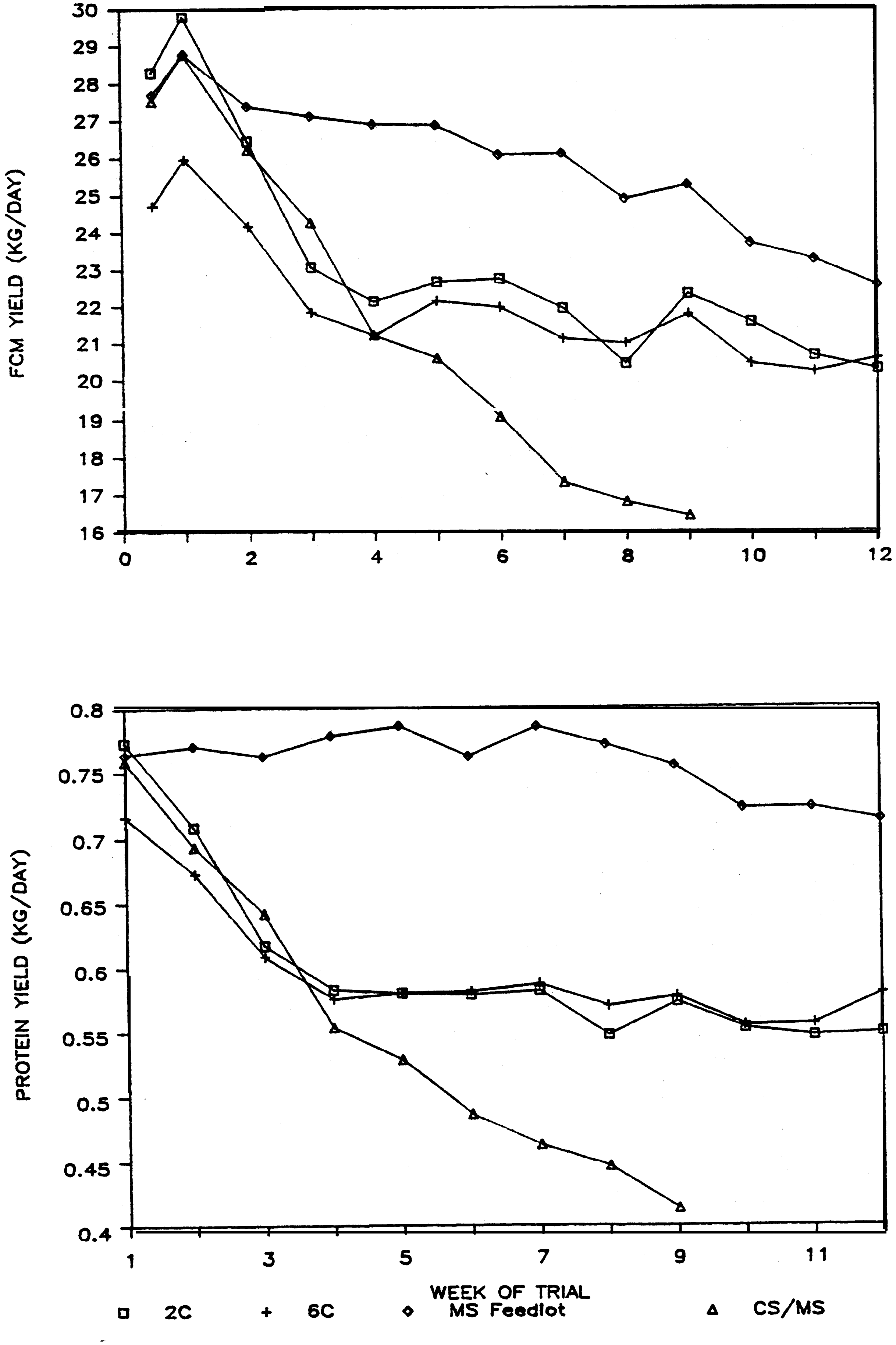
TABLE 4 Intakes of maize silage and pasture DM, animal performance and pasture quality in four grazing trials at Kyabram involving maize silage supplementation during early or mid lactation

