Silage Making in the Tropics with Particular Emphasis on Smallholders

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Cover photos (clockwise from large photo, left):

Fodder crop of fertilized Sadabahar, a multicut sorghum x Sudan grass hybrid; near Muzzaffarabad, Azad Jammu and Kashmir, Pakistan (Ian R. Lane)

Little bag silage (LBS) making in the Terai, Nepal - chopping fodder (Napier grass and Centro) with guillotine and knife (Ian R. Lane)

LBS making - squeezing and sealing the first bag layer (Ian R. Lane)

Sampling LBS (Ian R. Lane)
A feed preference trial for cattle fed silages made in plastic drums. The silage in the far trough is unwilted and unchopped while the silage in the near trough is the same source material, but chopped, then wilted to approximately 35% DM. The source material is Rumput Taiwan (i.e. Taiwan grass), a hybrid variety of *Pennisetum purpureum*. It was approximately 40 days old when harvested (Chris Regan)

Feeding LBS made from Sadabahar to Nili-Ravi buffalo near Muzzafarabad, Pakistan (Ian R. Lane)

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Foreword

The use of silage has long been an integral component of temperate feeding systems worldwide, as a means to ensure year-round feed supply for high production animals. However, its use in the tropics has been restricted to isolated cases, usually involving higher-return enterprises, and particularly the dairy industry. What are the reasons for its apparent lack of application in the tropics? This electronic conference examined this question and various aspects of silage making in the tropics. In particular, it reviewed the potential for use of tropical silage for livestock production, with special reference to the smallholder situation.

The conference was structured around ten invited papers, each of which was supported by shorter poster papers (twenty-six in all) contributed by participants who were invited to present details of their experiences or results. The conference was moderated by Professor Len ‘t Mannetje from Wageningen University, with technical assistance from Hector Osorio, CIPAV, Colombia.

Altogether, there were some 355 subscribers from 68 countries, and the conference represented a very low cost and effective method of reaching many interested persons worldwide. The very active participation of the many subscribers is acknowledged, as it was their comments, observations and enthusiasm that contributed so much to the conference.

The contributions of Caterina Batello and Stephen Reynolds of the Grassland and Pasture Crops Group of the Crop and Grassland Service, Plant Production and Protection Division, Andrew Speedy of the Feed Resources Group of the Animal Production Service, Animal Production and Health Division, and Max Shelton, University of Queensland, towards the success of the conference, are acknowledged.

It is hoped that this publication will contribute towards and stimulate debate about the use of silage in tropical livestock production systems.

Marcio C.M. Porto
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Abbreviations commonly used in the text

a<sub>W</sub>  water activity
BW  body weight
CIAT  Centro Internacional de Agricultura Tropical [International Centre for Tropical Agriculture]
CF  crude fibre
CFU  colony-forming units
CP  crude protein
DM  dry matter
DDM  digestible dry matter
FDN  fibra detergente neutra [= NDF]
LAB  lactic acid bacteria
masl  metres above sea level
ME  metabolizable energy
NDF  neutral detergent fibre
TDN  total digestible nutrients
WSC  water-soluble carbohydrate(s)

All prices are in US Dollars unless otherwise indicated.
All units are metric (SI system) unless otherwise indicated.
INTRODUCTION

Forage, crop residues and by-products are usually consumed fresh by domestic animals. However, it is possible to conserve them for use during future periods of feed shortages. Conservation can be achieved by sun drying (hay), artificial drying (meal), and addition of acids or fermentation (silage).

Hay making is difficult in tropical regions because at the time when the forage is of acceptable quality for conservation (early in the wet season), the weather is likely to be too unreliable for sun drying. Artificial drying is expensive and facilities are not widely available. Addition of acids may be beyond the resources of smallholders and can be dangerous. There remains fermentation by silage making, which can be done using fresh or, preferably, wilted material.

Silage is forage, crop residues or agricultural and industrial by-products preserved by acids, either added or produced by natural fermentation. Fresh forage is harvested, or crop residues and by-products are collected; the material may be chopped or conditioned; additives may be added; and it is then stored in the absence of air so that facultative anaerobic bacteria, present on the forage or added as inoculants, can rapidly convert soluble carbohydrates into acids. The quality of the ensiled product depends on the feeding value of the material ensiled and on the fermentation products present: the types of acids and the amount of ammonia. The resulting pH of a well-ensiled product becomes so low that all life processes come to a halt and the material will be preserved for as long as it remains in airtight storage.

There are three important considerations to take into account before embarking on a silage making programme:

(i) Is there a need for silage making?
(ii) If so, are there enough good quality forages or other products available to ensile?
(iii) If so, can the conditions for good silage making be met?

IS THERE A NEED FOR ENSILED FORAGE?

Silage making is practised widely in intensive animal production systems in temperate regions, mainly for two reasons. Firstly, because during the winter period...
there is no high quality feed available in the fields; and, secondly, in order to feed high quality conserved supplements (e.g. maize) at any time of the year to complement grass to improve milk production or nitrogen utilization.

Whether silage making is recommendable in the tropics depends on the type of farm system and on the climate. For a start, feed conservation is generally only an economic proposition for intensive farm systems, such as milk production for a liquid milk market. Secondly, in humid and subhumid climates with green forage available year-round, forage conservation is generally not profitable. If the quality of forage from permanent sources (pastures, road-sides) is inadequate, it is nearly always possible to grow a fodder crop (Saleem, 1985) or harvest stockpiled forage (Andrade et al., 1998) or use fodder banks (Milera et al. 1994; Peters et al., 1994).

Materials to be ensiled can be grasses, legumes, fodder crops (sorghum, maize), crop residues or by-products. The storage period, after which the silage is fed, depends on the purpose of the silage making. If silage is made from forage or a fodder crop of exceptional quality that is only available at a certain time of the year, it will most probably be used in a matter of months. It may also be used for an annual recurrence of periods of shortage or for unseasonable droughts that occur every number of years. Silage can also be a standard feed supply in feedlot systems.

Is there enough good quality forage to ensile?

Only excess forage, crop residues or by-products for which there is no other economic use should be ensiled. In other words, if rainfall is unreliable, farmers will not know until late in the growing season that there will be excess forage. This points to a conflict between availability of forage to ensile and its quality. The quality is highest early in the growing season, but the farmer cannot take the risk of preserving forage if he is not sure that there will be excess. Once he can be sure of that, the quality is too low to make it worthwhile to conserve it. To overcome this problem, it is possible to grow a fodder crop to be harvested, or reserve crop residues and by-products or other waste materials to be collected for silage making.

Can the conditions for good silage making be met?

Silage making is useful only if the ensiled product is of good quality, i.e. well preserved, with high digestibility and protein concentration. The main prerequisites for ensilable forage are that it should be harvested at a young stage of growth from a feeding value point of view, and that it should contain enough sugars for fermentation. The material to be ensiled should be easily compactable, and covered to exclude air. If the material is of adequate quality, but lacking in sugars, molasses or another source of sugar may be added. Chopping before ensiling will also help to compact the material. Tropical grasses (C4) are inherently low in soluble carbohydrates, with the exception of maize and sorghum species. To ensure good quality silage, it may be better to grow a crop of maize or sorghum for silage than to ensile tropical grasses. Problems with silage can also arise when it is being fed out, due to spoilage caused by moulds that grow particularly fast at the high temperatures common in the tropics. Therefore, silage pits or heaps for smallholders should be small, so that they can be fed out in a very short time (1 or 2 days). Poorly made silage can cause health problems in animals and man.

Catchpoole and Henzell (1971) wrote an early review, which clearly sets the scene for silage making from tropical forages.

THE CONFERENCE

The aim of the conference is to review the potential of silage making for livestock production in the tropics, with special reference to the smallholder situation.

There are main papers and posters to cover the main issues of silage making under
these conditions. The first main paper deals with the theory of silage making, the fermentation processes, and what problems could be encountered in meeting the requirements for good silage making. This is followed by other main papers and posters on silage making in large- and small-scale animal production systems; the use of grass-legume mixtures, of cereals and fodder crops, of agricultural by-products and industrial, non-agricultural residues, harvesting and ensiling techniques; and the use of additives to improve the silage making process for tropical forages.

REFERENCES


INTRODUCTION

In many developing countries of the humid tropical region of Southeast Asia, ruminant livestock production is mainly carried out by smallholders, who are largely dependent on natural forages for their feed resources. Natural forages grow freely along the roads and on idle agricultural land. In Malaysia, as in many humid tropical countries, green forages are plentiful for most of the year. However, at times, such as during a drought, livestock farmers will experience a shortage of forages and feeding of ruminant livestock will become a problem. Fodder conservation is promoted with the main objective of ensuring feed availability during periods of feed limitation (Mohd Najib et al., 1993).

JUSTIFICATION FOR FEED CONSERVATION

For subsistence farmers, with a few animals, harvesting of livestock feed from roadsides and unused agricultural land is becoming less common. The economic boom of the 1980s and early 1990s changed the dairy livestock perspective of Southeast Asian farmers. As they become more progressive, the need for feed security in their ventures must be ascertained, and as they become more affluent, social activities increase in the community (Hassan Wahab and Devendra, 1982).

The farmers lack time for cutting forage, especially during the main crop-planting period and harvesting season, and especially during major festive and religious events. In addition, rainfall in recent years has been less reliable. Production of DM can be reduced tremendously during prolonged droughts, whilst excessive rainfall causes flooding that can affect production, harvesting and transportation. As nations become more developed, the accessibility of animals to roadside pastures becomes limited for reasons of safety to motorists. Nowadays, the super highways are out-of-bounds to animals.

It is becoming increasingly clear that the rising population has put increased pressure on agricultural land use in this part of the world. There is increasing illicit use of gazetted grazing reserves for intensive crop production. This has resulted in reduced availability of free feed resources from common grazing lands. Hence, forage conservation is needed during periods of high forage productivity. Silage
making of forages that are plentiful during the wet season is one of the answers to feed shortages in other parts of the year.

**SILAGE MAKING IN THE TROPICS**

The silage concept is more relevant to temperate regions - with their distinct seasons - than to the evergreen tropics. Nevertheless, over time, in Malaysia silage production has become more relevant to fulfill the forage needs of smallholder dairy farmers. Silage making is less dependent on weather conditions than is haymaking.

The reasons for the major interest in silage conservation in the tropics are many. As the countries of the tropics become more developed the aspirations of the farmers also become more sophisticated. No longer are they content with labour-intensive and mundane chores like cutting grasses every day for ruminants, irrespective of the climatic conditions. Many of them are looking for alternatives where cheap animal feed can be obtained, stored and utilized at their convenience. Silage making offers one solution.

In addition, the progressive farmers are keeping more animals and are aware of the need for nutritious feed for their animals. As livestock husbandry becomes more a financial investment than a form of social security, farmers want an assurance of readily available good quality feed for their animals. Silage making offers one option to secure feeds during seasons of high production for conservation and storage, for later use in periods of relative shortage. The silage can be kept for months or even years. Silage can be used at any time as and when required, especially during periods of drought (Koon, 1993).

**SILAGE QUALITY**

Whole-maize silage has been a basic fodder for cattle in North America, and - to a lesser extent - in Europe. Maize has a high rate of conversion of radiant energy into plant matter. The high starch content of the grain makes the energy content of maize higher than that of hay or forage sorghum and thus is good material for silage production (Mooi, 1991). In contrast, many available tropical forages and agricultural by-products are generally low in nutritive quality. Silage can be made from these, but cannot sustain high animal productivity because of the low digestible energy content. New methods of silage making may be needed. In Malaysia, the oil palm plantations produce an abundance of pruned fronds every week, which can be exploited as animal feeds. Although the nutritive quality of palm fronds is low, there is a need to develop proper ensiling processes to upgrade the frond silage quality without much nutrient loss. A new approach to silage production from tropical forages is an area that needs to be further explored.

**REFERENCES**


The Department of Veterinary Services (DVS) in Malaysia undertakes silage making as a form of fodder conservation. This activity has been pursued since the 1960s. Silage crops include grasses, maize and forage sorghum varieties. Silos include horizontal ground types, such as wooden and concrete bunkers, earthen trenches and surface stacks. Receptacles such as plastic bags and drums are also used for silage making. Mechanized film wrapping of small, round, grass bales to produce “silawrapped” grass silage is also carried out.

Horizontal silos have been used for grass, maize and forage sorghum ensilage activities. These horizontal silos consist mainly of above-ground wooden bunkers, surface stacks and below-ground earthen trenches. Bunker silos range in size from the small-scale, 4-m square, wooden walled type, to large-scale, permanent, twin-walled, concrete bunkers, measuring 13 m × 5 m, with walls 125 to 175 cm high. Silage making activities with the larger, twin-wall ed bunkers are highly mechanized. Forage harvesters, both tractor-mounted bin and tractor-drawn wagon types, as well as tipper lorries, are used for harvesting, transporting and filling of the silage stores. Packing and compaction is achieved by the pressure of the wheels of a heavy-duty tractor, driven systematically over the heap. Permanent concrete bunkers are available on several livestock farms for ensilage work. Earthen trench-type silos, constructed through earth excavation, have dimensions of 20 m × 5 m. Since these trench silos are normally located on sloping ground, they usually have a depth of about 3 m at the closed end, decreasing to zero at the open end. The stack silage system was successfully used at the DVS training institute farm between 1983 and 1985. Four hundred tonnes of grass silage from signal grass (Brachiaria decumbens), Kazungula grass (Setaria sphacelata cv Kazungula), Guinea grass (Panicum maximum) and Napier grass (Pennisetum purpureum) were produced using this method during that period.

In 1985 and 1986, production of silage in small, round, concrete, tower-type silos, using forage sorghum (e.g. cvs Sugargrazze and Jumbo), maize and Napier grass, was carried out in the northern part of the country. Dairy farmers in the area, which experiences an annual dry period, have been encouraged to conserve fodder in the form of silage to ensure year-round forage availability. Each small tower silo, of 2-m diameter and 3-m height, was capable of ensiling 10 t of fresh material, which resulted in about 7.5 t of silage. During the two-year programme, 250 t of forage sorghum silage, 66 t of maize silage and 30 t of Napier grass silage were produced.
Increasingly, local crop residues, such as sweet corn stovers and oil-palm fronds, are being used as forage and roughage feed following ensilage. Currently, sweet corn stover silage is being produced using container-type silos consisting of plastic drums and plastic bags. Since the inception of the corn stover ensilage programme in 1994, an estimated 400 t of sweet corn stover silage have been produced for feeding farmers' cattle. Farmers involved in integration of cattle with oil palm have also been encouraged to ensile chopped oil palm fronds in plastic drums to supplement grazing wherever there is a problem of insufficiency of understorey forage. Ensilage in plastic drums has become a popular method of making silage in the country, as the drums are convenient for filling, packing, sealing, handling and feeding-out. Silage making involving mechanized “silawrapping” of small round bales was introduced in 1991. This method of silage production, which involves mainly grasses, has been undertaken on three ruminant farms, as well as on reserve grazing land. Annually, about 500 bales of “silawrapped” silage, equivalent to 15 t, have been produced to feed cattle and sheep during the dry season. To date, production of about 290 t of such “silawrapped” silage has been achieved.

The DVS ensilage work has also involved cultivating a crop of maize on a freshly sown signal grass pasture and harvesting the mixture for ensilage. It successfully tested the concept of cultivating maize as a one-off silage crop on newly developed or redeveloped pasture fields, before the latter were permanently used for grazing. The concept aims at maximizing the usefulness of land being developed or redeveloped for permanent grazing.
INTRODUCTION

In Pakistan, the livestock industry has annually to face two periods of severe fodder scarcity (May-June and October-November) that have a big effect on animal production. Conserving surplus fodder in the form of silage and using it during periods of shortage can avoid these problems. Silage technology was introduced into Pakistan almost two decades ago by various government and international agencies. Despite heavy inputs in terms of time and money, silage production has not found a place in traditional livestock feeding and production systems. The present study aimed to investigate the question of failure of silage making and feeding in Pakistan.

MATERIALS AND METHODS

Using a pre-tested questionnaire, 150 livestock producing farmers, 50% living in areas under government institutions influence (AUGII) and 50% at a distance (FAD), in different agricultural communities, were selected at random and interviewed for 30 minutes, about silage making, costs, feeding and other allied problems.

RESULTS AND DISCUSSION

Results show that more than 90% of AUGII farmers were aware of silage making and its feeding, whilst only 10% of FADs had knowledge of this technology (Table 1).

Table 1. Farmers responses about silage technology (%)

<table>
<thead>
<tr>
<th></th>
<th>Knowledge of silage technology</th>
<th>Feeding experience</th>
<th>Wanting to make</th>
<th>Wanting commercially prepared silage</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUGII</td>
<td>90</td>
<td>70</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>FAD</td>
<td>10</td>
<td>5</td>
<td>-</td>
<td>20</td>
</tr>
</tbody>
</table>

It was noted that farmers living in AUGII, because they had more knowledge about silage feeding, wanted to continue with this practice, but due to high production and labour costs were not able to do so. However, they showed a positive response to the use of silage if it could be commercially made and sold at reasonable prices, as is the case with poultry rations. The impact of government and international agencies was restricted to those farmers living near government institutes and in peri-urban
Small areas of land available and small animal units were major factors that affected silage production (Table 2). Most farmers owned only a few acres of land (3 to 5 acres per family) and their major concern was with cash crop production, and they owned small animal units of 1 or 2 animals to meet their daily household needs. For such a small unit, farmers can easily get fodder from barren lands, roadsides and canal sides, or by working in larger-scale farmers' fields.

**CONCLUSIONS**

(i) High production cost, limited land available and small animal units are major constraints that militate against farmers selecting silage production.

(ii) The cost:benefit ratio is not impressive due to small size of animal units.

(iii) To reduce the production cost, large-scale commercial production of silage should be started.

(iv) Effective extension work and feedback is required.

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Time</th>
<th>Small area or animal unit</th>
<th>Quality of silage</th>
<th>Cost: Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUGII</td>
<td>80</td>
<td>60</td>
<td>90</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>FAD</td>
<td>NI</td>
<td>80</td>
<td>70</td>
<td>NI</td>
<td>NI</td>
</tr>
</tbody>
</table>

Notes: NI = No idea.
D.V. Rangnekar

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INTRODUCTION

A lot of research and development effort has been invested in India on silage making, but with very poor adoption. Based on experience in the West, the technology of ensiling fodder crops has been strongly pushed as a means of maintaining nutritional status of livestock during the dry season, when green fodder is not available. The recommendations were based on the hypothesis that surplus green fodder would be available in the rainy season that could be conveniently ensiled and used in the dry season to supplement dry fodder, and that the feeding of ensiled fodder would be more economical than supplementation with concentrates. Several research projects, field demonstrations and special schemes (with subsidies) were initiated in the colonial period and are still continuing. Except for institutional farms, the adoption of ensiling technology by small farmers is very low (virtually nil).

The author is associated with a development NGO (BAIF) implementing large, livestock-based, integrated rural development activities in six states of the country, and has been closely involved with development of activities in three western states. BAIF’s activities involve about half-a-million farmers, of whom 80% have small farms, and involvement is mostly in rainfed and less-developed areas. Livestock development is looked upon as a means of generating employment and income in rural areas, and has been taken up in a big way as part of poverty alleviation programmes. Thus, besides breed improvement, one of the major concerns has been developing feed resources and improving the nutritional status of animals, so that the expected productivity could be attained. BAIF started getting suggestions for introducing several promising technologies, including production and ensiling of fodder. However, it soon became clear that what looked highly promising, technically and economically feasible, was often not acceptable to the small-scale farmer. Hence it was necessary to learn why the technology was not adopted. Involvement and experience in rural areas showed that answers or explanations are not available from technical persons, but have to be sought from farmers, and that there is much to be learnt from them.

THE DILEMMA OF NON-ADOPTION OF A TECHNICALLY SOUND TECHNOLOGY, AND STUDIES WITH FARMERS
Like a few other technologies in agriculture, ensiling was one that was considered technically sound and beneficial, since the nutritional status of animals can be maintained in the dry season at lower cost. Most of the research and demonstration reports on silage making are favourable. Special programmes, with subsidies, were implemented to encourage small-scale farmers to construct silo towers, pits or trenches, as well as to purchase a chaff cutter for chopping the crop. It was presumed that, at least during the rainy season, some surplus fodder or naturally growing grass would be available for ensiling. A number of institutional farms (research institutes, university and State Government farms, etc.) adopted ensiling and use of silage for feeding during dry periods, although even on these farms the use of ensiled fodder has been rather limited.

Studies were implemented with farmers and extension officers in parts of three States in western India, namely Gujarat, Rajasthan and Madhya Pradesh. Participatory exercises were conducted with extension officers, farmers (both men and women) through a series of small group discussions and ranking exercises, and discussions with randomly chosen individuals. More than 300 farmer families were involved in these exercises. Of these, more than 100 farmers were involved in demonstrations of silage making by State Governments and Dairy Co-ops. The results of the participatory studies are summarized below.

**About technology**

- Most extension officers were aware of silage making processes and had basic information but lacked in-depth knowledge and practical experience. Only 15% had practical experience of silage making.

- Most extension officers indicated that tower or well-type silos were not appropriate, being far too costly. Shallow pits or trenches with the use of plastic sheets were worth trying, but were labour intensive. Chopping fodder was cumbersome, labour intensive and not commonly practised.

- Farmers with whom demonstrations were arranged had some knowledge about ensiling, acquired during meetings. There was considerable negative impact from the technology in cases where ensiling was not effective (for various reasons) and many lost faith.

- Most women had no knowledge about ensiling, as they had not participated in demonstrations. Some women got information through training programmes and extension meetings. Almost all the women felt that the technology was cumbersome and costly in view of the chopping and filling operations, and were not convinced about benefits, taking into account the efforts and cost.

- The extension officers did not try alternative ways of ensiling fodder.

- about 90% of the farmers considered the recommended process of silage making to be cumbersome and labour intensive.

**Adoption.**

- Studies indicated that about 30% of the farmers who were involved in demonstrations and received a subsidy adopted silage making for a short period. Long-term adoption by farmers was not seen in any of the regions, while many institutional farms continue to make silage. Reasons for non-adoption included:

  - Most of the farmers felt that benefits were not commensurate with effort and time.

  - Many women mentioned that their animals were low milk yielders and cost and trouble of silage making did not provide sufficient returns.

  - There was no surplus fodder in rainfed areas for ensiling. Fodder production was
mainly carried out in winter (legumes are grown in small plots and these did not ensile well).

- Farmers having irrigation facilities preferred to grow 2-3 crops of fodder and feed these fresh.

- Surplus grass was available in some rainfed areas but its ensiling was too labour intensive.

- The process was cumbersome: it was more convenient to dry and store good quality fodder (this is a traditional practice and preferred by most farmers - particularly women).

- The majority of women did not like the smell of silage and reported that some animals took time to adapt and some refused to eat the material.

CONCLUDING REMARKS

While discussing with research colleagues about ensiling and such other technologies, a common attitude was that “We have done our job and it is up to the extension officers and the farmers to take it or leave it.” As in many other cases, this is also a case of research outpacing development. The replies from women were very interesting and worthy of serious consideration, namely that unless a common farmer has animals producing sufficient to warrant the trouble and cost of silage making, the adoption would be poor and subsidies would be of little help.

The cost factor was also not very straightforward. It was linked with fodder production and the farmer would compare crops and technologies before making a decision. It again boiled down to returns from animals. There is therefore need to compare costs of concentrates versus silage. However, the convenience factor may override the cost factor. It is much more convenient to supplement with concentrates during the summer, with hay or straw, albeit of lower quality. Chopping of fodder is not common in western India and this adds to time and hassle in silage making.

The lesson learnt is to undertake production system studies and have repeated discussions with farmers to understand their situation, and to look for those farms where the technology would fit well. It is crucial to ensure that benefits are visible to farmers and that they feel the need. This applies particularly to the women.

However, there are not many such situations, and one can save a lot of time and money through situation analysis before deciding to introduce a technology or any other intervention. Unfortunately, such an approach is not common in livestock development or research in India.
INTRODUCTION

In Thailand, a major limitation in raising dairy cattle is insufficient feed, especially during the dry season. Farmers are very familiar with the use of crop by-products as animal feed, but less familiar with forage conservation. Despite much research work on silage production at research centres and universities in Thailand, adoption has been generally low. There are many reasons for this, including:

- a lack of herbage;
- silage making is deemed complicated; and
- a lack of investment capital for new machinery.

This paper discusses the potential for adoption of forage ensiling techniques in Thai smallholder dairy farms and the factors affecting this potential. The study area was Sung Nuen District, Nakornratchasima, in northeast Thailand, located between latitude 14° 30’ and 15° 15’ N, longitude 101° 43’ and 101° 56’ E, with an average annual rainfall of 805 mm. The principal crops grown were rice, maize, cassava and sugar cane.

Participatory diagnosis of livestock feeding problems was conducted with dairy farmers in 1997. The major problem was a lack of good quality roughage in the dry season. Two other feed resources the farmers had been commonly using to reduce this problem were crop residues (especially rice straw) and sugar cane tops. Formerly, crop residues were available free of charge, but rising demand had resulted in increased prices, with crop residues becoming increasingly scarce. In addition, the low protein content of these residues was not adequate for productive cattle during the dry season. As a result, farmers had become interested in testing forage conservation methods, including silage making.

SILAGE MAKING DEMONSTRATION

The Animal Nutrition Research Centre at Pakchong collaborated with a district livestock officer to conduct a silage making demonstration in the village, with 53 dairy farmers participating. Three different techniques of silage making demonstrated were:

- bunker silos;
- black polythene bags of 40-kg capacity; and
- plastic bags of about 800-kg capacity.

Because they were in a maize growing area, maize silage was made in the demonstration. Farmers provided chopped maize leaves and their labour. The development workers provided labour, materials (plastic bags) and technical advice. Follow-up visits were conducted to check for problems and discuss with farmers their experiences with silage making. All 53 farmers were interested in trying to make silage on their farms. One farmer modified the technique to make silage in plastic buckets and in a below-ground pit silo for sale.

The preference ranking among the three types of silo were that 38% of the farmers preferred bunker silos; 31% selected the plastic bucket technique; 23% chose black polythene bags; and 8% used the 800-kg plastic bags.

FARMERS’ COMMENTS

- Black polythene bag: cheap and easy to feed the product to animals.
- Plastic bag (800kg): can make a large amount at one time.
- Plastic bucket: even if it is more expensive than plastic bags at the beginning, it can be re-used many times, and also protects the silage from insects and rodents.
- Bunker silo: Large initial capital investment for construction, but lasts for a long time

FACTORS AFFECTING THE POTENTIAL FOR ADOPTION OF SILAGE MAKING ON FARM

- Farmers realized that the lack of good quality roughage in the dry season was their main constraint.
- Learning by doing: farmers found that, in fact, silage making is not difficult or as complicated as they had heard and read.
- The development workers have to know the needs of farmers and be able to provide various alternatives for them to observe, compare and evaluate, before choosing the best possible solutions.
- Farmers must have sufficient material available locally to be ensiled.
- As they are smallholder farmers, not all ensiling technologies are appropriate. The cost of the ensiling technology needs to be balanced with the availability of capital on-farm.

CONCLUSIONS

There is some potential for broader application of silage making on smallholder dairy farms in Thailand. However, the particular methods used for silage making will have to be adapted by farmers to fit their own situations. Work is continuing with these farmers to monitor adoption and discuss their needs so as to have a better understanding of which silage technologies have the best potential under the local conditions.
INTRODUCTION

Fresh forage crops, such as maize, grasses, legumes, wheat and lucerne, can be preserved by ensiling. In many countries, ensiled forages are highly valued as animal feed. In European countries, such as The Netherlands, Germany and Denmark, more than 90% of the forages locally produced are stored as silage. Even in countries with generally good weather conditions for hay making, such as France and Italy, about half of the forages are ensiled (Wilkinson et al., 1996). It is essential to have a good microbial fermentation process to produce high quality silage. A good fermentation process is not only dependent on the type and quality of the forage crop, but also on the harvesting and ensiling technique. In this paper, our current knowledge on general silage microbiology is reviewed with the aim of assisting in the choice of the best ensiling strategy to produce high quality silage.

THE ENSILING PROCESS

Ensiling is a forage preservation method based on a spontaneous lactic acid fermentation under anaerobic conditions. The epiphytic lactic acid bacteria (LAB) ferment the water-soluble carbohydrates (WSC) in the crop to lactic acid, and to a lesser extent to acetic acid. Due to the production of these acids, the pH of the ensiled material decreases and spoilage micro-organisms are inhibited. Once the fresh material has been stacked and covered to exclude air, the ensiling process can be divided into 4 stages (Weinberg and Muck, 1996; Merry et al., 1997).

Phase 1 - Aerobic phase. In this phase - normally taking only a few hours - the atmospheric oxygen present between the plant particles is reduced, due to the respiration of the plant material and aerobic and facultative aerobic micro-organisms such as yeasts and enterobacteria. Furthermore, plant enzymes such as proteases and carbohydrates are active during this phase, provided the pH is still within the normal range for fresh forage juice (pH 6.5-6.0).

Phase 2 - Fermentation phase. This phase starts when the silage becomes anaerobic, and it continues for between several days and several weeks, depending on the properties of the ensiled forage crop and the ensiling conditions. If the fermentation proceeds successfully, LAB develop and become the predominant population. Due to the production of lactic and other acids, the pH decreases to
3.8-5.0.

**Phase 3 - Stable phase.** For as long as air is prevented from entering the silo or container, relatively little occurs. Most micro-organisms of phase 2 slowly decrease in numbers. Some acid-tolerant micro-organisms survive this period in an almost inactive state; others, such as clostridia and bacilli, survive as spores. Only some acid-tolerant proteases and carbohydrases and some specialized micro-organisms, such as *Lactobacillus buchneri*, continue to be active at a low level. The activity of *L. buchneri* will be discussed in more detail later in this paper.

**Phase 4 - Feed-out phase or aerobic spoilage phase.** This phase starts as soon as the silage is exposed to air. During feed-out this is unavoidable, but it can start earlier due to damage to the silage covering (e.g. by rodents or birds). The process of spoilage can be divided into two stages. The primary spoilage stage is the onset of deterioration due to the degradation of preserving organic acids by yeasts and, occasionally, by acetic acid bacteria. This will cause a rise in pH, and thus the second spoilage stage is started, which is associated with increasing temperature, and activity of spoilage micro-organisms such as bacilli. The last stage also includes the activity of many other (facultative) aerobic micro-organisms, such as moulds and enterobacteria. Aerobic spoilage occurs in almost all silages that are opened and exposed to air. However, the rate of spoilage is highly dependent on the numbers and activity of the spoilage organisms in the silage. Spoilage losses of 1.5-4.5% DM loss per day can be observed in affected areas. These losses are in the same range as losses that can occur in airtight silos during several months of storage (Honig and Woolford, 1980).

To avoid failures, it is important to control and optimize each phase of the ensiling process. In phase 1, good silo filling techniques will help to minimize the amount of oxygen present between the plant particles in the silo. Good harvesting techniques combined with good silo filling techniques will thus minimize WSC losses through aerobic respiration in the field and in the silo, and in turn will leave more WSC available for lactic acid fermentation in phase 2. During phases 2 and 3, the farmer cannot actively control the ensiling process. Methods to optimize phases 2 and 3 are therefore based on the use of silage additives applied at the time of ensiling, as will be discussed in the section on additives, below. Phase 4 will start as soon as oxygen is available. To minimize spoilage losses during storage, an airtight silo is required, and any damage to the silo covering should be repaired as soon as possible. During feed-out, spoilage by air ingress can be minimized by a sufficiently high feed-out rate. In addition, silage additives capable of decreasing spoilage losses can be applied at the time of ensiling.

**THE SILAGE MICROFLORA**

The silage microflora plays a key role in the successful outcome of the conservation process. The flora can basically be divided into two groups, namely the desirable and the undesirable micro-organisms. The desirable micro-organisms are LAB. The undesirable ones are the organisms that can cause anaerobic spoilage (e.g. clostridia and enterobacteria) or aerobic spoilage (e.g. yeasts, bacilli, Listeria and moulds). Many of these spoilage organisms not only decrease the feed value of the silage, but also have a detrimental effect on animal health or milk quality, or both (e.g. Listeria, clostridia, moulds and bacilli).

**Desirable micro-organisms - Lactic acid bacteria**

LAB belong to the epiphytic microflora of plant material. Often the population of LAB increases substantially between harvesting and ensiling. This is probably mainly due to the resuscitation of dormant and non-culturable cells, and not by inoculation by the harvesting machinery or growth of the indigenous population. Crop characteristics, including sugar content, DM content and sugar composition, combined with LAB properties such as acid- and osmo-tolerance, and substrate
utilization will decisively influence the competitiveness of the LAB flora during silage fermentation (Woolford, 1984; McDonald et al., 1991).

LAB that are regularly associated with silage are members of the genera *Lactobacillus, Pediococcus, Leuconostoc, Enterococcus, Lactococcus* and *Streptococcus*. The majority of the silage LAB are mesophilic, i.e. they can grow at temperatures between 5° and 50°C, with an optimum between 25° and 40°C. They are able to decrease the silage pH to between 4 and 5, depending on the species and the type of forage crop. All LAB are facultative aerobes, but some have a preference for anaerobic conditions (Holzapfel and Schillinger 1992; Hammes et al., 1992; Devriese et al., 1992; Weiss, 1992; Teuber et al., 1992).

Based on their sugar metabolism LAB can be classified as obligate homofermenters, facultative heterofermenters or obligate heterofermenters. Obligate homofermenters produce more than 85% lactic acid from hexoses (C₆ sugars) such as glucose, but cannot degrade pentoses (C₅ sugars) such as xylose. Facultative heterofermenters also produce mainly lactic acid from hexoses, but in addition they also at least degrade some pentoses to lactic acid, and acetic acid and/or ethanol. Obligate heterofermenters degrade both hexoses and pentoses, but unlike homofermenters they degrade hexoses to equimolar mounts of lactic acid, CO₂ and acetic acid and/or ethanol (Hammes et al., 1992; Schleifer and Ludwig 1995). Obligate homofermenters are species such as *Pediococcus damnosus* and *Lactobacillus ruminis*. Facultative heterofermenters include *Lactobacillus plantarum, L. pentosus, Pediococcus acidilactici, P. pentosaceus* and *Enterococcus faecium*. To the obligate heterofermenters belong members of the genus *Leuconostoc*, and some *Lactobacillus* spp., such as *Lactobacillus brevis* and *Lactobacillus buchneri* (Devriese et al., 1992; Weiss, 1992; Holzapfel and Schillinger, 1992; Hammes et al., 1992).

**Undesirable micro-organisms**

**Yeasts**

Yeasts are eukaryotic, facultative anaerobic, heterotrophic micro-organisms. In silages, anaerobic as well as aerobic yeast activity is considered undesirable. Under anaerobic silage conditions, yeasts ferment sugars to ethanol and CO₂ (Schlegel, 1987; McDonald et al., 1991). This ethanol production in silage not only decreases the amount of sugar available for lactic acid fermentation, but it can also have a negative effect on milk taste (Randby et al., 1999). Under aerobic conditions, many yeast species degrade the lactic acid to CO₂ and H₂O. The degradation of lactic acid causes a rise in silage pH, which in turn triggers the growth of many other spoilage organisms (McDonald et al., 1991).

Yeast populations can reach up to 10⁷ colony forming units per gram during the first weeks of ensiling; prolonged storage will lead to a gradual decrease in yeast numbers (Jonsson and Pahlow, 1984; Middelhoven and van Baalen, 1988; Driehuis and van Wikselaar, 1996). Factors that affect the survival of yeasts during storage are the degree of anaerobiosis and the concentrations of organic acids. The presence of oxygen enhances survival and growth of yeasts during storage (Jonsson and Pahlow, 1984; Donald et al., 1995), whereas high levels of formic or acetic acid reduce survival during storage (Driehuis and van Wikselaar, 1996; Oude Elferink et al., 1999). Initial yeast activity appears to be enhanced in crops with a low initial pH (<5), for example, due to the addition of acid additives, and in crops with a high sugar content, such as potato, orange peel or sugar beet. These crops often result in silages high in ethanol and low in lactic acid (Henderson et al., 1972; Ashbell et al., 1987; Weinberg et al., 1988; Driehuis and van Wikselaar, 1996). Silage additives developed to inhibit yeast activity are described in the section on additives, below.
**Enterobacteria.**

Enterobacteria are facultatively anaerobic. Most silage enterobacteria are considered to be non-pathogenic. Nevertheless, their growth in silage is undesirable because they compete with the LAB for the available sugars, and in addition they can degrade protein. This protein degradation not only causes a reduction in feeding value, but also leads to the production of toxic compounds such as biogenic amines and branched fatty acids. Biogenic amines are known to have a negative effect on silage palatability (Woolford, 1984; McDonald *et al.*, 1991; van Os and Dulphy, 1996), especially in animals that are not yet accustomed to the taste (van Os *et al.*, 1997). Moreover, the ammonia formed through proteolysis increases the buffer capacity of the ensiled crop, thus counteracting any rapid decrease in silage pH. A special characteristic of enterobacteria is their capability to reduce nitrate (NO$_3^-$) to nitrite (NO$_2^-$) under silage conditions. In silage, nitrite can be degraded by enterobacteria to ammonia and nitrous oxide (N$_2$O), but it can also be chemically degraded to NO and nitrate (Spoelstra, 1985, 1987). With air, NO is oxidized into a mixture of gaseous, yellow-brown nitrogen oxides (NO$_2$, N$_2$O$_3$, N$_2$O$_4$). Gaseous NO and NO$_2$ have a damaging effect on lung tissue and can cause a disease with pneumonia-like symptoms known as “silo filler’s disease” (Woolford, 1984). To prevent animals from being in contact with gaseous nitrogen oxides, they should not be housed in buildings adjoining silos during silo filling or the first week of silage storage (O’Kiely *et al.*, 1999). Despite the above-mentioned problems, a little nitrite reduction is considered positive for silage quality, because the nitrite and NO formed are very effective inhibitors of clostridia (Woods *et al.*, 1981; Spoelstra, 1985).

Enterobacteria will not proliferate at low pH. Ensiling methods that induce a rapid and sufficient drop in silage pH will therefore help to decrease enterobacterial growth (McDonald *et al.*, 1991).

**Clostridia**

Clostridia are endospore-forming anaerobic bacteria. Many clostridia ferment carbohydrates as well as proteins, thus causing problems such as reduction in feeding value and the production of biogenic amines, similarly to that described for enterobacteria. Furthermore, clostridia in silage impair milk quality. This is due to the fact that clostridial spores can survive the passage through the alimentary tract of a dairy cow. Clostridial spores present in silage are transferred to milk via faeces and faecal contamination of the udder. The acid-tolerant *Clostridium tyrobutyricum* is the most relevant species for the dairy industry. In addition to carbohydrate fermentation, *C. tyrobutyricum* can degrade lactic acid to butyric acid, H$_2$ and CO$_2$ according to the following overall reaction:

$$2 \text{ lactic acid} \rightarrow 1 \text{ butyric acid} + 2 \text{ H}_2 + 2 \text{ CO}_2$$

This butyric acid fermentation not only counteracts lactic acid fermentation in silage and cheeses, but it is also responsible for significant gas production, causing a cheese defect called “late blowing” in hard and semi-hard cheeses such as Emmental, Graná, Gouda and Parmesan (Gibson, 1965; Goudkov and Sharpe, 1965; Klijn *et al.*, 1995).

Some clostridia can cause serious health problems. One extremely toxic species is *Clostridium botulinum*. This organism can cause botulism, which can be deadly for cattle. Fortunately, *C. botulinum* has a limited acid tolerance, and does not grow in well-fermented silage. Incidences of animal botulism caused by silage contaminated with *C. botulinum* could nearly always be attributed to the presence of a cadaver (e.g. mouse, bird, etc.) in the silage (Kehler and Scholz, 1996).

A typical “clostridial silage” is characterized by a high butyric acid content of more than 5 g/kg DM, a high pH (over pH 5 in low DM silages), and a high ammonia and
amine content (Voss, 1966; McPherson and Violante, 1966). Ensiling methods that cause a rapid and sufficient drop in silage pH will help to prevent the development of such clostridial silage, because, as for enterobacteria, clostridia are inhibited at low pH. Furthermore, clostridia are more susceptible to a low availability of water (i.e. a low water activity ($a_w$)) than LAB (Kleton et al., 1982, 1984; Huchet et al., 1995). For this reason, decreasing the $a_w$-value of a crop, such as by wilting to a higher DM content, can be a way of selectively inhibiting clostridia (Wieringa, 1958). Finally, clostridia will also be inhibited by nitrite and NO, or compounds that are degraded in silage to nitrite and NO (Spoelstra, 1983, 1985).

