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# IMPROVING FORAGE NUTRITIVE VALUE: SOME RECENT FINDINGS IN FORAGE CONSERVATION RESEARCH IN EUROPE

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## INTRODUCTION

Over the past decade there have been many new developments in forage conservation research in Western Europe. These include improved methods of harvesting and storage, improvements in nutritive value of the conserved products, and the conservation of new crops. This paper reviews these developments and discusses their relevance to New Zealand conditions.

## HAYMAKING

In most West European countries the majority of grass conservation is as hay. Although some hay is removed from the field at moisture contents as high as 40% and dried with cool air in the barn, a much larger proportion is cured entirely in the field with drying periods commonly of around 7 days. Research has concentrated on ways of reducing the time that material is exposed to weather risks in the field. This period may be reduced by increasing the drying rate or by removal from the field at a higher than normal moisture content for barn drying or moist storage.

The National Institute of Agricultural Engineering in the U.K. has examined the efficiency of different mowing and conditioning machinery. A mower-conditioner was developed in which the crop is cut with a drum mower and conditioned directly after cutting by flails with open V-form metal elements, which scuff and abrade the cuticular layer of the crop without causing serious fragmentation (Klinner, 1975, 1976). The flails are located so that more work is done on the basal parts of the plant tissues. Use of the conditioning attachment produced more even drying in the swath, increased the rate of drying to 40 and 65% DM by 61 and 43%, respectively, and increased the amount

of DM that was recovered in bales by 10%. These principles are now being developed commercially.

Thaine and Harris (1973) found that treatment with formic acid improved the drying rate of single leaves and concluded that this arose through damage to the cuticle. Treatment of crops with formic acid at cutting has resulted in improvements in drying rate to moisture contents of around 50%, but no advantage thereafter (Tetlow *et al.*, 1975). It appears that the acid will accelerate water loss from the leaf blades, but the rapid drying of the leaf will then restrict the movement of stem water to the atmosphere via the leaf blade. The full potential for chemical desiccants applied at cutting cannot yet be realized, but they can be exploited in the treatment of standing crops. Formic acid applied at 5 l/t of fresh crop reduces the water in the standing crop by c. 25% within 1 or 2 days, thus achieving "wilting" before the crop is cut for haymaking, ensiling or dehydration (Pirkelmann, 1972; Tetlow, 1973; Tetlow *et al.*, 1974; Zimmer, 1974). This quantity of acid should be mixed with 3 parts of water and the 25% solution applied at 20 l/t.

Removal of hay from the field at 40% moisture content rather than the normal 20% may halve the time required in the field. Application of propionic acid in the laboratory at 0.5 and 2% to hay of 30 and 50% moisture content, respectively, has prevented heating and mould growth (Lacey, 1969). In field experiments much higher rates of propionic acid were required, largely because of uneven application. However, only twice the laboratory rate was required using an improved applicator to spray a windrow directly before baling (Klinner, 1976). Ammonium propionate, which is less volatile and corrosive than propionic acid, is now being examined as a hay preservative with promising results (Klinner, 1976; Lacey, 1976).

#### GRASS AND LEGUME SILAGE

In untreated silages approximately 50% of the protein is degraded to amino acids by liberated plant enzymes; amino acids can be further degraded to ammonia by proteolytic clostridia. Water-soluble sugars (WSC) are fermented by lactic acid bacteria to lactic and acetic acids until the pH falls to 4.0 to 4.2. If the pH does not fall this low owing to insufficient WSC, then lactic acid is decomposed to butyric and acetic acids by saccharolytic clostridia; this is generally accompanied by an increase in proteolytic clostridial activity. High moisture contents also encourage clostridial growth.

The effect of the silage fermentation on nutritive value is to reduce voluntary intake and the efficiency of nitrogen (N) utilization (Wilkinson *et al.*, 1976a). Extensive N degradation and lactic acid formation are the major factors responsible for the intake depression. Under European conditions silages which have undergone extensive N degradation will have a much lower intake than those where the lactic acid content is high (Wilkins, 1974).