	Early lactation				Mid lactation	
Trial	A	A	B	C	D	D
Season*	Sp/S	Sp/S	Sp	A/W	S/A	S/A
Maize silage DM intake (kg/day)	0	3.1	7.3	9.8	0	6.6
Pasture DM intake (kg/day)	16.3	14.5	10.1	6.6	15.8	9.8
Proportion of maize silage	0	0.18	0.42	0.56	0	0.40
Milk yield (l/day)	19.5	20.9	22.3	21.1	13.9	14.0
Liveweight change (kg/day)	0.35	0.53	0.18	-0.26	0.50	0.57
Pasture N content (g/kg DM)	23	23	32	37	20	20
Pasture DM digestibility	0.66	0.66	0.76	0.70	0.62	0.62

* Sp, spring; S, summer; A, autumn; W, winter.

Cows grazed perennial ryegrass/white clover pastures in Trials A, B and D and annual subterranean clover pastures in Trial C. Other groups of cows grazed less pasture in Trial A but were offered more maize silage (10 g N/kg DM, 0.61 DMD). Once they consumed more than 8 kg/day silage DM, there was a significant milk response to additional protein (in this case cottonseed meal) in the supplement (Moran *et al.* 1986). Similar interactions between maize silage intake and additional protein were observed in grazing cows in Queensland (Davison *et al.* 1982). Therefore, as concluded from the pen feeding trials, at moderate N levels in pastures (up to 25 g N/kg DM), additional protein is required when supplementing grazing cows with more than 40% maize silage in the total diet. The summer perennial pastures grazed in Trial D were of lower quality than those grazed in Trials A and B but the cows were in mid lactation, hence had lower dietary protein requirements. Therefore their milk yields were not reduced through the inclusion of 40% silage in their diet.

Cows grazed annual clover pastures in Trial C for either 2 or 6 hours per day and were then fed *ad libitum* maize silage on a feedpad. Other cows in this study were pen fed either a complete feedlot diet (26 g N/kg DM, 0.72 DMD) or a mixed diet of 0.6:0.4 of red clover silage:maize silage (23 g N/kg DM, 0.64 DMD); the clover silage had been heat damaged during ensilation as DMD was only 0.61 despite it containing 32 g N/kg DM. All cows were fed the feedlot diet in the first week of the 12 week study. Milk and protein yields are presented in Fig. 3 from which it is apparent that the feedlot diet led to consistently higher protein yields However after 12 weeks, milk yields on the feedlot diet approached those of the two grazing groups (Moran and Wamungai 1988). Cow performance on the clover silage/maize silage ration was so poor that these cows were removed from the trial after only nine weeks. Therefore the quality of the basal ration has an important effect on milk responses to maize silage.



Fig, 3 Yields of fat corrected milk (FCM) and protein in cows grazing clover-based pastures for two (2C) or six (6C) hours and supplemented with maize silage or pen fed a feedlot diet (MS Feedlot) or clover silage/maize silage (CS/MS) mixture during early lactation (Moran, unpublished data)

Cow performance in the two grazed herds in Trial C was similar despite large differences in maize silage intakes, namely 11.7 kg DM/day or 73% of total diet DM with 2 hours/day grazing versus 9.8 kg DM/day or 56% of total diet DM with6 hours/day grazing. However the former herd lost excessive liveweight (-0.63 v -0.26 kg/day) and this could be detrimental to fertility; it would also have to be regained later in lactation. Therefore our recommendation when using clover-based pastures would be to graze cows between morning and afternoon milkings and then feed them on maize silage on a feedpad overnight.

Cows in Trial B were offered silage either in the morning only or throughout the day to assess the importance of pattern of feeding on maize silage utilization. Cereal grains or concentrate supplements are fed out at each milking to reduce the imbalance between the rate of ammonia release (from pasture digestion) and energy production (from supplement digestion) in the rumen. There were periods during the day when this rumen imbalance is critical with maize silage supplementation (Moran and Jones, unpublished data). However milk production in cows with silage freely available all day did not differ tothatin cows fed silage in the morning only (Moran et *al.* 1987). This is in agreement with a recent report by Bruins (1988) who reported similar milk yields in cows fed grass silage and maize silage together or separately.