**Acetic acid bacteria**

Acetic acid bacteria are obligate aerobic, acid-tolerant bacteria. Thus far, all acetic acid bacteria that have been isolated from silage belong to the genus *Acetobacter* (Spoelstra et al., 1988). The activity of *Acetobacter* spp. in silage is undesirable because they can initiate aerobic deterioration, as they are able to oxidize lactate and acetate to CO$_2$ and water. Generally, yeasts are the main initiators of aerobic spoilage, and acetic acid bacteria are absent, or play only a minor role. However, for whole-crop corn silages there is evidence that acetic acid bacteria alone can initiate aerobic deterioration (Spoelstra et al., 1988). Furthermore, selective inhibition of yeast can also increase proliferation of acetic acid bacteria in silage (Driehuis and van Wikselaar, 1996).

**Bacilli**

Bacilli are like clostridia: endospore-forming, rod-shaped bacteria. Nevertheless, they can easily be distinguished from clostridia as they are (facultative) aerobes, whereas all clostridia are obligate anaerobes (Claus and Berkeley, 1986; Cato et al., 1986). Facultative aerobic bacilli ferment a wide range of carbohydrates to compounds such as organic acids (e.g. acetate, lactate and butyrate) or ethanol, 2,3-butanediol and glycerol (Claus and Berkeley, 1986). Some specific *Bacillus* spp. are able to produce antifungal substances, and have been used to inhibit aerobic spoilage of silage (Phillip and Fellner, 1992; Moran et al., 1993). Except for these specific strains, the proliferation of bacilli in silage is generally considered undesirable. Not only are bacilli less efficient lactic and acetic acid producers than LAB (McDonald et al., 1991), they can also enhance (later stages of) aerobic deterioration (Lindgren et al. 1985; Vreman et al., in press). Furthermore, high numbers of bacillus spores in raw milk have been associated with high spore numbers in fresh cow faeces (Waes, 1987; te Giffel et al., 1995). It seems very plausible that bacillus spores are transferred from silage to milk via faeces, as occurs with clostridial spores (Vreman et al., in press). Psychrotrophic *Bacillus cereus* spores are considered to be the most important spoilage organism of pasteurized milk (te Giffel, 1997). High numbers of these (psychrotrophic) *B. cereus* spores have been found in silages (Labots et al., 1965; te Giffel et al., 1995).

To decrease bacillus growth in silage, storage temperatures should not be too high (Gibson et al. 1958) and air ingress should be minimized (Vreman et al., in press). In addition, initial contamination of fresh plant material with soil or manure should be prevented (McDonald et al., 1991; Rammer et al. 1994).

**Moulds**

Moulds are eukaryotic micro-organisms. A mould-infested silage is usually easily identified by the large filamentous structures and coloured spores that many species produce. Moulds develop in parts of the silage where (a trace of) oxygen is present. During storage, this is usually only in the surface layers of the silage, but during aerobic spoilage (phase 4) the whole silage can become mouldy. Mould species that regularly have been isolated from silage belong to the genera *Penicillium*, *Fusarium*, *Aspergillus*, *Mucor*, *Bysschlamys*, *Absidia*, *Arthrinium*, *Geotrichum*, *Monascus*, *Mucor melesii*, *Aspergillus flavus*, *Fusarium oxysporum*, *Penicillium italicum*, *Penicillium chrysogenum*, *Penicillium notatum*, *Penicillium verrucosum*, *Penicillium verrucosum*, *Penicillium nalgiovense*, *Penicillium roqueforti*, *Penicillium italicum*, *Penicillium chrysogenum*, *Penicillium notatum*, *Penicillium verrucosum*, *Penicillium verrucosum*, *Penicillium nalgiovense*, *Penicillium roqueforti*.
Scopulariopsis and Trichoderma (Pelhate, 1977; Woolford, 1984; Frevel et al., 1985; Jonsson et al., 1990; Nout et al., 1993). Moulds not only cause a reduction in feed value and palatability of the silage, but can also have a negative effect on human and animal health. Mould spores are associated with lung damage and allergic reactions (May, 1993). Other health problems are associated with mycotoxins that can be produced by moulds (Oldenburg, 1991; Auerbach, 1996). Depending on the type and amounts of toxin present in the silage, health problems can range from minor digestive upsets, small fertility problems and reduced immune function, to serious liver or kidney damage, and abortions (Scudamore and Livesey, 1998). Some important mycotoxin-producing mould species are Aspergillus fumigatus, Penicillium roqueforti, and Byssochlamys nivea. P. roqueforti, a species which is acid tolerant and can grow at low levels of oxygen and high levels of CO₂, has been especially detected as the predominant species in different types of silages (Lacey, 1989; Nout et al., 1993; Auerbach et al., 1998; Auerbach, 1996). There is still uncertainty concerning the conditions under which mycotoxins are formed in silage. A heavily infested silage does not necessarily contain high levels of mycotoxins, and not all types of mycotoxins that a mould species can produce are necessarily present in one silage lot (Nout et al., 1993; Auerbach, 1996). For Aflatoxin B1, a mycotoxin of Aspergillus flavus, it is known that it can be transferred from animal feed to milk. However, so far it is unknown if a similar transfer can occur with mycotoxins from P. roqueforti or A. fumigatus (Scudamore and Livesey, 1998).

Ensiling methods that minimize air ingress (e.g. good compaction and covering of the silo), and additives that prevent initiation of aerobic spoilage, will help to prevent or limit mould growth.

Listeria

Members of the genus Listeria are aerobes or facultative anaerobes. Regarding silage quality, the most important species is the facultative anaerobe L. monocytogenes, because this species is pathogenic to various animals and man. Animals with a suppressed immune system (e.g. pregnant females and neonates) are especially susceptible to L. monocytogenes infections (Jones and Seeliger, 1992). Silage contaminated with L. monocytogenes has been associated with fatal cases of listeriosis in sheep and goats (Vázquez-Boland et al., 1992; Wiedmann et al., 1994). In addition, Sanaa et al. (1993) have identified poor quality silage as one of the main sources of contamination of raw milk by L. monocytogenes. Growth and survival of Listeria spp. in silage are determined by the degree of anaerobiosis, and the silage pH. L. monocytogenes can tolerate a low pH of 3.8-4.2 for long periods if oxygen is present, even if only at low levels. Under strictly anaerobic conditions, it is rapidly killed at low pH (Donald et al., 1995). Silages that have a higher chance of aerobic surface spoilage, such as big bale silages, seem to be particular liable to Listeria contamination (Fenlon et al., 1989). L. monocytogenes generally does not develop in well-fermented silages with a low pH. So far, the most effective method to prevent growth of L. monocytogenes is to keep the silage anaerobic (McDonald et al., 1991).

SILAGE ADDITIVES

In the 1990s, it became increasingly common to use silage additives to improve the ensiling process. The choice of additives appears to be almost limitless if one looks at the large number of chemical and biological silage additives that are commercially available. The UKASTA Forage Approval Scheme of the UK, for example, listed more than 80 products (Rider, 1997). Fortunately, the choice of a suitable additive is less complicated than it seems, because the modes of action of most additives fall into a few categories (Table 1).

Between products of a particular category, differences exist in product properties, such as general effectiveness, suitability for certain crop type, and ease of handling.
and application. These factors, together with price and availability, will determine what product will be the most appropriate for a specific silage. A drawback of some of the chemical additives is that they can be corrosive to the equipment used, and can be dangerous to handle. The biological additives are non-corrosive and safe to handle, but they can be costly. Furthermore, their effectiveness can be less reliable, since it is based on the activity of living organisms. Proper storage of these biological additives by the manufacturer, retailer and farmer is of vital importance. Despite these disadvantages, in Europe and the USA bacterial inoculants have nowadays become the most commonly used additives for maize, and grasses and legumes that can be wilted to above 300 g DM/kg (Bolsen and Heidker, 1985; Pahlow and Honig, 1986; Bolsen et al., 1995; Kung, 1996; Weinberg and Muck, 1996). In the Netherlands, the absolute as well as the relative amount of silages treated with bacterial inoculants has increased between 1995 and 1998, and in 1998, 13.7% of all grass silage in the Netherlands was ensiled with an additive, of which 31% was treated with an inoculant, 37% with molasses and 29% with fermentation inhibitors (Hogenkamp, 1999).

**Table 1. Categories of silage additives (adapted from McDonald et al., 1991)**

<table>
<thead>
<tr>
<th>Additive category</th>
<th>Typical active ingredient</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Fermentation stimulants</td>
<td>LAB</td>
<td></td>
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<tr>
<td></td>
<td>Sugars (molasses)</td>
<td></td>
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<tr>
<td></td>
<td>Enzymes</td>
<td></td>
</tr>
<tr>
<td>Fermentation inhibitors</td>
<td>Formic acid*</td>
<td>Inhibition of clostridia</td>
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<tr>
<td></td>
<td>Lactic acid*</td>
<td></td>
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<tr>
<td></td>
<td>Mineral acids</td>
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<tr>
<td></td>
<td>Nitrite salts</td>
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<td></td>
<td>Sulphite salts</td>
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<tr>
<td></td>
<td>Sodium chloride</td>
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<tr>
<td>Aerobic deterioration inhibitors</td>
<td>LAB</td>
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<tr>
<td></td>
<td>Propionic acid*</td>
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<tr>
<td></td>
<td>Benzoic acid*</td>
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<tr>
<td></td>
<td>Sorbic acid*</td>
<td></td>
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<tr>
<td>Nutrients</td>
<td>Urea</td>
<td>Can improve aerobic stability</td>
</tr>
<tr>
<td></td>
<td>Ammonia</td>
<td>Can improve aerobic stability</td>
</tr>
<tr>
<td></td>
<td>Minerals</td>
<td></td>
</tr>
<tr>
<td>Absorbents</td>
<td>Dried sugar beet pulp</td>
<td></td>
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<tr>
<td></td>
<td>Straw</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** *or corresponding salt

**Additives improving silage fermentation**

Assuming good harvesting and ensiling techniques, initial silage fermentation (phase 2) can still be sub-optimal. This can be due to a lack of sufficient numbers of suitable LAB or a lack of sufficient amounts of suitable WSC, or both.

The amount of WSC necessary to obtain sufficient fermentation depends on the DM content and the buffer capacity of the crop. Weissbach and Honig (1996) characterized the relation between these factors as follows,

$$ FC = DM (%) + 8 \frac{WSC}{BC} $$

Where:

- $FC$ = fermentation coefficient
- $DM$ = dry matter content
- $WSC$ = water-soluble carbohydrates
- $BC$ = buffer capacity
Forages with insufficient fermentable substrate or too low a DM content have an FC <35. In these forages, sufficient fermentation can only be achieved if the sugar content of the material is increased, either by adding sugars directly (e.g. molasses) or by adding enzymes that release extra sugars from the crop. In forages with an FC of 35 or more, sufficient fermentable substrate is available. Also, adding suitable LAB can accelerate and improve the ensiling process. In high DM silages with reduced water availability, the presence of suitable, osmo-tolerant LAB could become a limiting factor in the ensiling process. It has been shown that these bacteria represent only a small percentage of the indigenous microflora on forage crops (Pahlow and Weissbach, 1996). Forages with a DM content above 50% are considered difficult to ensile (Staudacher et al., 1999).

The formula of Weissbach and Honig (1996) does not apply for crops with a low nitrate content, such as extensively managed grasses and immature whole-crop cereals, because these crops are more liable to clostridial fermentations than crops with a moderate nitrate content (Spoelstra, 1983, 1985). Inoculants that increase lactic acid fermentation might be useful to inhibit clostridial activity. The minimum number of LAB required to inhibit clostridial activity was found to be at least 100 000 colony-forming units per gram of fresh crop (Weissbach and Honig, 1996; Kaiser and Weiss, 1997).

**Additives inhibiting silage fermentation**

Fermentation inhibitors could in theory be used for all types of forages. However, in practice they are generally only used in wet crops with a low WSC content and/or high buffer capacity (McDonald et al., 1991). In the Netherlands, salts of acids have become the most popular fermentation inhibitors (Hogenkamp, 1999). An advantage of these salts is that they are easier and safer to handle than the corresponding acids.

Silage additives inhibiting silage fermentation can reduce clostridial spore counts. In wilted grass silages, a decrease in spore counts by a factor 5 to 20 has been observed. A similar decrease in spore counts could be obtained by adding molasses, a fermentation stimulant. To inhibit clostridial growth, the most effective fermentation inhibitors appear to be additives based on formic acid, hexamethylene and nitrite (Hengeveld, 1983; Corporaal et al., 1989; van Schooten et al., 1989; Jonsson et al., 1990; Lattemae and Lingvall, 1996).

**Additives inhibiting aerobic spoilage**

It is clear that to inhibit aerobic spoilage, spoilage organisms, in particularly the ones causing the onset of deterioration (i.e. yeasts and acetic acid bacteria) have to be inhibited in their activity and growth. Some additives that have proven to be effective in this respect include chemical additives based on volatile fatty acids such as propionic and acetic acid, and biological additives based on bacteriocin-producing micro-organisms such as lactobacilli and bacilli (Woolford, 1975a; McDonald et al., 1991; Phillip and Fellner, 1992; Moran et al., 1993; Weinberg and Muck, 1996).

Furthermore, it is known that sorbic acid and benzoic acid have a strong antimycotic activity (Woolford, 1975b; McDonald et al., 1991). Recently, it was discovered that *Lactobacillus buchneri* is a very effective inhibitor of aerobic spoilage. The inhibition of spoilage appears mainly due to the capability of *L. buchneri* to anaerobically degrade lactic acid to acetic acid and 1,2-propanediol, which in turn causes a significant reduction in yeast numbers (Driehuis et al., 1997, 1999; Oude Elferink et al., 1999). This reduction in yeast numbers is in agreement with the finding that volatile fatty acids such as propionic acid and acetic acid are much better inhibitors of yeasts than is lactic acid, and that mixtures of lactic acid and propionic or acetic acid have a synergistic inhibitory effect (Moon, 1983). The results of Moon (1983) also explain why, in most cases, biological inoculants that promote homofermentative lactic acid fermentation do not improve, and may even decrease,
aerobic stability (Weinberg and Muck, 1996; Oude Elferink et al., 1997).

Biological additives based on the propionate-producing propionibacteria appear to be less suitable for the improvement of silage aerobic stability, due to the fact that these bacteria are only able to proliferate and produce propionate if the silage pH remains relatively high (Weinberg and Muck, 1996).

Additives used as nutrients or absorbents

Certain crops are deficient in dietary components essential for ruminants. The nutritional quality of these crops can be improved by supplementation with specific additives at the time of ensiling. Additives that have been used in this respect are ammonia and urea to increase the crude and true protein content of the silage, and limestone and MgSO4 to increase the calcium and magnesium contents. The above mentioned additives generally have no beneficial effect on silage fermentation, but urea and ammonia can improve the aerobic stability of silage (Glewen and Young, 1982; McDonald et al., 1991).

Absorbents are used in crops with a low DM content to prevent excessive effluent losses. Good results have been obtained with dried pulps such as sugar beet pulp and citrus pulp. Straw can also be utilized, but has a negative effect on the nutritive value of the silage (McDonald et al., 1991).

Combined additives

Most commercial additives contain more than one active ingredient in order to enhance efficacy and have a broad range of applicability. Very popular are, for example, combinations of inoculants stimulating homofermentative lactic acid fermentation together with sugar releasing enzymes, or combinations of fermentation and aerobic deterioration inhibiting chemicals such as formic acid, sulphite salts and propionic acid (Rider, 1997; Anon., 1999). New additives are currently being developed that decrease the negative effect of homofermentative lactic acid fermentation on aerobic stability. Promising results have been obtained by combining homofermentative or facultative heterofermentative LAB with chemicals such as ammonium formate and sodium benzoate (Kalzendorf, 1992; Bader, 1997), or by combining facultative heterofermentative LAB with the obligate heterofermentative L. buchneri.

SILAGE FERMENTATION IN TROPICAL SILAGES

Ensiling of forage crops or industry by-products could make an important contribution to the optimization of tropical and sub-tropical animal production systems, but thus far it has not yet been widely applied (Wilkins et al., 1999). This is due not only to the low prices for animal products, the low levels of mechanization and the high costs of silo sealing materials, but also to a lack of ensiling experience. More research is needed to address the specific problems associated with tropical silages. Tropical grasses and legumes have, for example, a relatively high concentration of cell wall components and a low level of fermentable carbohydrates compared to temperate forage crops (Catchpoole and Henzell, 1971; Jarrige et al., 1982). Furthermore, on average, storage temperatures in tropical climates are higher than in temperate climates, which might give bacilli a competitive advantage over LAB (Gibson et al., 1958). In addition, it has to be taken into account that some silo sealing materials cannot withstand intense sunlight, and this might impair the aerobic stability of the silage. Nevertheless, it seems likely that ensiling technologies from temperate climates can be modified for tropical conditions.

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INTRODUCTION

Large-scale intensive systems of ruminant production are relatively new to tropical and subtropical zones. Although traditional systems of feeding were often intensive, utilizing hand-harvested forages and crop by-products, it is only recently that herds are being aggregated together in large-scale production units. This has been made possible by improvements in pasture and forage crop technology, or the availability of crop by-products from centralized processing facilities.

Silage has played an uneven role in these developments. There has been a tendency to equate the role of silage in these systems with that in temperate zones, and consequently much of the attention has been on the harvesting and storage of excess growth in the growing season for subsequent feeding during the dry season. The results of this practice have generally been disappointing. More recently, attention has focused on the ensiling of special-purpose crops, using these to increase productivity of the land, and this approach shows more promise. Ensiling has also been a convenient way of storing some wet by-products, such as pineapple skins and brewers’ grains.

Over the past 20 years, there have been major advances in the technology of making and feeding silage (O’Kiely and Muck, 1998). Much of this development has occurred in temperate zones, and there is need for further research in tropical zones, in areas such as manipulation of microbial fermentation and the development of grass and legume crop silage. In general, however, the technology is adequate, and the difficulties are in integrating silage into profitable feeding systems.

This paper attempts to provide some guidelines to assist in integrating silage into feeding systems. Much of the information will be drawn from the experiences of dairy production systems in tropical and subtropical Australia.

USES OF SILAGE

In large-scale farming, the use of silage is a business input. As with any business input it is essential to understand clearly the purpose of this input, and the likely consequences of its use. With silage, the question is somewhat complicated by the fact that it is often a re-arrangement of inputs already in the feeding system, rather than an additional input. It is consistently more difficult to demonstrate a profitable outcome from the rearrangement of inputs compared with an additional input.
The reason for using silage has often been poorly defined. Very few feeding systems experiments have been done, and the bulk of the literature is on the making and feeding of silage. The introductions to these reports are dominated by reference to surpluses or gross deficiencies of forage at particular times of the year, and it is assumed that overcoming these will be advantageous to the farm business.

The advantages of using silage have generally been grouped under the following headings:

- **As a drought reserve**, where silage is made from pasture or crop in times of plenty and stored for a period of 1 to 20 years. The silage is fed to animals only in times of extreme feed deficiency.

- **To increase productivity**, where silage is routinely made as a means of increasing the amount of feed available to livestock. The storage period is consistently less than one year, and the practice is often associated with a change from pastures to crops as a form of land use.

- **To aid in the management of pasture or crop**, where the pasture or crop is removed as silage to enable benefits to be accrued from other management practices. Examples are the increased tiller density and production of temperate pastures when excess growth is removed early in the growing season, and the removal of a crop to enable the earlier planting of a subsequent crop.

- **To use excess growth**, where the rationale is that it is a waste to allow excess growth to mature and decay *in situ*, and it should be harvested for use in the future.

- **To balance the nutrient content** of the diet, where the silage is made with the intention of feeding it to provide nutrients otherwise lacking in the feeds available at that time. Examples are the use of legume silage to feed with maize silage, maize silage to feed with grazed legume pastures, or silage of relatively high fibre content to feed with pastures of low fibre content.

- **To enable storage of potentially unstable material**, where the ensiling process ensures the feed can be used over an extended period. An example is the ensiling of wet by-products. This use is similar to that of preservation of feeds, through the addition of chemicals or exclusion of air from feeds such as high-moisture grains.

All of these have the underlying assumption that it will be profitable to use silage in the feeding system.

**FINANCIAL MODEL**

Given the wide array of potential types of silage and purposes of use, it is important to have an overall framework for the financial assessment of incorporating silage into the feeding system (Cowan and Kerr, 1984). The model below allows at least the main sources of revenue and cost to be taken into account in planning a silage programme.

| Net financial benefit | = | increased income during feeding | + | indirect benefits | - | penalty during silage making | - | costs of silage |
The key parameters influencing additional income during feeding are the quantity of silage fed and the quality of the silage in relation to the other feeds available to the animal at that time. The increased income must be substantial for the practice to be profitable, and to achieve this a large quantity of silage must be fed. In northern Australia, many farmers found that making small amounts of silage did not improve their financial position. Costs do not reduce in direct proportion to the amount of silage made, and a small advantage in milk production at one time of the year does not generate sufficient income to cover these costs. For example, farmers with herds of around 100 cows found that making in the order of 100 to 300 tonnes of maize silage did not provide a net benefit. These farmers have quickly separated into those who stopped using silage and those who make larger quantities, in the order of 1000 tonnes.

The quality differential is very important in intensive production systems. Although silage is normally fed during periods when alternative feed supply is low, poor quality silage can further reduce intake of paddock feed and give only a small net gain in milk output. This has been most obvious in attempts to use tropical grass silage in dairy feeding programmes. The quality of the tropical grass silage is relatively low, with DM digestibility of the order of 55%, and it is usually fed during the cool dry season, when the quality of the scarce feed resource is high. In northern Australia, this is often grazing oats, irrigated ryegrass pasture or tropical grasses that are growing slowly at this time, but are of a higher quality. The net effect has been a very modest increase in milk yield during the feeding period, which did not cover the costs of silage making (Davison et al., 1984; Cowan et al., 1991).

In contrast, the feeding of maize silage in combination with grazed clover or lucerne pastures has given substantial increases in milk output (Stockdale and Beavis, 1988; Cowan et al., 1991). The combination of high energy content in the maize and high protein content in the legume made these feeds complementary.

The estimation of indirect benefits is often specific to the farm, although the two cases referred to above occur relatively widely. Fulkerson and Michell (1985) found that by removing the early growth of a temperate pasture they achieved an increase in milk yield per cow over the spring to autumn period. By removing a maize crop as silage rather than grain, farmers are able to obtain an additional 50 days active growth from land by using it for another crop.

There is often a penalty to milk production during the silage making period, where silage is made from tropical pastures or crops that are being grazed, as the removal of paddocks from the grazing rotation reduces the selection differential available to the animal. Cows select strongly for leaf material and restrictions in the area allocated for grazing can reduce the selection ability (Cowan and Lowe 1998). In this situation, cows consume a higher proportion of stem in the diet, and consequently the DM digestibility of the diet is reduced.

There may also be an indirect penalty, through less time being available for tasks such as pasture management and fertilization, ration formulation and cow health care during busy periods of silage making.

There is a large volume of local data on the operating costs of silage. These analyses show the main variable inputs, such as land preparation, seed and fertilizer, casual labour and harvesting costs. Sensitivity analyses show that variations in crop yield and harvest and storage losses have the greatest impact on
cost, rather than differences in the cost of the above inputs (Brennan, 1992). However, the commitment in terms of capital and the farm manager’s time are invariably undervalued. Often the feed-out costs are also omitted. There are virtually no total farm analyses of the cost of silage when used as a component in a feeding programme based on grazed pasture or forage. In contrast, there are total farm costs for feedlot operations (Nixon, 1992), which invariably show a higher cost than the marginal cost often quoted for silage in grazing systems (GRM, 1997).

DROUGHT FEEDING

There have been consistent difficulties in justifying the use of silage as a drought reserve in intensive feeding systems. The investment in silage is often made a number of years before the silage is fed to cattle, and so the opportunity cost of the feed is high. In other words, the money could have been used to pay for a more direct input to production. Secondly, the object of drought feeding is only to maintain animals, so the additional milk or beef output is very small. In large-scale and intensive feeding systems, there are unlikely to be substantial numbers of cattle deaths during drought, and so silage is unlikely to be used to keep cattle alive. The net effect is a very small increase in income during feeding, but a high cost of conservation.

INCREASING PRODUCTION

A more positive use for silage in the tropics is as a means of increasing land productivity (Cowan et al., 1993). There is a continuing increase in the pressure to use natural resources more effectively, primarily land and water. Associated with this pressure are demands for greater control over the production system, to meet quality assurance targets, ensure animal welfare and facilitate sustainable land management practices. It can be argued that each of these goals is more likely to be achieved in a system of feeding that has a high reliance on conserved crops.

In northern Australia, a typical dairy farm has 100 milking cows and uses an area of 100 ha. However, on average, two-thirds of the milk production from the farm is produced from 20 ha. This is the highly fertile and irrigated land. In other countries, it is the total farm area that is limited (Simpson and Conrad, 1993). In many areas, irrigation is used to grow high quality feed for cows, and the efficient use of water is a high priority. The combination of cropping and conservation can increase DM production per hectare compared with pasture systems, and achieves a higher ratio of feed production to water input (Kerr et al., 1987).

The cropping activity developed must use crops that can be efficiently used in the feeding system. Feeds such as maize, barley and lucerne have high conversion rates to milk production; soybeans and sorghums are intermediate; while Napier (or elephant) grass (Pennisetum purpureum) and sugar cane are low. Napier grass has been shown to produce very high yields of DM with high water use efficiency, but, because of low digestibility, cannot be used in systems producing in excess of 15 litres/cow/day (Anindo and Potter, 1986). In contrast, maize and lucerne are capable of supporting levels of production in excess of 40 litres/cow/day. In northern Australia, dairy production systems have made increasing use of maize, lucerne and forage sorghum silage to complement grazed pasture, and maintain production levels in the order of 25 litres/milk/cow/day (Ashwood et al., 1993; Cowan, 1997). In 1994-95, an average of 400 kg DM/cow was fed as silage (Kerr et al., 1996). A similar development, using a pasture and crop rotation for dairy production, was described for Uruguay (Wallis, 1997).

Kerr et al. (1991) used time-series analyses to evaluate the effects on the productivity of a dairy farm of incorporating maize silage into a grazing system, and two further cases were reported by Cowan et al. (1991). Productivity increases were 21 000 to 150 000 litres of milk/farm/year above the previous system based solely on grazed pasture. Much of this extra production occurred during autumn and winter,
a period when there were increased price incentives for milk production. It has been consistently shown that dairy farms that persist with using maize silage have larger herd sizes (by 40 to 60 cows), higher milk production per cow (by 600 to 2,000 litres), and greater total milk output (by 300,000 to 700,000 litre/year), than farms not using silage (Cowan et al., 1991; Kaiser and Evans, 1997). In a separate survey, Kerr and Chaseling (1992) observed an increase in milk yield of 0.73 litre/kg of hay or silage DM used in the feeding programme.

Trends in the development of feeding systems in subtropical Australia indicate an increasing input of conserved forage (Figure 1). The development of intensive irrigation and conservation has resulted in a decline in the proportion of milk being produced from grains and tropical grasses, and it is projected these trends will continue. Much of the silage is made from crops during summer, and fed in the autumn and spring periods when pasture supply is normally low. This has resulted in a relatively stable pattern of production throughout the year (Figure 2).

**Figure 1.** Past estimates and projections of the milk output from feeds on a typical Queensland dairy farm (from Cowan et al., 1998).

![Graph showing milk output from feeds](http://www.fao.org/docrep/005/x8486e/x8486e0a.htm#fig1)

**Figure 2.** Seasonal change in feed intake for a dairy cow producing 5,200 litres of milk annually in a typical feeding system in northern Australia (from Cowan and Lowe, 1998).

![Graph showing seasonal change in feed intake](http://www.fao.org/docrep/005/x8486e/x8486e0a.htm#fig2)
In feedlot operations, there has been an increase in the amount of silage, particularly maize, in the diets of beef and dairy cattle (Kaiser et al., 1993; GRM, 1997). High quality silages are capable of supporting the high levels of animal production demanded in such operations, are often lower in cost than grains and hay, enable higher productivity from land, and maintain a more stable rumen environment (GRM, 1997). Kaiser and Simmul (1992) and Kaiser et al., (1998) measured daily liveweight gains of 1.0 kg for steers given diets of grain:maize silage ratios of 0:100, 54:46, and 80:20.

The increasing level of control needed over the production system is also influencing the move towards conserved crop systems. Farmers need to be confident they can produce a certain level and quality on a specified date. This is difficult to manage under many grazing systems, and farmers in northern Australia have adopted a combination of grazing and crop conservation to enable this control. The management of stress on the cow - from heat, parasites and walking - is sometimes a consideration.

There is increasing importance being placed on the sustainability of intensive ruminant production systems, and measures taken to enhance this may restrict cow movement to certain paddocks. For example, the use of creek banks for shade and grazing may not be possible, and tree-planting schemes to address salinity may preclude grazing those areas by cows. However, those areas could still be used to produce conserved fodder.

**MANAGEMENT OF LAND AND PASTURE**

This aspect of forage conservation has received considerable interest in pasture grazing systems in temperate areas. Removal of the early growth encourages greater tiller density and subsequent DM production (Fulkerson and Michell, 1985). Such an effect has not been shown for tropical grasses, and frequent cutting almost always leads to reduced DM production (Blunt and Haydock, 1978).

The benefits in cropping systems can be significant. As noted above, a silage crop can be taken some 30 to 50 days before a grain crop, thus increasing the number of days on which another crop can potentially be grown. As the land is often used for two or more crops annually, there is an increase in potential growth in the order of 30%.

**USE OF EXCESS GROWTH**
In the modern, business approach to farming, the idea of ensiling an excess of forage growth simply because it is there may seem illogical, but it is often used as the justification for research and development. Davison et al. (1984) conserved the excess growth in a green-panic-based pasture in each of three years, and fed this back to cows during the dry season. Though the pasture was conserved as a stable and palatable silage, a result in common with other experiments (Moss et al. 1984), the net effect on milk production was zero. This was largely attributed to the low digestibility of such silage, and the low milk production response when fed to cows.

In contrast, silage made from temperate pasture, such as ryegrasses (Lolium spp.) grown with irrigation during winter, has a high quality differential when compared with the grazed pasture on offer to cows during summer and autumn. The milk response to feeding this silage is likely to be high, and, in northern Australia, dairy farmers place high priority on conserving any excess of this pasture, rather than conserving the much greater excesses of summer pasture.

Recent experiments have attempted to enhance the digestibility of conserved Rhodes grass (Chloris gayana) by “ensiling” with sodium hydroxide (Chaudhry et al., Cowan and Klieve, 1999). The treatment was shown to cause a significant increase in digestible DM intake of very mature grass, but no improvement with young grass. The DM digestibilities of treated grasses were 60% and 65% respectively - levels that are unlikely to provide a positive quality differential compared with grazed summer and winter pastures.

BALANCE OF NUTRIENTS IN THE DIET

In northern Australia, there has been a rapid adoption of irrigated temperate pastures for provision of grazing during winter and spring (Kaiser et al., 1993). These pastures are high in digestibility, very high in crude protein concentration and often contain a high percentage of legumes, although the quantity is usually insufficient for the total forage requirements of the herd. The supplementation of these pastures with maize silage has shown substantial benefits. Moss et al., (1996) showed that this combination removed the need for protein supplementation of the diet unless very high levels of maize silage were being fed, and the use of maize silage in this way reduced the excessively high ammonia levels in the rumens of cows. Stockdale and Beavis (1988) demonstrated an additive effect of this combination of feeds.

Recently, there has been increasing interest in the use of legumes for ensiling in the tropics. Legumes such as lablab (Lablab purpureus), cowpea (Vigna unguiculata) and soybean (Glycine max) have been shown to be compatible with sustainable land management practices, including zero tillage, and to conserve as silage of acceptable digestibility (Ehrlich et al., 1999). DM yield of soybean silage was 6 t/ha, containing 17% crude protein and 42% leaf, and DM intakes of up to 12.5 kg/day were recorded (Ehrlich and Casey, 1998). The high crude protein concentration is an advantage in tropical feeding systems, where many of the grass forages are low in protein. The legume silages are also relatively high in mineral concentration, and have a high buffering capacity. The potential benefits of these characteristics are currently being investigated (David McNeill, personal communication).

STORAGE OF WET BY-PRODUCTS

There are substantial quantities of vegetable and fruit waste produced from centralized food processing facilities. Much of this material is fed to dairy cows. Because of the uneven nature of supply, it is often ensiled in trenches in the ground, for subsequent use as feed. Pineapple skins were found to fall to a pH of 3.5 within 2 days of delivery, and remain at that level with no apparent reduction in feeding value (Cornack, 1995).

CONCLUSION
The record of development of silage in tropical regions has been characterized by unclear objectives in making silage, a lack of a whole-farm approach to silage evaluation, and a preoccupation with utilizing excess pasture growth during the growing season.

It is concluded that where silage is considered appropriate to the feeding system, the activity should concentrate on using crops, making large amounts for individual properties, combining feed sources to enhance efficiency of nutrient use, and integrating feed planning with other demands of modern production systems, such as quality assurance and sustainability.

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The Philippines

INTRODUCTION

Sarangani Agricultural Co., Inc. (SACI) is a diversified, all-Filipino company offering a diverse range of agricultural products, with head office in Maribulan, Alabel, Sarangani Province, Philippines. Over the years, it has distinguished itself as the premier cattle producer in the country, maintaining a herd of 5 000 pure-bred and graded American Brahman cattle, with upgraded horses raised in General Santos City, Malungon and Alabel, all located in Southern Mindanao. From Sarangani Brahman, SACI has expanded into the production of banana, pummelo and bangus, tilapia, prawn and specialty fishes. It has initiated vegetable production and tree planting for industrial uses.

Along with the breeding of quality Brahman cattle, SACI has continuously developed feeding technologies using farm by-products, such as banana rejects, pineapple pulp, corn (maize) stover and cobs, rice straw, ipil-ipil (Leucaena leucocephala) and silage among others. This paper gives special reference to our experience with corn silage on Alabel farm.

CATTLE FEEDING MANAGEMENT ON THE FARM

Two systems of feeding - grazing and confinement, or feedlot - are used on the farm. The breeding herd, which at present is composed of 230 cows and 24 bulls, along with 140 calves and 96 yearlings, are grazed on 186 ha of Para grass (Brachiaria mutica) + Leucaena, and 223 ha of native pastures. Other groups of animals (marketable bulls, marketable heifers, culled cows from ranch operations, fattening bulls and fattening steers) are kept in the feedlot.

PLANTING AND PREPARATION OF MAIZE FOR SILAGE

Maize is planted on 25 ha throughout the year, where four crops are harvested with irrigation. Following harvesting, land is prepared after 15 days and planted a week later. Each crop is harvested at 75 days after planting, using tractor-mounted harvester-chopper machines, dumped and piled in stacks in an area near the feedlot. The area for the stack pile is lined with plastic sheets before dumping the chopped maize plants. The stack from each day's harvest is immediately covered with special, strong plastic sheets after compacting by several passes of a tractor over the pile.
Recovery of ensiled materials ranges from 80 to 92%, reflecting age of plants at the time of harvest. Maize harvested at 80 days from planting has higher recovery compared to that harvested at 70 days, but ensiled younger maize is more palatable and has less wastage during feeding.

**UTILIZATION OF MAIZE SILAGE**

Ensiled maize is generally kept from 90 to 100 days during the rainy season (July to October), but shorter in the dry season, sometimes for only 18 days when severe drought occurs, as during the *el niño* months in 1997/1998. At one point there was a shortage of maize silage for 14 days, so we harvested 38 ha of Para grass as green-chop on the farm (at the expense of our breeder herd) and purchased 65 t of green-chop maize to support the animals in the feedlot.

**FEEDING OF MAIZE SILAGE**

Maize silage is the principal feed given to cattle kept in the SACI feedlot. Below are the general feeding schemes used for the different groups of animals.

**Table 1. Feeding schemes**

<table>
<thead>
<tr>
<th>Group</th>
<th>Feed per head per day</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Corn Silage (kg)</td>
<td>Concentrate (kg)</td>
</tr>
<tr>
<td>Marketable bulls</td>
<td>18</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Marketable heifers</td>
<td>17</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Fattening bulls (rejects)</td>
<td>20</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Fattening steers</td>
<td>20</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Culled cows</td>
<td>20</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>

Corn silage is important in maintaining well-conditioned and uniform breeder heifers and bulls that we offer for sale to customers. It is also an important tool for conditioning culled thin cows (with average liveweight of 280 kg) from the ranch. If these cows are sold immediately to butchers, the price would be only pesos 30/kg liveweight (Exchange rate at time of writing: US$ 1 = peso 39.8), but if passed through the feedlot on maize silage-based rations, these cows gain 1.6 kg/head/day over 2 months, and are sold at pesos 36/kg.

For fattening steers and bulls, feeding of concentrates is done by mixing them with the silage to obtain uniformity. Earlier observation showed that if they are simply top-dressed over the silage, the more aggressive animals get more access to the concentrate and perform better. Our concentrate mixture is composed of rice bran, palm kernel cake and ipil-ipil, plus mineral supplements.

Maize silage is crucial to the Alabel cattle operation, allowing SACI to maintain a population of 410 head of two-year-old bulls and heifers, culled cows, fattening bulls and steers at any given time in the feedlot, in conjunction with the breeding herd raised on pasture.
INTRODUCTION

Livestock is recognized as being an integral component of the mixed farming systems that predominate in the tropics, particularly in the developing world. Animal manure and traction make the land more productive than would be the case in their absence. Yet, it has been recognized with equal force that livestock owned in the developing world have had a devastating effect on the environment through overgrazing the natural vegetation, leading to soil erosion, and, ultimately, desertification. Technologies aimed at achieving a balance whereby livestock can increase in productivity, so enhancing wealth for the livestock owner, while resource degradation is minimized, must be developed (Steinfeld, 1998). One such technology is the conservation of forage produced during the wet season, which can be fed to livestock kept in at least partially zero-grazed systems during the dry season. This may, in fact, be the only such technology that would ensure satisfaction of the high demand for nutrients for livestock production operations such as small-scale dairy farms in the semi-arid regions of the tropics (Dube, 1995).

To put into perspective the importance of ensiling tropical grasses and legumes to feed as conserved forages in the dry season in the tropics, one might ask the questions “Why silage? Why not hay? Surely with all that sun in the tropics, it should be easier and cheaper to make hay rather than silage?”

The answer to this lies in both season and plant physiology. A comparison can be made with countries where temperate climates allow both ensilage and haymaking of ryegrasses and legumes, which retain high nutritional quality and, which, with persistent rains and good soils, will provide sufficient regrowth for several cuts (New Zealand, Europe). Then there are those countries where irrigation is plentiful and cheap and legumes such as lucerne (alfalfa) can be grown in abundance for both silage and hay (parts of USA). Other countries again have winter rainfall (Israel, Western Australia and the Cape area of South Africa) where lucerne and winter wheat can be produced with relative ease.

In much of the rest of the tropics, the conditions are harsh for conserved forage. High temperatures combine with short rainy seasons on largely poor soils to produce grasses and legumes that, while able to produce high yields under good management, still deteriorate rapidly in nutritional quality after only three months of growth. Protein and digestibility both decline rapidly in tropical grasses and legumes...
after flowering, as lignification proceeds. In order to harvest grass and legumes of high nutritional quality, cutting has to take place at the early stage of growth, in fact while the rains are still prevalent. Unless a mower-conditioner is used with the harvested crop and it is then taken for treatment with bulk dryers in large hay sheds, it is unlikely that a good hay crop can be produced at this time. This needs expensive machinery and buildings and even on large livestock farms it is questionable as to whether it is economically justifiable.

The rains are hard and driving and will wet the entire crop, which then leaches and rots. If harvesting for hay takes place after the rains, not only is the nutritional quality low but, in legumes, leaf shattering is likely to occur at cutting, leaving largely poor quality stemmy hay. One could argue that with irrigation, winter (temperate) grasses and legumes could be produced for hay. This is certainly true and indeed is carried out on some of the large commercial dairy farms in the tropics. For smaller dairy farms, however, and certainly for the common small-scale farm, irrigation is expensive and likely to provide better returns with horticultural crops than hay crops for livestock feeding. Thus we are left with the other option for conserving grasses and legumes, namely ensilage.

THE FEASIBILITY OF SUCCESSFUL ENSILAGE OF TROPICAL GRASSES AND LEGUMES

Tropical grasses and legumes are not ideal ensilage material, largely because at cutting they have a low level of the WSC that are essential to successful ensilage (Table 1). Therefore they have a higher buffering capacity, and this leaves their proteins susceptible to proteolysis (Woolford, 1984).

However, there are several practices that contribute to improving the levels of fermentable carbohydrates, reduce buffering and prevent proteolysis, and can therefore assisting in producing good quality silage. These practices include:

(i) Mixing legumes with cereal crops.
(ii) Wilting.
(iii) Using silage additives.
(iv) Conserving in small-scale silos.