In unwilted lucerne silages it was deduced that intake was limited by fermentation of amino acids by proteolytic clostridia rather than by the degradation of protein to amino acids (Barry *et al.*, 1977). Methods by which proteolytic clostridial action can be controlled and intake increased include the use of conventional management procedures such as wilting, and the use of additives. Two kinds of additive are widely used in Europe — first, those with special action against clostridia; formic acid at 2.5 to 3.5 l/t is the most popular; secondly, mixtures of formaldehyde and acids. The effectiveness of these depends on restriction of microbial activity, resulting mainly from the acid component, and on the restriction of N degradation based on the protein-binding properties of formaldehyde. Mixtures of formaldehyde and sulphuric acid, applied at 4.5 l/t, are used in both the U.K. and in Finland.

McLeod *et al.* (1970) showed that neutralizing silage with sodium bicarbonate to pH 5.5 increased intake, whilst the addition of lactic acid depressed both pH and intake. Hence the silage fermentation should be controlled such that high levels of free lactic acid are not formed. This can be accomplished by wilting (Jackson and Forbes, 1970) and by the application of higher rates of formic acid than are generally necessary to control clostridial fermentation (5 l/t; Wilson and Wilkins, 1973). Application of the formaldehyde-containing additives at 3 to 5 g formaldehyde/100 g crude protein (Wilkinson *et al.*, 1976a) will reduce lactic acid formation *per se*, and, because silages made in this manner also have a higher pH (4.7 to 4.9), the proportion of lactic acid that is in the free acid form is also reduced. Wilting has a similar effect (Jackson and Forbes, 1970).

Reducing particle size to 1 to 2 cm by using a precision-chop harvester also increases intake compared with silages made with a flail harvester. This is due partly to reducing particle size *per se* and partly to improved fermentation characteristics resulting from better compaction (Dulphy and Demarquilly, 1973; Barry *et al.*, 1977).

Because of their effects on increasing intake, the treatments previously mentioned will also produce increases in N retention. However, when fed at constant intake, both wilting (Durand *et al.*, 1968) and application of formic acid (Waldo *et al.*, 1971) have increased N retention. This could be due to these treatments conserving WSC, which functions as a source of available energy for stimulating rumen microbial protein synthesis. Application of a formaldehyde-formic acid mixture increased voluntary intake, liveweight gain and the efficiency of food conversion in yearling heifers (Waldo, 1975), but responses in all three parameters were also obtained to protected protein supplements with the animals fed both silages. This shows that amino acid supply was still not high enough to support maximum production on the additive-treated silage.

Large differences between silages in the pattern of protein and amino acid digestion have been reported by Beever *et al.* (1977). In untreated and formaldehyde-treated ryegrass silage (6 g/199 g crude protein) the proportions of dietary amino acids degraded in the rumen were respectively 85 and 22%. However, formaldehyde treatment reduced the amount of microbial protein synthesized in the rumen from 95 to 31 g/day, with the result that this treatment increased the quantity of amino acids absorbed from the small intestine by only 13%. Formaldehyde treatment also increased the amount of energy available to the animal by 11%. These data help to explain the responses in animal production obtained from silages that have been treated with additives containing formaldehyde.

Through application of the principles described here it has been possible to obtain liveweight gains of 0.6 to 1.0 kg/day in 3- to 6-month-old calves fed grass silage without supplements (Tayler and Wilkins, 1975).

#### MAIZE SILAGE

There has been a very large increase in the amount of forage maize grown in Europe over the last ten years. This has occurred because early maturing hybrid varieties have been developed which regularly achieve yields of 10 to 12 t DM/ha at a relatively low input of fertilizer N (recommended application in U.K. is 80 to 100 kg N/ha). In most years the crop can be harvested 50 to 60 days after flowering at 25 to 30% DM content. Although the ensiled product is relatively high in energy (average content of metabolizable energy is 10.7 MJ/kg DM), a major nutritional limitation is its low content of total N (*c.* 1.4% DM). Fermenta-

tion quality, however, is invariably good since the crop has a low buffering capacity and adequate fermentable carbohydrate to produce a low pH with lactic acid the major fermentation acid. Although the level of ammonia N in maize silage is low (5 to 10% total N), about half of the protein N is fermented to NPN.