Forage maize can be fed out as greenchop in the autumn or silage throughout the year. Additional cows in Trial D were fed greenchop to supplement the summer/autumn perennial pastures and produced similar milk responses to those presented in Table 4 (Moran *et al.* 1987). Although greenchop and silage are of similar nutritive value for cows in mid lactation, there is a yield penalty if a maize crop is harvested too early, as DM accumulation during grain fill can amount to 200 to 300 kg DM/ha/day (Pritchard and Moran 1987).

Substitution of pasture for supplement invariably occurs when grazing cows are offered additional feed and depends greatly on pasture availability and quality. Feedinghighlevels (>6 kg DM/day) of starch-rich supplements can reduce milk responses through depressed pasture digestion (Kempton 1983). This is less likely to occur with quality fibre supplements such as maize silage as the rate of pasture substitution should be lower (Meijs 1986) and rumen digestion is less affected (Moran, unpublished data). Pasture substitutionwas measuredin Trial A in which 0.6 to 0.8 kgless pasture DM was eaten per kg maize silage supplement DM offered (Moran *et al.* 1986). It was also measured in a recent grazing trial in which cows were supplemented with different levels of rolled wheat or maize silage; preliminary results suggest similar rates of pasture substitution for both supplements (0.8 - 1.1 kg less pasture DM/kg supplement DM) (Moran and Croke, unpublished data).

MEAT FROM MAIZE

Maize silage can have a dual role in beef finishing, either as a supplement in pasture-based systems (for the domestic meat trade) or as a component of feedlot rations (for both domestic and export meat trades). It can be used to grow cattle out prior to finishing and also be a major part of preconditioning diets in feedlots. As with dairy cattle, little attention has been given to its role as a supplement for grazing animals. With lower dietary protein requirements than dairy cows (12% v 16%, National Research Council 1978), grazing systems incorporating up to 60% in diet DM or more should be possible. Furthermore, these could be more simplistic than those for dairy cows because there is little change in energy and protein requirements during beef finishing, compared to those in dairy cows during a full lactation cycle, Utilization of available pastures should be greatly improved through increases in grazing pressures made possible by feeding large amounts of maize silage Research is now under way at Kyabram in which beef steers will graze perennial and/or annual pastures at different stocking rates with different levels of maize silage supplements.

Only 10% of Australia's beef herd is currently finished in feedlots. However,' this could dramatically increase in the future through current demands by supermarkets and exporters for high quality, grain-fed beef. The potential for maize silage to replace more expensive high-energy components of feedlot diets is soon to be investigated at Wagga Wagga. Earlier trials in South Australia (Hawthorne 1978) led to growth rates of only 0.6 to 0.7 kg/day in 270 kg steers fed maize silage plus urea andthisincreasedto 1.0 kg/day with the inclusion of 45% barley in the ration DM. Preliminary results from more recent studies (Kaiser and Piltz, unpublished data) are presented in Table 5 in which 180 kg steers were offered 12 different maize silages (plus minerals and urea at 20 g/kg DM) for 80 days. The resulting growth rates and feed efficiencies compare favourably with those from young steers fed maize silage plus urea in Europe (Kilkenny 1978).

TABLE 5 Performance of 180 kg steers offered 12 maize silages *ad libitum* (plus minerals and urea at 20 g/kg DM) (Kaiser and Piltz, unpublished data)

	Mean	Range
DM intake (g/kg liveweight)	25.0	21.4 - 29.2
Liveweight gain (kg/day)	1.06	0.98 - 1.15
Feed conversion ratio (kg DMI/kg gain)	5.2	4.8 - 5.7

Kilkenny (1978) cites examples of intensive beef production systems in the U.K. incorporating 75 - 80% maize silage DM and leading to slaughter liveweights of 490 kg by 14 months of age. Beef feedlots in the U.S. also use maize earlage (silage made from the cob fraction of the maize plant) to increase nutritive value and the intake of the conserved crop. There are beef feedlots in Queensland and N.S.W. currently growing maize for silage or contracting nearby farmers to grow the crop and this is likely to greatly increase in the future.