Table 1. WSC of silage forage crops (mean values followed by range in brackets)

<table>
<thead>
<tr>
<th>Crop</th>
<th>WSC - mean (range) (g/kg DM)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryegrass</td>
<td>79 (5 - 220)</td>
<td>Thomas and Thomas, 1985</td>
</tr>
<tr>
<td>Maize</td>
<td>350 (280 - 510)</td>
<td>McDonald et al., 1991</td>
</tr>
<tr>
<td>Grain sorghum</td>
<td>75 (56 - 132)</td>
<td>Havilah and Kaiser, 1992</td>
</tr>
<tr>
<td>Sweet Forage sorghum</td>
<td>220 (180 - 250)</td>
<td>Mhere et al., 1999</td>
</tr>
<tr>
<td>Kikuyu</td>
<td>31 (23 - 41)</td>
<td>de Figueiredo and Marais, 1994</td>
</tr>
<tr>
<td>Lucerne (alfalfa)</td>
<td>15 (4 - 20)</td>
<td>Waldo and Jorgensen, 1981</td>
</tr>
</tbody>
</table>

MIXING LEGUMES WITH CEREAL CROPS

The main focus of research in intercropping legumes with cereal crops has been to increase grain yields of crops while improving soil fertility in farming systems in the semi-arid tropics (Willey, 1979), but little attention has, until recently, been paid to the benefits of intercropping cereals and legumes for the production of high quality silage for livestock feeding.

Maize silage plays an important role as a winter feed in the livestock industries of many countries, including in the (sub)tropics. The main reasons for the popularity of maize for silage purposes are the high yield obtained in a single harvest, the ease with which it can be ensiled and its high energy value as a feed. However, its major
shortcoming is its low crude protein content, which is usually of the order of 70 to 80 g/kg DM (Topps and Oliver, 1993). In the high rainfall subtropical areas of Zimbabwe and South Africa, maize remains the preferred cereal crop for silage (Titterton, 1997), producing higher yields and higher energy content than grain sorghum, forage sorghum or Kikuyu grass, as shown in Table 2.

**Table 2.** Yield, DM and energy content of maize, grain sorghum and forage sorghum compared to Kikuyu grass silages produced on sand and clay soils

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield and energy content of silage</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t DM/ha</td>
<td>MJ/kg DM</td>
</tr>
<tr>
<td>Maize (cv SC BW93(^{(1)}))</td>
<td>14.7</td>
<td>10.2</td>
</tr>
<tr>
<td>Kikuyu grass</td>
<td>4.1</td>
<td>7.5</td>
</tr>
<tr>
<td>Grain sorghum (cv MR Buster)</td>
<td>7.3</td>
<td>10.0</td>
</tr>
<tr>
<td>Forage sorghum (Sugargraze)(^{(1)})(^{(2)})</td>
<td>7.4</td>
<td>9.5</td>
</tr>
</tbody>
</table>

**Notes:** (1) These crops were produced at Henderson Research Station, Mazowe, Zimbabwe (980 mm/year average rainfall). (2) cv Sugargraze is a variety of forage sorghum recommended for silage, produced by Pacific Seeds, Australia.

In the semi-arid regions of the tropics, however, maize, being very susceptible to moisture stress, is questionable as the crop of choice for silage. In general, yields are poor and energy values much lower than those found in the higher rainfall areas. Alternative crops, such as grain sorghum, forage sorghum and forage pennisetums, which are drought tolerant yet high yielding, have been investigated as silage crops and found to be suitable (Havilah and Kaiser, 1992; Mhere *et al.*, 1999), although it has been concluded after an evaluation of grain and forage sorghums in Australia that sweet forage sorghums offered better potential than grain sorghums under dryland conditions (Cole *et al.*, 1996). Sweet forage sorghum yields have been higher under dryland conditions (Mhere *et al.*, 1999) than in the high rainfall area of Zimbabwe. Again, however, the limitation in terms of nutrient quality is the low protein content, which was approximately 70 g/kg DM and 95 g/kg DM in forage sorghum and pennisetums, respectively (Mhere *et al.*, 1999). One method of improving the protein content of the silage is to add a protein rich crop to the cereal crop. This can be done either by intercropping the cereal crop with a legume or growing them as sole crops and mixing them at ensilage. The feasibility, therefore, of ensiling these crops with legumes has been investigated.

Maasdorp and Titterton (1997) examined the effect of intercropping (in-row) of fifteen tropical legumes with a variety of long-season maize cultivars popularly used for silage in Zimbabwe. Of these, forage and grain soybeans, lablab (dolichos bean) velvet bean, sunn hemp and cowpea proved the most promising, but in-row intercropping with the maize, which was at a density of 65 000 plants/ha, did not prove to be viable; with the exception of velvet bean and lablab, the proportion of legume in the biomass was only 15%, insufficient to make a significant difference to protein yield. Velvet bean and lablab swamped the maize, reducing maize yield. Indeed, it has been shown that the proportion of legume and crude protein content of the silage was significantly affected by maize plant density and the time of sowing of each crop. Kaiser and Lesch (1977) showed dolichos bean proved to be at its maximum proportion of 24% when maize plant density was at 54 000 plants/ha and crude protein content of the silage was 110 g/kg DM. In the same study, however, there was apparently no benefit in intercropping soybean with maize for mixed crop silage, whatever the density of maize. Maasdorp and Titterton (1997) showed that,
by planting lablab and velvet bean into a maize crop two weeks after sowing maize, maize yield was not depressed and the legume DM yield constituted about 30% of total DM yield, bringing silage crude protein content to about 10.5%. Further research is required into the planting pattern and sowing times of maize and legume. When in-row intercropping is apparently the preferred regime for machine harvesting, where single-row cutting is the common practice, between-row intercropping may be more beneficial in the case of small-scale farming systems, where crops are cut by hand. Here, it is likely there would be less competition between maize and legume and there should be a greater contribution of legume to total yield, with significant improvement in protein content. There are many other benefits of intercropping: reduced soil erosion, lower incidence of pests and less labour requirements for weeding (Saleem, 1995).

When sole crops of maize and legumes were mixed at harvesting 50:50 by volume for ensilage (Titterton and Maasdorp 1997) it was found that with all fifteen legumes, fermentation quality was acceptable (pH in the range 3.7-4.5; NH\textsubscript{3}:N ratio <12.0), with the exception of velvet bean, sunn hemp and silverleaf desmodium, while crude protein content had increased from 77 g/kg DM in pure maize silage to between 93 g/kg DM (yellow lupin) and 153 g/kg DM (forage soybean). In the case of maize and dolichos bean, it was 128 g/kg DM. This trial used recycled plastic garbage bags, in which the maize and legume was layered before compression with a tobacco press, and the bags sealed with string. The quality of the silage gave an indication that this might be a suitable method for ensilage of mixed crops for small-scale dairying.

When seven legumes (forage soya, grain soya, silverleaf desmodium, lablab, cowpea, lupin and velvet bean) were layered with maize for ensilage in pits, the silage was similar in quality to that of the same legumes proportionately mixed with maize in bags, with the exception of silverleaf desmodium, to show no significant difference to that of pure maize silage in palatability (DM intake) and effect on milk yield in Holstein dairy cows (Taruona and Titterton, 1996).

Agroforestry also offers potential for improving protein content of mixed silages. The addition of wilted *Amaranthus hybridus* to maize (1:1) at the time of ensiling resulted in good fermentation and raised the CP content of the silage from 6.9% to 11.6%, and reduced the crude fibre content (Bareeba, 1977). Maasdorp and Titterton (1999) successfully ensiled, (fresh mass ratio of 50:50) the leaf material of four forage tree legumes with maize, with improvement of crude protein content to 14%, 15.5%, 17.2% and 18.7% in maize + *Calliandra calothyrsus*, maize + *Gliciridia sepium*, maize + *Leucaena leucocephala* and maize + *Acacia boliviana* silages, respectively. Only in the maize + *Calliandra* silage was organic matter digestibility significantly reduced, while in the other three it was similar to that of maize silage. A similar trial has been planned for forage tree legumes ensiled with forage sorghums and pennisetums.

As with maize, soybean has proved to be of little benefit when intercropped with grain sorghum (Kaiser *et al.*, 1993). Sweet forage sorghum, in contrast, when intercropped with lablab in a planting pattern of 1 row sorghum and 1 row lablab, produced silage of good fermentable quality with a crude protein content of 120 g/kg (Mhere *et al.*, 1999). Sorghum and lablab silage has been produced elsewhere with reasonable success (Ojeda and Diaz, 1992; Singh *et al.*, 1988).

Forage pennisetums have been successfully intercropped with legumes (Gill and Tripathi, 1991; Bhagat *et al.*, 1992; Mhere *et al.*, 1997) and ensiled with and without legumes (Mhere *et al.*, 1999; Crowder and Chheda, 1982; Bareeba, 1992). Mhere *et al.* (1999) found however, that soil type, planting pattern and weather had significant effects on proportion of legume in both forage sorghum and forage *Pennisetum* crops.

**WILTING**
Tropical grasses and legumes need to be cut early in the vegetative stage for ensilage while protein and digestibility are high. However, militating against this is the relatively high moisture content of the plants at this stage, which can adversely affect fermentation quality of the silage (McDonald et al., 1991).

Ensiling material with less than 30% DM may create an environment that is totally anaerobic (suited to clostridial bacteria) rather than micro-aerophilic (suited to lactic acid bacteria). In addition, it may result in the loss of valuable nutrients because water and soluble nutrients accumulate at the bottom of the silo as silage effluent. In pit or bunker silos, this effluent can seep away and be lost to the silage. At the same time, research into time of wilting has produced extremely variable results due, apparently, to weather conditions such as humidity, wind speed and ambient temperature prevailing at the time of the trial (McDonald et al., 1991). Warm humid conditions, such as are found in the high-rainfall tropics, are not conducive to rapid field drying. Biochemical losses from respiration could be higher than losses from unwilted silage and digestibility of the silage is reduced (Thomas and Thomas 1985). At the same time, in the semi-arid tropics, it may be possible to achieve rapid wilting in the ideal three to five hours (Michelina and Molina, 1990; Alberto et al., 1993) without a resultant decline in digestibility (Mayne and Gordon, 1986) and improvement in fermentable quality of silage (Thomas and Thomas, 1985). This may only occur in silages that are below 30% DM without wilting. Where et al. (1999) found that although increasing wilting time within 12 hours had no effect on digestibility of mixed forage sorghum/legume and Pennisetum/legume silages, pH increased significantly. The DM content of these silages was already about 30% and higher without wilting, and within 6 hours was up to 40% and higher. This indicates that wilting reasonably dry crops in the field may actually result in poorer fermentation, probably due to decreasing effective compression in the silo. If the wilting period is extended over several days, soluble carbohydrates will be lost, protein nitrogen contents may be reduced and de-amination of amino acids may increase (Henderson, 1993). Another factor that may be of importance is the silo. In pits or bunkers, where the large quantities of effluent produced by very wet material is lost and indeed may be a serious pollutant, wilting under the right conditions may be of benefit. In silos, particularly small ones, where the effluent is sealed in, however, this may not be so critical. In a study of small-scale silos (Ashbell et al., 1999; Titterton et al., 1999) there are indications that the effluent, being retained in the silage, prevents mould and contributes to good fermentation in forage which has been coarsely chopped and manually compressed in the silo. In other words, the normal criteria for successful ensilage do not apparently apply when the silage is sealed into small, portable silos.

In summary, wilting only appears to be necessary if crops in the field are still very wet at harvesting, conditions are conducive to rapid drying, and large silos are used to store the silage.

ADDITIVES

Additives are used to improve silage preservation by ensuring that lactic acid bacteria dominate the fermentation phase. Additives can be divided into three general categories: 1) fermentation stimulants, such as bacterial inoculants and enzymes; 2) fermentation inhibitors, such as propionic, formic and sulphuric acids; and 3) substrate or nutrient sources, such as maize grain, molasses, urea or anhydrous ammonia (Woolford; 1984; Henderson; 1993; Bolsen et al., 1995). A number of trials produced the conclusion that only strong acids, either alone or in combination with formaldehyde, have the potential consistently to modify fermentation (Thomas and Thomas, 1985). However, these have largely lost popularity due to both cost and handling difficulties on the farm. Bacterial inoculants have inherent advantages over other additives, including low cost, safety in handling, a low application rate and no residue or environmental problems. However, results of their application are variable, probably due to the differing ensilage
conditions prevailing at the time of application. However, when applied together with enzymes that degrade plant cell walls and starch, which could provide additional sugars for fermentation to lactic acid, they appear to have achieved improvement in fermentation and nutritional quality of tropical grasses and legumes (Bolsen, 1999) Studies with Kikuyu grass silage, however, suggested that the grass needs to be rapidly wilted before an inoculant is added if improved fermentation is to be achieved (de Figueiredo and Marais, 1994) since there was no improvement when inoculants were added to unwilted grass. In a comparison of maize meal with a commercial silage additive (containing bacterial inoculant and enzymes), Mhere et al. (1999) found however that when added to forage sorghum/legume and forage Pennisetum/legume mixtures, maize meal (5% of biomass) improved DM, and both additives improved the nutritional content but had no significant effect on fermentation quality. This may be due to the fact that the silages were stored in small, sealed silos where, since the effluent was retained in the silage, there was no benefit to fermentation of the addition of either additive.

On small-scale farms, commercial additives, namely inoculants and enzymes, may be too costly or simply not available. It is likely therefore that the third category of additive - substrate or nutrient sources - will be of most benefit to silage made on smallholdings. Possibly the most important benefit of additives such as maize or sorghum grain or cassava meal is to improve DM in early-cut crops when moisture content is high and rapid drying (wilting) is not possible, or where effluent is lost to the silage through seepage. Tropical grasses have been successfully ensiled when supplemented with maize meal (van Onselen and Lopez, 1988), cassava meal (Panditharane et al., 1986) and sorghum grain (Alberto et al., 1993).

Molasses is the carbohydrate source used most frequently, and is of particular benefit when applied to crops low in soluble carbohydrates, such as tropical legumes and grasses. Good silages have been reported when molasses was applied at 3-5% (Bareeba, 1977; Sarwatt, 1995). However, if the treated silage has a very low DM content, most of the carbohydrate source may be lost in the effluent during the first few days of ensilage in pits or bunkers.

Applying urea or anhydrous ammonia to silages has an adverse effect on fermentation and nutrient quality of silages, particularly high-moisture forage sorghums (Bolsen, 1999), although Sarwatt (1995) obtained good silage by applying 0.5% urea to maize, sorghum and Rhodes grass in Tanzania. An additive with a urea/molasses blend is possibly the best combination to apply to tropical grasses if they are cut in the early vegetative stage (Bolsen, 1999). More research is needed in this field, particularly in the ensilage of tropical natural pasture grasses.

CONCLUSION

In the tropics, particularly the semi-arid tropical regions, where the major constraint to livestock production is the lack of availability of fodder, conservation through ensilage of forage produced during the wet season is likely to be the practice adopted by most small-scale livestock owners, particularly those in dairy or beef production. It has been shown that ensilage of forage can be carried out with simple technology and that forages such as tropical grasses, forage legumes, forage tree legumes, forage sorghum and pennisetums can be produced and ensiled successfully in this way. However, there is still much to be researched in how the quality of these silages, both in terms of fermentation and nutrition, can be improved through the use of intercropping or mixing at ensilage, and with the use of additives. There is also potential for the ensilage of many agro-industrial by-products with forages and legumes and this needs increased attention in the field of research into low-cost feeds for livestock.

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Titterton, M., Mhere, O., Maasdorp, B., Ashbell, G., Kipnis, T., Weinberg, Z., Hen, Y. 1999. The use of plastic bags and simple technology to ensile mixed cereal and


INTRODUCTION

There is a need for silage making technology under local conditions, especially in those areas experiencing drier months or where monsoonal conditions restrict the routine cutting of forages. The need for silage making is even more significant for dairy cattle feeding, where the demand for uniform and high quality feed is of great importance. The tedious daily harvesting of green forages throughout the year also poses problems for small-scale producers, particularly when family labour is insufficient.

The objective of this paper is to evaluate the performance and suitability of six tropical grasses and three forage crops for silage making and a feeding trial for milk production.

METHODS

Nine species were planted for the first experiment: six grasses, namely setaria (Setaria sphacelata var. splendida); signal grass (Brachiaria decumbens); B. humidicola; MARDI Digit (Digitaria setivalva); Napier (Pennisetum purpureum); and three crops, namely maize (Zea mays); forage sorghum (Sorghum bicolor); and Sorghum almum. The grasses were cut at six-weekly intervals. Maize was harvested at 75 days, forage sorghum at 70 days and S. almum at 63 days after planting. Fresh samples were taken for analysis of DM and WSC (Dubois et al., 1956) and for silage making in the laboratory. The silage samples were analysed for pH, lactic acid (MAFF, 1973) and physical characteristics.

In the second experiment, six multiparous Sahiwal-Friesian cows in mid-lactation were used to test three dietary treatments in a double switch-over experiment (Cochran et al., 1941). Treatments were three levels of silage in the diet in direct substitution for cut fodder, as follows:

(a) fodder ad libitum;
(b) fodder+silage (1:1) ad libitum; and
(c) silage ad libitum.

In addition, each animal received 6 kg of concentrate once daily. Feed samples were taken once weekly and composited by cow-period. Feed intake and milk production
were recorded daily.

RESULTS AND DISCUSSION

The mean values for WSC and DM in the crops and the quality of silage produced (pH and lactic acid content) are shown in Table 1. Maize and forage sorghum produced good silage with pH <4.0 and lactic acid levels of 2.72 and 3.7%, respectively (Table 1). For the grasses, it was found that, without additives, setaria and Napier could be turned into acceptable silage with pH 4.07 and 3.96, respectively. The pH of the grass silage was reduced with the addition of 4% molasses.

The nutritional composition of sorghum silage and guinea grass used in the second experiment are shown in Table 2. Treatment means for feed DM intake, milk yield and feed efficiency are given in Table 3. Intake of DM from roughage was highest (P<0.05) in treatment (b). The higher roughage intake of treatment (b) was attributed to a stimulatory effect of silage on intake. The difference in the total DM intake reflected differences in roughage DM intake. Expressed as percent body weight, total DM intakes in the respective treatments were within the range 2.0 to 2.4%. Average daily milk yield was higher (P<0.5) for cows fed sorghum silage compared with the control. The difference in milk yield was 13% between treatments (c) and (a). Mean feed efficiency value for cows on the silage-based diet was nearly twice as good as either treatment (b) or the control group (a) (Table 3).

Of the crops, forage sorghum and maize can be made into excellent silage without additives. It is suggested that grasses are cut at about six-weeks regrowth. Napier and setaria can be ensiled into reasonable silage, but the quality can be improved with the addition of 4% molasses before ensiling. From the second trial, sorghum silage appears to be a better feed than the average guinea grass commonly fed to lactating cows in Malaysia. This is reflected in its effect on milk yield and feed efficiency.

Table 1. Silage made from tropical grasses and forage crops

<table>
<thead>
<tr>
<th>Species</th>
<th>Fresh material</th>
<th>Simple silage</th>
<th>Silage + 4% molasses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DM (%)</td>
<td>WSC (%)</td>
<td>pH</td>
</tr>
<tr>
<td>Grasses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setaria sphacelata</td>
<td>15.30</td>
<td>6.17</td>
<td>4.07</td>
</tr>
<tr>
<td>Brachiaria decumbens</td>
<td>20.37</td>
<td>8.64</td>
<td>5.07</td>
</tr>
<tr>
<td>Brachiaria humidicola</td>
<td>20.85</td>
<td>2.35</td>
<td>5.32</td>
</tr>
<tr>
<td>Digitaria setivalva</td>
<td>18.21</td>
<td>1.26</td>
<td>4.32</td>
</tr>
<tr>
<td>Pennisetum purpureum</td>
<td>15.77</td>
<td>9.88</td>
<td>3.96</td>
</tr>
<tr>
<td>Panicum maximum</td>
<td>19.35</td>
<td>3.03</td>
<td>4.71</td>
</tr>
<tr>
<td>Crops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zea mays</td>
<td>21.20</td>
<td>22.99</td>
<td>3.72</td>
</tr>
<tr>
<td>Sorghum bicolor</td>
<td>21.35</td>
<td>11.69</td>
<td>3.68</td>
</tr>
<tr>
<td>Sorghum almum</td>
<td>18.40</td>
<td>n.d.</td>
<td>4.40</td>
</tr>
</tbody>
</table>

Notes: n.d. = not done

Table 2. Percentage chemical composition of feedstuffs

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>DM</th>
<th>CP</th>
<th>TDN</th>
<th>CF</th>
<th>EE</th>
<th>NFE</th>
<th>Ash</th>
<th>Ca</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Guinea grass</td>
<td>24.1</td>
<td>11.7</td>
<td>61.6</td>
<td>33.6</td>
<td>2.4</td>
<td>46.1</td>
<td>6.2</td>
<td>0.57</td>
<td>0.27</td>
</tr>
<tr>
<td>Sorghum silage</td>
<td>29.4</td>
<td>8.7</td>
<td>60.1</td>
<td>33.4</td>
<td>2.6</td>
<td>51.0</td>
<td>4.2</td>
<td>0.47</td>
<td>0.17</td>
</tr>
</tbody>
</table>
Table 3. Feed intake and efficiency and milk yield for the different treatments

<table>
<thead>
<tr>
<th>Variables</th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed DM intake (kg/day)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roughage</td>
<td>4.95b</td>
<td>6.22a</td>
<td>4.50b</td>
</tr>
<tr>
<td>Concentrate</td>
<td>5.40</td>
<td>5.40</td>
<td>5.40</td>
</tr>
<tr>
<td>Total</td>
<td>10.35b</td>
<td>11.63a</td>
<td>9.90b</td>
</tr>
<tr>
<td>DM intake per 100 kg BW</td>
<td>2.1</td>
<td>2.4</td>
<td>2.0</td>
</tr>
<tr>
<td>Milk Yield (kg/day)</td>
<td>7.01c</td>
<td>7.54ab</td>
<td>7.93a</td>
</tr>
<tr>
<td>Feed Efficiency (kg total DM intake per kg milk)</td>
<td>2.16b</td>
<td>2.65b</td>
<td>1.37a</td>
</tr>
</tbody>
</table>

Notes: The values within rows with different letters are significantly different (P<0.05)

REFERENCES


Poster 4.2: Silage quality and losses associated with ensiling of Napier grass, Columbus grass and maize stover under smallholder conditions in Kenya - P.J.M. Snijders and A.P. Wouters

P.J.M. Snijders and A.P. Wouters
E-mail: p.j.m.snijders@pr.agro.nl

INTRODUCTION

On behalf of the National Dairy Development Project, several ensiling experiments were conducted at the National Animal Husbandry Research Centre (NAHRC) at Naivasha, Kenya, in the period 1983-1989. The aim of the experiments was to develop methods and techniques suitable for smallholders for the ensiling of Napier grass, Columbus grass and maize stover to overcome feed shortages during the dry season.

MATERIALS AND METHODS

Six series of ensilage experiments were conducted:

- **Series A**: 2 silages of chopped, wilted Napier grass with or without addition of molasses, ensiled in an number of netted nylon bags and placed inside a larger silage clamp.

- **Series B**: 6 pits of wet, long or chopped Napier grass with addition of no, 3.5% or 6% molasses.

- **Series C**: 4 pits of wet, long or chopped Napier grass with addition of 3.5% molasses or molasses/urea mixture (MUM).

- **Series D**: 6 pits of wet, long or chopped Napier grass with addition of 3% molasses.

- **Series E**: 4 pits of wet, long or chopped Columbus grass with addition of 3% molasses.

- **Series F**: 3 pits of chopped maize stover or maize stover mixed with lablab, without additive.

Silages were made in small earthen pits in quantities varying from 1 000 to 2 000 kg fresh material, thus more or less representing conditions typical for small-scale farmers. Sides and top of the pit were covered with 2-m-wide polyethylene plastic sheets covered with a layer of about 50 cm of sand on the top and sides.

RESULTS
The percentage of inedible silage (mouldy or rotten silage) varied from negligible to 2.5%, indicating that sealing with polyethylene sheet and soil cover was good. Levels of butyric acid and contents of ammonia nitrogen were often below 0.3% and 12% respectively for silages of wilted Napier grass and wet-chopped Columbus grass with the addition of molasses and for silage of maize stover. These fermentation characteristics indicate good silage quality. Smell was also good. For some wet Napier grass silage and for silages made with addition of MUM to unchopped Columbus grass, results were less good.

Long, unchopped Napier grass wilted for one or two days to about 30% DM, with the addition of molasses and with proper compaction, also often resulted in good silage.

DM losses due to ensiling of Napier grass averaged between 15.2 and 4.2%. Losses were lower for silages made of grass wilted for one or two days and higher for silages made of wet, unchopped grass and grass with the addition of MUM. For wet Columbus grass, there was also a clear positive effect from chopping. Average DM loss for ensiled maize stover was 8.1%.

CP losses averaged 16.9%, but variation was large, partly due to sampling errors. Losses were lower for wilted silages and much higher for silages with the addition of MUM.

In vitro organic matter digestibility decreased due to ensiling and was more than 10 units lower in the case of poor quality silages. For well-preserved silages, the decrease in digestibility was often limited to 5 units or less. Losses of digestible organic matter for Napier silages averaged between 28.5 and 7.9%. Losses were lower for wilted silages and much higher for wet silages of Series D and silages made with the addition of MUM.

Results show that under smallholder conditions, good silage can be made. However, poor quality silages of poorly digestible Napier grass will not meet maintenance requirements of animals.

CONCLUSIONS AND PRACTICAL RECOMMENDATIONS

1. Under small-scale farming conditions, good silage can be made, provided that airtight sealing with plastic (polyethylene) sheets is used, with at least a cover of 50 cm of soil on top and sides of the pit, and with good drainage of rain water. Ensiling and covering has to be completed within one day.

2. As shown by good fermentation characteristics and smell, wilting one or two days to reach a DM content of 30% often results in good silage, especially when molasses is added. Wilting to a DM content of more than 30%, or wilting of old stemmy material, are not recommended, because of the higher weather risks and difficulties with compaction.

3. DM losses due to ensiling of wilted or wet-chopped Napier grass with the addition of molasses could be limited to 15%.

4. DM losses of silages made of wilted, unchopped long Napier grass are probably slightly higher than from chopped Napier grass. Provided proper compaction, addition of molasses, airtight sealing and covering with at least 50 cm of soil, making silage from long, wilted Napier grass may be a good alternative for small-scale farming conditions.

5. Although it is not very clear from the limited experience provided by these experiments, addition of 3% molasses to wet and long wilted Napier grass will probably be sufficient to obtain good quality silage, especially when hand-mixed through chopped silage. To increase chances for good quality silages, addition rates of up to 6% are suggested when molasses is applied in the silage pit on layers of
grass. For chopped, wilted Napier grass and for chopped Columbus grass, addition of molasses can be lower.

6. MUM as an alternative additive for molasses does not produce good silages.

7. Silages of chopped Columbus grass with molasses and chopped maize stover without molasses made good silage. DM losses appeared to be lower compared to Napier grass.

8. Because of a greater risk of leaching, dilution of molasses with water in order to ease application should not exceed a 1:1 ratio. A relatively small quantity of molasses should be used in the bottom layers of the pit, and more to be added to the middle and top layers.

9. Losses of crude protein and digestible organic matter were not accurately measured in these experiments, because of the limited number of samples and because of sampling errors. Based on good quality silages in these experiments, losses are about 15% and 25% for crude protein and digestible organic matter respectively.

10. Poor silages of overgrown Napier grass will - at best - supply sufficient energy for maintenance. Feeding overgrown Napier grass as standing hay, or mulching might then be a better alternative. Proper storage and utilization of crop residues like maize stover and preserving feeds like sweet potato vines, fodder beets, cassava or fodder trees may prove better in those situations.
FEED RESOURCES IN THE WET TROPICS

The main limiting factor for ruminant production in the Tropical Top End of Australia is the lack of good quality feed throughout the year. Seasonal rainfall provides a period of abundant herbage at its peak nutritional value during the wet season, followed by a period of lower quality mature herbage in the dry season. It makes sense to try and conserve the abundance of good quality vegetation when it is available in the wet season and use it later in the dry season, when plant growth is severely restricted, natural feed in short supply and commercially available feed relatively expensive.

This is exactly what has been done at Taminmin High School, near Humpty Doo, about 40 km SE of Darwin, Northern Territory, Australia. The precise location is 12°24′ S, 131°15′ E.

TAMINMIN’S SILAGE PROGRAMME

As a regular part of their farm management strategy, Taminmin makes baled silage during late January or early February each year. Making hay at this time is not an option because it is too difficult to dry the plant matter to the required 85% dry matter (DM) or more. In contrast, wet season pasture can be baled at lower DM content and higher moisture than hay, wrapped in plastic film and allowed to ferment into silage.

Almost any pasture can be made into silage, but the best silage is made from the best pasture. At Taminmin, silage is regularly made from Pangola grass (*Digitaria eriantha* subsp. *eriantha*) and the legumes Cavalcade centurion (*Centrosema pascuorum*) and Wynn Cassia (*Chamaecrista rotundifolia*). The trick is to watch the weather, then cut no more pasture than you can comfortably wilt, bale, wrap and stack in a single day without any rainfall.

A TYPICAL DAY OF MAKING SILAGE

As long as we are confident of getting a rain-free day, we go ahead. Trial and error has taught us to process no more than 1.5 ha. We check with the Weather Bureau. They regularly track tropical storms by radar and are very competent predictors of storm incidence, arrival times, intensity and duration. We have found their accuracy decreases as distance inland increases, but for the cost of a telephone call, they are
a terrific advisory service.

Pasture is cut at 09:00. Sunrise is usually just after 07:00, and the two hours are enough to get most of the free water evaporated from the pasture. A second tractor follows the cutter and forms up the windrows almost immediately. This is usually done by 10:30. We turn the windrows over just once, starting at 11:00. This is usually done by 12:30. We sample the windrows and estimate the dry DM content. This is easily done in 10 minutes using a microwave oven, but we are lucky enough to have a probe (Farmscan 2180) to do this in the field. We start baling as soon as the DM content is 40% or more. (Recently, for the last two seasons, the contractor has made this process much more efficient as he has used a mower/conditioner to cut, condition and windrow in one operation. This has also allowed the cut pasture to dry out more quickly.)

We get about 60 bales, and baling is normally finished by 17:30. We start wrapping as soon as the bales are formed. This takes longer than baling, but is usually completed just before 19:00.

We do not use any additives such as molasses, urea, or lactic acid bacteria inoculant. Our research has shown that the cost of the additive cannot be justified. Weight increases of stock being fed silage with or without additives were not significantly different. However, it is extremely important to wilt the material to about 40% DM before baling. Ensiling wet material (e.g. less than 30% DM) will almost certainly result in production of poor quality silage, with high levels of wastage, and a high degree of rejection by stock.

It is a very busy day that we usually repeat, weather permitting, two or three times in 7-10 days. The end result is a harvest of between 70 and 80 t of reasonable quality feed stored away for use later, in the dry season.

After baling, we spread fertilizer. Late wet season rains give us a good regrowth, which can be grazed or harvested a second time. The second harvest is usually made into hay as is normal practice for our area.

**BENEFITS**

- Fodder conservation from our improved pastures has increased by more than 40%.

- We get two harvests instead of one (plus a grazing period).

- The same small areas were previously only lightly grazed and turned into hay during May. Although it was good quality hay, it was nutritionally poorer than the silage made in February.

- Weed control is improved. Small amounts of weed that are present are ensiled before they flower and set seed. Consequently we spend less time and money on weed control, whilst continually giving our pastures a competitive advantage.

- The process manages Wynn Cassia really well. It makes good silage, but very poor hay (see section below).

- Our feed costs during the dry season are dramatically reduced. We still buy supplements, but the vast bulk of the feed is provided by silage.

- Conserved forage is a cash crop. We have always sold our excess hay, but also having baled silage for sale improves our management options as well as our annual income.

**DISADVANTAGES**

The major difficulty with the programme is the need to use a contractor. The making
of silage is not difficult, but the programme depends on having the equipment readily available. Although late January/early February is a time of inactivity for baling contractors, most do not have wrapping machines, and anyhow it is costly to move the equipment about in order to process a relatively small amount of forage.

Hopefully, as more people try this management strategy, costs will reduce, and efficiencies due to processing larger amounts of forages can improve.

**SPECIAL BENEFIT: WYNN CASSIA**

This vigorously growing tropical legume has a positive benefit for soil nitrogen content, and is an excellent ground cover for weed control. However:

- cattle and buffalo only eat Wynn Cassia reluctantly under normal grazing conditions; and
- it is extremely difficult to make into hay. This is because the plant is very leafy. The leaves shatter easily as they dry out. They also shatter and drop off when moving through a baler. If you are successful at all in making a bale of Wynn Cassia hay, it will be nearly all stem.

The positive benefit is that Wynn Cassia silage is easy to make; the higher moisture leaves do not shatter, and the bale is much easier to form. Silage made from a mixed Wynn Cassia/grass pasture is even easier to make, and usually better quality. Secondly, stock love Wynn Cassia silage: they accept it immediately, and eat it all when it is presented.

**FOR THE TECHNICALLY MINDED**

A summary of the silage quality parameters, including nutrition data is shown, in Table 1.

**Table 1.** Harvest summary: Baled silage

<table>
<thead>
<tr>
<th></th>
<th>Pangola</th>
<th>Cavalcade</th>
<th>Wynn Cassia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>42</td>
<td>45</td>
<td>52</td>
</tr>
<tr>
<td>In vitro digestibility</td>
<td>57</td>
<td>55</td>
<td>58</td>
</tr>
<tr>
<td>Metabolizable energy</td>
<td>8.5</td>
<td>9.0</td>
<td>8.8</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>9.1</td>
<td>13.5</td>
<td>12.0</td>
</tr>
<tr>
<td>Mean bale weight (kg)</td>
<td>383</td>
<td>430</td>
<td>390</td>
</tr>
<tr>
<td>Number of bales produced</td>
<td>57</td>
<td>75</td>
<td>45</td>
</tr>
<tr>
<td>Productivity (t DM/ha)</td>
<td>6.1</td>
<td>7.3</td>
<td>6.1</td>
</tr>
</tbody>
</table>
INTRODUCTION

Kikuyu grass (*Pennisetum clandestinum*), often top-dressed with nitrogen (N) fertilizer, is an important summer-growing pasture along the east coast of Australia, especially in New South Wales (NSW) and SE Queensland. Cutting surplus summer and autumn growth for silage would improve forage utilization and the management of these pastures (Kaiser *et al*., 1993). Strategic silage cuts could be integrated with grazing to maintain the grass at a more vegetative, higher quality stage of growth for dairy and beef cattle. In order to ensile Kikuyu grass with an organic matter digestibility of 0.60 to 0.70, a regrowth interval of 20 to 50 days would be required. This interval would vary with the prevailing growing conditions. There are few data on the ensiling characteristics of Kikuyu grass when cut at this stage of growth.

MATERIALS AND METHODS

Fresh Kikuyu grass samples were collected at silage cutting in 11 experiments conducted in the Nowra district of coastal NSW. Regrowth intervals varied from 20 to 50 days and N fertilizer was applied at 50 or 100 kg N/ha at the commencement of the regrowth period. Samples were dried in a forced-air oven at 80°C for 24 h to determine DM content, and were then ground prior to analysis for WSC, starch and total N content. Buffering capacities were determined on fresh forage using the method of Playne and McDonald (1966). A summary of the data from the 11 experiments is presented in Table 1.

Table 1. Composition of Kikuyu grass at the time of cutting for silage (summary of results from 11 experiments)

<table>
<thead>
<tr>
<th></th>
<th>DM content (g/kg)</th>
<th>WSC (g/kg DM)</th>
<th>Starch (1) (g/kg DM)</th>
<th>Total N (g/kg DM)</th>
<th>Buffering capacity (2) (meq/kg DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>195.9</td>
<td>44.5</td>
<td>38.9</td>
<td>25.6</td>
<td>350.6</td>
</tr>
<tr>
<td>Range</td>
<td>108.5 - 323.0</td>
<td>23.4 - 68.4</td>
<td>14.2 - 57.8</td>
<td>17.4 - 35.1</td>
<td>224.7 - 495.7</td>
</tr>
</tbody>
</table>

Notes: (1) Starch data from four experiments. (2) Buffering capacity from two experiments.
RESULTS AND DISCUSSION

Although there was some variation in Kikuyu grass composition, it generally had low DM content, low WSC content, high N concentration and intermediate buffering capacity. Low DM content in the range 100 to 160 g/kg is common, and it is only under dry conditions, when Kikuyu grass is moisture stressed, that DM content can reach 300 g/kg at cutting. The mean buffering capacity - an indicator of the ability of the forage to resist pH change - was similar to published values for temperate grasses (McDonald et al., 1991).

The results from four experiments indicate that Kikuyu grass contains an appreciable quantity of starch. While starch will not contribute directly to the silage fermentation, as silage bacteria cannot ferment starch, hydrolysis of starch to sugars during wilting and prior to the establishment of anaerobic conditions in the silo could boost the supply of sugars available for fermentation, provided there are not significant losses due to respiration.

The low WSC content, low DM content and intermediate buffering capacity indicate that there is a significant risk of a poor fermentation if Kikuyu is ensiled without wilting or with only a minimal wilt (<300 g/kg DM content). Data based on UK studies with temperate grasses have shown that the critical sugar level for successful (low risk) silage production is 25-30 g/kg fresh crop (Wilkinson, 1990). In our experiments, the mean sugar content of Kikuyu grass on a fresh crop basis was only 8.7 g/kg, well below this critical level.

CONCLUSION

Because of its low DM content, low WSC content and intermediate buffering capacity, farmers ensiling Kikuyu grass will need to rely on wilting or silage additives to improve the probability of achieving a satisfactory lactic acid fermentation.

ACKNOWLEDGMENTS

We are greatly indebted to the Australian Dairy Research and Development Corporation and NSW Agriculture for funding this research, and for assistance from local dairy producers who provided access to land and equipment.

REFERENCES


INTRODUCTION

The legume *Cratylia argentea* (syn. *C. floribunda, Dioclea floribunda*), which occurs naturally south of the Amazon river through the area east of the Andes in Brazil, Peru, Bolivia and Argentina, is a shrub that branches from the base of the stem and reaches 1.5 to 3.0 m in height (De Queiroz and Coradin, 1995). It is well adapted to subhumid climates with a five- to six-month dry season and infertile acid soils with high aluminium content in tropical areas below 1 200 m above sea level.

Germplasm of *C. argentea* has shown good regrowth capacity after cutting, and adaptation to biotic and abiotic constraints in several lowland sites in tropical America (Isla in Mexico, La Ceiba in Honduras, and several sites in Costa Rica, Colombia and Brazil), and in West Africa (CIAT, 1995). CIAT together with national agricultural research systems have carried out studies on management and feed value of *Cratylia* in the region. Results indicate that yield of *Cratylia* fodder banks is increased when plant density is at least 20 000 plants/ha. As expected, digestibility (50-60%) and CP (20-25%) vary with plant part and maturity. Intake of fresh material is increased when *Cratylia* is cut and wilted, given that direct animal intake of freshly harvested immature *Cratylia* forage is low (Raaflaub and Lascano, 1995).

The value of *Cratylia* as a cut-and-carry protein supplement with sugar cane or king grass fed during the dry season to lactating dairy cows is being evaluated in smallholder dual-purpose cattle farms in Costa Rica (Argel and Lascano, 1998). In addition, farmers are currently evaluating the option of utilizing for ensiling excess *Cratylia* forage produced in the wet season.

In this paper, we present results from the on-station and on-farm evaluations of *Cratylia* when used as silage to supplement milking cows in the dry season.

METHOD OF MAKING SILAGE WITH CRATYLIA

Ensiling *Cratylia* is a farmer-based initiative and consequently researchers in Costa Rica are now in the process of producing information for farmers in order to allow them to make good quality silage with this legume. Farmers testing the use of
Cratylia for silage have developed their own system of harvesting and ensiling the harvested forage. Leaf and stem material from three- to four-month regrowth is cut and mechanically chopped into 2-5 cm pieces. Harvested material is then placed in stack-type silos and after good compaction is covered with plastic sheeting. Molasses is added when ensiling pure Cratylia (10-15% DM basis), while a silage inoculum is added in a proportion of 1 kg/ton of silage when mixed with King grass (30:70 proportion of legume:grass silage).

**USE OF CRATYLIA SILAGE AS A SUPPLEMENT FOR LACTATING COWS**

In areas with a five- to six-month dry season in Costa Rica, there is a need to supplement dairy cows with concentrates or chicken manure to maintain acceptable levels of milk production. However, farmers are looking for alternatives, as grain imports are becoming too expensive and milk prices are decreasing. An alternative considered by farmers in order to reduce supplementation costs is to replace concentrates and chicken manure by fresh or ensiled Cratylia fed in combination with sugar cane or king grass during the dry period.

An initial experiment was carried out in the Escuela Centroamericana de Ganaderia (ECAG), Atenas, Costa Rica (460 m above sea level, annual mean temperature 23.7°C, mean annual precipitation 1 600 mm). Six mature Jersey cows (50 days postpartum) were randomly assigned to the following treatments arranged in a 3 × 3 crossover Latin Square design:

- **T1** = sugar cane (1.0% BW) + rice polishings (0.5% BW) + concentrate (1.48% BW) + urea (0.02% BW);
- **T2** = sugar cane (1.3% BW) + concentrate (0.5% BW) + freshly cut *C. argentea* (1.2% BW); and
- **T3** = sugar cane (0.1% BW) + concentrate (0.5% BW) + silage of *C. argentea* (2.4% BW).