When ensiled at 25% DM, the starch in the grain portion of the crop remains unfermented during ensiling. This makes maize silage particularly prone to aerobic deterioration during the feed-out period. Propionic acid, added at 0.5% of the crop fresh weight, has been found to control heating and reduce loss of dry matter when the silage is exposed to air (Cook, 1973; Honig and Zimmer, 1973), but the cost of applying the acid to the whole crop at harvest is rather high.

Research in Europe has centred on establishing the levels of animal performance which might be expected from beef and dairy cattle given *ad libitum* maize silage as the predominant source of energy in the diet. The relatively high content of free acids and the extensive protein degradation are limiting factors to its consumption when offered *ad libitum* as the sole source of energy to beef cattle less than 200 kg liveweight (Thomas and Wilkinson, 1975; Wilkinson *et al.*, 1976b). Thus with young calves given maize silage alone, the response in growth rate to additions of NPN at the time of feeding has been poor (Thomas *et al.*, 1975a). Growth rates of 1 kg/day have, however, been obtained in calves initially 100 kg liveweight when ensiled maize was given *ad libitum* with supplements of dried lucerne (Thomas *et al.*, 1975a), a compounded protein concentrate (Wilkinson and Penning, 1976), fishmeal (Cottrill *et al.*, 1976), or a concentrate containing barley, dried ryegrass, and urea (Thomas *et al.*, 1975b) to increase the crude protein content of the diet to around 16% DM. With cattle in excess of 200 kg liveweight, gains of 1 kg/day have been achieved from maize silage supplemented solely with urea (Thomas *et al.*, 1975a). Acceptable carcasses have been produced from Friesian bulls given maize silage, urea and limited barley grain from 100 kg to slaughter at 450 kg liveweight at 17 months of age (Wilkinson and Penning, 1976).

Additives containing NPN are used in farm practice in the conservation of maize. In one study there was no difference in liveweight gain when calves were given a diet consisting of 66% maize silage and 33% concentrate, to which urea was added either to the silage at harvest, to the silage at feeding, or in the concentrate (Thomas *et al.*, 1975b). There is evidence that aerobic stability of maize silage is increased following addition of urea

or ammonia to the crop at harvest (Honig, 1975). Experiments in France with cows given maize silage *ad libitum* and different levels of concentrate established that, for the first three months of lactation, maize silage of 25% DM (treated with urea at 1.5% of the DM at harvest) was eaten in sufficient quantity to supply energy for 11 kg of 4% fat-corrected milk per day. DM intake of silage of 35% DM was greater (2.15% of LW compared with 1.95% of LW for 25% DM material) and provided sufficient energy for 18 kg milk/day (Verité and Journet, 1973; J. P. Dulphy, pers. comm.). In one trial, inclusion of a small quantity (3 kg/head/day) of lucerne hay, in diets which on average contained 76% of the DM as maize silage, did not improve total DM intake, milk yield or milk composition (Verité and Journet, 1973).

Although maize silage has an organic matter digestibility of 65 to 70%, cell walls in the maize plant account for about 50% of the total plant DM, and cell wall digestibility decreases markedly during maturation (Deinum, 1976; Wilkinson, unpublished). Recent work in France showed that intake and digestibility by sheep was greater for a low-lignin, brown midrib mutant than for the isogenic normal strain by 11 and 6%, respectively (Gallais *et al.*, 1976).

A major attraction of maize silage in European beef production is that the crop can give levels of output of beef per hectare in excess of other beef systems with much lower levels of supplementary cereal concentrate input. Thus, in the European situation of relatively high costs of both cereal-grain and vegetable protein, the utilization of maize silage together with NPN provides the farmer with the opportunity of achieving high levels of output of animal products per hectare of land at relatively low inputs of purchased supplements.