INTEGRATING MAIZE SILAGE INTO EXISTING FARMING SYSTEMS

The high yields of foragemaize and the high nutritive value of legume pastures provide great opportunities to improve on-farm productivity of milk and meat in Australia Research data from Kyabram have been integrated into a farming system based on grazed annual and perennial legumes together with conserved summer and winter forage crops. This so-called "Kyabram Dairy System" is still being developed at the research and farm levels and Table 6 presents theoretical data on the productivity gains achievable.

Introducing perennial legumes should improve total utilized ME by 28% yet increase milk fat yield by 48% because milk fat per cow would have to improve from the current 178 to 250 kg per year prior to increasing cow numbers. With one quarter of the farm under double cropping, utilized ME should increase by 60% and total farm yield by 83%. With optimum grazing and cropping management, it should be feasible to run 185 cows and increase total farm yield by 145%. Such theoretical productivity gains have been calculated for dairy farms in both New Zealand (Taylor and Hughes 1978) and England (Doyle and Phipps 1987). In the latter case, a mathematical model calculated an increase in profits by 70% per cow through allocating 25% of the conservation area for maize rather than pasture silage. At this stage, we have insufficient data on on-farm maize production costs and productivity gains to allow for such economic extrapolations. This is being collected and initial estimates (Earle 1987; Pritchardand Moran1987) cost a 20 tonne DM/ha crop of forage maize at between 8 and 10 cents/kg maize silage DM taking into account growing and ensiling costs and a 20% loss from harvest to feeding out. This compares favourably with costs of conserved hay and silage (10 to 12 cents/kg DM), cereal grains (16 to 18 cents/kg DM) and commercial concentrates (20 to 22 cents/kg DM).

TABLE 6 Theoretical yields of utilized metabolizable energy (ME), milk and milk fat on a typical 80 ha farm in northern Victoria with 500 ML irrigation water allocation running spring calving cows.

Farm system	Utilized ME (MJ x 10^6/annum)	Herd size (cows)	Total farm yield milk	(tonnes/annum) milk fat	Relative total farm yield
1 (Typical)	4.89	105	467	18.7	100
2 (Perennial legumes)	6.26	112	692	27.7	148
3 (10 ha cropping)	6.97	125	772	30.9	165
4 (20 ha cropping)	7.80	140	855	34.2	183

The high costs of machinery for growing and conserving maize are obvious barriers to its acceptance by farmers but as the technology is adopted, more contractors will become available for sowing and harvesting the crop. This year for the first time, there are cropping farmers growing irrigated maize under contract in northern Victoria and selling it standing in the paddock for 6.5 cents/kg DM. Therefore livestock farmers will now be able to purchase regular supplies of forage maize without having to learn the skills and devote the time to ensure high forage yields.

OONCLUSION

With the increasing costs of pasture supplements, more maize silage will be fed to grazing animals in years to come. Dairy farmers on milk quotas rely heavily on concentrates to overcome pasture deficiencies particularly during autumn and winter. Consequently they feed more concentrates than do farmers with seasonal calving herds. For example, in 1988 dairy farmers in N.S.W. fed on average 600 to 800 kg/cow/year (and up to 1500 kg/cow/year on farms close to Sydney) whereas Victorian farmers only fed 300 to 500 kg/cow/year (Moran and Ashwood, unpublished data). Maize silage can be grown on-farm for about half the cost of purchased concentrates. Furthermore, it is generally of better quality than conserved excess pasture, the traditional supplement for dairy farmers. Maize silage could constitute up to three quarters of the finishing ration of beef cattle and this could replace much of the grain currently fed in feedlots. Plant breeders are working towards better quality forage maize hybrids with acceptable DM yields. The availability of suitable machinery and contractors to sow and harvest the crop is increasing. Finally, more cropping farmers are seeing the profits to be made in contract growing of the crop. Therefore it is highly likely that maize silage will be playing an ever increasing role in the livestock industries of Australia.

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