Each treatment period comprised 12 days, of which 7 were for adaptation and 5 for measurement. Concentrate (0.5% BW) was fed with the *Cratylia* treatments as cows used in the experiment were accustomed to receiving some concentrate during milking.

Results, shown in Table 1, indicate that milk yield in cows supplemented with concentrate was similar to that from cows supplemented with *Cratylia*, fresh or ensiled. However, it was interesting to observe that milk fat was greater in cows fed *Cratylia* silage. The higher cost and lower benefit:cost ratio of feeding *Cratylia* silage were due to high labour cost in ECAG for harvesting and separating edible portions of six-month old *Cratylia* regrowth, which is not the case for farms, as indicated in a subsequent on-farm trial.

**Table 1.** DM intake and milk production by Jersey cows fed different diets during the dry season in Costa Rica
One farmer in the Central Pacific subhumid coast area of Costa Rica evaluated with the assistance of researchers the use of *Cratylia* as silage. Six cross breed Swiss Brown × Brahman dual-purpose cows in the third month of lactation were assigned to the following treatments arranged in a 3 × 3 cross-over Latin Square design:

- **T1** = 12 kg sugar cane + 6 kg *C. argentea* silage + 0.6 kg rice polishings;
- **T2** = 12 kg sugar cane + 6 kg *C. argentea* fed fresh + 0.6 kg rice polishings; and
- **T3** = 12 kg sugar cane + 3 kg chicken manure + 0.6 kg rice polishings.

The results shown in Table 2 corroborate on-station results, namely little difference in milk yield, but higher milk fat when chicken manure was replaced by *Cratylia* silage. Results also indicate that the cost of supplementation was lower when *Cratylia* was fed fresh or ensiled, which resulted in higher economic benefit for the farmer when compared with use of chicken manure.

**Table 2.** Average milk yield of dual-purpose cows supplemented with *Cratylia* either fresh or as silage and with chicken manure.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Milk yield (kg/cow/day)</th>
<th>Total solids (%)</th>
<th>Fat (%)</th>
<th>Cost of supplement ($/kg DM)</th>
<th>Benefit:cost ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 - <em>Cratylia</em> silage</td>
<td>5.1 b</td>
<td>12.3</td>
<td>3.6</td>
<td>0.17</td>
<td>1.58</td>
</tr>
<tr>
<td>T2 - Fresh <em>Cratylia</em></td>
<td>5.5 a</td>
<td>12.2</td>
<td>3.4</td>
<td>0.11</td>
<td>2.37</td>
</tr>
<tr>
<td>T3 - Chicken manure</td>
<td>5.3 a b</td>
<td>11.7</td>
<td>3.0</td>
<td>0.22</td>
<td>1.14</td>
</tr>
</tbody>
</table>

**Notes:** a and b indicate significant differences.

**Source:** M. Lobo, V. Acuña and A. López, unpublished data

**CONCLUSIONS**

The use of *Cratylia argentea* for making silage has been a farmer-led initiative in dual-purpose cattle farms in hill areas of Costa Rica. On-farm use of *Cratylia* silage as a supplement to milking cows has been shown to be a viable option for small-scale dairy farmers, given that it economically replaces expensive concentrates with no effect on milk yield, but gives a higher percentage milk fat yield. Research is underway to better define ways of producing high quality *Cratylia*-based silage.

**REFERENCES**


CIAT. 1995. West and Central African animal feed research project *Adaptation of*


http://www.fao.org/docrep/005/x8486e/x8486e0h.htm#TopOfPage
EXPERIMENT LOCATION

This small study was conducted at Humpty Doo, approximately 40 km SE of Darwin, Northern Territory, Australia (12° 24′ S, 131° 15′ E). The area receives a mean annual rainfall of between 1 500 and 2 000 mm, 80% of which falls in four months: December to March.

DESCRIPTION OF THE EXPERIMENT

The nutritive values of cavalcade (*Centrosema pascuorum*) and pangola grass (*Digitaria eriantha* subsp. *eriantha*) were compared with those of the same species preserved as 7-month old hays and silages. The materials were cut when cavalcade and pangola were 125 days and 45 days old, respectively (cavalcade by slashing and pangola with a disc mower) and wilted. The materials were wilted to DM contents ranging from 221 to 865 g/kg and made into small cylindrical bales (800 mm long × 450 mm wide), which were wrapped in plastic film for preservation as silage, or left unwrapped as hay. Each bale was sampled and analysed for nutritive value (DM, DDM, ME, and CP).

The results are given in Table 1.

The nutritive values of the cavalcade and the pangola grass forages decreased as DM content increased, but nutritive values during storage were maintained. Silages had better nutritive value than hays. Silage quality was good. The cavalcade silage had high lactic acid content, lower acetic, and minor butyric acid production associated with low pH. Spoilage was generally low (11.5%). In the pangola grass silage, the main fermentation product was ethanol, but the silage quality was still good, with lactic acid content higher than acetic acid content, minor butyric acid production being associated with high pH (4.95). Spoilage was consistently low (2.82%). Ammonia-N production, which was always less than 60 g/kg total N, was highest for low-DM-content silages for both species.

Table 1. A comparison of the nutritive value of cavalcade pasture and pangola grass preserved as wilted silage or as hay¹

<table>
<thead>
<tr>
<th></th>
<th>Silage</th>
<th>Hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (g/kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDM (g/kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME (MJ/kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP (%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ More details
<table>
<thead>
<tr>
<th></th>
<th>Cavalcade</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pasture</td>
<td>Minimum Wilt</td>
<td>Wilted</td>
<td>Heavily Wilted</td>
<td>Hay</td>
</tr>
<tr>
<td>DM (%)</td>
<td>23.3</td>
<td>41.4</td>
<td>61.8</td>
<td>92.2</td>
<td></td>
</tr>
<tr>
<td>Digestibility (%DM)</td>
<td>55.1</td>
<td>53.4</td>
<td>50.1</td>
<td>42.5</td>
<td></td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>8.2</td>
<td>7.8</td>
<td>7.3</td>
<td>6.1</td>
<td></td>
</tr>
<tr>
<td>CP (%DM)</td>
<td>20.4</td>
<td>16.1</td>
<td>16.1</td>
<td>13.1</td>
<td></td>
</tr>
<tr>
<td>Bale Weight (kg)</td>
<td>25.7</td>
<td>15.9</td>
<td>9.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>4.50</td>
<td>4.60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethanol (g/kg DM)</td>
<td>2.49</td>
<td>1.44</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetic acid (g/kg DM)</td>
<td>13.99</td>
<td>5.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butyric acid (g/kg DM)</td>
<td>1.79</td>
<td>0.34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lactic acid (g/kg DM)</td>
<td>16.61</td>
<td>13.44</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia N (g/kg total N)</td>
<td>52.30</td>
<td>32.20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pangola grass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM (%)</td>
<td>22.1</td>
<td>44.3</td>
<td>55.4</td>
<td>63.7</td>
<td>91.9</td>
</tr>
<tr>
<td>Digestibility (%DM)</td>
<td>59.8</td>
<td>60.8</td>
<td>57.0</td>
<td>55.5</td>
<td>48.7</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>9.0</td>
<td>9.0</td>
<td>8.4</td>
<td>8.1</td>
<td>7.1</td>
</tr>
<tr>
<td>CP (%DM)</td>
<td>13.0</td>
<td>10.7</td>
<td>10.8</td>
<td>11.3</td>
<td>9.8</td>
</tr>
<tr>
<td>Bale weight (kg)</td>
<td>24.8</td>
<td>22.3</td>
<td>18.4</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>4.50</td>
<td>4.90</td>
<td>5.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethanol (g/kg DM)</td>
<td>16.27</td>
<td>12.52</td>
<td>7.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetic acid (g/kg DM)</td>
<td>4.12</td>
<td>1.87</td>
<td>1.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butyric acid (g/kg DM)</td>
<td>0.45</td>
<td>0.06</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lactic acid (g/kg DM)</td>
<td>11.74</td>
<td>5.05</td>
<td>2.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia N (g/kg total N)</td>
<td>40.00</td>
<td>30.70</td>
<td>28.90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** (1) The data present the nutritive values of the silages and hays after 7 months in storage. This corresponded to a complete dry season. Other data are available on request showing the nutritive values of the silages and hays at the time of formation (i.e. at the beginning of the storage period).
INTRODUCTION

Forages have been preserved using acids for many years, and the process is referred to as ensilation. This term has also been adopted to describe the preservation and storage of protein-rich materials such as fish and animal products to be used as animal feeds. More recently, this process has been used to preserve carbohydrate rich materials, either alone or through fermentation with other materials.

The essential feature of this means of preserving organic materials is the use of acids. These can either be mineral or organic, which can be provided by direct addition or produced by fermentation. Clearly, the choice of acid will affect the composition and use of the ensiled product, as well as having financial implications for the economic viability of its use.

For such a system to be suitable for smallholders in the tropics it must: -

- have low investment costs;
- be reliable and repeatable;
- use uncomplicated technology;
- use locally sourced equipment and consumables;
- be safe; and
- give rapid and significant returns on investments.

This paper will therefore consider the various alternative silage production systems in the context of the above requirements. Furthermore, this paper will focus on the use of wastes and by-products that otherwise would be under- or not utilized, as well as the non-conventional use of forage silage by species other than ruminants.

CONVENTIONAL PROCESSING OF PERISHABLE WASTES AND BY-PRODUCTS

Traditionally, most wastes used as animal feeds are heat-treated to sterilize the materials and if the heat-treated product cannot be utilized locally or in a short time, the product would then be dehydrated to facilitate storage and transport. Such processing is generally carried out where waste materials are available in large quantities on a regular basis and where the final product is of medium to high value.
Such circumstances are unlikely to apply to the smallholder situation.

Whilst cooking of perishable materials is commonly and successfully carried out by smallholders for materials that are to be used within a short time, the dehydration process is less commonly and successfully practised. The exception to this is where local fish products are manufactured using solar drying. This type of processing is generally carried out in unhygienic conditions, with the product frequently becoming contaminated with bacteria.

Smallholders are likely to have only small to medium quantities of materials available for processing, which are likely to be used for local consumption.

In such circumstances, and where materials cannot be used immediately, the use of ensilation for the processing and storage of small to medium quantities of organic material could be a useful system.

**MATERIALS SUITABLE FOR ENSILATION BY SMALLHOLDERS**

Almost all organic materials could be suitable substrates for ensilation in one form or another. The decision on the approach and technique to apply will depend upon:

- the composition of the material, including DM content;
- the type and degree of pathogenic and fermentative bacteria contamination;
- the buffering capacity of components of the material;
- the presence of potential autolysing enzymes in the main substrate, or of naturally present bacteria;
- the availability of other materials, such as acids, fermentable substrates and fermentative bacteria, to assist in ensilation; and
- the cost of preservation using the technique in the prevailing circumstances.

Considering these criteria, it is clear that the range of possible ensilation processes consist of the following:

- ensilation using acids produced by the fermentation of carbohydrates within the material by naturally present bacteria or cultures of added bacteria;
- ensilation using acids produced by the fermentation of carbohydrate-rich materials added to the substrate to be preserved using naturally present or added fermentative bacteria;
- ensilation using added inorganic acids such as hydrochloric or sulphuric acids, or mixtures of such acids; or
- ensilation using organic acids such as formic, propionic or acetic acids, or mixtures of such acids.

**ENSILATION USING NATURALLY PRESENT BACTERIA**

This type of ensilage is typical of that carried out with plant materials having a low buffering capacity, a DM content higher than 20%, a fermentable carbohydrate concentration of between 5 and 20% and with naturally occurring lactic acid fermentative micro-organisms present.

This traditional silage making process has been extensively reviewed and the
present paper will only consider the possible use of this type of material for animal species not traditionally fed such materials.

Use of ensiled forages for non-ruminant animals

Whilst ensiled forages have commonly been fed to ruminants in all parts of the world, such materials have rarely been fed to monogastric animals, such as pigs, in commercial situations.

Currently, there is considerable interest in the possibility of feeding forages, including those preserved by ensilation, to pregnant sows in order to improve their reproductive performance through improved welfare (Lee and Close, 1987). In this situation it is agreed that most pregnant sows suffer stress through being fed relatively small quantities of compound feeds (approx. 2.2 kg) when their appetite would be for two or three times that amount. The main objective is to prevent such animals becoming over-fat, which is associated with breeding problems. It is proposed that by feeding such animals on low nutrient dense feeds to appetite, they would be less stressed, stay within targeted weights, which could result in improved reproductive performance, longer reproductive life and lower feed costs.

Ensiled forages would be ideal materials for use in such circumstances, since pigs would be able to digest all enzymically digestible components in the upper gut and then through fermentation in their lower gut digest fibrous materials and absorb the associated products.

Similarly, work with such materials has been carried out with growing pigs. It has been demonstrated that the guts of commercial-type pigs (Large White, Landrace, etc.) are able to use such materials from about 50 kg liveweight (Machin, 1990). However, where such a feeding system is practised, the rate of gain has been correspondingly less than where commercial feeds were used. Nevertheless, such low-cost feeds might well be financially attractive in circumstances where compound feeds are expensive and where through lower labour and housing costs a better margin can be obtained using such an approach.

The use of ensiled forages could offer considerable benefit for smallholder pig farmers in the feeding of gestating sows and growing/fattening pigs. However, due to the high nutrient demands of lactating animals this system would not be recommended for lactating sows.

The remainder of this paper will concentrate on the application of the ensilation process to store and preserve non-forage, nutrient-rich, perishable materials.

NON-FORAGE MATERIALS FOR SILAGE PRODUCTION

The materials that have been preserved by ensiling can be divided into those that produce acids through anaerobic fermentation, which preserve the unfermented remainder of the substrate, and those that are preserved by acids added directly or produced by the fermentation of materials mixed with them. Many of these materials also undergo autolysis of the substrate, using naturally containing autolytic enzymes as a secondary phase of preservation.

Fermentable substrates

These materials contain carbohydrates that can be fermented to produce acids such as lactic or acetic acid. Clearly, such a process requires the presence and action of micro-organisms. These may be naturally occurring or may be added as a separate culture (Martin and Bozoglu, 1996). Similarly, some substrates may contain insoluble carbohydrates that are not readily fermentable and require enzymes to break them down into simple soluble carbohydrates that can be fermented. These can then generate acids to preserve the remainder of the material or mixture.
Table 1. Examples of materials that have been used as fermentable substrates

<table>
<thead>
<tr>
<th>Material</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar Industry By-products</td>
<td></td>
</tr>
<tr>
<td>Molasses - sugar cane</td>
<td>Evers and Carroll, 1998</td>
</tr>
<tr>
<td>Molasses - beet</td>
<td>Fagbenro and Jauncey, 1998</td>
</tr>
<tr>
<td>Sugar cane wastes</td>
<td>Alimon et al., 1994</td>
</tr>
<tr>
<td>Fruit Wastes</td>
<td></td>
</tr>
<tr>
<td>Banana</td>
<td>Ash and Elliott, 1991</td>
</tr>
<tr>
<td>Papaya</td>
<td>Bello and Fernandez, 1995</td>
</tr>
<tr>
<td>Pineapple</td>
<td>Bello and Fernandez, 1995</td>
</tr>
<tr>
<td>Citrus</td>
<td>Megias et al., 1998</td>
</tr>
<tr>
<td>Apple pomace</td>
<td>Nikolic and Jovanovic, 1986</td>
</tr>
<tr>
<td>Kiwi fruit</td>
<td>Ciruzzi et al., 1996</td>
</tr>
<tr>
<td>Grape waste</td>
<td>Nour et al., 1981</td>
</tr>
<tr>
<td>Other Agro-industrial Wastes</td>
<td></td>
</tr>
<tr>
<td>Brewery and distillery wastes</td>
<td>Pelz and Hoffman, 1997</td>
</tr>
<tr>
<td>Vegetable processing wastes</td>
<td>Ashbell et al., 1995</td>
</tr>
<tr>
<td>Milk by-products</td>
<td>Sander et al., 1995</td>
</tr>
<tr>
<td>Flower wastes (carnations)</td>
<td>Ceron et al., 1996</td>
</tr>
<tr>
<td>Taro roots</td>
<td>Ash and Elliott, 1991</td>
</tr>
<tr>
<td>Cassava root wastes</td>
<td>Fagbenro and Bello, 1997</td>
</tr>
<tr>
<td>Bakery by-products</td>
<td>Bastian, 1990</td>
</tr>
<tr>
<td>Olive waste</td>
<td>Hadjipanayiotou and Koumas, 1996</td>
</tr>
<tr>
<td>Tofu cake</td>
<td>Niwa and Nakanisi, 1995</td>
</tr>
<tr>
<td>Sisal waste</td>
<td>Rodriguez et al., 1985</td>
</tr>
<tr>
<td>Oil palm fronds</td>
<td>Abu Hassan et al., 1996</td>
</tr>
</tbody>
</table>

In contrast, materials rich in soluble carbohydrates, such as fruits, sugar cane or beet products, are capable of preserving materials at relatively low DM levels through osmotic effects alone, without the need for acid fermentation. The list of materials that have been successfully ensiled (see Table 1) demonstrates the broad range of products that can be preserved in this way. However, only those with high levels of soluble carbohydrate, such as sugar and fruit products are likely to be able to produce sufficiently high levels of acid by fermentation to assist in the storage of non-fermentable materials.

Clearly, ensilation could be a useful means of preserving a wide range of perishable materials that would otherwise be unused as animal feeds.

Table 2. Examples of non-fermentable materials that have been preserved by ensilation

<table>
<thead>
<tr>
<th>Material</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slaughterhouse Wastes</td>
<td></td>
</tr>
<tr>
<td>Poultry carcass waste</td>
<td>Machin et al., 1984</td>
</tr>
<tr>
<td>Poultry viscera</td>
<td>Fagbenro and Fasakin, 1996</td>
</tr>
<tr>
<td>Hatchery waste</td>
<td>Deshmukh and Patterson, 1997</td>
</tr>
<tr>
<td>Feather meal</td>
<td>England et al., 1991</td>
</tr>
<tr>
<td>Large animal carcass waste</td>
<td>Machin, 1986</td>
</tr>
</tbody>
</table>
Many of these materials (see Table 2) are available to smallholders in small to medium quantities in a variety of locations around the world. A simple, low-capital process such as ensilation could be an attractive way of preserving such materials. Quite clearly, matching the availability of suitable supplies of fermentable materials to mix with these types of materials could cause logistical difficulties. In such circumstances, the use of low cost by-products such as fruit wastes would be the first choice, with more expensive sugar by-products used as back up materials.

However, the main problem with such an approach for smallholders would be the higher degree of technical knowledge required to be able to change systems to meet variations in raw material availability. Unless fermentable and non-fermentable proteinaceous material supplies are available at the same time, it might be best to place most emphasis on the use of storable fermentable materials, such as molasses, for this type of processing for smallholders.

### USE OF DIRECTLY-ADDED ACIDS IN ENSILATION

Considerable research has been carried out on the preservation of perishable proteinaceous wastes using added acids (Machin, 1986; Perez, 1995). Initial studies focused on the use of mineral acids such as hydrochloric, sulphuric or phosphoric acids, but these alone were shown to be poor preservers of silages (Disney et al., 1977). Silages have, however, successfully been made using mixtures of organic (formic, propionic, citric, etc.) acids and mineral acids, or organic acids alone (Perez, 1995). Nevertheless, the use of direct addition of organic and/or mineral acids is very unlikely to be a means by which smallholders could process feed materials due to the cost and danger of handling strong acids in low-technology situations. For this reason it would appear that the most appropriate way that smallholders will be able to use the acid ensilage process will be through a natural fermentation system.

### USE OF FERMENTATION SILAGE

In recent years, most researchers in this field have focused on this approach to processing small to medium quantities of perishable organic materials. Although some researchers have been able to get successful fermentation using sources of fermentable carbohydrates alone mixed with non fermentable materials (Raa and Gildberg 1982) most have used lactic acid bacterial cultures to stimulate fermentation. Some of the most successful bacteria have been *Lactobacillus plantarum*, *Streptococcus faecium* and *Pediococcus acidilactici* (Deshmukh and Patterson, 1997).

However, the use of bacterial cultures would obviously be a deterrent for low-technology processing by smallholders. It is therefore interesting to note that, although raw materials low in LAB content generally benefit from the use of suitable inoculants, it is not always essential that they be included (Martin and Bozoglu, 1996).
There are also reports that if the raw material already has a high concentration of LAB, inoculants do not improve the process (Desmukh and Patterson, 1997). It would therefore appear that smallholders could well be able to produce fermented silages without the need to produce or purchase starter cultures, provided that appropriate mixtures of fermentable and non-fermentable materials are selected. In contrast, where mixtures not capable of generating a rapid fermentation and sufficiently low pH have been tried, successful silage production has not been achieved (Urlings et al., 1993).

In this context it is interesting to note that non-fermentable materials have been preserved by mixing them with fermentable carbohydrates, include poultry slaughterhouse wastes, hatchery waste, large animal slaughterhouse waste, whole waste fish (fish viscera, shrimp by-catch), shrimp and prawn heads and crab waste.

**HEALTH IMPLICATIONS OF FEEDING SILAGE**

There is considerable concern about the presence of pathogenic bacteria in food materials fed to farm animals. Unfortunately, many of the materials listed above as possible substrates for preservation through ensilage could well be contaminated with such bacteria. The acid ensilage process has been shown to be an effective means of reducing or eliminating pathogens and indicator organisms in materials such as poultry slaughter house wastes, hatchery waste and fishery waste. Many other researchers reviewed in Machin (1986) showed a range of silages to be free from coliformes, *Salmonella* spp., *Clostridium* spp., *Staphylococcus* spp. and faecal *Streptococcus*, and to have a very low bacteria count or to be bacteria free. This conclusion is supported by Frazier and Westhoff (1978), who showed that all common bacteria that cause food-borne infections are inhibited at pH values below 4, and in the case of *Clostridium botulinum*, toxification is prevented below pH 4.5.

In particular, fermentation of such inedible wastes has been shown to decrease the numbers of Gram-negative pathogens (Talkington et al., 1981) and viruses (Wooley et al., 1981).

The means by which this occurs relates to the effect of low pH, the presence of antibiotic substances produced by LAB and the ability of organic acids to pass over the cell membranes of micro-organisms by dissociation and lower the organisms internal pH to destructive levels (Raa and Gildberg, 1982). LAB also produce antibiotics and bacteriocins which are often bacteriostatic against other bacterial species (Urlings et al., 1993). Mineral acids do not have the same dissociating ability as organic acids and so are much less effective in silage production.

Many wastes of animal and fish origin contain autolytic enzymes, which at low pH are able to break down large organic molecules, so exposing any micro-organisms present in the waste to anti-microbial action (Backhoff, 1976).

**USE OF ENSILED WASTES**

Following ensilation, most animal wastes have been successfully processed and fed to a wide range of domestic animals without problem. Perez (1995) noted that fish silages were suitable for feeding to pigs, poultry, ducks, ruminants and camels. Other researchers have successfully fed fish silages to farmed fish. Many others have shown that materials such as poultry slaughter house and hatchery waste as well as ruminant offal silage could be successfully fed to pigs, poultry, mink, fish (catfish - *Clarias gariepinus*; common carp - *Cyprinus carpio*) compared with control feeds.

**CONCLUSION**

It is clear that the ensilation of waste materials could offer a simple and inexpensive means by which smallholders in certain circumstances might be able to process and
preserve a wide range of materials for use in animal feeding. However, there are likely to be many situations where the correct balance of materials and knowledge are not in place and so this approach should not be applied without due care. In particular, most benefit is likely to occur using fermentation not requiring the use of prepared bacterial inoculants.

REFERENCES


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INTRODUCTION

This paper summarizes the development of “Little Bag Silage” (LBS) during 1988-1992, while the author was fodder and livestock consultant on development projects in northern Pakistan and in Nepal. It relates to the mechanics of ensiling on a small scale, and how this fits within the overall livestock and farming system.

While working in northern Pakistan, the problem was: How to improve the nutrition of farmers’ milking animals when each family keeps only one dairy cow or buffalo? During the cold, continental winter, the major fodders available were maize stover and wheat or rice straw, together with very poor quality hay made from mature summer hillside pastures after the rains had ended. Although loans were made to farmers for the purchase of high yielding improved buffaloes from the lowlands, farmers were disappointed that yields soon fell to those of local stock as a result of feeding the same rations as before. As a minimum, it was essential to provide a green fodder supplement to enhance rumen function for these animals. One course was to develop winter fodder crops, but this still left three months without green feed. Strong plastic shopping bags were available in the lowlands, and it was found that these had a minimum capacity of 5 kg of fresh chopped green fodder sorghum. If these were used for silage, it would mean that one buffalo could be fed one bag of silage per day, providing the minimum 5 kg of green fodder needed as a supplement. This was the birth of the concept of “Shopping Bag Silage,” or “Little Bag Silage” as it became known.

METHODS

The same basic method for making LBS was used in both North Pakistan and Nepal:

(i) strong, high density plastic shopping bags with a capacity of 5 kg of chopped green fodder and with no obvious holes in the seams were purchased in packs of a hundred;

(ii) at least 100 kg of summer fodder crop such as multi-cut fodder sorghum was cut and carried to the chopping floor. The fodder was either hand chopped with a large knife against a wooden chopping block, or chopped through a chaff cutter with a rotating blade;

(iii) 5 kg of chopped green fodder was carefully packed into one of the
shopping bags so as to avoid making any holes in the bag;

(iv) the bag was gently but firmly squeezed by hand to expel air, and while compressed the neck of the bag was twisted then turned over and tied with twine [it is possible to close bags by tying the two handles in a knot, but this does not result in an airtight closure];

(v) the bag of silage was then inverted into a second empty shopping bag, which was also closed and tied;

(vi) the bag of silage was then inverted into a third empty shopping bag and sealed. Each bag of silage was therefore triple wrapped, and seams which might be expected to leak air were doubly protected;

(vii) the bags were carefully stacked in a room protected against rats, mice and other pests;

(viii) after a minimum period of one month, LBS was fed to buffaloes at a rate of one bag per head per day; and

(ix) the outer two plastic bags of each LBS unit were kept for re-use.

RESULTS

In North Pakistan, the method was initially developed with a farmer-cum-storekeeper who had a couple of Nili-Ravi dairy buffaloes and who had planted 0.1 ha to Sadabahar, a local multi-cut sorghum × Sudan grass hybrid. Some 120 kg of fodder chopped with a chaff cutter and made as LBS and stored under the farmer’s bed was compared with 120 kg of fodder conserved in a single bag made from heavy-gauge plastic. Both lots of fodder ensiled well, and the farmer was pleased with milk yields from the buffalo fed silage, although no records were kept. He was especially pleased with the LBS, since it was much easier to feed individual bags, instead of having to untie and re-tie the large bag of thick plastic. His practise was to feed half of each LBS unit in the morning and the remainder in the evening. Neighbouring farmers were impressed that at a time when they had only dry fodders, this farmer had green fodder. In response, our entrepreneur was planning to plant up much of his land with Sadabahar, so that he could make sufficient LBS to sell it to his neighbours in the following winter!

The first trial of LBS in Nepal was on-station. Leafy paspalum grass was harvested at Kathmandu, chopped and ensiled. Bags were well conserved, although the fermentation was not strongly lactic acid. Results were good enough to proceed.

In the second station trial in Nepal, LBS was made from Napier grass in the Terai (100 masl), and from maize grown for fodder harvested at the soft dough stage with chopped cobs included at Kathmandu (1 250 masl) and at Jiri (1 800 masl).

After two months, excellent lactic acid fermentation resulted from all lots of LBS, and undamaged bags kept well for six months, with little fungal spoilage. However, LBS from fodder maize appeared to attract every mouse from a mile radius, and when the door to the store was opened to remove a bag, mice were seen to leap in. Once in, mice could easily hide between the bags. Mice then chewed through the plastic bags, so most of the bags were lost as aerobic spoilage ruined the silage.

The third trial in Nepal was an extension trial with Livestock Development Groups at three locations. In Kathmandu, there was a small factory making bags, using machinery from Thailand and plastic prills from the Gulf; special bags of thicker gauge and without loops cut out to make handles were ordered. At each site, kits were issued to 20 farmers. Each kit included a pack of 100 high-strength plastic bags, an illustrated guide to making LBS, and a record sheet. The making of LBS was demonstrated to each Group by project staff, and the local livestock technician
assisted farmers during the trial. Details on the crop to be conserved, the look and smell of the silage, and the milk yield of the selected cow or buffalo before and during a thirty-day feeding period were recorded by each farmer.

At Pokhara (800 masl) the farmers were delighted with the bags for a hundred and one uses, but since they were already growing irrigated winter fodder oats, making LBS was not one of them! At Jiri (1800 masl), farmers used wet mature summer grasses, which unfortunately turned to compost! Within Kathmandu Valley, however, there were peri-urban milk producers who stall-fed buffaloes and who had to purchase all their feeds, including paddy straw. In the Valley there was also a tradition of threshing paddy while it was still green, with the production of a cooked beaten rice which was sold as a snack food. These milk producers made LBS from the green paddy straw, and found their traditional buffalo could eat one bag of silage a day in addition to their normal ration of dry straw and bran. As a result, milk yield increased by fifty percent, from 2 litre per day to 3 litre. The extra litre of milk, sold in Kathmandu diluted with water, was worth NRs 20. It had cost NRs 3 to produce, being the cost of 3 plastic bags @ NRs 1 per bag, plus the minimal cost of 5 kg of green paddy straw. With care, two of the three bags could be re-used, reducing the total cost for the extra litre of milk to little more than NRs 1.

DISCUSSION

Making LBS is labour intensive, and demands care and attention for success. It has to fit the local livestock and farming systems, and - having expenses - has to be linked to semi-commercialization of production. The place of LBS within the overall strategy for fodder development in North Pakistan and Nepal has been described elsewhere (Lane, 1999).

The quality of bags used for LBS production is important. High- rather than low-density plastic reduces the potential for tearing. The seal must be without holes, and this may relate to factory practice. If holes are present along the seal, sticky tape or tar/mastic may be used to repair seals as the bags are tied. Inner bags do tend to get damaged, but the thicker gauge bags used for the extension trial in Nepal were less damaged, to the extent that two rather than three layers of bags might have been sufficient. Initially, commercially available shopping bags were used. These happened to be strong enough for the purpose. Some bags are thin and flimsy, as found in China, and these would not be suitable. As in Nepal, discussions with local plastic-bag makers would be useful. It happened in Pakistan and Nepal that shopping bags could readily hold 5 kg of chopped green fodder; if larger bags were available, or if handles were omitted, larger quantities could be made per bag. This would reduce the costs of bags per kg silage stored, and reduce losses from damage and surface moulds. However, the amount stored per bag should relate to feeding practices, although it is easy to resell little bags so that feeding of silage from individual bags could readily be spread over 1-2 days, even in hot climates.

Fermentation characteristics of LBS depend on the fodder being conserved, and the old saying “Rubbish in, Rubbish out” applies equally to silage made in little bags. Fodder with high sugar content, whether from specialized temperate or tropical fodder crops or from temperate leafy pasture, will conserve well. Fodder with low sugar content is more likely to rot than ferment, and this has led to a bad reputation for silage in general in the tropics, LBS included. Problem feeders include mature C4 pasture grasses harvested in the rains, legumes in general, and possibly tree fodder. Wet grasses must be partially dried before ensiling, under shelter if it is still raining, and legumes should also be wilted.

The example of peri-urban dairy farmers making good LBS from green paddy straw is important, since many crop residues lose much of their soluble carbohydrates during the final stages of grain ripening, and while the residue is left to dry in the field. Under smallholder systems, paddy is frequently harvested comparatively...
green, and the crop sun-dried in the field, with consequent loss of nutrients from the straw; heating in the stack before threshing completes the loss of sugars. In the Sudan, M. Wade encouraged the ensiling of maize stover in trench silos on commercial dairy farms to improve fodder value of the stover when fed to cows; while maize with stay-green fodder characteristics has been widely adopted by farmers in North Pakistan. Improved utilization of crop residues through ensiling needs further attention.

A key feature of LBS is that it allows conservation of available fodder in small quantities over a long period of time. This strongly contrasts with traditional silage making techniques, where large amounts of fodder must be harvested and chopped at one time. Thus a smallholder family might be able to conserve a couple of bags of LBS a day over a 100-day growing season, which would allow their milking animal to be fed one bag of LBS a day over a 200-day dry season. This fodder might include leafy grass weeds harvested from the crop fields, terraces and bunds, which could readily be partly air-dried under shelter a little at a time before chopping and ensiling. In Nepal, leaves were progressively removed from maize plants as they commenced to senesce, and these would make excellent LBS.

Although summer fodder crops were frequently used in the trials above, they take land away from food production and would only be financially attractive to families in commercial animal production. Lane (1999) allocated them to high-cost systems likely to be adopted by only 25% of farmers. A range of fodder sorghums and millets were, however, grown in trials in both North Pakistan and Nepal at three sites in each country, and fodder yields were doubled by application of 200 kg N per ha. In the Mediterranean countries, conservation of temperate fodder crops for feeding in the dry summer is relevant, and this also applies to countries in monsoonal zones. In 1976, the author was working in Tanzania and carried out small-scale ensiling trials with cassava, and produced silages from chopped cassava root, leaves, and root+leaf mixtures. Although the fermentation characteristics differed between the silages, they were all edible by sheep. These feeds could easily be ensiled as LBS, and allow cassava to be fed throughout the dry season, when harvesting is difficult due to hard ground and when leaves have been lost. In common with silage making in general, there is interest in the use of additives to assist conservation of the problem crops outlined above. A small station trial was made with sodium bisulphate, but as maize fodder was used, no benefit resulted. Any compound for smallholder use must be cheap, non-toxic, non-corrosive and easy to apply. While various additives used in industrialized countries might be reduced in scale and packed in individual sachets for use on individual 5-100-kg lots of fodder, they would not meet the above criteria. Even molasses, which does meet the criteria, is not widely available. It was concluded that sugar, in the cheaper, less refined, brown lump form, would be most applicable. However, it would still be relevant to partly dry the fodder to reduce the amount of sugar required for effective conservation, and to reduce the quantity required relative to the actual quantity of fodder being preserved. Where very difficult crops are to be ensiled, the use of common salt (NaCl) as a straight preservative also needs evaluation, as many livestock are also deficient in salt as a nutrient.

Essential for success with LBS is protection of the bags, for up to 4 to 6 months. This has been a major weakness, but may be related to the crop being ensiled. As noted, maize fodder with chopped cobs was a major problem, but green crop residues may be less attractive. Fodder sorghums do still produce HCN in LBS, which may be a deterrent to pests, and no problems of damage by mice were reported in North Pakistan. Otherwise, some form of construction may be required. This might be within an existing store such as large cement or clay storage jars with strong lids. Alternatively, specialized buildings might be constructed, with legs to keep the store off the ground and shaped to prevent rats and mice climbing in, such as the mushroom shaped stones traditionally used in England for grain stores, or protected with metal horizontal discs or downward facing cones. In Nepal, a relish for
human consumption known as *Gundruk* is made by fermenting wilted cabbage leaves in air-proof clay pots. Thus, the actual nature of the vessel used for making small quantities of silage is open to local variation and adaptation of available items and materials.

For harvesting pastures, rather than fodder crops, the Swiss scythe has been successfully introduced into the hills of Nepal, and is used by contractors for making hay along with the hay fence technique. Unfortunately the grass is cut when over-mature but while the rainy season continues, so that the hay is moist when stored and is of little fodder value. Swiss farmers now use a system of a two-wheeled mechanical mower with a tedder and hay rake, and this range has now been extended to a mini-roundbaler and a bale wrapper for making silage. In hay, the bales weigh about 20 kg; in silage, following wilting, about 50-60 kg. Many of the benefits of LBS would result from use of this equipment with young leafy wilted pasture crops, and it would be relevant for commercial dairy farmers with 5 to 20 cows, such as in the highlands of Kenya.

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In North Pakistan: to all colleagues on the World Bank Integrated Hill Farming Development Project, 1988-89; in Nepal: to all colleagues on the ADB 2nd Livestock Development Project; plus all family, friends and colleagues who continue to provide support and inspiration.

**REFERENCE**

INTRODUCTION

The livestock sector plays a significant economic role in most developing countries, and is essential for the food security of their rural population. It contributes to poverty alleviation and provides elements that are essential to the national economy, such as: traction power, transport, manure as fertilizer and fuel, food, fibre, leather, savings bank, and by generating significant household cash income through sales of live animals or livestock products.

However, among the major constraints limiting the development of livestock production in many developing countries, inadequacy of animal feed resources is most often the crucial factor. Feed shortages, both quantitative and qualitative, limit livestock productivity. During ploughing of crop fields, these shortages seriously affect the working ability of oxen, and they also depress the production of dairy and meat units managed by small-scale commercial farmers.

In many tropical countries, e.g. in Africa, Latin America and the South Pacific Islands, the bulk of livestock feed resources comes from grazing poor quality annual and perennial grasses on natural pastures, often at a late stage of maturity. In other countries, such as those in Southeast Asia, livestock farming is increasingly being limited by the restriction of grazing lands. During the long dry season (at least 6-7 months each year), animals are on poor quality feeds, characterized by low palatability, low intake and low nitrogen. However, crop residues (straw and stover from sorghum, millet, wheat, barley, rice, maize, etc.) play a key role in animal feeding, especially in Asia and Africa.

As there is an incipient urban market demand for milk around the largest cities in most developing countries, there is an increasing development of small-scale peri-urban dairy units, based mainly on pure Friesian cows. However, the smallholder dairy producers often face low milk yields from these exotic cattle due to poor feeding management (lack of rations with balanced nutritive content) and/or high production costs because their feeding system is primarily based on purchased feeds and concentrates.
It is recognized in developed countries that the production of silage of high quality cultivated forage can be a valuable component for the development of a high-performing and low-cost system of animal production, using a relatively low level of purchased concentrates. However, this appears inappropriate for smallholders in tropical countries, primarily due to:

- lack or high cost, or both, of equipment for harvesting and conservation; and
- production of cultivated forage being often limited due to lack of available land.

Most farmers in developing countries rely for their food security on the cultivation of cereals, root crops and high-value crops such as fruits and vegetables, which understandably take priority in the allocation of land.

Fruit, vegetables and root crops are increasingly integrated in the farming system and play a key role as staples in the human diet in most developing countries. Consequently, there is a wide range of valuable by-products and residues resulting from food cropping systems and food processing, which are often inefficiently or totally under-utilized and wasted.

The ensiling of by-products is a simple and appropriate method of conservation. It is the most effective way to improve animal feed resources through the rational use of locally available agricultural and industrial-by-products likely to be available to small-scale farmers at village level. In developed countries, herbage ensiling is now accepted as the major method of forage conservation, and much research has been undertaken in that field (McDonald, 1983; Thomas, 1985). However, very few research and extension activities are related to the various aspects of silage production from by-products.

This paper aims to examine some of the practical aspects of making and utilizing silage from by-products by small-scale farmers. There are very large amounts of various by-products in tropical countries and it is not possible to provide a global review on this topic. Our contribution is therefore restricted to our experience in North Africa (from the first author) and experience in two projects financed by the Technical Cooperation Programme of FAO, first in Samoa, repeated subsequently in Tonga, managed by both authors.

ADVANTAGES OF SILAGE MAKING FROM LOCAL CROP RESIDUES AND BY-PRODUCTS

The problem usually encountered with agro by-products is seasonality of supply, which is often accentuated by their high moisture content. High-moisture agro-industrial by-products are often of high nutritional value. In industrial countries, there are well-developed technologies for recovering by-products and converting them into protein-rich meals and/or energy-rich concentrates. However, such facilities are rarely found in tropical less-developed countries, especially at the level of small villages, where by-products often become contaminating wastes: they quickly go sour, mouldy and lose considerable quantities of soluble nutrients in the effluent. Dehydration increases cost: between 250 and 300 litre of fuel and 200 kWh of electricity are required to produce 1 t of dry product (88 - 90% DM). Research has shown that the ensiling of by-products is the most suitable method of conservation for long periods (Lien et al., 1994; Bouqué and Fiems, 1988; Hadjipanayiotou, 1993, 1994; Kayouli, 1989; Kayouli et al., 1993; Kayouli and Lee, 1998).

The main advantages of silage are:

(i) it can be efficiently used for strategic off-season feeding;
(ii) it is a means of increasing feed resource availability and a form of insurance, especially for calving dairy cows;

(iii) it can be fed to reduce pressure on pasture when required;

(iv) it can be an efficient supplement to grazing cattle during the dry season;

(v) it is an inexpensive home-made feed, resulting in the production of milk and beef at lower cost;

(vi) it improves palatability, reduces significantly toxic substances present in some fresh vegetables to safe level concentrations (such as cyanogenic glucosides in fresh cassava leaves) and destroys harmful micro-organisms possibly present in poultry litter or fish wastes; and

(vii) it can provide a major diet source, as basal ration as well as a feed supplement for grazing animals.