#### TREATMENT OF STRAW WITH ALKALI

Large quantities of straw are available in Europe for feeding to ruminants, but because of low digestibility (40 to 45%) and low protein content (3 to 4% DM), the scope for using straw in rations for productive livestock is limited. Treatment of straw with alkali hydrolyses the chemical linkages between lignin and hemicellulose, which increases digestibility.

At the Grassland Research Institute, chopped barley straw has been mixed with twice its weight of a 3.5% solution of NaOH (7 g NaOH/100 g straw DM) then allowed to stand for 24 h before being mixed with grass silage of pH 4.0 to produce a

neutral mixture (1:1 ratio of silage DM to straw DM). Intake of the silage-straw mixture by calves was greater than that of silage given alone, despite the fact that the mixture had a higher cell wall content and lower OMD than that of the silage alone. Liveweight gains were similar for the two diets (Terry *et al.*, 1975).

Research is now being directed towards the exploitation of alkalis other than NaOH. In Denmark, straw treated with NH<sub>3</sub> at 2.6 g/100 g straw DM and "incubated" at 62°C in a sealed chamber for four days gave an increase in *in vitro* digestibility of organic matter from 40 to 67%, and an elevation in crude protein content from 4 to 10% DM (Waagpetersen, 1976). Studies of the long-term anaerobic storage of straw treated with alkalis are currently in progress at the Grassland Research Institute and preliminary results indicate that Ca(OH)<sub>2</sub> may be of considerable value in improving the digestibility of straw which is ensiled for several months after treatment.

#### APPLICATION TO NEW ZEALAND CONDITIONS

Ruminant production in New Zealand is geared to a lower cost structure than in the industrialized European countries. Of the techniques now being examined in Europe, it is those with the least costs that are most likely to find application in New Zealand. Developments in machinery to accelerate field drying could have great relevance in New Zealand, both in relation to haymaking and to the making of wilted silage.

The principles involved in controlling the ensilage fermentation undoubtedly have application in New Zealand. Experiments with pasture silage at Ruakura suggest that lactic acid formation limits intake at a lower level than found in Europe (Hutton *et al.*, 1971; Lancaster *et al.*, 1975; Lancaster, 1976). Examination of these data suggests that intake increased when lactic acid was decomposed to yield butyric acid by saccharolytic clostridial action, with the extent of proteolytic clostridial action not being greatly affected. Silages containing butyric acid are unpleasant to handle and ensilage procedures based on butyric acid formation will not encourage the adoption of silage making by the industry. A much more realistic approach is to use harvesting procedures and/or additive treatments which simultaneously restrict both lactic acid formation and proteolytic clostridial activity.

Wilting, precision chopping and the use of additives can be used either separately or in combination to improve silage quality. Herbage for ensilage should always be cut in the leafy immature

state; this can be combined with wilting where possible and using additives when weather conditions are unfavourable. In European countries where silage making is increasing, both in total tonnage and as a percentage of total conservation, the use of additives is recommended in addition to wilting so that the quality of the final product can be guaranteed.

The European work with maize silage is relevant to the work being done with NPN and pasture supplementation of this product at Ruakura (Reardon *et al.*, 1976). Current interest in New Zealand is centred upon ensiling maize grown at high plant densities (250 000 plants/ha), compared with conventional plant densities (80 000 plants/ha; Reardon, pers. comm.). With high density crops cut at an early stage of maturity, it is possible that the ensilage fermentation may reduce nutritive value more than with silage made from maize grown at conventional plant densities. Research on the control of fermentation of grasses and legumes through additives is likely to be relevant in this situation.

Increasing straw digestibility through alkali addition could be of value with wheat straw grown in Southland and barley-straw grown in Canterbury. Because of the lower costs, ensiling straw with alkali would seem the most logical choice for New Zealand conditions; however, this subject is very much in its infancy and no recommendations can be made at this stage.

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