**BY-PRODUCTS WIDELY AVAILABLE IN TROPICAL AND SUB-TROPICAL COUNTRIES POTENTIALLY SUITABLE TO SILAGE MAKING**

In tropical and sub-tropical countries, there is a wide range of by-products and residues from food crops and food processing that are potentially valuable feed supplements, without considering residues from cereal grain. The most common by-products from various root and tuber crops, fruit crops, agro-industry and animal industries are discussed in the following sections.

**Brewer’s spent grains**

The extracted malt or spent grain contains 75-80% water when filtered off. Wet spent grain spoils quickly and should be used fresh or stored out of contact with air. It can be stored for up to two weeks quite successfully by heaping it, treading it well and covering with sacks or plastic sheets. For longer storage, it may be ensiled in an airtight trench silo with drainage. Ensiling in tightly tied plastic bags is also an effective storage method (this method will be described in detail later). Wet spent grain can be ensiled alone or in association with other ingredients, such as with 2-3% molasses (to ensure proper fermentation), chopped banana by-products (trunk, pseudostems, fruit, peel) or chopped cassava. The latter has the advantage of absorbing the juice from spent grain and consequently limiting losses during fermentation. The quantities to be incorporated depend on availability. However, in any case, the DM content in the ensiled mass should not exceed 45%, in order to ensure proper fermentation.

Brewer’s spent grain is a valuable potential supplementary feed for livestock. It is a safe feed when it is used fresh or properly stored. It is a relatively bulky feed, but a good source of energy and protein (Table 1). It can be used to feed beef cattle (10-15 kg daily) and calves (2-4 kg daily). However, it is far more suitable in rations for dairy cows. Spent grain is a balanced feed for dairy cows and has a good reputation for stimulating milk production. Milk yield response is very rapid and production significantly increases when lactating cows are fed spent grain as a supplement. Wet grain can be given in large amounts to dairy cows, up to 15 kg per day. In order to avoid off-flavours in the milk, it is recommended that spent grain be fed to cows after rather than before milking. When it is eaten in large quantities (15-20 kg/day), distribution of 100-150 g of sodium bicarbonate given twice daily is recommended in order to prevent rumen acidosis disorder.

**Banana by-products**

Bananas are grown in almost all farms in the humid tropics and constitute one of the
staple foods for human consumption. Banana plant waste is of considerable importance in feeding ruminants. The by-products are the following:

**Rejected banana.** Rejected bananas - both green, immature and ripe - are a good source of energy supplement for grazing or penned animals. Dairy cows relish them and can consume them in fairly large amounts. However, bananas have low contents of CF, CP (see Table 1) and minerals, and should therefore be fed together with grass or another source of roughage (in order to avoid rumen disturbance) as well as with protein and mineral supplementation. When the rejected bananas are widely available, a good silage can be made from chopped bananas mixed with one or several protein-rich feeds, such as poultry litter, dry spent grain, fish waste and cassava leaves.

**Banana leaves and pseudostems (trunks).** Banana pseudostems (trunks) and leaves are useful sources of roughage in many tropical countries, mainly during the dry season. They can be chopped and fed fresh or ensiled. As pseudostems are low in protein and minerals, they are more efficiently used when supplemented with rich-protein ingredients, such as copra meal, multi-nutrient feed blocks, cassava leaves, poultry manure or spent grain.

<table>
<thead>
<tr>
<th>Feed</th>
<th>DM (%)</th>
<th>Per kg DM</th>
<th>Per kg Fresh Matter</th>
<th>Inclusion rate fresh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ME (MJ/kg)</td>
<td>CP (g/kg)</td>
<td>CF (g/kg)</td>
</tr>
<tr>
<td>Spent grain</td>
<td>22.0</td>
<td>8.2</td>
<td>260</td>
<td>130</td>
</tr>
<tr>
<td>Banana stems</td>
<td>9.5</td>
<td>5.5</td>
<td>20</td>
<td>210</td>
</tr>
<tr>
<td>Banana skin (ripe)</td>
<td>15.0</td>
<td>6.7</td>
<td>42</td>
<td>77</td>
</tr>
<tr>
<td>Rejected banana (ripe)</td>
<td>30.0</td>
<td>11.5</td>
<td>54</td>
<td>22</td>
</tr>
<tr>
<td>Cassava leaves</td>
<td>16.0</td>
<td>6.7</td>
<td>235</td>
<td>190</td>
</tr>
<tr>
<td>Cassava roots</td>
<td>28.5</td>
<td>12.5</td>
<td>16</td>
<td>52</td>
</tr>
<tr>
<td>Molasses</td>
<td>78.0</td>
<td>11.5</td>
<td>15</td>
<td>0.00</td>
</tr>
<tr>
<td>Breadfruit (ripe fruit)</td>
<td>29.8</td>
<td>10.8</td>
<td>57</td>
<td>49</td>
</tr>
<tr>
<td>Taro leaves</td>
<td>16.0</td>
<td>6.2</td>
<td>223</td>
<td>114</td>
</tr>
<tr>
<td>Taro Roots</td>
<td>25.0</td>
<td>13.2</td>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>Sweet potato (leaves)</td>
<td>12.0</td>
<td>5.8</td>
<td>200</td>
<td>145</td>
</tr>
<tr>
<td>Sweet potato (tuber)</td>
<td>30.0</td>
<td>13.5</td>
<td>70</td>
<td>25</td>
</tr>
<tr>
<td>Yam (leaves)</td>
<td>24.0</td>
<td>7.3</td>
<td>120</td>
<td>250</td>
</tr>
<tr>
<td>Yam (root)</td>
<td>34.0</td>
<td>13.5</td>
<td>80</td>
<td>25</td>
</tr>
<tr>
<td>Poultry litter</td>
<td>82.8</td>
<td>8.2</td>
<td>265</td>
<td>145</td>
</tr>
<tr>
<td>Olive cake</td>
<td>45.5</td>
<td>3.8</td>
<td>40</td>
<td>465</td>
</tr>
<tr>
<td>Olive leaves</td>
<td>56.8</td>
<td>5.7</td>
<td>105</td>
<td>300</td>
</tr>
<tr>
<td>Grape marc</td>
<td>37.1</td>
<td>4.9</td>
<td>138</td>
<td>410</td>
</tr>
<tr>
<td>Sugar-beet pulp</td>
<td>19.5</td>
<td>9.8</td>
<td>91</td>
<td>316</td>
</tr>
<tr>
<td>Tomato pulp</td>
<td>22.5</td>
<td>8.0</td>
<td>215</td>
<td>350</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>89.1</td>
<td>8.1</td>
<td>160</td>
<td>137</td>
</tr>
</tbody>
</table>
The use of chopped and ensiled pseudostems is particularly recommended when the bunch has been harvested and plants are cut down; the large quantity of trunks available at harvest time can be safely preserved through a well-planned silage operation. The silage is of good quality when chopped pseudostems are properly mixed with an easily fermentable carbohydrate (such as molasses or sliced root vegetables) and protein-rich feeds (such as poultry litter or wet spent grain).

**Root crops**

The major root crops that are potentially available for animal feeding in tropical countries are cassava, taro, sweet potato and yams.

**Cassava by-products.** Both the roots and the leaves are valuable feed resources for dairy cattle. Fresh and sun-dried cassava roots are consumed by ruminants in different forms (sliced, chopped, ground) and used as a substitute for cereal grains in many countries. Cassava roots are a good energy source for dairy cattle, because they are high in carbohydrate, which is an important and readily available energy source for rumen microbes. However, they are low in protein (Table 1). They are particularly efficiently used by high producing cows and in the first stage of lactation. Cassava roots can be given in large quantities: up to 25% of total DM intake. However, protein and mineral supplements must be fed in order to balance the ration. As cassava roots are rich in easily fermentable carbohydrates, they constitute an excellent energy additive when they are chopped and ensiled with other feed resources, such as fish waste, cassava leaves, banana pseudostems, spent grain, poultry litter, etc. The cassava leaves are also a potential and valuable protein feed for ruminants (Table 1). It is estimated that when leaves are harvested at the same time as the roots, yields are in the range of 1 to 4 t DM/ha. Fresh cassava leaves have been successfully fed to cattle, including dairy cows, in many countries.

Fresh raw cassava contains cyanogenic glucosides (HCN compounds) that are toxic to monogastrics, but leaves can be fed fresh to ruminants, as rumen micro-organisms appear to be able to detoxify the HCN. However, this is easily removed during processing by sun drying or ensiling. Ensiling cassava leaves is the simplest method, not only to significantly reduce HCN concentrations to safe levels for monogastrics, but also to preserve the nutritive value of harvested cassava leaves for efficient use for off-season feeding of dairy cows. The freshly harvested leaves are first chopped, and can be ensiled alone or mixed with energy-rich feeds, such as banana wastes, root vegetables, wet spent grain, etc. The whole cassava plant (including root and aerial parts) can also be chopped and ensiled in the same way. The silage is fairly balanced for dairy cows.

**Taro.** Taro is the staple food of the population in many tropical countries. Taro by-products include roots, trimmings, leaves and stems: all potentially valuable feed supplements. Taro roots are outstanding as a feed, being particularly rich in energy. Raw taro contains substances that irritate the tongue and palate of animals, so that it must be cooked to improve its nutritional usefulness, mainly for monogastrics. The leaves are rich in protein (Table 1) and are relished by cattle. Taro by-products can be chopped and ensiled in association with the aforementioned feed resources. Silage making reduces considerably undesirable substances in taro by-products, which thus become more appetising.

**Sweet potato.** Sweet potato is another root crop grown by farmers in many tropical countries. The by-products are roots, offcuts, leaves and vines. Roots have low
protein, fat and fibre concentrations (Table 1), but they are high in carbohydrates, whilst foliage has a lower carbohydrate concentration but higher fibre and protein concentrations (Table 1). The vines, which are usually wasted, can serve as a nutritive and relished green supplement for cattle. A mixture of waste bananas, cassava roots and sweet potato tubers and leaves can be ensiled effectively without the need for additives.

Yams. Yams are also widely grown in many tropical countries. Their nutritional value is limited by their bitter alkaloid concentration, as well as of tannins and saponins. Yams must be cooked to improve their nutritional usefulness if they are to be fed to monogastrics or calves. The by-products include roots, offcuts, leaves and vines. Vines are a valuable cattle feed and can be successfully ensiled mixed with other feed ingredients indicated above.

Wet pulps from fruit and vegetables (citrus and pineapple pulps and leaves)

Many fruits are grown in tropical countries: mango, papaya, pineapple, citrus, etc. Fruit wastes and leaves are potential feed resources. The most suitable method for conserving these materials is to ensile them with the aforementioned ingredients, to ensure good fermentation and enhance the silage quality with their high sugar concentration.

Almost all Mediterranean countries produce large amounts of citrus for local consumption and export. Citrus pulp is the residue remaining after the extraction of citrus juice: it represents approximately half of the fruit and has a mean DM content of 20% (Boucqué and Fiems, 1988). Citrus pulp is an energy-rich feed resource with high metabolizable energy content (Table 1). The ensiling of the citrus pulp, damaged fruits and leftovers, in combination with other by-products with high protein concentration, such as poultry litter and wheat bran, is a simple and appropriate method of conservation that can make a significant contribution to the feeding requirements of ruminants, mainly for high-yielding cows in early stages of lactation. In addition, ensiling citrus wastes has advantages over traditional drying, in that less energy is used, cost of processing is much reduced and there is improved palatability.

Fish by-products

Fish by-products are usually obtained from inedible whole fish or from waste from fish processing industries. This is an excellent source of protein and minerals for livestock, mainly for cows that have recently calved and for high-yielding cows. The ensiling of the by-products in combination with other easily available feeds rich in fermentable carbohydrates, such as molasses, sweet potato or cassava roots, is a simple and appropriate method of conservation that has been successfully applied recently in some countries. In all cases, the maximum amount of fish wastes that can be included in the silage is 50% with a dry source of carbohydrates, and much lower - about 10% - with fresh sources.

Poultry litter

Another potential feed resource is poultry litter, which is available from some intensive poultry farms in developing countries. Poultry litter and manure contain about 25% crude protein on a DM basis, about half of which derives from uric acid, which can be efficiently used by rumen microbes for protein production. Poultry litter is also rich in minerals. The results of many experiments around the world indicate that dried or ensiled poultry litter can be successfully included in the feed of ruminants as a protein supplement. The ensiling of the poultry litter is a simple and appropriate method of conservation. It has proved to be an excellent ingredient for cattle feeding, and the process significantly destroys harmful micro-organisms possibly present in poultry litter. Silage made from poultry litter, chopped root crops and banana by-products provides a balanced diet for dairy cows.
Tomato pulp

Tomato is the most popular vegetable crop grown in Mediterranean countries where there are numerous tomato-processing plants. Tomato processing residues called tomato pulp (a mixture of peel and seed) accounts for about one-fifth of fresh weight and has a high nutritional value. It is a particularly protein-rich feed resource (Table 1). Fresh tomato pulp becomes sour and mouldy rapidly because it is traditionally processed during summer and has a high moisture content, approximately 80-84%. Consequently, it is advisable to ensile tomato pulp in alternate layers with dry by-products, such as chopped straw, wheat bran and poultry litter, so that the liquid effluent is absorbed and used. Good-quality silages made from such combinations are successfully used by small farmers in Tunisia to feed dairy cows and fattening steers (Kayouli, 1989).

Pressed olive cake

The production of olive oil is basically confined to the Mediterranean basin. Large amounts of crude olive cake, a residue of kernels and pulp left after oil extraction, are produced yearly. Despite its low nutritive value (Table 1), this by-product is a potential feed resource, mainly during periods of feed shortage. Usually, crude olive cake stored in heaps next to the processing plant deteriorates quickly because of its high lipid concentration - between 10 and 14%. The voluntary intake of such cake decreases with storage duration. Ensiling fresh olive cake either alone or with high-quality by-products, such as wheat bran, poultry litter or tomato pulp, improves storage quality and gives a well-preserved, palatable feedstuff. This technique was tried ten years ago in Tunisia (Kayouli et al., 1993), and then successfully adopted by many smallholders in the vicinity of olive oil processing plants.

Grape marc

After pressing 100 kg of grapes, there remains 5 to 10 kg of grape marc (seed and pulp), with about 50% DM content and relatively low nutritive value (Table 1). Ensiling fresh grape marc either alone or with high-quality by-products, such as wheat bran, poultry litter or tomato pulp, improves storage quality and gives a well-preserved, palatable feedstuff (Hadjipanayiotou, 1987).

SILAGE-MAKING FROM BY-PRODUCTS

The basic principles of silage making from by-products are the same as for silage-making from green forage, so attention must be paid first to ensuring anaerobic conditions, i.e. the by-products must be stored under airtight conditions at all times, and, second, there must be sufficient natural acid in the silage to restrict the activities of undesirable bacteria (for this the ensiled material must be sufficiently rich in carbohydrates).

In order to achieve a successful ensiling of by-products, the following parameters require very careful attention:

(i) **Moisture content** Ensiled material should contain more than 50% moisture so that it is easy to compress it tightly in order to obtain good compaction and to eliminate air. However, excessive moisture, more than 75%, can also be harmful, leading to an undesirable fermentation in later phases, producing sour silage, which reduces palatability and intake. Water can be added and/or wet and dry feeds can be mixed to get the desired moisture content.

(ii) **Length of chopping** The finer the chopping, the better the compaction and therefore the more successful the storage, due to the effective exclusion of air. Chopping into small pieces can be done by hand or with a stationary forage chopper.
(iii) The time it takes to fill a silo
The rapid filling and sealing of the silo is very important because slow filling or delayed covering can easily increase feed losses due to extended aerobic fermentation.

(iv) Presence of enough easily fermentable energy (naturally present or added)
The major objective in silage fermentation is to achieve a stable low pH at which biological activity virtually ceases. In this way preservation is obtained whilst minimizing nutrient losses and avoiding adverse changes in the chemical composition of the material. The final pH of the ensiled by-product depends largely on the carbohydrate content in the original materials. Hence, protein-rich feeds with low energy content are very difficult to ensile successfully, and should be mixed with easily fermentable, energy-rich products, e.g. molasses, banana waste or root crops.

The technique of silage making from by-products was extensively described by Kayouli and Lee (1998). The silage can be stored in stacked layers, packed in succession on a soil surface that has been covered beforehand with a plastic sheet or banana leaves. This heap, once finished, is then tightly covered with banana leaves or plastic sheets, pressed down by some heavy objects, which are placed on top. Packed silage in plastic bags that are tightly closed is also an effective storage method. This storage method is easy to handle and has the potential to produce high quality silage with less waste in a well-sealed bag. However, it is not recommended for coarse materials, such as banana trunk and cassava leaves, which can puncture the bag and render the contents useless.

After approximately 6 weeks, the farmer can open the silo and start to feed silage to animals. Silage can be suitably preserved for as long as air is kept away from the ensiled material; it is therefore possible to store airtight silage for more than 6 months. Once the silo is open, care must be taken to cover again the ensiled material after each opening that is made to feed the animals.

PRACTICAL EXAMPLES OF SUCCESSFUL SILAGE COMBINATIONS

Crop residues and by-products vary in their composition and physical structure. Within this paper, it is impossible to provide a review of all combinations possible in silage making and therefore it will be restricted to those that have been successfully applied. However, in order to succeed in silage making, the following should be borne in mind:

(i) Carbohydrate or energy-rich feeds, such as crop roots, rejected bananas or fruit wastes, can be successfully ensiled alone.

(ii) Energy- and protein-rich by-products, such as spent grain or tomato pulp, can be successfully ensiled alone.

(iii) Fibre-rich feeds with low energy and protein concentrations, such as banana pseudostems, olive cake and grape marc, are better utilized ensiled in combination with energy-rich by-products.

(iv) Protein-rich materials with low energy content, such as cassava leaves, fish waste or poultry litter, should not be ensiled alone. However, this type of feed can be successfully ensiled when mixed with one or several energy-rich products such as crop roots, rejected bananas, spent grain or molasses. This type of silage is highly recommended because it provides a balanced diet.

(v) Incorporation of molasses in silage is optional; nevertheless, this is an excellent additive to ensure good conservation and enhance the silage quality of any ensiled feed resource.
Incorporation rate of the different ingredients to be ensiled is function of:

- the amount of by-product(s) available; and
- the animal types to be fed.

Thus a high-quality silage, containing increased proportions of energy-rich ingredients such as spent grain or crop roots, should be prepared for high-yielding dairy cows, while high proportions of cassava leaves and banana pseudostems can be used when there is seasonal feed shortage and therefore when silage would compose the bulk diet during off-season feeding.

Several silage combinations from various by-products and crop residues were successfully developed in two projects funded by the Technical Cooperation Programme of FAO, first in Samoa: (TCP/SAM/6611, Milk Production Areas and Small Milk Processing Units), repeated subsequently in Tonga (TCP/TONGA/8821, Smallholder Forage-Based Dairy Production) and expanded to a South Pacific Sub-Regional basis as GCP/SAM/007/FRA, Dairy Production and Processing Units.

As an example, the following silage combination (on a % weight basis) was efficiently preserved, with a good smell and low pH (between 3.5 and 4.5):

- chopped cassava leaves (15%);
- chopped cassava roots (25%);
- chopped banana pseudostems (10%);
- spent grain (30%);
- poultry litter (10%); and
- molasses (10%).

The silage, when fed as a supplement to grazing dairy cows, gave a big increase in milk production in those South Pacific Islands. The impact has been excellent; smallholders were particularly impressed by the ease with which they could use locally available materials to quickly and cheaply increase milk production. The improved performance due to supplementary feeding with silage appeared as fast and very significant increases in milk production. As most of the project cooperating farmers were selling milk, this positive production effect of feeding silage has been directly translated into immediately increased financial returns.

Two suitable dairy rations using the above silage combination are presented in Table 2, where the basal diet is from either grazing improved pasture under coconut plantations or cut-and-carry elephant grass.

Table 2. Dairy rations based on grazing or cut-and-carry in combination with silage

<table>
<thead>
<tr>
<th>Feed Supplement kg/day (fresh basis)</th>
<th>Milk yield (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Case 1 - Basal diet from grazing improved pasture under coconut plantations</td>
<td></td>
</tr>
<tr>
<td>Copra meal</td>
<td>1</td>
</tr>
<tr>
<td>Spent grain</td>
<td></td>
</tr>
<tr>
<td>Silage^{(1)} (30% DM)</td>
<td>10-15</td>
</tr>
<tr>
<td>Case 2 - Basal diet from chopped elephant grass (cut-and-carry system)</td>
<td></td>
</tr>
<tr>
<td>Chopped elephant grass</td>
<td>40</td>
</tr>
<tr>
<td>Copra meal</td>
<td>1</td>
</tr>
<tr>
<td>Spent grain</td>
<td>10</td>
</tr>
<tr>
<td>Silage^{(1)} (30% DM)</td>
<td>10</td>
</tr>
</tbody>
</table>

Notes: (1) Silage combination as described in the text
Large amounts of agro-industrial by-products and crop residues produced in the Mediterranean basin (citrus pulp, grape marc, tomato pulp, olive cake, wheat bran, etc.) have been successfully ensiled in different ways as sole ingredients or in different associations. Such silage making practices are extensively practised by numerous farmers and replace conventional feedstuffs, including imported concentrates (Kayouli et al., 1993; Kayouli, 1989; Hadjipanayiotou, 1987, 1993).

Table 3. Feed intake and performance of growing lambs fed a diet of ensiled poultry litter or of concentrates

<table>
<thead>
<tr>
<th></th>
<th>Ensiled poultry litter diet(1)</th>
<th>Concentrate diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>In vivo organic matter digestibility (%)</td>
<td>61.4</td>
<td>74.9</td>
</tr>
<tr>
<td>Retained nitrogen (g/day)</td>
<td>33.0</td>
<td>37.2</td>
</tr>
<tr>
<td>Feed intake (g DM/day)</td>
<td>1 520.0</td>
<td>1 098.0</td>
</tr>
<tr>
<td>Daily gain (g/day)</td>
<td>252.8</td>
<td>221.2</td>
</tr>
<tr>
<td>Feed conversion (kg DM/day)</td>
<td>6.1</td>
<td>5.4</td>
</tr>
<tr>
<td>Carcass yield (%)</td>
<td>47.5</td>
<td>45.1</td>
</tr>
<tr>
<td>Feed cost (US$/kg gain)</td>
<td>0.4</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Notes: (1) For details, see text. Experimental parameters: 12 animals per treatment; 66-day trial.

Source: Kayouli et al., 1993

Screened poultry litter has been successfully ensiled with olive cake and wheat bran (45:45:10% w/w/w, DM basis). Water was added to obtain 50% DM in the silage, based on DM content of the ingredients. After 6 weeks, results indicated that the ensiling technique was efficient for conservation of poultry litter at low cost, and eliminated health hazards. The litter silage was substituted for commercial concentrate and soybean meal and fed to lambs in a growing trial over 66 days (Kayouli et al., 1993). Results in Table 3 show that daily gain and feed intake registered with the experimental diet were higher than those on the concentrate diet, while feed cost was lower by 50% with the poultry-litter-silage group.

In another trial on beef fattening (Kayouli, 1989), an experimental diet containing ensiled sugar beet pulp and poultry litter was compared to a control diet (sugar beet pulp and concentrate with a high content of soybean meal) fed to fattening beef over a 150-day period. Animal performances (growth rate, feed conversion and carcass quality) were similar, while feeding cost was reduced by 20% with the experimental diet.

CONCLUSION

In order to increase farm incomes from livestock in developing countries, an adequate low-cost feeding system must be developed. Making silage from agricultural, agro-industrial and fishery by-products is a proven system offering considerable potential to improve farm incomes and profits. Agriculture Ministries should survey the types, qualities, quantities and seasonal availability of by-products available in their country. The current levels of utilization should also be assessed.

Whilst farmers will tend to opt for utilizing by-products they can easily identify and acquire locally, government officers can improve by-product utilization by assessing the “whole picture” of by-product availability, and advising farmers accordingly.

Practical programmes of research and extension are recommended in each country. These should create and demonstrate a range of model feeding systems based on ensiled by-products in addition to other available feeds. Such feeding systems would
have formulations based on local or national by-product availability, feeding requirements and critical annual periods of feed shortage.

Development of by-product silage production can yield continuity of good quality feed availability even in times of drought, at low cost. Small-scale farmers easily make such feeds with simple technology.

Different types of silage can be made by altering the formula - i.e. varying the choice and mix of by-products. In this way, the individual needs of different classes of livestock can be met.

Wider adoption of these technologies will benefit low-income rural communities through improved income and food security, and also the wider community through the better availability of reasonably priced animal products and by a decrease in pollution formerly caused by by-product waste.

REFERENCES


INTRODUCTION

In Ilocos Norte (Philippines), there are very distinct dry (October to May) and wet seasons (June to September) and the average landholding of farmers is 0.30 ha. The available feed from grasses, weeds and crop residues on the farm are limited, feeding one or two work animals throughout the year. Hence, the need to make optimum use of available crop residues and agro-industrial by-products.

Rice straw is available after the harvest season (September to November). This is poor quality roughage (92% DM, 3.3% CP, 1.5% ether extract and 32.8% CF), coarse when dry and has very low voluntary intake when fed as-is.

Tomato pomace is a by-product from the processing of tomato paste. It contains 15% DM, 14.5% CP, 2.2% crude fat, 38.4% CF, 30.2% nitrogen-free extract, 0.43% calcium and 0.30% phosphorus (Caluya and Sair, 1995). This is available from January to April when the only thing that can be used as feed for livestock is dry and mature grass.

Fresh tomato pomace would spoil in two days if exposed to the air, hence we tried to preserve this material by ensiling it with rice straw to possibly improve the acceptability and feeding value of these materials and also come up with a feed that could be used later.

Methodology

Rice straw was chopped (2-3 cm) and mixed thoroughly with the fresh tomato pomace in a proportion that would give a mixture containing 35% DM. This mixture was then packed tightly in a 200-litre drum lined with foil (bags rejected from the paste factory) and kept in storage for the duration of the study, although feeding out commenced after only 14 days. After the feeding trial, extra silage was kept for further observation.

The roughage ration was supplemented with a concentrate mixture composed of 75% rice bran, 23% copra meal, 1% salt and 1% lime at the rate of 1 kg per animal per day.

Results and Discussion
Table 1 shows that the quality of the silage deteriorated as the storage time increased. This could be due to poor storage conditions, i.e. cracks or holes in the foil lining the drum and exposure to the heavy rains that occurred in the third month of storage. Table 2 presents the performance of animals fed with varying levels of the tomato pomace and rice straw silage (TPRSS). After 90 days of feeding, the animals fed with 50% TPRSS had gained the most weight, while those fed with 75% TPRSS had the lowest. In terms of feed consumption, it was observed that the intake increased with decreasing level of TPRSS in the ration, with animals fed with 25% TPRSS taking in the highest amount and animals fed with 75% TPRSS taking the lowest.

Table 1. Quality of the tomato pomace and rice straw silage over time

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>TIME OF OPENING AFTER ENSILING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14 days</td>
</tr>
<tr>
<td>Colour</td>
<td>Greenish yellow</td>
</tr>
<tr>
<td>pH</td>
<td>3.98</td>
</tr>
<tr>
<td>Acceptability</td>
<td>Very acceptable</td>
</tr>
<tr>
<td>Presence or absence of moulds</td>
<td>Absent</td>
</tr>
</tbody>
</table>

Table 2. Performance of growing cattle fed with varying levels of tomato pomace and rice straw silage

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total weight gain (kg)</th>
<th>Average daily gain (kg)</th>
<th>Total feed consumption</th>
<th>Feed efficiency</th>
<th>Feed cost per kg gain in weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>75% roughage + 25% TPRSS</td>
<td>49.33</td>
<td>0.55</td>
<td>469.09</td>
<td>10.79</td>
<td>14.96</td>
</tr>
<tr>
<td>50% roughage + 50% TPRSS</td>
<td>54.00</td>
<td>0.60</td>
<td>424.31</td>
<td>8.56</td>
<td>12.38</td>
</tr>
<tr>
<td>25% roughage + 75% TPRSS</td>
<td>33.17</td>
<td>0.37</td>
<td>408.71</td>
<td>17.57</td>
<td>16.93</td>
</tr>
<tr>
<td>cv%</td>
<td>22.76</td>
<td>21.81</td>
<td>12.81</td>
<td>5.30</td>
<td>25.85</td>
</tr>
</tbody>
</table>

From this, it can be seen that animals fed with 50% TPRSS were the most efficient, requiring 8.56 kg of feed for 1 kg weight gain. In terms of cost of feed per kg weight gain, animals fed with 50% TPRSS incurred the least cost.

There was an obvious potential for ensiling rice straw or maybe other crop residues with tomato pomace, for producing feed for growing cattle, especially during periods of feed scarcity. This type of silage could also be fed to other ruminants, including buffaloes, sheep and goats. However, the kind of silo and storage should be improved to ensure good quality silage over a longer period.

CONCLUSION

Ensiling may offer a way of preserving highly perishable feed materials and improving the feeding value of poor quality roughage in a place like Ilocos Norte. This is a potential additional feed resource for the smallholder livestock raiser. This may also be an opportunity to provide a better quality feed for ruminants and improve the production of these animals.

REFERENCE
INTRODUCTION

The use of molasses not only improves the energy content of silage but also ensures low pH and prevents proteolysis. The nitrogen (N) concentration of the cereal and grass silages, which is generally low, can be improved considerably, without affecting its fermentation characteristics, by the addition of poultry waste at the time of ensiling. Ensiling poultry waste with cereal forages and grasses not only considerably increases their inherent low N concentration but also provide many basic nutrients such as energy, calcium, phosphorus and micronutrients. In this way the poultry waste can be recycled as feed for livestock with no undesirable effects on animal health. The aim of this study was to determine the effect on the rumen metabolism of sheep of feeding silage containing broiler litter.

MATERIALS AND METHODS

Commercial broiler house litter was sun dried, ground and stored for silage making. A representative sample of litter was analysed for total N, protein N, ammonia N, ash, fibre fractions, silica (Van Soest and Robertson, 1982) and non-fibre carbohydrates. Dried broiler litter(1) (30% DM) and cane molasses (60% of DM) were added to chaffed Sudax fodder (SPL-Silage) for silage making. Control silage without litter was also prepared. To determine chemical changes during ensiling, triplicate samples of each silage were analysed at the start and on 40th day, when opened. Samples were analysed for DM, total N, protein N, ammonia N and lactic acid. Since the poultry litter had a high silica concentration, which dissolves in neutral detergent but not in acid detergent, adding the difference in silica between ADF and NDF to the apparent hemicellulose values made a correction. Lignin was determined as acid detergent (AD) lignin and cellulose as lignin free ADF (see Table 1).

Table 1. Comparative analysis of broiler litter and Sudax fodder

<table>
<thead>
<tr>
<th></th>
<th>Broiler litter</th>
<th>Sudax fodder</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (%) at 103°C</td>
<td>90.16</td>
<td>24.88</td>
</tr>
<tr>
<td>Organic matter</td>
<td>79.78</td>
<td>93.97</td>
</tr>
<tr>
<td>Neutral detergent fibre (NDF)</td>
<td>38.97</td>
<td>61.23</td>
</tr>
</tbody>
</table>
Acid detergent fibre (ADF) | 35.97 | 34.02  
Hemicellulose | 3.00 | 27.21  
Cellulose | 18.10 | 29.32  
Non-fibre carbohydrates | 16.01 | 22.08  
Lignin | 2.82 | 3.58  
Silica | 14.56 | 1.12  
Total N | 3.84 | 1.62  
Protein N | 1.28 | 1.47  
Ammonia N | 0.29 | 0.09  
Non-protein N | 2.56 | 0.15  

Notes: All values are on a % DM basis.

Three adult rumen cannulated mature sheep were randomly allotted to one of the following rations in an experiment based on a 3 × 3 Latin Square design:

1. Ration A: Complete farm ration.
2. Ration B: SPL-silage.
3. Ration C: Sudax silage + 30% concentrate mixture

All rations were formulated at 14% crude protein (CP) and 70% total digestible nutrients (TDN). Each ration was fed to a rumen-cannulated sheep for a period of 10 days as adjustment period. In the following three days, the rumen liquor samples were collected at 0, 3 and 6 hr post-feeding. The pH of rumen liquor was recorded immediately after collection with a Beckman pH meter. The rumen liquor samples were strained through four layers of cheese cloth and the filtrate was collected in 50-ml plastic bottles, each containing 2 drops of Normal H₂SO₄. After adding a few drops of chloroform, the samples were stored in a deep freezer until analysis after thawing, for total N, protein N and ammonia N.

The data on chemical analysis of rumen liquor were analysed statistically using analysis of variance technique in a factorial model (3 × 3 with interactions) in a Latin Square design (Steel and Torrie, 1981).

RESULTS

Data on average pH and different N fractions in rumen liquor of sheep fed on different rations is shown in Table 2. Significantly (P<0.05) higher pH was observed in rumen liquor of sheep fed the ration containing SPL silage as compared to that having Sudax silage + concentrate mixture. The changes in pH of rumen liquor of sheep at different times post-feeding were found to be non-significant (P>0.05).

Sheep fed on the complete farm ration had significantly (P<0.05) higher total N than those on SPL silage or Sudax silage + plus concentrate mixture. The sheep on SPL silage had the lowest total N concentration, and it was significantly higher (P<0.05) when Sudax silage was supplemented with concentrate mixture (Table 2). Significant differences (P<0.05) were also observed in total N concentration of rumen liquor of sheep at different times post-feeding. At zero hours post-feeding, the total N concentration of ruminal fluid of sheep on complete farm ration was significantly higher (P<0.05) than that of the other rations. The ruminal total N concentration of sheep on SPL silage and Sudax silage + concentrate mixture rations were similar at 0 hours post-feeding. At 3 hours post-feeding, the total N concentration of rumen liquor of sheep on Sudax silage + concentrate mixture ration increased and was higher (P<0.05) than those on SPL silage ration.

The protein N concentration of rumen liquor was significantly higher (P<0.01) on complete farm ration, followed by regime Sudax silage + concentrate mixture and
SPL silage. The protein N concentration of rumen liquor of sheep on all rations at different times post-feeding followed a pattern similar to total N concentration.

The ammonia-N of rumen fluid of sheep fed SPL-silage was significantly higher (P<0.05) compared to complete farm ration or Sudax silage + concentrate mixture (Table 2). An ammonia-N concentration of rumen fluid was the lowest at 0 hours but it increased significantly (P<0.05) at 3 hours post-feeding, and then decreased again at 6 hours post-feeding. Following this pattern, the final ammonia-N concentration of ruminal fluid was not significantly different from that determined at 0 hours post-feeding.

Table 2. Average pH and different N fractions in rumen liquor of sheep fed different rations

<table>
<thead>
<tr>
<th>Ration</th>
<th>Time post feeding (hr)</th>
<th>pH</th>
<th>Total N (mg%)</th>
<th>Protein N (mg%)</th>
<th>Ammonia N (mg%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>6.39&lt;sup&gt;c&lt;/sup&gt;</td>
<td>127.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>89.13</td>
<td>23.16</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.24&lt;sup&gt;c&lt;/sup&gt;</td>
<td>120.3&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>83.31</td>
<td>33.64</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>148.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>105.36</td>
<td>30.53</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>6.357&lt;sup&gt;c&lt;/sup&gt;</td>
<td>132.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>92.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.11&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>6.91&lt;sup&gt;a&lt;/sup&gt;</td>
<td>89.4&lt;sup&gt;f&lt;/sup&gt;</td>
<td>46.53</td>
<td>40.62</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>96.5&lt;sup&gt;def&lt;/sup&gt;</td>
<td>58.76</td>
<td>37.77</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>92.1&lt;sup&gt;ef&lt;/sup&gt;</td>
<td>55.99</td>
<td>36.08</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>6.826&lt;sup&gt;a&lt;/sup&gt;</td>
<td>92.66&lt;sup&gt;c&lt;/sup&gt;</td>
<td>53.76&lt;sup&gt;c&lt;/sup&gt;</td>
<td>38.16&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>6.66&lt;sup&gt;b&lt;/sup&gt;</td>
<td>88.4&lt;sup&gt;f&lt;/sup&gt;</td>
<td>56.22</td>
<td>20.52</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.58&lt;sup&gt;b&lt;/sup&gt;</td>
<td>109.2&lt;sup&gt;dc&lt;/sup&gt;</td>
<td>72.38</td>
<td>27.83</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6.59&lt;sup&gt;b&lt;/sup&gt;</td>
<td>104.5&lt;sup&gt;de&lt;/sup&gt;</td>
<td>71.33</td>
<td>24.75</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>6.608&lt;sup&gt;b&lt;/sup&gt;</td>
<td>100.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>66.64&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24.37&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Notes: (1) Ration A: complete farm concentrate; B: SPL-silage; C: Sudax silage + concentrate mixture. (2) Means within column with different superscripts differ significantly (P<0.05).

DISCUSSION

The results as shown in Table 2 indicate that the difference among rations were significant (P<0.05). It has been observed that when 3.1 to 6.0 kg poultry litter was fed to cattle in a daily ration, ammonia concentration in rumen fluid was 3 to 5 times higher than the optimal level of 10 mg/dl for maximum fermentation and optimal microbial protein synthesis (Silanikove and Tiomkin, 1992). It was stated that once the microbial requirements for N in the rumen are met, there should be no further increase in the rate of fermentation. Excessive consumption of poultry litter exposes the cow to metabolic burdens, as reflected in ammonia (>20 mg/dl) concentration and reduces the cell life span (Visck, 1984).

Ammonia concentration in rumen fluid had a direct relationship with poultry litter intake and the parallel increase with pH would encourage the absorption of ammonia from the gut (Harmeyer and Martens, 1980). Excessive ammonia, which is not utilized by the microbes, is absorbed in the blood circulation and converted to urea in the liver, with consequent metabolic burden on liver.

Rumen pH, concentration of total N, protein N and ammonia N very much depend upon the physiological status of the animal, as appeared in the experiment reported...
here, when sheep were fed on SPL-silage. When Sudax silage was fed with supplemental concentrate mixture, the concentrations of total N and protein N increased and that of ammonia N decreased compared with SPL-silage, yet it was less (P<0.01) than the control. The reason being that increased DM intake reduced cell wall or structural carbohydrates, with a corresponding increase in cell contents and thus increased rate of digestion due to microbial stimulation with corresponding increases in microbial population and protein synthesis.

The pH of rumen fluid on three diets indicated the highest value on SPL-silage, probably due to high ammonia concentration. The ammonia N of the rumen fluid increased to a significantly (P<0.01) higher level, on all the three rations, at 3 hours post-feeding and again decreased to a lower level. It was probably either utilized by microbes or crossed the rumen wall, because during this time the pH of the rumen fluid was in the range of favourable ammonia absorption. The results of this trial indicate that SPL-silage alone could not support growth because it was deficient in energy, had higher concentration of soluble N, low concentration of less soluble protein and a high proportion of structural carbohydrates with correspondingly decreased microbial stimulation and low ruminal fermentation.

REFERENCES


INTRODUCTION

Oil palm frond (OPF) is one of the most abundant agricultural by-products in Malaysia. Almost all pruned fronds are discarded in the plantation, mainly for nutrient recycling and soil conservation. OPF has great potential for use as a roughage source or as a component in compound feed for ruminants. Much research has been carried out by MARDI and JIRCAS on use of OPF for animal feeding, either fresh, or processed as silage or pellet (Abu Hassan, Ishida and Mohd Sukri, 1995). Detailed studies on the fermentation characteristics and palatability of OPF silage, as well as on animal performance, have been reported (e.g. Abu Hassan and Ishida, 1991; Ishida and Abu Hassan, 1997; Oshio et al., 1999). The objective of this trial was to study the effect of processing methods of OPF on its digestibility and voluntary intake.

MATERIALS AND METHODS

Four processing methods for OPF (pelleting, dry chopping, silage, and NaOH treatment) were compared for \textit{in vivo} digestibility and intake using 16 Kedah-Kelantan (KK) cross yearling heifers (mean liveweight 160 kg). The fresh OPF collected from the UPM farm in Serdang, Selangor, Peninsular Malaysia, was chopped to 2-3 cm length and blended uniformly. A portion of the chopped OPF was directly packed in plastic drums (approximately 100 litre) for making silage. The material was kept for one month before feeding to the animals.

Simultaneously, a portion of the chopped OPF was mixed with 10% NaOH solution at the ratio of 15 kg NaOH to 100 kg of fresh OPF. The material was packed similarly in the drums and kept for one month until feeding. For making dry chopped OPF, a portion of the chopped OPF was chopped again using the same machine, dried under the sun for one day, and then completely dried in an oven. OPF pellets were produced with a 12-mm diameter pelletizer after being dried the same way as chopped OPF, and were ground through a 4-mm screen grinder.

These four types of OPF were mixed at various ratios with a basal ration comprising 50% palm kernel cake (PKC), 20% palm oil mill effluents (POME), 16% tapioca
waste, 10% rice bran, 2% minerals and vitamin mixture, 1% salt, and 1% urea. Rations consisting of 40% and 60% OPF pellets, 40% chopped OPF, 40% OPF silage and 40% NaOH-OPF were used to measure the apparent digestibility of each form of treated OPF at maintenance level, with 3-4 animals for each ration. Each ration was fed for 14 days and faeces from each animal were collected for measuring the digestibility throughout the last 5 days. OPF pellets and chopped OPF were mixed at the ratio of 25, 40, 60 and 75% of the total feeds on DM basis with the basal ration, as mentioned above. Each diet was voluntarily fed to each group of 3-4 heifers. OPF silage and NaOH-treated OPF were also mixed with the basal ration and were fed to the animals in the same ratios, except the 75% rations. Each ration was fed to the animals daily at 10-20% above the saturation level for 9 days. The weight and DM content of the remainder were measured in the morning. Collection of faeces was carried out for the last 3 days to measure the digestibility.

RESULTS AND DISCUSSION

Table 1 outlines the voluntary intake and digestibility of the treated OPF rations. At maintenance level, the digestibility of OPF pellets was the lowest. The intake of OPF pellets mixed with the basal ration was maintained even at the 75% inclusion level. While chopped OPF and OPF silage did not reveal much difference in digestibility, intake was higher for the chopped OPF ration than for OPF silage. Nevertheless, the intake at 75% level of chopped OPS was depressed to 58% of that at the 25% level.

Table 1. Voluntary intake and digestibility of treated OPF rations

<table>
<thead>
<tr>
<th>Ratio of OPF</th>
<th>OPF pellets</th>
<th>Chopped OPF</th>
<th>OPF silage</th>
<th>NaOH-OPF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DM intake (gDM /kg)</td>
<td>DM digestibility (%)</td>
<td>DM intake (gDM /kg)</td>
<td>DM digestibility (%)</td>
</tr>
<tr>
<td>25%</td>
<td>104.5</td>
<td>63.7</td>
<td>97.8</td>
<td>61.8</td>
</tr>
<tr>
<td>40%</td>
<td>101.7</td>
<td>56.1</td>
<td>83.0</td>
<td>57.6</td>
</tr>
<tr>
<td>60%</td>
<td>107.9</td>
<td>47.4</td>
<td>65.4</td>
<td>56.2</td>
</tr>
<tr>
<td>75%</td>
<td>87.6</td>
<td>35.8</td>
<td>57.2</td>
<td>51.0</td>
</tr>
</tbody>
</table>

The digestibility and intake of NaOH-treated OPF were the highest. Although grinding and pelletizing lowered the digestibility, due to the faster rate of passage through the rumen, these processes were more effective for enhancing the intake. At the same time, NaOH treatment improved not only the digestibility but also the intake remarkably.

Therefore, this treatment has great potential for improving OPF quality. However, as NaOH is caustic and dangerous, a safer and more cost-effective procedure for treatment is needed. Ammonia treatment, an alternative to NaOH treatment, was not carried out in this experiment. Although ammonia treatment could be adopted for improving frond quality, there is a high possibility that reaction between soluble sugars in OPF and ammonia will produce toxic substances, such as 4-methylimidazole. Thus, if ammonia treatment is adopted for improving the quality, it will be important to identify the occurrence of toxic materials.

CONCLUSION

The digestibility and intake of NaOH-treated OPF were higher than those of chopped OPF or OPF silage. More studies are needed to determine if NaOH treatment is...
suitable, or can be replaced with ammonia, for improving OPF quality. Intake was lower for OPF silage than for chopped OPF, but the digestibility was comparable. Compared to fresh-chopped OPF, OPF silage has advantages for animal feeding, in terms of ease of handling, storage, less labour usage, easy to transport, etc. Fresh chopped OPF needs to be processed daily. This is not only time-consuming but in the long-term it is not practical and not cost-effective.

Although pelletizing of OPF is effective for improving intake, it depressed the digestibility. Therefore, an alternative processing method such as cubing is required to maintain the same level of digestibility as chopped OPF and simultaneously to improve the intake.

REFERENCES


INTRODUCTION

In Malaysia, livestock production is mainly in the hands of smallholders, who are largely dependent on forages for their feed resources. With the assistance of the Department of Veterinary Services (DVS), more farmers are now cultivating forages, especially those involved in the milk collecting centre (MCC) dairy projects. Owing to events such as droughts and floods, fodder conservation is likely to play an important role in livestock production among smallholders in certain areas of the country.

Sweet corn is a popular crop in Malaysia. After its cobs have been harvested, the stover still remains a good source of nutrients, suitable for cattle feeding. With 9.6% CP concentration, as found in an earlier study, it is comparable to that of stover harvested at 75 days of age (Yacob et al., 1992). The ME value - 7.82 MJ/kg of fresh stover - is comparable to or in some cases better than most fodder grass species being used in Malaysia. Although this by-product is a valuable forage by itself in the fresh state, at harvesting time the quantity would be too much to be utilized in the short time before it started to decompose. This material needs to be conserved for feeding in adverse seasons. Ensiling the stover is thought to be the best form of conservation. At present, the production of sweet corn silage is carried out in the state of Terengganu, with an estimated production of 120 t annually. Since the inception of the sweet corn stover ensilage program in 1996, an estimated 400 t have been produced for feeding farmers’ cattle.

MATERIALS AND METHODS

The stover of sweet corn harvested after 75 days was collected and chopped into 2 cm lengths, using a portable forage chopper. The chopped stover was tightly packed into 128-litre plastic drums, taking care to exclude as much air as possible so to maintain anaerobic conditions for successful ensilation.

The ensiled material was opened after 30 days and samples were sent to the laboratory for analyses using AOAC (1984) methods. Calcium concentration was determined using an atomic absorption spectrophotometer; phosphorus using the molybdate metavanadate complex; ME by the gas test procedure, as outlined by Menke et al. (1975); and the fibre components using the method of Goering and Van Soest (1970).

RESULT AND DISCUSSION
Yacob et al. (1992) estimated production of 10 t of DM of stover per ha of sweet corn - a figure close to the average of 12 t achieved here. Clearly, a substantial quantity of forage could be obtained if stover from all sweet corn crops were ensiled and used by dairy smallholders.

At the normal harvesting age of 75 days, the protein and ME contents of corn stover were 9.6% and 7.82 MJ/kg respectively. In the silage product, the protein concentration had decreased to 8.2% and ME value to 5.86 MJ/kg. Very negligible spoilage was observed in the drums during the project.

REFERENCES


INTRODUCTION

The preservation of forages by ensiling has been a well known technology for many years and is popular in North America and Europe. This technology requires high investment in facilities, accurate timing in the several stages of the ensiling process, and better understanding of the whole process than hay making demands. In addition to these demands, silage making and management in tropical conditions needs special attention and care with regard to three key points:

- **Crop maturation** This depends on the climatic conditions. In warm areas, the lengths of maturation stages might be shorter and changes are faster than in a temperate climate. In such cases, it is more difficult to control the correct stage for harvesting, and this is especially crucial with cereal crops in the last stages of maturity.

- **DM content** The correct DM content in the plant before ensiling is an important factor for the fermentation success. Unexpected weather (dry, wet or hot) can damage the crop and increase losses.

- **Aerobic stability** Rapid deterioration of silage, especially during the feeding-out phase is a real problem in a hot climate: it reduces quality and results in losses. High temperatures enhance mould and yeast activities all year round, so special attention should be taken in silage making to eliminate air penetration into the bunker (fine chopping, good compaction and sealing). The feeding-out of the silage should be done in such a way as to avoid destruction of the structure of the face and to leave it smooth. Aerobic stability should become a routine test in hot areas (Ashbell et al., 1991).

This paper will discuss silage making of three main cereal-fodder crops in the tropics, viz. sorghum, maize and wheat.

**SORGHUM** (*Sorghum bicolor* (L.) Moench)

**Introduction**

Sorghum was cultivated in Egypt as early as 2000 BC. Usually it is grown in areas...
with inadequate rainfall for satisfactory maize cropping. Several qualities in which it differs from maize (an alternative forage crop) have made this a summer crop worldwide. The sorghum plant is not fastidious in moisture and irrigation requirements and it can be sustained on 300 mm of water (rain or irrigation), or grow on dry land, relying on winter rain. Its demand for fertilizers is also modest. Sorghum can grow in a relatively saline environment (soil and water). In a hot and long summer, it can re-grow during the same summer after cutting. Of course, yield is affected by growth conditions.

Poisoning by hydrocyanic acid occurs mainly through grazing of young sorghum. Therefore it is recommended to graze sorghum only when the plants are taller then 60 cm.

There are many varieties of sorghum; most of them were developed to provide grain for human and animal consumption.

Whole plant sorghum - qualities and ensiling

In the last few decades, forage sorghum has become progressively more popular. Genetic work has been done to improve and adjust the sorghum qualities for forage too, and get a “whole plant sorghum forage.” Much work on sorghum silage has been done in the USA (Dickerson, 1986; Smith, 1986; Dost, 1989).

Sorghum is a seasonal crop; the only way to preserve the whole plant for cattle feeding is by ensiling. Several characteristics of the plant have to be taken into account to succeed with the ensiling technology and to obtain high quality silage, including digestibility, as poorly digestible parts of the plant reduce its total nutritional value. Most of these parts are associated with the cell wall structure, especially lignin, which is dominant in the stem. Therefore, reducing the proportion of stem in the plant will increase its digestibility, so, in practice, shorter hybrids are preferable.

Important properties determining the value of sorghum silage.

High energy

From a cereal crop we can expect mainly energy supply, and less protein. WSC, structural carbohydrates and starch are the main energy resources in cereal crops. Starch is mainly accumulated in the grain, the amount of which greatly affects the total energy content. The higher the proportion of grain in the plant, the more the total energy. The positive effect of the presence of starch is especially important for dairy cows. Therefore, we are looking for a high-grain sorghum hybrid.

DM content

Ensiling technology requires at least 30% of DM in the forage. With less than 30% DM, undesirable fermentation takes place and results in effluent, which creates an environmental pollution problem and increases losses. Such wet material encourages the activity of clostridial bacteria, enhances the production of butyric acid, increases losses, and reduces silage quality. Most of the water content in the sorghum plant is in the stem, therefore, wilting should be avoided because the stem will spoil before drying. A solution is needed that will enable us to harvest directly a whole sorghum plant that contains at least 30% DM. In the later stages of maturation (milk and dough), the grains are the driest part of the plant. High yield of grains, harvested between the milk and dough maturation stages will increase the total DM content to a level suitable to avoid effluent and clostridia fermentation. In this stage of maturity, the DM content of the grain is around 50%. In other words, to increase the DM content of whole-crop sorghum for silage, the recommended maturation stage for harvesting is between the milk and dough stages. Harvesting at late-dough maturity or later will increase the undigested amount of the grains and reduce the nutritional value. Processing the grain in the silage will increase its digestibility. Such
a solution should be applied only if it is economic. A close ratio between the grain and the rest of the plant (stem and leaves) will help to reach the goal of increasing the DM content. Reducing the moisture content or excessive WSC in forage sorghum hybrid for silage can be done by mixing it with a grain sorghum hybrid while ensiling (Ashbell et al., 1999)

Table 1 gives the changes in whole plant forage sorghum during maturation, and the corresponding silages. DM increased, whilst WSC and NDF (neutral detergent fibre) contents decreased mainly between the milk and dough stages; this is attributed to the grain filling with starch; in vivo DMD (DM digestibility) was not affected by stage of maturity; pH of the silages prepared from sorghum harvested at the dough stage were highest; however, all silages were stable upon aerobic exposure; acetic acid and ethanol were found in all silages at 10-20 g/kg (data are from Ashbell et al. (1999), unpublished results).

Table 1. Changes in sorghum composition during maturation (g/kg)

<table>
<thead>
<tr>
<th>Maturation stage</th>
<th>DM</th>
<th>WSC</th>
<th>NDF</th>
<th>DMD</th>
<th>Silage pH</th>
<th>Lactic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowering</td>
<td>274+1</td>
<td>120+21</td>
<td>512+7</td>
<td>604+11</td>
<td>3.7+0.3</td>
<td>58+12</td>
</tr>
<tr>
<td>Milk</td>
<td>288+8</td>
<td>149+20</td>
<td>489+1</td>
<td>607+9</td>
<td>3.9+0.2</td>
<td>45+12</td>
</tr>
<tr>
<td>Dough</td>
<td>340+14</td>
<td>69+10</td>
<td>425+3</td>
<td>617+8</td>
<td>4.2+0.1</td>
<td>30+10</td>
</tr>
</tbody>
</table>

**Lodging**

Sorghum plants are susceptible to lodging. Harvesting lodged plants is complicated, takes more time and field losses are higher. Tall sorghum plants usually do not have heavy heads, but have a strong and a thick stem; both of these are negative factors. Therefore short hybrids will be more lodging resistant, and are preferable.

**Tannins**

The grains of some hybrids may contain tannins, which have a negative effect on the digestibility rate of the protein in the diet. Large amounts of tannins are mainly found in “bird-resistant hybrids.”

In places where sorghum grain is used for human consumption, it is possible to ensile the vegetative parts of the plant - the stem and leaves - for feeding animals. In this case, the sorghum is dual-purpose. Some hybrids of sorghum can “stay young” even in the late maturation stages, and retain fair digestibility.

Adding LAB inoculant during ensiling sorghum improved the fermentation process, but reduced the aerobic stability of the silage (Meeske et al., 1993). The decision to use additives, especially bacteria, has to be decided after performing experiments under the particular local conditions.

**MAIZE (Zea mays L.)**

Maize, a summer forage crop, originated in Mexico or Central America, but today it is a worldwide crop for grain, and it is a perfect crop for silage. Requirements for water and temperature are relative high, and often it is an irrigated crop.

Much scientific research has been done on maize for silage, from the agronomic, ensiling and nutritional points of view. Harvesting at the correct maturation stage is a very important factor, especially in tropical areas, where vegetation and maturation processes are rapid. The maturation stage for harvesting is between the milk and dough stages. This requires opening the cob, inspecting the grain, and determining the ratio between the solid (starch) part and the “milk” part inside the grain. When each of the two components reaches 50% it is time to start harvesting, and it should end when 75% of the grain is in the solid form. At that stage it is expected to reach
maximum total harvesting yield. An earlier harvest will cause potential loss, and a later harvest will increase field losses and reduce the digestibility of the grains.

In a hot climate, the correct maturation stage for harvesting can be reached after around 115 days of growth. In places with a long summer it is possible to obtain two harvests in the same year, one in summer and one in autumn. There is a big difference in the quality and the yield between crops in the two harvesting seasons.

The first maize crop has better climatic conditions for growth, and can complete a cycle of the vegetation period. While the days are getting shorter and cooler towards the end of the growth period of the second crop, the yield is lower, and the plant does not have the correct conditions to produce a mature cob. When harvesting the first maize crop, grains form the dominant energy source: almost 50% of the total nutritional value, mainly starch, (which is important for dairy cows) comes from the grains. Grains strongly affect the total DM content by increasing it, and bring the total DM of the whole maize plant to a moisture content suitable for ensiling. To increase the yield and improve the quality of the second-harvest maize, it is recommended to sow more densely (according to conditions), and to wilt before ensiling if possible.

Ashbell and Lisker (1988) studied the aerobic deterioration of maize silage stored in commercial bunker silos in Israel (subtropical climate). Losses in DM were between 4 and 7.5% in well-sealed sites, and up to 36% at locations where air penetrated (upper layer and along the walls).

WHEAT (\textit{Triticum aestivum} L.)

Agronomic considerations

Wheat has been grown since the beginning of civilization, mainly for its grains. Nowadays, whole-crop wheat is used in some areas as a forage crop, which is preserved either as hay or as silage. Whole-crop wheat provides both digestible fibre and energy (9.0 MJ/kg DM) and its nutritional value may approach that of maize silage, so that it can serve as an excellent forage for high-lactating cows or beef cattle (Adamson and Reeve, 1992). There are numerous varieties and cultivars that have been adapted for different climates and soils. In tropical and subtropical climates, only spring wheat is grown, sown just before the rainy season. Wheat for silage is harvested at the milk-dough ripening stage, with a DM content of 30-35%. DM yields of whole-crop wheat for silage are around 10 t/ha, depending on cultivar and on growing conditions. The advantage of growing wheat for silage in tropical and subtropical climates is that the early harvesting enables the farmer to grow an additional summer crop such as maize, potato or groundnut. Such double-cropping has the advantages of more efficient utilization of soil, water and fertilizers, and providing crop rotation (Ashbell and Sklan, 1985). In Israel, with a subtropical climate, this system even enables farmers to squeeze in a third crop of autumn maize for silage; this is irrigated with treated sewage water and is harvested after 80 days of growth, before the cob develops.

Spring wheat cultivars can be early or late maturing, with a 2- to 3-week difference between them in the time needed to reach adequate ripening. Advantages attributed to late-maturing cultivars used for silage in subtropical climates include:

- a longer growth period in semi-arid areas facilitates more efficient use of moisture remaining in the soil from late rains, providing higher yields at a given stage of maturity;
- the time window available for silage making is extended, relieving some of the logistics pressure on the operating system; and
- the harvest period of the late-maturing cultivars offers a greater possibility of avoiding rainfall during silage making.
It is possible to grow wheat along with annual legumes such as vetch, peas and sulla (*Hedysarum coronarium*) and to ensile them together. Advantages attributed to such systems are:

- the wheat may alleviate the lodging problem of the legumes;
- improved soil ecology and reduced incidence of plant disease; and
- improved silage quality and reduced preservation losses of the legumes.

The last-named advantage arises from the fact that the carbohydrate-rich cereals complement the moist, protein-rich legumes with regard to ensiling properties, aerobic stability of the silage and nutritional aspects. For example, Ashbell *et al.* (1997) found that the best combination was obtained when the silages were prepared from wheat and vetch at 3:1 (wet-weight basis), with 31% DM in the mixture. The problems that might be associated with such systems include growth domination of one type over the other, problems with using herbicides, and that the cereal and the legume may not reach optimal maturity for harvest simultaneously.

**Changes during maturation**

Changes that occur in the whole-wheat plant during maturation are very rapid in warm climates, and the intervals between the various maturation stages are short. These changes affect DM yields, chemical composition, ensiling characteristics and nutritional value. During the short period between flowering and the soft dough stage, the wheat plant undergoes remarkable changes; although there is a certain variability in composition between years and among cultivars, some tendencies are apparent (Table 2): DM content increases with advancing maturity, whereas CP decreases, mainly between the flowering and milk-dough ripening stages; starch accumulates in the grains while soluble carbohydrates decrease; fibre contents (both NDF and ADF, expressed as percentages of DM) peak at the flowering stage. The fibre content affects the nutritional value of this forage. Based on these facts, and considering yields, ensiling characteristics and nutritional properties, we believe that it is optimal to harvest wheat for silage at the milk ripening stage (Ashbell *et al.*, 1997; Weinberg *et al.*, 1991).

**Table 2. Changes in wheat composition during maturation (g/kg)**

<table>
<thead>
<tr>
<th>Maturation stage</th>
<th>DM</th>
<th>WSC</th>
<th>Ash</th>
<th>CP</th>
<th>NDF</th>
<th>ADF</th>
<th>ADL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shooting</td>
<td>170-190</td>
<td>-</td>
<td>108</td>
<td>133</td>
<td>562</td>
<td>360</td>
<td>57</td>
</tr>
<tr>
<td>Flowering</td>
<td>200-246</td>
<td>62-110</td>
<td>81-111</td>
<td>96-132</td>
<td>585-640</td>
<td>366-405</td>
<td>59-90</td>
</tr>
<tr>
<td>Milk</td>
<td>279-388</td>
<td>51-136</td>
<td>62-110</td>
<td>77-104</td>
<td>510-598</td>
<td>251-408</td>
<td>49-108</td>
</tr>
<tr>
<td>Dough</td>
<td>355-466</td>
<td>30-32</td>
<td>57-91</td>
<td>81-90</td>
<td>481-509</td>
<td>239-278</td>
<td>57-67</td>
</tr>
</tbody>
</table>

**Key:** DM = dry matter; WSC = water-soluble carbohydrate; CP = crude protein; NDF = neutral-detergent fibre; ADF = acid-detergent fibre; ADL = acid-detergent lignin.

**Ensiling of wheat**

Although yields are somewhat lower at the milk ripening stage, compared to the dough ripening stage, it is preferable to harvest at the earlier stage because the wheat at the dough stage may be too dry and its fibres less digestible. In contrast, wheat at flowering is too moist and requires prolonged wilting, and its ensiling properties are inferior.

Before ensiling, the wheat is usually subjected to a short wilting period in order to reach a DM content of 33-38%. It is difficult to control the DM content of the wheat at
harvest because of the rapid changes mentioned above. In addition, in subtropical climates, the wheat for silage is harvested in spring, when the weather is unstable and changes rapidly from cool to hot and dry. This affects maturation and drying rates during wilting.

Compaction of the chopped wheat in the silo is affected by its DM content and chopping length: the drier it is, the more elastic it is, and therefore more difficult to compact. Because wheat stems are hollow, removal of air demands more intensive compaction. Therefore, a drier crop requires a shorter chopping length. The recommended chopping length in Israel is 10 mm; however, excessively short pieces are not desirable because they are more costly to produce, and they may escape quickly from the rumen, and function less effectively as roughage for ruminants.

Ensiling rates of wheat in subtropical climates are variable and depend on DM content, carbohydrate availability and development of adequate LAB in the silage. There are not many data on microbiological dynamics during ensiling of wheat in warm climates. Weinberg et al. (1987) found that the number of lactobacilli in the fresh crop varied between 102 and 106 colony-forming units (CFU) per gram. After 2 days of ensiling in mini-silos, the numbers increased to 108-109 CFU/g in all cases. Ashbell and Kashanchi (1987) and Ashbell and Weinberg (1992) studied DM losses in commercial wheat bunker silos in Israel. DM losses ranged from 3 to 16% in the centre of the silo; from 10 to 22% near the walls; and from 14 to 27% under the cover. The shoulders of the bunker (where the walls and plastic sheeting meet) are the parts of the silage most susceptible to air penetration, and their DM losses ranged from 54 to 76%.

The aerobic stability of wheat silage is variable. In warm climates detrimental micro-organisms (yeasts, moulds) proliferate more rapidly, resulting in enhanced aerobic spoilage. In general, many factors may affect aerobic stability, including the presence of weeds, the management of the silage in storage (compaction and sealing), composition of the silage, additives, and the method and rate of feeding-out. In bunker silos in a warm climate it is important to refresh the face frequently by feeding-out 30-40 cm every day, in order to minimize its exposure to air. Aerobic deterioration of wheat silage is associated with increased numbers of yeasts and moulds, heating and, consequently, DM losses. The roles of DM content, residual soluble carbohydrates and lactic acid in destabilization of the silage are not clear as yet. As in other silages, volatile fatty acids (such as acetic, propionic and butyric) produced during the ensiling fermentation inhibit yeasts and moulds.

Moulds are of concern in wheat silages because of the risk of mycotoxins. Several mycotoxins at various levels have been detected in wheat silage in Israel; there are not yet enough data to correlate their presence with disease incidence in cattle.

Additives

Both chemical and biological additives have been tried in wheat silage. A sulphur-based chemical, which inhibits yeasts and moulds, is applied commercially in Israel; reduced losses and improved aerobic stability are attributed to it. On some farms, coarse sodium chloride is applied to the top layer (at 3-4 kg/m²) of the bunkers for the preservation of this susceptible part of the silage. Anhydrous ammonia has also been tried on maize, wheat and sorghum silages: it improved aerobic stability, increased the NPN content, but it is hazardous to use, and therefore not used in practise (Ashbell and Weinberg, 1993).

Bacterial inoculants comprising homofermentative LAB were not found suitable for wheat silage in Israel: silages treated with such inoculants tended to deteriorate faster than the respective controls, and to enhance yeast and mould development (Weinberg et al., 1993b). It was hypothesized that not enough volatile fatty acids, which inhibit yeasts and moulds, were present in such silages. Inclusion of special
bacterial strains alleviated this problem. Heterofermentative \textit{L. buchneri} are being tried in several research laboratories and results are promising (e.g. Weinberg et al., in press).

Cell-wall-degrading enzymes (cellulases, hemicellulases and pectinases) have also been tried. The expected benefits to be derived from such enzymes are the release of fermentable sugars, and improved rumen digestibility. The enzymes have been found to reduce fibre content and to increase fibre digestibility only in silages made from moist wheat at the flowering stage, but not in those from drier, more mature wheat (Weinberg et al., 1993a; Weinberg et al., 1995).

**Nutritional properties**

The nutritional value of wheat for silage is strongly affected by the stage of maturity at harvest, because that affects yields, the ratio between grain and vegetative plant parts, and DM and cell-wall contents and quality. In Israel, wheat silage forms the main roughage in the rations for high lactating cows and silage quality is therefore of the utmost importance; it forms approximately one third of the ration, and is fed at about 7 kg DM per cow per day.

Ashbell et al. (1997) compared the ensiling properties and rumen degradability of wheat silage from early- and late-maturing cultivars, at four stages of maturity: shooting, flowering, milk and dough. Although NDF degradability of young-wheat silage (shooting and flowering) was higher than at the milk or dough stages, yields of degradable DM and NDF (in terms of t/ha) increased as the wheat matured. Ben-Ghedalia et al. (1995) found \textit{in vitro} OM digestibility of 69.2 and 70.5% and NDF digestibility of 63.3 and 56.3%, at the flowering and soft-dough ripening stages, respectively, of whole-plant wheat.

**Research needs**

Wheat cultivars that have been used for silage making were mainly developed for increased grain yield, and are actually dual-purpose types. Research should focus on development of cultivars intended solely for ensiling. Such cultivars should be adapted to specific climate and soil conditions, with higher yields and improved quality. Another possibility involves plants with intrinsic antimycotic properties, the silage of which should be more stable under aerobic exposure.

Development of more suitable inoculants for wheat silage in warm climates warrants research. The characteristics of such inoculants should include crop specificity, improved ensiling fermentation with reduced losses, improved aerobic stability, and a probiotic effect on animal performance (Weinberg and Muck, 1996). Genetic engineering might also play a role in the development of ideal inoculants.

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Dost, M. 1989. Grain yield, forage yield, and forage quality of different sorghum types under irrigated and dryland conditions. PhD thesis, Kansas State University, Manhattan, Kansas, USA.


Smith, R.L. 1986. Yield, composition, and nutritive value of grain sorghum harvested as silage: stage of maturity and processing effect. MSc thesis, Kansas State University, Manhattan, Kansas, USA.


*Lactobacillus buchneri* and *L. plantarum*, applied at ensiling, on the ensiling
Biotechnol.*, In press.
An experiment was carried out to evaluate corn [maize] grain and corn [maize] forage variety productivity and the nutritive value of silage based on the performance of cattle in a feedlot. A completely randomized design was used with a 2 × 2 factorial arrangement based on two cattle breeds (Nelore and Canchim) and two corn [maize] types (grain and forage). The corn [maize] was harvested 120 days after sowing, when plants showed more than two-thirds of dry leaves and grain was in the dough stage. The silage was stored in 400-ton silos.

Table 1. Corn [maize] silage - yield characteristics and composition

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Corn [maize] type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forage</td>
</tr>
<tr>
<td>As-fed yield(1) (ton/ha)</td>
<td>45.0</td>
</tr>
<tr>
<td>DM (%)</td>
<td>32.0</td>
</tr>
<tr>
<td>Yield DM (ton/ha)</td>
<td>14.4</td>
</tr>
<tr>
<td>Grain yield (ton/ha)</td>
<td>5.4</td>
</tr>
<tr>
<td>Remainder(2) (ton/ha)</td>
<td>9.0</td>
</tr>
<tr>
<td>Grain in DM (%)</td>
<td>37.5</td>
</tr>
</tbody>
</table>

Notes: (1) As fed matter. (2) Remainder of the plant.

The experimental diet consisted of grain or forage corn [maize] silage, 7.2 litre of liquid yeast (1.5 kg of dry yeast/head/day) and 1.1 kg of ground corn [maize] (1.0 kg DM/head/day). The experiment duration was 110 days, with a 20-day adaptation period and 90 days for data collection. Animals were weighed every 28 days. It was concluded that corn [maize] grain was more appropriate for silage than corn [maize] forage, because at the same stage of growth it produced a better quality silage with a higher DM content and a 41.3% higher grain yield, promoting higher weight gain and better feed:gain ratio in the feedlot beef cattle.

Table 2. Corn [maize] silage - chemical characteristics and pH
### Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Forage</th>
<th>Grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (%)</td>
<td>34.80*</td>
<td>45.60*</td>
</tr>
<tr>
<td>CP (%)</td>
<td>7.37</td>
<td>8.32</td>
</tr>
<tr>
<td>Acid detergent fibre (%)</td>
<td>26.10*</td>
<td>23.80*</td>
</tr>
<tr>
<td>Lignin (%)</td>
<td>4.10*</td>
<td>2.80*</td>
</tr>
<tr>
<td>(\text{NH}_3)-N (^{(1)}) (mg)</td>
<td>8.73*</td>
<td>6.52*</td>
</tr>
<tr>
<td>Acid detergent insoluble nitrogen (mg)</td>
<td>8.02*</td>
<td>6.12*</td>
</tr>
<tr>
<td>pH</td>
<td>3.96</td>
<td>3.20</td>
</tr>
<tr>
<td>Cellulose (%)</td>
<td>19.53</td>
<td>18.62</td>
</tr>
</tbody>
</table>

**Notes:** (1) Ammoniacal nitrogen as a percentage of total nitrogen. * Significant at the 5% level of probability.

### Table 3. Animal performance during 90 days in feedlot

<table>
<thead>
<tr>
<th>Breed</th>
<th>Forage Corn [maize]</th>
<th>Grain Corn [maize]</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DG</td>
<td>DFI</td>
<td>FG</td>
</tr>
<tr>
<td>Nelore</td>
<td>0.79</td>
<td>10.09</td>
<td>12.77</td>
</tr>
<tr>
<td>Canchim</td>
<td>1.29</td>
<td>9.39</td>
<td>7.28</td>
</tr>
<tr>
<td>Mean</td>
<td>1.04</td>
<td>9.74</td>
<td>10.03</td>
</tr>
</tbody>
</table>

**Key:** DG = Daily weight gain (kg/day). DFI = DM intake (kg/day). FG = Feed:gain ratio (kg DM/kg DG).

**Coefficients of variation:** (1) CV = 16.0%. (2) CV = 6.9%. (3) CV = 7.3%

### Table 4. DM intake

<table>
<thead>
<tr>
<th>Intake (kg/day)</th>
<th>Corn [maize] type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grain</td>
</tr>
<tr>
<td>DM</td>
<td>9.93</td>
</tr>
<tr>
<td>Concentrate</td>
<td>2.50</td>
</tr>
<tr>
<td>Ground corn [maize]</td>
<td>1.00</td>
</tr>
<tr>
<td>Yeast</td>
<td>1.50</td>
</tr>
<tr>
<td>Silage</td>
<td>7.43</td>
</tr>
<tr>
<td>Grain from the silage</td>
<td>3.94</td>
</tr>
<tr>
<td>Rest(^{(1)})</td>
<td>3.49</td>
</tr>
<tr>
<td>Total intake (Concentrate + silage)</td>
<td>4.94</td>
</tr>
<tr>
<td>Total concentrate (concentrate + grain from the silage)</td>
<td>6.64</td>
</tr>
<tr>
<td>Total forage</td>
<td>3.49</td>
</tr>
<tr>
<td>Forage:concentrate ratio</td>
<td>35.65</td>
</tr>
<tr>
<td>Daily gain</td>
<td>1.28</td>
</tr>
</tbody>
</table>

**Notes:** (1) Rest = Remainder of the plant
INTRODUCTION

Many smallholder livestock owners in semi-arid areas of Zimbabwe would like to start commercial dairy farming. However, it is not feasible unless one of the major constraints to productivity in their cows is overcome, namely the very poor availability of forage for feed in the dry season. Rain-fed forages are grown to feed in the wet season, but conservation as high quality hay is difficult due to leaching and rotting of the harvested material. Ensilage of forage, can, if done correctly, maintain productivity throughout the dry season. However, storage in a pit or bunker requires expensive machinery for chopping and compaction. Experience has shown, furthermore, that pit silage, through frequent exposure, suffers large spoilage losses. The authors examined the use of low-cost technology to produce silage from semi-arid adapted crops in a small-scale silo, in this case, an easily portable plastic bag. In order to produce a high quality silage, a mix was used of either sweet forage sorghum or Napier grass (*Pennisetum purpureum*) with a legume, dolichos bean (*Lablab purpureus*).

METHODS

The crops

Two forage crops were used: sweet forage sorghum (FS) (cv. Sugargraze) and *Pennisetum* (PS) (cv. SDBN3b) and a legume: dolichos bean (DB).

Ensilage was carried out in each plastic bag with either one of the forage crops mixed on a 50:50 by fresh weight basis with legume to produce 8 kg total fresh
weight, or with one of the forage crops alone, also at 8 kg fresh weight. The crop materials ensiled were therefore: FS+DB; FS; PS+DB; PS.

Treatments

Chopping was done in one of two ways: either with the use of a petrol-motor-driven chaffer, producing a chop with an average length of about 2.5 cm, or manually, using pangas, producing a chop with an average length of about 7.5 cm.

Compression was done in one of two ways: either with the use of a manual tobacco press, which comprises a manually driven screw pressing on to a metal plate sitting on the bag of crop material, or by leaning as hard as possible on the bag, using hands to remove as much air as possible.

The silos

The silos were recycled plastic bags used for garbage and of a size that could hold up to 50 kg of material. Upon filling and evacuating the bags of air, they were tightly tied with twine and stored in a closed storeroom.

RESULTS

The fermentation quality of all silages was good, showing pH less than 5.0, ammonia to total nitrogen ratio of less than 10%, DM loss of less than 20%, lactic acid content ranging from 2 to 7%, acetic acid content ranging from 1-2.5% and butyric acid ranging from 0 to 1.8% (Table 1). Visual and sensory evaluation of the silages also indicated good results. However, while treatments of chopping method and compression method had no effect on fermentation, crop type showed significant differences in pH, NH$_3$-N ratio, lactic and volatile fatty acids. Sorghum silages had better fermentation quality than *Pennisetum* silages, with or without legume. This was probably due to the high levels at ensiling of WSC in sweet forage sorghum (averaging 220 g/kg) compared with *Pennisetum* (about 75 g/kg).

Nutrition quality of silages showed that addition of legumes produced silage with significantly higher CP content (range: 13 to 14%) compared to sorghum and *Pennisetum*, and improved digestibility (range 52 to 56%) compared to *Pennisetum* alone (Table 2).

**Table 1.** Fermentation quality of different forage crops ensiled after differing treatments

<table>
<thead>
<tr>
<th>Crop material</th>
<th>DM loss (%)</th>
<th>pH</th>
<th>NH$_3$-N (%)</th>
<th>Lactic acid (%)</th>
<th>Butyric acid (%)</th>
<th>Acetic acid (%)</th>
<th>Ethanol (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All sorghum (FS)</td>
<td>9.36</td>
<td>3.70</td>
<td>4.07</td>
<td>5.63</td>
<td>0.05</td>
<td>2.04</td>
<td>2.12</td>
</tr>
<tr>
<td>All <em>Pennisetum</em> (PS)</td>
<td>18.00</td>
<td>4.30</td>
<td>4.99</td>
<td>4.25</td>
<td>1.17</td>
<td>1.89</td>
<td>0.97</td>
</tr>
<tr>
<td>FS+DB</td>
<td>12.30</td>
<td>3.78</td>
<td>4.37</td>
<td>6.55</td>
<td>0.30</td>
<td>2.34</td>
<td>0.72</td>
</tr>
<tr>
<td>FS only</td>
<td>7.15</td>
<td>3.63</td>
<td>3.85</td>
<td>4.76</td>
<td>0.07</td>
<td>1.74</td>
<td>2.81</td>
</tr>
<tr>
<td>PS+DB</td>
<td>16.46</td>
<td>4.25</td>
<td>5.26</td>
<td>2.32</td>
<td>1.70</td>
<td>2.42</td>
<td>0.68</td>
</tr>
<tr>
<td>PS only</td>
<td>19.79</td>
<td>4.40</td>
<td>4.71</td>
<td>1.92</td>
<td>0.57</td>
<td>1.34</td>
<td>0.72</td>
</tr>
<tr>
<td>All materials fine-chopped</td>
<td>12.43</td>
<td>3.84</td>
<td>4.40</td>
<td>4.65</td>
<td>0.50</td>
<td>2.12</td>
<td>1.22</td>
</tr>
<tr>
<td>All materials coarse-chopped</td>
<td>15.31</td>
<td>4.20</td>
<td>4.70</td>
<td>4.62</td>
<td>0.72</td>
<td>1.80</td>
<td>1.60</td>
</tr>
<tr>
<td>All materials tobacco-pressed</td>
<td>15.04</td>
<td>4.05</td>
<td>4.50</td>
<td>4.18</td>
<td>0.50</td>
<td>1.74</td>
<td>1.38</td>
</tr>
<tr>
<td>All materials hand pressed</td>
<td>12.88</td>
<td>4.01</td>
<td>5.20</td>
<td>3.59</td>
<td>0.67</td>
<td>2.13</td>
<td>1.45</td>
</tr>
</tbody>
</table>
Table 2. Nutritional quality of silages made from different crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>DM (%)</th>
<th>Digestibility (g/kg)</th>
<th>CP (g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS</td>
<td>30.55</td>
<td>471.05</td>
<td>66.50</td>
</tr>
<tr>
<td>SE</td>
<td>0.41</td>
<td>10.76</td>
<td>1.66</td>
</tr>
<tr>
<td>PS+DB</td>
<td>27.50</td>
<td>523.17</td>
<td>133.23</td>
</tr>
<tr>
<td>SE</td>
<td>0.76</td>
<td>8.92</td>
<td>9.22</td>
</tr>
<tr>
<td>FS</td>
<td>32.80</td>
<td>544.15</td>
<td>64.98</td>
</tr>
<tr>
<td>SE</td>
<td>1.34</td>
<td>16.20</td>
<td>7.90</td>
</tr>
<tr>
<td>FS+DB</td>
<td>30.10</td>
<td>536.29</td>
<td>144.88</td>
</tr>
<tr>
<td>SE</td>
<td>0.94</td>
<td>11.55</td>
<td>12.13</td>
</tr>
</tbody>
</table>

CONCLUSION

Forages and legumes adapted to semi-arid conditions can be mixed and ensiled successfully in plastic bags with only manual chopping and compression. On-farm trials on four farms have subsequently shown the same success.

Forty farmers are currently participating in farmer-controlled, researcher-monitored trials in Gulathi communal area in the semi-arid region of Matabeleland in Zimbabwe.
Sweet sorghum (Sorghum bicolor (L.) Moench) is a C₄ plant, ranging in height between 3 and 5 m. It is not only known as a “high energy crop” because of its high photosynthetic rate, but it is also called “the camel among crops” due to its characteristics such as drought resistance, tolerance to waterlogging and saline-alkali resistance, as well as its wide adaptability. Sweet sorghum is a versatile crop that can be used for silage making, alcohol production and as a grain crop.

Since 1974, a large number of good varieties of sweet sorghum have been introduced by the Beijing Botanical Garden. Comparative experimentation has shown that the yield of green forage of the cultivars ‘M-81E’ and ‘Theis’ reached 128 and 125 t/ha, respectively (Table 1). Sweet sorghum is an excellent crop for silage making.

The sown area of sweet sorghum cv ‘Rio’ in the Nanjiao Livestock Farm of Beijing increased from 10 ha in 1979 to 400 ha in 1982. The average yield of green forage of sweet sorghum per unit area was 76.8% more than that of maize in 1980 and 1981. According to the statistics of the Beijing Administrative Bureau of Farming, since 1989 the sown area of ‘M-81E’ has reached over 1 333 ha in the outskirts of Beijing every year, and since 1991, the sown area of 'M-81E' has occupied 84% of the total harvested area in summer in the Beijing region. Because of the high yield of 'M-81E', an area of about 1 300 ha could be released for sowing winter wheat and other grain crops. Most sweet sorghum is used for silage making.

There are similar situations in many other provinces and cities. In the Tianjin Municipality Worker-Peasant Alliance Agriculture-Livestock Farm, for example, the yield of green forage of sweet sorghum was 149% compared with maize and 191% compared with barley. The Institute of Agricultural Science of Changde District, Hunan Province, found that the yield of 'M-81E' reached 125 t/ha of biomass, which is 181% that of maize.

Sweet sorghum can be grown not only in northern China but also in southern China. For example, the total accumulative harvested area in recent years has been about 1 000 ha in Bright Farm, Shenzhen City.

Table 1 shows the yields of different fractions of the crop of a number of cultivars tested in China.

It will be of great significance through popularization of sweet sorghum as a silage crop to change the livestock farming structure by devoting greater effort to the...
development of grazing-livestock farming (cattle, sheep, rabbits, geese, etc.), in
order to increase the total output of meat and reduce the pressure on grain used for
poultry.

Table 1. Mean yield of stalk, fermentable sugar, alcohol, fresh biomass and seed of
sweet sorghum in experiments at the Beijing Botanical Garden

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Theis</th>
<th>M-81E</th>
<th>Wray</th>
<th>Keller</th>
<th>Brandes</th>
<th>Rio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stalk (kg/ha)</td>
<td>95</td>
<td>89</td>
<td>76</td>
<td>76</td>
<td>62</td>
<td>52</td>
</tr>
<tr>
<td>Fermentable sugar (t/ha)</td>
<td>10.6</td>
<td>9.6</td>
<td>10.3</td>
<td>10.5</td>
<td>6.4</td>
<td>6.2</td>
</tr>
<tr>
<td>Alcohol (l/ha)</td>
<td>6 159</td>
<td>5 607</td>
<td>5 981</td>
<td>6 131</td>
<td>3 696</td>
<td>3 617</td>
</tr>
<tr>
<td>Fresh material (t/ha)</td>
<td>125</td>
<td>128</td>
<td>106</td>
<td>107</td>
<td>89</td>
<td>82</td>
</tr>
<tr>
<td>Seed (kg/ha)</td>
<td>6 674</td>
<td>6 213</td>
<td>1 426</td>
<td>1 960</td>
<td>3 500</td>
<td>2 866</td>
</tr>
</tbody>
</table>
INTRODUCTION

The long (5-7 month) dry season of the savannah region (cerrados) of central Brazil makes imperative the conservation of forage to maintain continuous production of milk.

Surveys conducted in the late 1970s and early 1980s indicated that in the State of Minas Gerais the conservation of maize, sorghum, elephant grass and mixtures of any two of these species were extremely common among dairy producers. Analysis of on-farm silage samples (Paiva et al., 1978) showed that the resulting silages were always of low nutritive value, with a mean in vitro organic matter digestibility (IVOMD) of 60% and 5.6% CP. A parallel survey (unpublished) also showed that the process of ensilage was slow and in small-scale dairy units it was frequently carried out manually.

It was therefore hypothesized that the low resulting nutritional value was due at least in part to the slow process of cutting, chopping and ensiling. A large number of experiments was carried out to determine maize growth curves; nutritional value throughout the vegetative period; various measurements of the efficiency (Pizarro and Vera, 1980) with which field operations can be carried out; material losses during cutting, chopping and conservation; and the resulting nutritional value of maize silages. Lastly, a computer model of the whole process and various alternatives was developed (Pizarro and Vera, 1979; Vera and Pizarro, 1981).

What follows is a brief summary of results, with emphasis on the inherent nutritional value of maize, and of the resulting silage, when the crop is grown under tropical conditions and on low-fertility oxisols.

RESULTS AND DISCUSSION

Locally bred and widely available maize cultivars were used in all of the trials, including ‘Agroceres 259’, ‘Dentado Composto’, ‘BR103’ and ‘Maia 13’. The last two were varieties released by the EMBRAPA National Centre for Maize and Sorghum Research.

The growth curves of the two last-named cultivars were studied for three consecutive years, and regular samples were collected between days 23 and 170 post-planting. Total yields and components of the biomass were quantified.
The maize crops were fertilized according to the then current recommendations, including 100 kg/ha N, 40 P and 40 K. A typical soil analysis (0-20 cm) was: clay - 65%; sand - 13%; pH - 5.2; P - 2 ppm; organic matter - 2.6%.

Analysis of the growth curves showed that, for all practical purposes, between-year differences were accounted for by differences in accumulated temperature (ACCTEMP) and rainfall (ACCRAIN), and these two variables, together with days since planting (AGE), provided a good prediction of DM yields:

\[
Yield = 8.22 \text{ ACCRAIN} + 0.00080 \text{ ACCRAIN}^2 + 4.803 \text{ ACCTEMP} - 52.402 \text{ AGE} - 0.2212 \text{ AGE}^2 - 2659 \quad (r = 0.96)
\]

DM percentage of the whole plant (DM PC) did not vary significantly between years, and was largely accounted for by AGE:

\[
\text{DM PC} = 7.66 (0.0120 \text{ AGE}) \quad (r = 0.95)
\]

The most striking result in terms of nutritional value was the rapid decline in the CP content of the crop, regardless of year and variety. CP tended to stabilize at 4 to 5% after the 100th day of growth, as follows:

\[
\text{CP} = 22.56 (-0.0285 \text{ AGE}) + 6.09 (-0.003085 \text{ AGE})
\]

DM digestibility (DMD) of the standing crop was evaluated in two sets of data. The first one determined the \textit{in vitro} DMD of samples collected throughout the growth period, as explained above. The second set of data was derived from a continuous digestibility trial carried out with penned sheep between days 49 and 177 of the growth period; it should be noted that over the period 140-177 days, the crop was fully mature and field-dried.

Up until 140 days of age, digestibility decreased linearly:

\[
\text{DMD} = 73.98 - 0.172 \text{ AGE} \quad (r = 0.84)
\]

This implies that over the period of 100-120 days of age, which corresponds to approximately 30% DM (the stage generally recommended for ensilage), DMD would be roughly 50 to 55% and CP 5%.

At approximately this stage of maturity, the contribution of grain to total yield was unexpectedly low, despite being reasonably high in absolute terms, as shown in Table 1.

\[
\begin{array}{|c|c|c|}
\hline
\text{Table 1. Total DM and grain yields in two tropical maize cultivars} \\
\hline
\text{BR 105} & \text{Maia 13} \\
\hline
\text{DM yield (kg/ha)} & 11 626 & 18 078 \\
\text{Grain yield (kg/ha)} & 3 288 & 4 237 \\
\text{Grain yield (% of total yield)} & 28.3 & 23.4 \\
\hline
\end{array}
\]

As shown in Table 2, soluble carbohydrates, and starch in particular, were low in the fresh forage. The low starch content in the fresh forage, relative to the ensiled material, is almost certainly due to a laboratory artefact, since later data determined in a different laboratory found that at a comparable stage of growth, starch in the DM of fresh forage ranged between 18 and 19% (Neto et al., 1984). Nevertheless, soluble carbohydrates in the latter case were even lower than above.

\[
\text{Table 2. Chemical composition of the fresh material and the resulting silage of cv ‘BR 105’}
\]
It is worth noting that Neto et al. (1984) analysed samples using “definitive” methods (Bailey, 1967, 1973) and were able to account for 85-90% of the DM, the remaining being ash and possibly minor fractions unaccounted for.

For the purpose of comparison, it should be noted that the expected composition of temperate maize is generally as follows: water soluble CHOs - 15%; starch - 25%; hemicellulose - 18%; cellulose - 23%; lignin - 5%; protein - 9%; DMD - 75%; and grain as % of total yield - 35-40%. A comparison with the data presented above shows that tropical maize in the experimental conditions reported here tends to be considerably higher in hemicellulose, somewhat higher in lignin and lower in protein and non-structural carbohydrates. It is hypothesized that this may be in part a plant adaptation to soil constraints, but mostly reflects the relatively low ratio of grain relative to the rest of the plant.

Numerous other results, particularly the partitioning of energy and nitrogen digestion in the gastro-intestinal tract of the animal, are available, but the above data should suffice to show the limitations of tropical maize silage, at least when grown on poor soils. In this environment, sorghum showed many of the same characteristics of maize (Pizarro et al., 1984), namely, high DM yields, moderate digestibility and marginal CP.

Not unexpectedly, the above tropical silages were unable to support weight gains in steers, unless supplemented with a protein supplement (Table 3).

**Table 3.** Liveweight gains of steers fed maize silage plus different levels of cottonseed cake

<table>
<thead>
<tr>
<th>Cottonseed cake (kg/day/head)</th>
<th>LWG (kg/day/head)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>-0.076</td>
</tr>
<tr>
<td>0.5</td>
<td>0.320</td>
</tr>
<tr>
<td>1.5</td>
<td>0.750</td>
</tr>
</tbody>
</table>

Contrary to our initial hypothesis, it is clear that the low nutritional value of farm silages cannot be attributed to the speed with which field operations are carried out, since the crop is of low quality throughout a relatively long vegetative period, including stages earlier than those most appropriate for ensilage.

**REFERENCES**


Horizonte.


INTRODUCTION

In recent years, the sowing of fodder crops during the rainy season (January to March) has become very popular. Generally, corn [maize] and sorghum are used, because they produce a well-preserved silage of good nutritive value. However, their DM yields and quality are uncertain from year to year, because of frequent drought stress.

Sunflower stands out as an alternative for forage production and conservation as silage because of its drought tolerance, its high DM yields, its resistance to cold and heat, its adaptability to different edaphoclimatic conditions and its relative independence of latitude, altitude and photoperiod (Cotte, 1959; Tomich, 1999).

To obtain silage of good quality and of high nutritive value, the material should be cut at the appropriate stage of maturity. Tan and Tumer (1996) ensiled sunflower at several stages of maturity and concluded that the final flowering stage was the best for silage making.

The present study was carried out at the EMBRAPA National Centre of Research in Corn and Sorghum. The objectives were to evaluate sunflower cultivars ‘V2000’, ‘DK180’, ‘M734’ and ‘Rumbossol-91’ grown in a completely randomized block with 3 replications and cut and ensiled 30, 37, 44 and 51 days after flowering.

RESULTS

Table 1 shows that many of the plots had inferior stands compared to those recommended by Castro et al. (1996) of 40 to 50 thousand plants per hectare. Rumbosol-91 was significantly taller than the other cultivars, but had the lowest percentage heads and the highest percentage stem. DM yield of V2000 was inferior to the others, except at the first harvest date (Table 2). The DM concentration of the
material is the most important factor for the quality of the ensiling process (McDonald et al., 1991) and it is recommended that it be between 30 and 35%.

Laboratory silos of PVC, 40 cm long by 10 cm in diameter, were used, and the silos were opened after 56 days.

**Table 1.** Stand density, height, head diameter and percentages of heads, stems and leaves at four maturities

<table>
<thead>
<tr>
<th>Days after flowering</th>
<th>Stand density (plants/ha)</th>
<th>Height (cm)</th>
<th>Diameter (cm)</th>
<th>Head (%)</th>
<th>Stem (%)</th>
<th>Leaf (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V2000</td>
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</tr>
<tr>
<td>30</td>
<td>39.59ABa</td>
<td>195.00Ba</td>
<td>16.84Aa</td>
<td>46.34Aa</td>
<td>35.56Ba</td>
<td>18.12Aab</td>
</tr>
<tr>
<td>37</td>
<td>26.74Ba</td>
<td>190.00Ba</td>
<td>20.44Aa</td>
<td>42.17Aa</td>
<td>37.34Aba</td>
<td>20.49Aa</td>
</tr>
<tr>
<td>44</td>
<td>33.34Aa</td>
<td>178.33Ba</td>
<td>17.56Aa</td>
<td>47.22Aa</td>
<td>37.16Aba</td>
<td>15.61Bab</td>
</tr>
<tr>
<td>51</td>
<td>19.44Aa</td>
<td>176.67Ba</td>
<td>15.55Aa</td>
<td>51.85Aa</td>
<td>37.68Ba</td>
<td>10.47Ab</td>
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<td>DK180</td>
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<tr>
<td>30</td>
<td>31.60Ba</td>
<td>205.00Ba</td>
<td>17.56Aa</td>
<td>44.38Aa</td>
<td>35.46Ba</td>
<td>20.16Aa</td>
</tr>
<tr>
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<td>15.56Aba</td>
<td>52.00Aa</td>
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<td>41.16Ba</td>
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<tr>
<td>M734</td>
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<td>30</td>
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<td>32.80</td>
<td>6.616</td>
<td>18.42</td>
<td>11.90</td>
<td>11.23</td>
<td>20.01</td>
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</tbody>
</table>

**Notes:** Capital letters compare harvest times among cultivars. Small letters compare harvest times within each cultivar.

The largest silage densities were observed for V2000, which may be explained by its having the lowest DM concentration. Within each cultivar, the densities decreased with time, due to the higher DM concentrations as plants matured, with the exception of V2000. These results are superior to those reported by Tomich (1999), who studied 13 genotypes with an average density of 677.4 kg/m$^3$, and they are also above those found for farm silos, with values of around 600 to 800 kg/m$^3$ for a good compression (Nussio, 1992). The quality of the preservation decreased with age of the plants, as shown by increasing pH, particularly for V2000, which also had high ammonia-nitrogen (NH$_3$-N) levels. In another experiment done at our laboratory with 13 genotypes (Tomich, 1999), the mean values of ether extract and in vitro DM digestibility of the silages were 13.7% and 50%, respectively, and showed normal profiles of lactic acid and AGV production.

**Table 2.** Production of fresh matter, DM, and DM of plants, heads, leaves and stems at four maturities

<table>
<thead>
<tr>
<th>Days after flowering</th>
<th>Fresh matter</th>
<th>DM</th>
<th>DM as percentage of</th>
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<tbody>
<tr>
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<td>DK180</td>
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<tr>
<td>RUMBOSOL 91</td>
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<td>Plants</td>
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<td>Leaves</td>
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<td>24.53Ab</td>
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</tr>
<tr>
<td>Coefficient of variation</td>
<td>26.50</td>
<td>19.97</td>
<td>26.60</td>
</tr>
</tbody>
</table>

Notes: Capital letters compare cutting times among genotypes. Small letters compare cutting times within each genotype.

Table 3. Density, DM, CP of the silages cut and ensiled at four maturities
<table>
<thead>
<tr>
<th></th>
<th>51</th>
<th>666.00Bb</th>
<th>64.57Aa</th>
<th>7.00Cb</th>
<th>*</th>
<th>*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of variation</td>
<td>18.87</td>
<td>24.49</td>
<td>8.45</td>
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</tr>
</tbody>
</table>

**Notes:** Capital letters compare harvest times among genotypes. Small letters compare harvest time within each genotype. * = Not determined.

**CONCLUSIONS**

1. The best harvest time for ensiling varied according to genotype, and was 37 days after flowering for DK180 and M734, more than 51 days for V2000, and about 30 days for Rambosol-91.

2. V2000 had the highest CP concentrations, but even with 35% DM at ensiling it provided silages with undesirable pH and NH₃-N. Within each genotype there were no differences between harvest times in the CP concentration, with the exception of Rumbosol-91, which had lower values at 51 days.

**REFERENCES**


INTRODUCTION

The principal objective of forage conservation is to supply nourishment that guarantees the productive function of livestock during periods of scarcity. Only a few studies have been made - and even less published - illustrating how small-scale farmers can produce good silage under tropical conditions with minimum resources. In this paper, different options for the preparation of silage will be examined, based on these principles and differentiating the implicit characteristics of small- and large-scale farmers. Many of the ideas and concepts presented are not only the fruit of research, they also summarize years of experience in silage production at different scales.

Even though an effort has been made to cover a wide range of situations and to generalize, without going into detail, it is a fact that each region and farming system has its own specific characteristics and the aim of this paper is not to supply rigid recipes.

PRODUCTION OF SILAGE

The silage production process can be divided into four stages: (1) forage harvesting; (2) transport to the silo; (3) compaction; and (4) sealing (airtightness).

The first management decision to take when planning to make silage is on the amount of silage required, which depends on the following factors:

- Number and type of livestock to receive silage.
- Length of the feeding period.
- Percentage silage in the full ration.
- Material resources available (equipment, labour, finances, technical assistance, etc.).

This is illustrated by the following example:

An adult bovine, consuming 50% of the ration of 10 kg DM per day as silage would receive 5 kg of silage DM. For a feeding period of 180 days, 900 kg of silage DM/animal would be required, equivalent to 3.6 t of fresh forage containing 25% DM. Assuming 15% silage loss, a total of 4.14 t/head of forage DM to be ensiled is
required. This is equivalent to 2.3 m$^3$ of silo capacity per animal, assuming a density of 0.6 t/m$^3$.

Using the same assumptions for a goat, the requirement would be 108 kg of silage DM at a rate of 0.6 kg/day, an amount of 497 kg fresh forage per animal would need to be ensiled, equivalent to a volume of 0.83 m$^3$ of silo capacity per animal.

This calculation can also be carried out in reverse, taking into account the resources available on the farm and the foreseen area to be conserved.

Irrespective of the amount of silage to be made, the following principles for good silage apply:

1. The material to be conserved must have a high nutritive value.
2. The forage must not be contaminated with soil.
3. The forage should be chopped into pieces no longer than 2 cm to facilitate good compaction and reduce air retention.
4. It is necessary to expel the maximum amount of air within the forage before closing the silo preventing air and water penetration.
5. The accumulation of the forage and sealing should be done in the shortest possible time.
6. During the feeding of the silage, the area exposed to air should be as small as possible and the time between opening and finishing the silo as short as possible.

Although the total silo capacity on a farm depends on the number and type of animals and the period of silage feeding, it is recommended that not all the silage required be kept in only one silo, to keep losses at a minimum. The best system is to create silos that can be emptied over short periods, so the actual silo size depends on the amount of silage per animal and the number of animals to be fed from that silo. The best strategy is to make silage at different times of the year and to feed it after approximately 60 to 70 days of conservation. This way the silage would have optimum fermentation and least chance of aerobic deterioration. However, the time of silage making also depends on the growing conditions and the availability of forage to be ensiled.

**SILO TYPE**

There are many different types of silo: permanent or temporary structures that may be vertical or horizontal. However, all kinds of receptacles can be used, including barrels made of steel or plastic; concrete water pipes of 2 m diameter and height; and 2 mm thick plastic packing bags, such as those used for fertilizers.

On large farms that are highly mechanized, silos with a capacity of 100 m$^3$ or more will normally be filled and emptied mechanically. This increases efficiency and reduces labour cost. However, on small farms with only a few animals, receptacles with a capacity of up to 200 litre that are filled manually make very effective silos. In all cases the material must be packed tightly and kept under anaerobic conditions. Bags must be tied at the top. These should then be piled under a cover, forming a pyramid.

For permanent silo sites, it is recommended that they have hard, impenetrable floors.

**Vertical silos**
Vertical silos may be made of wood, concrete, zinc, steel or plastic and should be cylindrical to facilitate compaction. Vertical silos are ideal for conservation, because of the high pressure accumulating inside as the forage is being added. This prevents the silage being exposed to air during the periods of conservation and of feeding. However, the forage to be ensiled this way should have at least 30% DM, in order to prevent the formation of effluents and, at the same time, take advantage of its maximum capacity.

**Horizontal silos**

Horizontal silos are the most commonly used and may be a trench or made on the surface. Surface silos can be with or without walls. They are popular because they are easily adapted to the specific conditions of a farm. However, with horizontal silos it is more difficult to ensure adequate airtightness.

**Trench silos**

Such silos are usually wedge-shaped excavations in the ground, to facilitate the entrance and exit of trailers during silage making and feeding. However, when their capacity is less than 2 m$^3$, they may be rectangular. The main disadvantage of trench silos is that the interior walls must be clad to avoid soil contamination and care must be taken to prevent surface runoff penetrating the silo.

**Surface silos without walls**

Silos without walls are the simplest because they do not require permanent construction. However, they are the most prone to damage of the covering material, which interferes with the necessary anaerobic conditions.

In Cuba, large silos containing 500 t or more were developed, which were not covered with polyethylene sheets. Airtightness was achieved only in the centre, as the outside forage decomposed. This led to heavy losses of over 25%.

For larger farms there are so-called vacuum silos, which consist of two plastic sheets. The forage is deposited on a sheet put on the ground and covered by the other, to a height that will allow joining the borders of both sheets. The silo is sealed by a rubber tube system. Through a corner of the package, vacuum is applied, which seals it once all the air has been extracted. This process is repeated on the third day after closing the silo, in order to extract the gasses formed during the initial fermentation, as well as a portion of the humidity produced by respiration and possible effluents.

Another variation of silos without walls is the so-called “sausage.” This consists of a polyethylene tube, closed on one end and fitted with a circular steel band at the other. A press is used to push the forage into the plastic tube, leaving a “sausage” of about 2 m in diameter and a length proportional to the volume of forage entered.

The same concept is used when high density round, cylindrical or rectangular bales are prepared by special machinery. These can be wrapped in polyethylene and placed one upon the other under a cover. Polyethylene-wrapped silos have a common problem, that the wrapping may be destroyed by animals, allowing air to enter, which leads to spoilage of the silage. Forage to be wrapped should have a minimum of 25% DM to take full advantage of volume reduction and to prevent loss of nutritive value, as well as to foster optimal fermentation.

**Surface silos with walls**

The most commonly used silos have 2, 3 or 4 walls. In the case of 4 walls, one must be mobile. Ideally, they should be covered with polyethylene and placed under a roof. The cheapest method is to build two lateral walls at right angles to an existing
In general, walled silos are less critical in terms of the forage DM content, because drainage systems for effluent can be incorporated, including a slightly sloping floor.

**FORAGE COLLECTION**

**Type of forage**

In the tropics, grasses have been, by tradition and for practical reasons, the main forage used for conservation. Recently, however, herbaceous and woody legumes have become an important part in livestock feeding. In spite of their importance, too few studies have been carried out to determine the best way to incorporate them into silages. Particularly in the case of woody protein banks, there are problems with mechanized pruning. When preparing silage of grasses and legumes together, the mixing should be done before loading the silo. The optimum grass:legume mixture is about 70:30. The best way to obtain proper mixing of the two components is to simultaneously introduce them into the chopper. If the forage is to be wilted, it is recommended to first cut the grass and then the legume because for the latter drying is generally more crucial as leaf loss may occur if the material becomes too dry.

**Pre-treatment**

The principal treatments after cutting prior to conservation of forages are, in order of importance: chopping, wilting and conditioning. Chopping is necessary to obtain good compaction to exclude air in order to promote a rapid initiation of the microbiological processes and to take optimum advantage of silo capacity. Chopping is done with specialized equipment. This may be a stationary chopper used when the forage is entered into the silo, or a pick-up trailer that chops the forage as it is collected in the field. Chopping to between 2 and 4 cm in length has the additional benefit of ease of ingestion, regurgitation and posterior rumination. Wilting forage before ensiling has many advantages. When DM levels are between 30 and 35%, effluents will not be produced, the development of undesirable micro-organisms will be reduced, better fermentation will be promoted and intake increased. Anti-nutritional metabolites (e.g. tannins and alkaloids) in certain forages (e.g. herbaceous and woody legumes and cassava leaves) will be eliminated or reduced. However, these species tend to lose their leaves during handling when dehydrated to over 40% DM. The field-drying time required to reach an optimum DM content depends on the species and on the weather conditions. The time may vary between 4 and 24 hours, depending on the thickness of the stems.

Drying time can be reduced when a mower-conditioner is used, which crushes the stems. Crushing cuts the fibres and compresses the forage so that cellular juices will be released. Tedding the cut forage immediately after cutting and once more afterwards will reduce drying time. The shorter the field drying time, the lower will be the risk of rain damage.

**Cutting systems for small farms**

The simplest cutting system is to cut forage with machetes, scythes or similar equipment. Manual cutting has a low productivity. Erect forage can be cut at a rate varying between 0.5 and 0.8 t/person/hr. With prostrate species, the rate of cutting is lower. It is not possible to give a general estimate of time required to prune shrubs and trees because it depends on the density of the edible material and the density of the plants. However, one could accept an estimate of 0.8 t/person/hour.

In addition to the time required to cut the material, there is also the time needed to carry it to the silo and to chop it before entering it into the silo.

The importance of making estimates of man-hours required to cut, carry and chop a
certain amount of forage is that it will determine the size of the silos and the number of people necessary to do the work in order to start and finish a silo within one day.

**Cutting systems for large farms**

Silage making on a large scale is a complex process. It requires coordination to cut the largest possible volume of forage in the least possible time.

Deciding factors in organizing the production process include: the power of the tractors, type of forage harvesters, quantity and capacity of trailers, condition of machinery, distance between forage area and silo, as well as pre-treatments and the use of additives.

**Harvesting machines**

Harvesting machines can be self-propelled or tractor-pulled. There are three types of cutting machines, classified according to their cutting mechanism, namely:

- **Impact.** These tractor-drawn machines have a group of knives mounted on a rotor blade that cuts the forage by impact and sends it to a chopper that cuts the material in lengths of 6 to 10 cm. The disadvantage of these machines is their low productivity, 8-10 t/hour. Additionally, soil is sucked in with the forage due to the circular movement of the rotor. They are not very effective for thick-stemmed species as the forage is cut at ground level, facilitating the attack of insects and fungi in the re-growth.

- **Rotating knives.** These tractor-drawn machines have the advantage of being very productive and of not affecting regrowth, producing clean cuts without harming the base of the plants. The size of the pieces is also better (2 to 4 cm). They are not suitable for uneven terrain because of a greater chance of breakage.

- **Plate shears.** The most modern self-propelled machines fitted with plate shears have a large cutting capacity (15-20 t/hour). The cutting system protects the regrowth. The machines are more efficient, because they can cut large areas in a short time. However, they require the land to be flat and free of obstacles. The chopping size can be adjusted between 0.5 to 2 cm.

**Pick-up trailers**

Pick-up trailers must be able to raise the forage off the ground, chop it and blow it towards a collection bin with a capacity of 8 m³ or more. The unloading mechanism can be on the side, at the back or with a moving floor. Trailers with a side-unloading system are practical for silos that are more than 6-m wide because they allow for rapid unloading.

In the case of wilted silage, it is important to have large trailers, since forage density decreases linearly with increasing DM content.

**Methods of compaction**

The method of compaction depends on the silo dimensions. In vertical silos of 2 t or less, compaction can be achieved by a person walking over the successive layers of forage.

In horizontal silos, less than 4-m wide, compaction may be done by animals or people walking over the material. Larger silos require wheeled or caterpillar tracked machines. The minimum width for mechanical compaction is 4 m. The tractor wheels or caterpillar must always pass over the inner border of the trail left during the
previous passage, in order to guarantee homogeneous compaction. Mud or water accumulation around the silos must be avoided to prevent contamination of the forage.

**Equipment for distribution of additives**

Different implements are used for the application of additives, depending on the type of additive and whether it is added during chopping or after the material has been deposited in the silo. With large amounts of silage, the best way to distribute the additives is directly at the forage elevation system associated with the pick-up trailer, taking advantage of the turbulence it creates. This will guarantee an efficient homogenization of the additive.

The simplest equipment for manual application of liquid additives in the silo consists of a container fitted with a small-diameter T-shaped pipe with holes, or a bag if the additive is solid. It is also possible to add additives during silo filling by using a pressurized sprayer or a small centrifugal fertilizer-spreader, if the silo has walls.

**ORGANIZATION OF THE SILAGE-MAKING PROCESS**

The golden rules that guarantee an efficient production process are:

1. The silo capacity available must be adequate for the amount of material to be ensiled.
2. The rate of silo filling should match the compaction capacity.
3. The whole process should be completed in as short a time as possible, ideally in one day, maximum three days.
4. Absolute airtightness must be obtained.

In order to understand the development of the silage production process and procedures to be employed, some typical examples are given below.

**Small farms**

The characteristic of small-scale silage production is that the only specialized machinery used is a stationary chopper. Human labour and animal power replace machine energy. To prepare 2 t of silage per day, two people, one animal traction cart and a stationary chopper powered by electricity or by a tractor, are required.

The routine work for silage production could be as follows:

- Manual forage cutting: 3 hours
- Loading the forage: 1 hour
- Transporting the forage (2 km round trip): 1 hour
- Forage chopping: 1 hour
- Silage preparation: 3 hours
- Airtight closing: 1 hour
- Total time required: 10 hours

If the forage is to be wilted, the cutting is done the previous day, preferably in the afternoon to guarantee the highest possible water-soluble carbohydrate content, or in the morning, depending on the expected drying time required.

It is important to only cut as much forage as can be transported during a day’s work in order to minimize the respiration loss and development of aerobic micro-organisms.

Polyethylene covering for airtightness does not necessarily need to be in one piece,
sheets from previous packaging may be used as long as there is sufficient overlap and so long as the entire silo is covered. Weights required to place on top of the polyethylene may be old tyres filled with concrete, bags of sand or earth, etc. The use of grills constructed with steel or wooden bars covering the top of the silos, on which additional weights are placed, has also been effective.

**Vertical silos and barrels (3 to 6 m³)**

Once the receptacle has been completely covered with polyethylene on the inside, it is filled with forage in successive layers no thicker than 20 cm each, with additives being added to each layer. It is not recommended to use forage with less than 25% DM. Compaction is achieved by a person walking in a circle, starting at the sides and moving towards the centre.

The silos should be filled until a small dome is formed on top, immediately followed by covering with polyethylene and positioning of weights on top. Steel or plastic barrels should be placed upside down. The barrels may be placed together under a roof or covered with loose plates or polyethylene.

**Horizontal silos**

Small horizontal silos (2 m high, 1 m wide) are best made under a roof, compacted by a person or animal. Ideally, there should be 4 walls in a rectangular shape. In silos with openings at both ends, loading should start from the centre of the silo, trying to gain height, avoiding unnecessary scatter of forage towards the ends, because even if covered with polyethylene, conservation will not take place in thicknesses of less than 40 cm. If silos are in the open, care should be taken that rain or runoff water cannot penetrate the silo.

The main problem with small-scale silos is to know when adequate compaction has been obtained. In well-chopped forages, placed in shallow layers, adequate compaction has been obtained when the loose green material under the person’s foot or animal’s hoof does not sink more than 2 cm. With wilted forages, adequate expelling of air can be expected only if the particles are less than 2 cm long. For longer pieces it is recommended to add a final layer (10-15 cm) of fresh green forage to weigh down the material before closing.

**Plastic bags**

Plastic bags are ideal for small farms. Filling and compaction are done by hand, taking care not to damage the sides. If a perforation should occur, it can be sealed with adhesive plastic tape.

**Large farms**

It is essential to have the following equipment available:

- a forage-harvester (with a tractor if it is not self-propelled);
- a tractor for compaction (except for vertical silos); and
- one tractor for each pick-up trailer (minimum two).

The quantity of forage that can be deposited in a silo in a single work day will depend on the minimum compaction time required. Based on past experience, these are: 15 t for forage chopped longer than 6 cm; 10 t for wilted; and 5 t for unwilted forage chopped to 2 cm or less. This means that during a 12-hour working day, an average of 48 t can be entered into a silo when the pieces are long, 72 t if wilted and 144 t if the forage is green. Because of the natural fragility of polyethylene, covers may only be used once. However, in order to lower costs, traders often accept the residues of each year to recycle the plastic and give discounts against the new purchase.
CONCLUSIONS

It is better to prepare smaller amounts of good silage, rather than large volumes of low quality that will have to be discarded as non-consumable or be of low nutritive value. Unfortunately, the processes involved in silage making are as yet not completely understood. Among the most difficult issues still to be resolved are:

- the parameters of incorporation of legumes into large-scale silage production;
- when is it most appropriate to use additives with respect to pre-drying technology; and
- how to analyse energy balances so as to make the most of the material and human resources involved in conservation.

Another limitation in the production of silage is the lack of knowledge of silage-making principles by the people and specialists involved in livestock farming. Nowadays, in sustainable livestock production, which is less dependent on external inputs, silage production has an important role to play.

BIBLIOGRAPHY OF LITERATURE USED


Poster 8.1: Sila-wrapped grass silage production using the small bale system (SBS) for feeding of goats and sheep - S.S. Shariffah Noorhani, A. Aini and A.B. Idris

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Department of Veterinary Services
Kuala Lumpur, Malaysia

Silage making involving mechanized sila-wrapping of small round bales was introduced into Malaysia in 1991. This method of silage production, which involves mainly grasses, has been undertaken on three ruminant farms as well as on grazing reserves. However, regular production using this method is now primarily carried out on two farms, the Sheep Multiplication Centres in the states of Kedah and Trengganu, which normally suffer from drought during part of the year.

Fresh grass is cut using a mower conditioner and then baled to produce small round bales averaging about 30 kg each. These bales are then collected from the field and delivered to the storage shed where the sila-wrapping machine is located, wrapped mechanically and stored. In some cases, sila-wrapping and storage are done in the field.

Annually, about 500 bales of sila-wrapped silage, equivalent to 15 ton, have been produced to feed cattle and sheep during the dry season. In the first 8 months of 1999, a record 2000 sila-wrapped bales were produced. To date, about 290 ton of sila-wrapped silage has been produced.

Grasses used are Brachiaria humidicola, B. ruziziensis, B. decumbens, Panicum maximum and Setaria sphacelata cv Kazungula. CP determined in the silages produced ranges between 5% and 13.4% in the grasses cut between 21 days and 2 months maturity.

The sila-wrapping system is considered a very convenient means of silage production. However, the main problem is in the high cost of sila-wrap film, which has to be imported. Another problem is rats chewing through the sila-wrap film to get at the silage, and thus causing spoilage.
**Poster 8.2: Effect of time of day on the WSC content of Kikuyu grass** - Alan G. Kaiser, John W. Piltz, John F. Hamilton and Euie J. Havilah

**INTRODUCTION**

In studies with temperate forage species WSC content has been observed to increase during the day due to photosynthetic activity within the plant. With warm and sunny conditions, the content of WSC in the plant is higher in the afternoon than early morning. It has been suggested that cutting of forages for silage should be delayed until the afternoon to maximize the amount of WSC available for fermentation. There are few data available on variation in WSC content of tropical grasses, so the current study was conducted to monitor changes during the day in the composition of Kikuyu grass (*Pennisetum clandestinum*).

**MATERIALS AND METHODS**

Two studies were conducted in which nitrogen (N) fertilized Kikuyu grass was sampled to monitor changes in WSC during the day. The first study was conducted over 3 days in March, with 30-day Kikuyu regrowth, and in adjoining plots over 3 days in April, with 30- and 45-day Kikuyu regrowths. A second study in April investigated the change in WSC content of 30- and 45-day regrowth Kikuyu mown for silage production at three times during one day. The two studies were conducted at different sites within the same paddock. The forage samples were analysed for DM, N, WSC, and starch content, and for in vitro organic matter digestibility (OMD).

**RESULTS AND DISCUSSION**

In the first study, weather conditions over the three days during the March sampling ranged from warm and sunny through to overcast. Warm and sunny weather was experienced on all days during the April sampling. No significant differences were observed between days in forage composition at either sampling (Table 1).

During the second study, warm and sunny weather conditions prevailed until just prior to the last mowing. Rainfall from local storms commenced during mowing and continued to fall during the collection of samples. This resulted in a decline in DM content but no differences in the composition of the DM (Table 2).

These study results confirm that sugar levels are higher in Kikuyu grass in the middle of the day and afternoon (60.6 g/kg DM), than in the morning (47.2 g/kg DM). Despite this increase in sugar content (to 12.0 g/kg fresh forage), the level was still...
well below the critical value (25-30 g/kg fresh forage) for low-risk preservation of unwilted forage (Wilkinson, 1990). Other effects of changing the time of cut to the afternoon were a small increase in forage DM content, a small reduction in N concentration, an increase in starch content, but no effect on digestibility.

Table 1. Effect of time of day on the composition of Kikuyu grass in Study 1

<table>
<thead>
<tr>
<th>Sampling time (Australian Eastern Standard Time)</th>
<th>March - 30-day regrowth</th>
<th>April - 30-day regrowth</th>
<th>April - 45-day regrowth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DM content (g/kg)</td>
<td>N content (g/kg DM)</td>
<td>WSC (g/kg DM)</td>
</tr>
<tr>
<td>07:35</td>
<td>167</td>
<td>34.6</td>
<td>50.2</td>
</tr>
<tr>
<td>11:45</td>
<td>167</td>
<td>34.9</td>
<td>68.4</td>
</tr>
<tr>
<td>15:55</td>
<td>171</td>
<td>33.6</td>
<td>66.1</td>
</tr>
<tr>
<td>Time of day</td>
<td>ns</td>
<td>P0.10</td>
<td>P0.01</td>
</tr>
<tr>
<td>s.e.d.</td>
<td>5.5</td>
<td>1.07</td>
<td>2.66</td>
</tr>
</tbody>
</table>

Table 2. Effects of regrowth intervals and time of day on composition of Kikuyu grass in Study 2

<table>
<thead>
<tr>
<th>Sampling time (Australian Eastern Standard Time)</th>
<th>30-day regrowth</th>
<th>45-day regrowth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DM content (g/kg)</td>
<td>Total N (g/kg DM)</td>
</tr>
<tr>
<td>10:30</td>
<td>221</td>
<td>19.8</td>
</tr>
<tr>
<td>14:15</td>
<td>231</td>
<td>20.4</td>
</tr>
<tr>
<td>16:15</td>
<td>204</td>
<td>19.9</td>
</tr>
<tr>
<td>10:30</td>
<td>208</td>
<td>19.8</td>
</tr>
<tr>
<td>14:15</td>
<td>214</td>
<td>18.6</td>
</tr>
<tr>
<td>16:15</td>
<td>191</td>
<td>17.4</td>
</tr>
<tr>
<td>Regrowth</td>
<td>P&lt;0.05</td>
<td>P&lt;0.10</td>
</tr>
<tr>
<td>Time of day</td>
<td>P&lt;0.01</td>
<td>ns</td>
</tr>
<tr>
<td>Interaction</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>s.e.d.</td>
<td>7.3</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Notes: ns = not significant. s.e.d. = significant difference. OMD = organic matter digestibility
CONCLUSIONS

The benefits of higher WSC content obtained by delaying cutting to the afternoon are small, as WSC levels were still well below the critical value required to ensure a good silage fermentation. In addition, cutting in the afternoon could have a negative effect on the ensiling process by slowing wilting. A slow wilt has been shown to adversely affect the fermentation quality of Kikuyu grass.

ACKNOWLEDGEMENTS

We are greatly indebted to the Australian Dairy Research and Development Corporation and NSW Agriculture for funding this research, and for assistance from local dairy producers who provided access to land and equipment.

REFERENCE

INTRODUCTION

Stable supply of forage throughout the year is the key constraint for further development in cattle production in northeast Thailand. Although Napier grass (*Pennisetum purpureum*) is not popular in the region, it may have good possibilities under intensive management with high manure input. The present study aimed to evaluate nutritive value and fermentative quality of silages made of either chopped or unchopped Napier grass harvested at different growth stages, and effects on intake and blood composition of cattle.

MATERIALS AND METHODS

Three kinds of silage were made using cylindrical concrete tanks (0.75 m diameter and 0.5 m height), compressed by foot and covered by plastic sheets with sand on top:

1. Using Napier grass 1 m high (about 30 days regrowth) - chopped.
2. Using Napier grass 1 m high (about 30 days regrowth) - unchopped.
3. Using Napier grass of 1.5 m high (about 80 days after transplanting) - chopped.

An aliquot of silage sample from each silo was placed into a bottle with water and kept in a refrigerator overnight. The extracted fluid was analysed for volatile fatty acids (VFAs) using gas chromatography; for lactic acid using a diagnostic kit; and for volatile basic nitrogen (VBN) and total nitrogen content.
Two castrated male native cattle (average body weight 166 kg) were used for digestion trials with the three feeds. All treatments were identical, namely silage was given to the animals *ad libitum* to measure maximum intake. Nutrient digestibility was examined by total collection method. Blood samples were collected from the jugular vein into a heparinized tube at the end of each collection period, before feeding and 3 hours post-feeding, and analysed.

**RESULTS AND DISCUSSION**

Although the original grass used in the treatments (1) and (2) was the same, CP and nitrogen-free extract (NFE) contents were lower in unchopped silage, which would be due to the difference in the fermentation process (Table 1).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Height of grass</th>
<th>Preparation</th>
<th>DM (%)</th>
<th>OM (% of DM)</th>
<th>CP</th>
<th>EE</th>
<th>NFE</th>
<th>CF</th>
<th>ADF</th>
<th>NDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 m</td>
<td>Chopped</td>
<td>16.9</td>
<td>89.3</td>
<td>11.9</td>
<td>3.9</td>
<td>42.7</td>
<td>30.7</td>
<td>37.7</td>
<td>64.2</td>
</tr>
<tr>
<td>2</td>
<td>1 m</td>
<td>Unchopped</td>
<td>16.1</td>
<td>86.9</td>
<td>10.2</td>
<td>3.6</td>
<td>39.1</td>
<td>34.0</td>
<td>40.9</td>
<td>64.3</td>
</tr>
<tr>
<td>3</td>
<td>1.5 m</td>
<td>Chopped</td>
<td>16.6</td>
<td>90.0</td>
<td>7.3</td>
<td>3.1</td>
<td>42.6</td>
<td>37.0</td>
<td>43.9</td>
<td>70.2</td>
</tr>
</tbody>
</table>

**Key to columns:** DM = dry matter; OM = organic matter; CP = crude protein; EE = ether extract; NFE = nitrogen-free extract; CF = crude fibre; ADF = acid detergent fibre; NDF = neutral detergent fibre.

CP content in treatment (3) was lower than in the others, which would be due to the difference in maturity. The fermentative quality of unchopped silage was also worse than that of chopped silage in treatment (1) (Table 2).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>Treatment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.02b</td>
<td>5.58a</td>
<td>3.87b</td>
</tr>
<tr>
<td>VBN/TN %</td>
<td>8.03b</td>
<td>17.40a</td>
<td>6.88b</td>
</tr>
<tr>
<td>Acetate %</td>
<td>0.127</td>
<td>0.460</td>
<td>0.232</td>
</tr>
<tr>
<td>Propionate %</td>
<td>0.007b</td>
<td>0.140a</td>
<td>0.002b</td>
</tr>
<tr>
<td>Butyrate %</td>
<td>0.007</td>
<td>0.243</td>
<td>0.161</td>
</tr>
<tr>
<td>V-score</td>
<td>93.2a</td>
<td>47.1b</td>
<td>82.2ab</td>
</tr>
<tr>
<td>Lactate %</td>
<td>1.21a</td>
<td>0.06b</td>
<td>0.99a</td>
</tr>
</tbody>
</table>

**Key:** VBN/TN = ratio of volatile basic nitrogen to total nitrogen; LSM = least square means; SE = standard error; No. = number of samples. a and b indicate that results with different superscripts among treatments differ significantly (p<0.05).

The unchopped silage showed higher pH and ratio of volatile basic nitrogen to total nitrogen (VBN/TN), and lower lactic acid concentration. If grass was ensiled without chopping, there was considerable space between the pieces of grass, which made anaerobic fermentation difficult. V-score was calculated from VBN/TN, total content of acetate and propionate, and butyrate content (Masaki, 1994), which is one method to evaluate silage quality, and used in Japan to evaluate low- and high-moisture silage using the same criteria. It clearly showed the difference in the fermentative quality in spite of not using the value of lactic acid contents for the calculation. It would be a useful method for the evaluation of silage quality, especially in developing countries, where the analysis of lactic acid is not practicable.
in terms of cost and facilities. The pH value itself may also be a useful and very simple indicator in the evaluation of silage quality.

The TDN content of the silage in treatment 1 was significantly higher than that in treatment 2 (Table 3). It was therefore concluded that large amounts of nutrients, especially NFE, were lost during the fermentation process in treatment 2. The voluntary intake of silage also decreased in treatment 2. Consequently, TDN intake in treatment 2 was about 68% of treatment 1.

**Table 3.** Body weight, feed intake and nutrient digestibilities with native cattle given Napier grass silage

<table>
<thead>
<tr>
<th></th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>Treatment 3</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bodyweight (kg)</td>
<td>166</td>
<td>166</td>
<td>166</td>
<td>0.4</td>
</tr>
<tr>
<td>DM intake (gDM)</td>
<td>4015a</td>
<td>3163b</td>
<td>3223b</td>
<td>48</td>
</tr>
<tr>
<td>Digestibilities (%) of</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>70.5</td>
<td>62.7</td>
<td>66.8</td>
<td>1.4</td>
</tr>
<tr>
<td>CP</td>
<td>71.7</td>
<td>60.8</td>
<td>62.3</td>
<td>1.8</td>
</tr>
<tr>
<td>NFE</td>
<td>70.1a</td>
<td>55.9b</td>
<td>61.8b</td>
<td>1.3</td>
</tr>
<tr>
<td>CF</td>
<td>77.5</td>
<td>74.5</td>
<td>77.1</td>
<td>1.3</td>
</tr>
<tr>
<td>TDN</td>
<td>71.8a</td>
<td>61.6b</td>
<td>66.9ab</td>
<td>1.3</td>
</tr>
</tbody>
</table>

**Notes:** a, b indicate means that differ significantly among treatments (p<0.05).

There was no difference in D-3-hydroxybutyric acid (BHBA) level between 0 hr and at 3 hr after feeding in cattle fed chopped silage (treatment 1). In contrast, BHBA level in cattle fed unchopped silage became higher after feeding (Table 4). It was considered that the difference of butyrate concentration in the silage influenced BHBA level in the blood. However, the physiological effects of butyrate on animals would be minimal even if cattle received such low quality silage for a longer period, as the values of BHBA and NEFA in blood were within the normal range and there was no change in glucose content.

**Table 4.** The Change of NEFA, glucose, total protein and BHBA contents in plasma of cattle given Napier grass silage, before and after feeding

<table>
<thead>
<tr>
<th></th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>Treatment 3</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEFA (mEq/l)</td>
<td>0.049</td>
<td>0.129</td>
<td>0.076</td>
<td>0.024</td>
</tr>
<tr>
<td>Glucose (mg/dl)</td>
<td>94.5</td>
<td>85</td>
<td>82</td>
<td>3</td>
</tr>
<tr>
<td>TP (g/dl)</td>
<td>5.78</td>
<td>6.05</td>
<td>5.91</td>
<td>0.21</td>
</tr>
<tr>
<td>BHBA (mM)</td>
<td>0.276</td>
<td>0.219</td>
<td>NA</td>
<td>0.012</td>
</tr>
</tbody>
</table>

**Key:** (1) NEFA = non esterified free acid; TP = total protein; BHBA = D-3-hydroxybutyric acid; Tr = Effect of treatment; Ti = Effect of time after feeding; T*T = Interaction between treatment and time after feeding.
Chopping of original grass before ensiling is highly recommended not only for making better quality silage but also for making better use of silo capacity. Proper preparation of silage minimizes the loss of nutrients during the fermentation process and increases voluntary intake, which results in higher TDN intake.

REFERENCE

Paper 9.0: Additives to improve the silage making process with tropical forages - Paulo R.F. Mühlbach

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INTRODUCTION

This contribution focuses on the ensilage of forages produced in tropical and subtropical climates. The low DM and WSC content of tropical (C₄) grasses results in poor fermentation of freshly cut material. Wilting could be beneficial, but during adverse climatic conditions wilting would need to be prolonged, which might lead to poor fermentation due to proteolysis by endogenous enzymes, which is reflected by a lower “true protein” proportion in the forage and, consequently, a higher ammonia-N proportion in the silage (Table 1). Use of certain additives may be an alternative to wilting, particularly with thick-stemmed, erect fodder crop grasses (*Pennisetum*, *Panicum*, etc.) that produce a large mass of plant material, where pre-conditioning and handling is difficult to mechanize and labour-consuming. Tropical forage grasses (*Cynodon*, *Brachiaria*, *Digitaria*, *Setaria*, *Chloris*, etc.) can be wilted more easily but, when wilted excessively it affects compression in the silo and thus fermentation quality (Catchpoole and Henzell, 1971). Even under controlled wilting conditions, additives are being recommended to improve fermentation and nutritive value of conventional as well as round bale silages (Bates, *et al.*, 1989; Staples, 1995).

In farm situations, silage making often faces drawbacks which compromise the basic principles of silage making, especially where technology is limiting, such as with small-scale producers in the tropics and subtropics (Bayer and Waters-Bayer, 1998). Additives can never be a substitute for good ensiling management. For example, additives will not make up for the negative effects on fermentation quality of tropical forages caused by practices such as the use of low quality, oxygen-permeable plastic covers, or extended storage under temperatures in excess of 30°C (Tjandraatmadja *et al.*, 1991).

It should also be emphasized that the efficacy of any additive will ultimately be assessed by animal performance and by DM recovery from the silo, which are parameters not commonly determined. Most of the experiments are restricted to measurements of traditional fermentation patterns under controlled laboratory conditions, where even untreated silages made from thick-stemmed *Pennisetum* species may show acceptable preservation (Woodard *et al.*, 1991; Spitaleri *et al.*, 1995). In contrast, bad fermentation products, such as biogenic amines that cause intake depression in ruminants (Phuntsok *et al.*, 1998) are not detected by conventional silage analysis. It has been suggested that the current parameters...
used to predict silage fermentation and quality may need some re-evaluation (Jones, 1995).

**BIOLOGICAL ADDITIVES**

Inoculants and enzyme preparations are regarded as natural products that are safe to handle, non-corrosive to machinery, and do not cause environmental problems. Consequently, their use has expanded remarkably in the last decades. Perhaps no other area of silage management has received as much attention among both researchers and livestock producers as bacterial inoculants (Bolsen, 1999). There are many commercial products with variable efficacy available. However, dosage and method of application are decisive for effectiveness.

**Inoculants**

Based on a survey of inoculant studies, Muck (1993) concluded that inoculants are most successful in alfalfa and temperate grass silages and that with corn [maize] silage their success has been limited. However, Bolsen (1999) emphatically recommended that bacterial inoculants should be applied to every load of forage ensiled, based on results from over 200 laboratory-scale studies and from 28 farm-scale trials where this type of additive consistently improved fermentation efficiency, DM recovery, food efficiency, and liveweight gain per ton of crop ensiled in corn [maize] and forage sorghum silages.

**Table 1. Effects of wilting on fermentation of tropical fodders**

<table>
<thead>
<tr>
<th>Forage</th>
<th>Silage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forage DM (%)</td>
</tr>
<tr>
<td></td>
<td>Elephant grass (120 days growth)^(1)</td>
</tr>
<tr>
<td>Unwilted</td>
<td>19.7</td>
</tr>
<tr>
<td>Wilted for 50 h</td>
<td>26.6</td>
</tr>
<tr>
<td></td>
<td>Millet (45 days regrowth)^(1)</td>
</tr>
<tr>
<td>Unwilted</td>
<td>16.0</td>
</tr>
<tr>
<td>Wilted for 48 h</td>
<td>31.0</td>
</tr>
<tr>
<td></td>
<td>78% Millet+ 22% Cowpea^(2)</td>
</tr>
<tr>
<td>Unwilted</td>
<td>20.8</td>
</tr>
<tr>
<td>Wilted for 26 h</td>
<td>46.2</td>
</tr>
<tr>
<td></td>
<td>60% Elephant grass+40% Cassava tops^(3)</td>
</tr>
<tr>
<td>Fresh</td>
<td>20.5</td>
</tr>
<tr>
<td>Wilted for 20 h</td>
<td>26.5</td>
</tr>
</tbody>
</table>

Notes: a, b indicate means within column differing at P< 0.05.


**Enzymes**
The addition of enzyme preparations either alone or combined with inoculants is proposed as a strategy to increase available substrate to improve lactic acid fermentation in silage or to increase nutritive value of forage, or both. With silages of temperate forages produced in subtropical conditions, an inoculant/enzyme mixture (Sill-All®) improved fermentation quality of unwilted forage oats (*Avena strigosa*) (Berto and Mühlbach, 1997) and reduced NDF contents of both unwilted and wilted alfalfa (Rangrab *et al*., 1996). The complex interactions occurring with the addition of both products is not completely understood and earlier results indicate varying degrees of success (Jaster, 1994). The first products were based on complexes containing ill-defined amounts of various enzymes from crude fermentations of fungi and results were inconsistent due to variable application rates, plant species, plant maturity and DM content of the materials (Muck, 1993).

Similarly, results have also been conflicting in experiments where enzymes were added to corn [maize] silage with no clear effects on fermentation characteristics, despite a decrease of ADF, NDF, and hemicellulose contents (Sheperd and Kung, 1996). Positive results with cellulase in combination with organic acid have been reported with the ensilage of temperate grass forages (Nadeau *et al*., 1996).

More recently, newer enzyme preparations have prompted a renewed interest in the potential of these products also as feed additives for ruminants, enhancing forage digestion and milk production (Yang *et al*., 1999; Schingoethe *et al*., 1999).

**Results with tropical forages**

If different types of additive suit different crops (Wilkinson, 1998) one should not expect that the effects achieved with biological additives on the ensilage of temperate forages will also be realized with tropical species, where fibre contents are generally much higher and more lignified. It stands to reason to consider that the constraints imposed by the structural, anatomical and chemical characteristics that are peculiar to tropical forages and which impair nutritive value, i.e. intake and fermentation in the rumen (Wilson, 1994, 1997), might also affect harvesting, wilting, chopping and compressing of the original material in the silo, as well as influence the direction of fermentation.

Whilst literature on the use of biological additives for temperate forages is relatively abundant, the information for tropical species is scarce. The data reviewed with this kind of additive is presented according to the type of tropical forage tested.

**Sorghum spp.**

Forage sorghum (*Sorghum bicolor* L.) is a fodder crop with a sweet juicy pith having types with finer, more numerous and more leafy stems (Bogdan, 1977). Of the tropical forages it is one of the best suited for ensiling.

When harvested at the soft dough stage (29% DM) it can have about 14% WSC and 50% NDF in DM, and after a 30-day fermentation period the silage can still present 10% WSC in DM. To such forage, a mixture of *Lactobacillus plantarum* and *Streptococcus faecium* (Pioneer brand® 1129) was added at $1.1 \times 10^5$ CFU per gram of fresh forage in a microsilo trial. Inoculation reduced silage pH but did not affect concentration or *in vitro* digestibility of NDF or ADF, neither did it prevent aerobic deterioration (Sanderson, 1993).

Froetschel *et al*., (1995) ensiled either untreated or inoculated forage sorghum harvested at the milk stage (61.5% NDF) in 900-kg capacity concrete tower silos. Silage lactic, acetic and total volatile fatty acids were increased 9.2 to 15.3%, and DM recovery was increased 7.1% with inoculation. The level of response was considered cost effective in a 1.7:1 return on investment based on average prices for silage and inoculant. In a feeding trial with steers, inoculation did not influence digestibility of DM or fibre components of silages and silage-based rations.
A sorghum-Sudan grass hybrid was harvested at 90 days of growth (26% DM) in Puerto Rico and ensiled in laboratory silos, either untreated or inoculated with $10^6$ CFU of *Lactobacillus plantarum* alone or mixed with a multi-enzyme complex containing arabinase, cellulase, β-glucanase, hemicellulase and xylanase, applied at 0.1% of fresh material. The addition of inoculant either alone or in mixture with the enzyme complex improved silage quality as shown by lower pH and a greater LAB population (Rodriguez *et al.*, 1994a). However, additives did not reduce aerobic deterioration of forage sorghum ensiled in a tropical environment (Rodriguez *et al.*, 1994b).

Similar results with the ensilage of *Sorghum bicolor* were obtained more recently by Cai *et al.* (1999), where selected strains of either *Lactobacillus casei* FG 1 or *Lactobacillus plantarum* FG 10 isolated from corn [maize] and *Panicum maximum* were used at $10^5$ CFU per gram of fresh matter. Both inoculants effectively improved fermentation, decreasing contents of volatile fatty acids and ammonia N and reducing gas production and DM loss as compared to the control silage. Again, the LAB-treated sorghum silages that contained relatively high concentrations of residual WSC and lactic acid suffered a faster aerobic deterioration than the control silage.

Johnson grass (*Sorghum halepense*) is a rhizomatous perennial, aggressive forage grass that can be established from seed for pasture and fodder (Mannetje and Jones, 1992). This forage was harvested at 45 (22.6% DM) and 110 days of regrowth (43.8% DM), chopped into 2.5-cm pieces, and ensiled in laboratory silos either untreated or treated with a mixture of *Lactobacillus plantarum* at a rate of $10^6$ CFU per gram of fresh material plus 0.1% of a multi-enzyme complex with arabinase, cellulase, β-glucanase, hemicellulase and xylanase (Rodriguez *et al.*, 1998). For both stages of regrowth, Johnson grass treated with microbial inoculant plus enzymes had lower pH and higher LAB populations and higher lactic acid contents than untreated silage. Silage additives also decreased butyric acid content in grass ensiled at 45 days regrowth, and reduced ethanol content in the more mature forage. However, the authors also concluded that the resulting silage did not meet the criteria for good quality silage, suggesting more research to evaluate other sources of additives, as well as the rates of additives used.

**Pennisetum spp.**

Elephant or Napier grass (*Pennisetum purpureum*) has thick, erect stems 2-6 m tall, with 30-120-cm long leaves and has been introduced to practically all tropical countries, being widely grown for fodder, and less often for grazing (Mannetje and Jones, 1992). Van Onselen and López (1988) reported on a trial from 1981 with the use of a commercial enzymatic product (sucrase and cellulase) added to elephant grass from a 105-day regrowth (19.4% DM) at a rate of 0.1% of fresh forage plus 0.9% corn [maize] meal. When compared to a control treatment with 7% corn [maize] meal the enzymatic product showed higher pH and ammonia-N values and a lower lactic acid content, resulting in a silage of bad quality.

A 60-day regrowth of elephant grass (14% DM, 70% FDN in DM) was ensiled in 200-litre plastic containers, testing the effects of two commercial products with bacteria and enzymes (Bio-Silo® and Bio-Silo P.U. soluble®, from Katec Kaíowa Ltda., Brazil). The product Bio-Silo was added at 0.1% of forage fresh matter plus 0.9% of corn [maize] meal, while Bio-Silo P.U. was diluted in water and also added at 0.1%, according to the manufacturer's recommendations. No effects of additive use were detected, neither on silage composition and pH and ammonia-N values nor on nutrient intake and digestibility coefficients measured with sheep (Henrique and Bose, 1992).

Tamada *et al.*, (1999) conducted experiments in different latitudes in Japan with different harvest dates of Napier grass and two silage storage temperatures to test the effects of a mixture of cellulosases (*Acremonium cellulolyticus* and *Trichoderma*...
viride) alone or mixed with a commercial inoculum (Lactobacillus casei, 10^8 CFU/kg wilted forage) and of a preparation of fermented green juice extracted from macerated Napier grass alone or mixed with the cellulases, as compared to a control. All treatments were applied to wilted Napier grass (averaging 22.7% DM and 4.6% WSC in DM) ensiled in 0.9-litre bottles; in two experiments, 40 g of glucose/kg wilted forage was included to each treatment with additive. Improved fermentations with lower pH values and ammonia contents and increased lactic acid over control were obtained only when sufficient fermentable substrate was secured by adding the cellulases or glucose.

Kikuyu grass (Pennisetum clandestinum) is a creeping perennial with strong, thick stolons, requires fertile soil, can be associated with white clover, but is not well adapted to high temperatures (Mannetje and Jones, 1992). De Figueiredo and Marais (1994) used wilted Kikuyu grass (30% DM, 3.2% WSC in DM) treated with inoculant alone (Lactobacillus acidophilus + Lactobacillus bulgaricus at 5 × 10^4/g grass ensiled) or in combination with two different enzyme preparations (either from Trichoderma reesei or from Aspergillus spp.). The best fermentation - with lower pH and ammonia-N and higher lactic acid - in micro-silos of polythene bags was obtained with the combination of inoculant plus the enzyme from T. reesei. In a second experiment, the authors used the same forage wilted (19.2% DM, 3.7% WSC) alone or with an inoculant (Lactobacillus plantarum strain MTD/1) alone and in combination with molasses meal (5 or 10% on a DM basis) at ensiling. The only significant effect as compared to untreated silage was a pH decrease with the inoculant combined to the 10% molasses level.

Pearl millet (Pennisetum americanum). A late summer crop of pearl millet grain hybrid (HGM-100) at the soft dough stage of grain maturity (18.9% DM, 60.2% NDF in DM) was wilted, treated with inoculant (Pioneer 1174®) and stored in a concrete stave silo. The resulting silage was poorly preserved, with a predominantly acetic fermentation (4.23% acetic acid in DM) and the need to add a low level of readily available carbohydrates was indicated (Utley et al., 1995).

Other genera

Bermudagrass (Cynodon dactylon) is a stoloniferous and rhizomatous perennial, growing in the tropical, subtropical and warm temperate regions, with cultivars that tolerate frosts (Mannetje and Jones, 1992). Wilted bermudagrass conserved as round bale silage is being used in the southeastern USA as an alternative to hay making, and some of the first tests with a combination of enzymes containing cellulase and an inoculant showed potential to improve fermentation and DM recovery (Bates et al., 1989).

A thorough study by Umaña et al. (1991) was conducted with bermudagrass cv. Tifton 81, harvested at the late jointing stage of growth and ensiled either unwilted (32.4% DM, 2.85% WSC in DM) or wilted (44.1% DM, 4.14% WSC in DM). Both materials were chopped and either left untreated or dried sugar cane molasses at 5% of forage DM added; inoculated with a mixture of Lactobacillus plantarum and Streptococcus faecium (1174 Pioneer ® at 3 × 10^5 CFU/g DM); prepared with a combination of the inoculant treatment plus the dried sugar cane molasses, all treatments being packed by hand in 19-litre plastic containers. According to the authors, all unwilted silages went through a less than satisfactory fermentation, whilst the application of molasses and inoculant to wilted bermudagrass had an additive effect and produced stable silages having the lowest pH, lowest concentration of ammonia, and greatest lactic acid concentration and in vitro organic matter digestibility. Hence, according to the Cooperative Extension Service from the University of Florida, adding a bacterial inoculant and molasses to wilted bermudagrass is more beneficial than adding just molasses or inoculant alone (Staples, 1995).
Rhodes grass (*Chloris gayana*) is a stoloniferous, creeping or occasionally tufted perennial that thrives under a wide range of tropical and subtropical temperatures (Mannetje and Jones, 1992). Ridla and Ushida (1998) used a first growth of Rhodes grass harvested at the heading stage (21.8% DM, 5% WSC and 66.4% NDF in DM) ensiled in 2-litre vinyl bottle silos. An inoculant with *Lactobacillus casei* was added at $10^5$ CFU/g fresh sample, either alone or combined with increasing levels of cellulases (‘A’ *Acremonium cellulolyticus* and/or ‘M’ *Trichoderma viride*). The combined treatment with inoculant plus enzymes showed lower pH values and higher lactic acid contents with increasing amount of cellulase addition. All combined treatments reduced NDF, ADF and *in vitro* DM digestibility of silages compared with the untreated silage, probably meaning that enzymes hydrolyzed especially the more digestible components of plant cell wall. The combinations inoculant plus cellulase ‘A’ were the most effective. A parallel test with fermentation temperatures suggested that samples incubated at 40°C resulted in better silages than those at 20° or 30°C. It was also concluded that the absence of effect in the inoculant treatment was due to the low WSC available in Rhodes grass. These same treatments were also applied to Italian ryegrass harvested at the heading stage (21.7% DM, 7.2% WSC and 59.2% NDF in DM) and the results on NDF and ADF disappearances of the inoculant and enzyme mixtures as compared to those with Rhodes grass suggest that the cell wall components in Rhodes grass silages were more resistant to degradation by the cellulases (Ridla and Ushida, 1999b). In general, within the various treatments for fermentation products and chemical composition, ryegrass produced better silages than Rhodes grass (Ridla and Ushida, 1999a).

Weeping lovegrass (*Eragrostis curvula*) is a densely tufted perennial, stems slender to robust, 30-120 cm high, drought-resistant (Bogdan, 1977). A six-week growth of this forage (37.8% DM, <2% WSC, 79.2% NDF) was ensiled unwilted, but treated with an inoculant/enzyme mixture (Sill-All® with *L. plantarum*, *S. faecium* and *Pediococcus acidilactici* at $10^6$ CFU/g fresh material) resulting in a silage with lower pH, ammonia-N, butyric and acetic acid content and a higher lactic acid content compared to the control silage (Meeske, 1998).

**FEED INGREDIENTS AND BY-PRODUCTS AS ADDITIVES**

The incorporation of easily fermentable feed ingredients such as sugar or molasses to low-DM, sugar-limited tropical forages is a way to improve silage fermentation. Feed-grade products such as grains in general and processed by-products such as corn [maize] or sorghum meal, rice bran, cassava meal, citrus pulp, etc., can also be used as additives, partly to provide fermentable substrate, but also to direct the course of fermentation by absorbing excessive moisture. To optimize their effectiveness by avoiding effluent losses, they have to be used in relatively high rates (aiming for a DM content >25% of the mixture) and adequately mixed with the chopped forage, which demands extra labour and/or appropriate equipment. This type of additive may be of seasonal and local supply, and cost effectiveness assessment should also consider the improvement achieved in nutritive value.

**Molasses**

Cane molasses (75% DM) has been widely used, added up to 10% w/w to provide fast fermentable carbohydrate for the ensilage of tropical herbages. Due to its viscosity, it is difficult to apply and should be diluted, preferably with a small volume of warm water to minimize seepage losses. When applied to tropical grasses, molasses should be used in relatively high concentrations (4 to 5%). With crops of very low DM content, a considerable proportion of the additive may be lost in the effluent during the first days of ensilage (Henderson, 1993).

However, according to Woolford (1984), the provision of extraneous sugar alone is not sufficient to permit the LAB to compete with other components of the silage microflora and thus ensure preservation. So, under high moisture conditions,
molasses can also induce a clostridial spoilage, especially with forages contaminated with soil.

Sugar cane molasses added at the rate of 3% (w/w, fresh basis) to Napier grass (12.9% DM, 6.6% WSC) produced silages of reasonably good fermentation quality, reducing, however, the nutrient recovery from the silo, as compared to formic-acid-treated silage (Boin, 1975). The same molasses dose also resulted in increased in vitro DM digestibility coefficients for Napier grass ensiled at 51, 96 and 121 days of vegetative growth (Silveira et al., 1973).

Dwarf elephant grass (cv. Mott) cut at 72 days regrowth (14.4% DM, 7.1% WSC) with a high buffering capacity, was treated with 4% molasses and ensiled in 4-kg polythene bags, with the resulting silage having lower pH and ammonia-N than the control silage (Tosi et al., 1995).

Four levels (0, 4, 8 and 12%) of dried molasses (97 % DM) were applied to chopped bermudagrass (32.4% DM, 70.2% NDF) pre-treated with 1174 Pioneer® silage inoculant (1.7 l/t of forage) and packed in 19-litre plastic containers. The increasing molasses levels lowered pH, ADF, and NDF percentages and increased in vitro DM digestibilities in bermudagrass silages (Nayigihugu et al., 1995).

Guinea grass (Panicum maximum) at 4- and 8-weeks old (18.6% DM, 26.5% DM, respectively) was ensiled untreated or with 4% molasses in 400-g laboratory silos. The pH varied from 4.4 to 5.4 and from 4.0 to 4.7, and ammonia-N ranged from 23.5 to 35.3 and from 15 to 39, respectively, for untreated and molasses-treated silages (Esperance et al., 1985).

Tjandraatmadja et al. (1994) tested the effects of 4% and 8% molasses added at the ensilage of Panicum maximum cv. Hamil, pangola grass (Digitaria decumbens) and setaria (Setaria sphacelata cv. Kazungula) harvested at 4, 8 and 12 weeks of growth. The results from a laboratory trial with 500-g vacuum-sealed silo bags kept in a dark, temperature-controlled room led to the conclusion that 4% (w/w) molasses should be sufficient to achieve effective preservation. Pangola grass, which had a highly significant different chemical composition prior to ensiling, with lower NDF and lignin content, presented a dominant homofermentative LAB population in silage, which was fairly well preserved even without molasses.

**Starch sources**

It is controversial to what extent starch is an available substrate for LAB (Woolford, 1984). Jones (1988) recovered 100 and 90% of starch from barley and oats, respectively, added at the ensilage of ryegrass, attributing an improved fermentation to the substrate available from 3 to 4% of soluble carbohydrates or from fractions such as β-glucan contained in the cereals, and not to a hydrolysis of starch.

The effects of adding molasses (5% w/w) or ground maize (5% and 10% w/w) to star grass (Cynodon nlemfluensis) alone or mixed with four levels (0, 15, 30, 45% w/w) of legume (Desmodium uncinatum) were studied in a laboratory trial by Sibanda et al. (1997). In general, both additives improved fermentation up to the level of 30% of legume inclusion, but addition of molasses resulted in lower levels of volatile N and higher lactic acid content compared to the control and both ground maize treatments.

A first growth of Napier grass was hand-harvested under rainy conditions (8.6% DM, 67.6% NDF), chopped to 3 cm, treated with 4% molasses and/or 15% de-fatted rice bran (2.0% crude fat) on a fresh grass basis and ensiled in plastic bags. DM contents of silages were 13.4%, 20.1% and 22.5%, and spoilage losses were 5.6%, 0.3% and 3.0% for treatments with molasses, rice bran and their mixture, respectively. Treatment with plain rice bran had the highest content of acetic (6.7% of DM) and propionic (1.4% of DM) acids and ammonia-N, but the lowest content of
lactic acid. The authors (Yokota et al., 1998) concluded that the combination of molasses and rice bran could improve the fermentation quality and enhance the utilization of the silage by goats, more than each additive as a single treatment.

Cassava (Manihot esculenta) tuber meal (72.1% WSC) and coconut (Cocos nucifera) oil meal (17.6% WSC) were both added (5% wet basis) to Guinea - A (Panicum maximum) with 17.7% DM and 6.3% WSC and to NB-21 (Pennisetum purpureum × Pennisetum americanum) with 16.3% DM and 9.9% WSC forages, chopped (1.5 cm) and ensiled in 2-kg laboratory silos. Both additives improved fermentation compared to untreated silages of both forages, with greater effects in silages with cassava tuber meal (Panditharatne et al., 1986).

Elephant grass was harvested at 75 days growth (19.4% DM, 72% NDF) and ensiled in 300-kg asbestos cement containers, either unwilted or wilted (29.6% DM), both materials with or without 8% ground sorghum grain (w/w). Wilting was achieved by exposing crushed forage stems three hours in windrow after harvesting with a New Holland mower-conditioner. Sorghum addition to both wilted and unwilted silage increased DM contents, reduced ethanol and acetic acid contents and increased intake of digestible energy as measured in sheep (Alberto et al., 1993). Silages of elephant grass cv. Guacu were obtained, adding 0, 8, 16 or 24% (w/w) either of ground ear corn [maize] with husks, wheat bran or “sacharin” (urea-treated sugar cane, with 12.6% CP, 17.5% crude fibre in DM) to unwilted forage (12.4% DM, 10.4% WSC) harvested with a precision chopper (3 mm chop length) and packed into 200-litre plastic containers with a layer of ground hay at the bottom to absorb effluent (Andrade and Lavezzo, 1998a). Ground ear corn [maize] was more effective in increasing DM content and restricting lactic acid production while reducing ammonia-N, which reached 31.3% and 36.2% for the “sacharin” and wheat bran treatments, respectively (Andrade and Lavezzo, 1998b).

The fermentation pattern of wilted elephant grass cv. Taiwan-A146 silage (8 hour wilting, 26.6% DM, 6.74% WSC) did not differ from silages made of unwilted grass (23.5% DM, 7.2% WSC) prepared with a cassava starch by-product added at 2, 4, 8 or 12% (w/w). According to the authors (Ferrari et al., 1999), the relatively low lactic acid levels demonstrate that the substrate was not available to LAB.

**Citrus pulp**

Fresh citrus peels have been added with levels up to 50% to the ensilage of Napier grass, improving fermentation quality as measured by low pH values and low butyric acid content and adequate lactic acid production (Faria et al., 1972). Citrus peel may contain 50% WSC in DM but the low DM content (14 - 21%) and intensive initial fermentation lead to high seepage losses, causing a serious pollution problem (Ashbell, 1992).

Dried citrus pulp added at the time of ensilage to low-DM forages may increase its weight by 145% by absorbing excessive moisture, thus preserving nutrients which otherwise would be lost by effluent and uncontrolled fermentation (Vilela, 1998). The DM, WSC and fermentation acids content of elephant grass silage was increased whilst pH was reduced with the use 0, 5, 10, 15 or 20% of dried citrus pulp (Faria et al., 1972). Levels up to 30% of dried ground citrus pulp were added to a 7-day regrowth cut of elephant grass, resulting in silages with a corresponding linear increase of DM content \( y = 0.49x + 24.0 \), a pH in a range from 3.49 to 3.68 and a linear decrease of ammonia-N (Evangelista et al., 1996).

**FORMIC ACID AND/OR FORMALDEHYDE TREATMENTS**

Commercial formic acid (85%) has been extensively used for the ensilage of unwilted temperate grasses, but is gradually being substituted by biological additives, certainly because it is dangerous in handling and application and corrosive to equipment. Information about the use of such additives on tropical forages is
limited to research data and no literature was found reporting farm-scale adoption.

Earlier studies by Boin (1975) on the ensiling of young, high-protein, low-WSC and -DM elephant grass have shown that a 0.8% rate of formic acid is needed for a reasonably good silage fermentation, while Vilela (1984) found no effectiveness based on silage composition when applying formic acid at various rates to unwilted or wilted elephant grass. In contrast, 0.5% formic acid treated elephant grass had not only an improved fermentation but also higher intake and digestibility compared to the untreated control (Silveira et al., 1980).

King grass (Pennisetum purpureum × P. typhoides) silage treated with formic acid (3.5 l/t) showed better fermentation quality than benzoic acid treated and untreated silages (Ojeda and Cáceres, 1984). In a review by Ojeda (1993) on the use of mineral or organic acids as well as of anti-microbials, it is concluded that for the ensilage of tropical forages, the kind of additive and application rate need to be determined specifically according to the type of forage.

Formalin (35-40% formaldehyde solution) has also been used as a silage preservative, especially aiming at reduced protein degradation in the silo and thus increasing undegradable protein in the rumen of silage-fed animals. Formaldehyde restricts considerably fermentation of silage: 0.8% formalin (w/w fresh basis) almost sterilized an ensiled mass of elephant grass and reduced digestibility of silage (Boin, 1975). A dosage of 0.5% formalin (w/w) applied to a mixture of elephant grass with cassava tops (20.3% DM, 8.5% WSC) reduced ammonia-N and increased precipitable protein in silage, however without suppressing a clostridial fermentation (Zanotelli and Mühlbach, 1989). Studies with a 70% formalin plus 26% formic acid plus 4% water mixture applied 0.2% (w/w) to elephant grass (13% DM), aiming at a rate of 4 g formaldehyde/100 g CP in the forage, resulted in poor fermentation quality and impairment of the nutritive value of silages produced (Lavezzo et al., 1984). Accurate formaldehyde rates necessary to improve fermentation in the silo as well as to obtain a protein protection effect in the rumen are difficult to achieve, especially under farm-scale conditions (Mühlbach and Kaufmann, 1979).

OTHER ADDITIVES

Salt

The addition of 1% sodium chloride to a mixture of wilted elephant grass and cassava tops (28% DM, 9.5% WSC) was not effective in improving fermentation of silage compared to the unwilted control (Zanotelli and Mühlbach, 1989).

Non-protein nitrogen additives

Non-protein nitrogen (NPN) additives, especially urea, when added to high-DM, low buffering forages (maize or sorghum grain) increase CP content and are claimed to improve aerobic stability of silage at feed out. In a review by Lavezzo (1993) on the use of urea as a silage additive for elephant grass, it was concluded that with low-DM forage and in the absence of additives rich in WSC, such a product should not be recommended when aiming at an improvement of fermentation. Generally, pH value, ammonia-N and acetic and butyric acid contents are increased. Singh et al. (1996) registered the highest pH values and ammonia-N levels, associated with higher anaerobic proteolytic bacterial populations, in Sorghum bicolor silages (34% DM) made with 0.5% urea. Other NPN sources, such as ammonium sulphate and biuret, either alone or in combination with urea, calcium carbonate or starch sources, have also been tested for their effects on silage fermentation, digestibility and intake. The results, as reviewed by Vilela (1984), do not favour their use as silage additives. According to Bolsen (1999), NPN always acts as a buffer during fermentation, requiring extra lactic acid to be produced to lower the pH enough for preservation, thus increasing DM loss.
Poultry litter

This waste product cannot be considered as a typical ensilage additive but has been mixed with easily fermentable forages as a means to increase CP content and to eliminate potential pathogens in litter through fermentation (Al-Rokayan et al., 1998; Rasool et al., 1998; Fontenot and Jurubescu, 1980). It can also be used to increase DM content of the ensilage of elephant grass (Lavezoz, 1993). It may present high protein together with a high ash content, which increases buffering capacity and may negatively affect fermentation. Almeida et al. (1986) ensiled elephant grass (20.3% DM, 7.9% WSC) together with 15% sugar cane and 5% broiler litter producing a silage of good fermentation quality; however the mixture with solely 10% litter produced silages with very high butyric acid content (2.36% of DM) and ammonia-N.

CONCLUSIONS AND RECOMMENDATIONS

- Biological additives, when applied to higher quality tropical forages that are more suitable to ensilage, such as forage sorghum, improve fermentation and reduce in-silo losses. However, silages are more liable to aerobic deterioration, demanding good feed-out management, particularly with large silos.

- With good quality (early growth stage) tropical pasture forages, which lend themselves to fast wilting, both wilting and biological additives (inoculant alone or in combination with an effectively proven enzyme mixture) can be recommended. Products so far tested, particularly with the ensilage of the thick-stemmed *Pennisetum* species, do not show consistent positive results regarding fermentation characteristics of silages. More field-scale research is needed to test additive effect on nutrient recovery with silage stored in small, well-sealed plastic silos, as might be realizable with small-scale producers. Biological additives are generally available as powders or granules, which need to be applied mixed with water to allow proper mixing with the forage. Under small-scale conditions, sprinkling homogeneously with a watering can could be an alternative to spraying with a metered liquid sprayer.

- High quality feeds and by-products are so far the best option found as additives for the hard-to-ensile forages such as the thick-stemmed *Pennisetum* and *Panicum* species. They may be relatively expensive, but cost-effectiveness should always consider the improvement in nutritive value of the ensiled forage. Molasses would be more adequate for wilted or higher DM (>25%) materials, while starch sources could be used alone, and also combined with molasses for the ensilage of low-DM, unwilted forages. Locally available and cost-effective absorbents such as dried citrus pulp can also be a good alternative.

- Additives with restricted use, such as formic acid, can improve fermentation but most probably will be neither cost effective nor realizable under small-scale conditions. More tests would be needed with other acids to determine dosage according to the type of forage. Formalin could be cheaper, but results with the ensilage of tropical forages have been inconsistent. NPN products are not the choice additives for low-DM, low-WSC forages; they could be used with wilted forage, preferably in combination with a readily fermentable substrate such as molasses.

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INTRODUCTION

Kikuyu grass (*Pennisetum clandestinum*) is a valuable forage resource for dairy and beef cattle in the coastal areas of eastern Australia. Production of wilted silages is often difficult due to wet weather during summer and autumn, the periods of maximum growth of Kikuyu pastures and when surplus material is available for conservation. Kikuyu grass is also low in the WSC required to support a lactic acid fermentation. As a result Kikuyu silages produced on farms are often characterized by low DM content, high pH and high ammonia nitrogen (N) levels, which indicate poor fermentation quality. Previous studies have shown that inclusion of molasses as a source of readily fermentable WSC has improved the fermentation of tropical pasture silages (Catchpoole and Henzell, 1971).

MATERIALS AND METHODS

Two experiments were done to determine if molasses could improve the silage fermentation of low-DM-content Kikuyu. In each experiment, 30-day regrowth Kikuyu pasture was mown using a conventional disc mower. Two field wilting treatments were compared. In the first, mown forage was left without windrowing (at near mower width) and then manually tedded (morning and afternoon) to maximize drying rate ('fast wilt'). In the second, forage was raked into windrows immediately post-mowing ('slow wilt'), simulating common Australian farming practice.

An unwilted control silage was made immediately post-mowing in both experiments. After each wilting interval, mown Kikuyu was collected and manually fed through a precision-chop forage harvester, and approximately 3 to 10 kg batches of fresh forage were ensiled in small plastic bag mini-silos (three units per treatment). Molasses (diluted 1:1 with water) was applied at varying rates (Table 1) to the material, using a watering can, just before ensiling.

RESULTS AND DISCUSSION

In both experiments silages differed significantly (P<0.01) in DM content, pH, and ammonia N content (Table 1). Ideal drying conditions in Experiment 1 enabled the fast wilt silages to be made after 6 hours and the slow wilt material after 28.5 hours.
Continual rainfall in Experiment 2 resulted in no drying and silages were made after 48 hours. The differences between silages in DM content in experiments 1 and 2 reflected effects of molasses treatment, initial forage DM (Experiment 1) and wilting treatment (Experiment 2).

In Experiment 2, the slow-wilt windrowed treatment seemed to retain more of the rainwater and there appeared to be more discoloration and yellowing of the forage compared to the fast-wilt material, which may be indicative of greater deterioration. Many of the silage ammonia N levels were very high (>150 g/kg total N) indicating severe degradation of the protein fraction. In general, silage fermentation characteristics were either poorer or unaffected as a result of the slow wilt treatment compared to the fast wilt. The greater difference in Experiment 1 was attributed to more favourable weather conditions that allowed wilting rate differences to be expressed.

### Table 1. Effect of molasses on the fermentation of Kikuyu silages

<table>
<thead>
<tr>
<th>Treatment (kg molasses/t fresh forage)</th>
<th>Experiment 1</th>
<th></th>
<th></th>
<th></th>
<th>Experiment 2</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DM content</td>
<td>pH</td>
<td>NH₃-N</td>
<td>DM content</td>
<td>pH</td>
<td>NH₃-N</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(g/kg)</td>
<td></td>
<td>(g/kg total N)</td>
<td>(g/kg)</td>
<td></td>
<td>(g/kg total N)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unwilted control</td>
<td>133</td>
<td>4.34</td>
<td>148.7</td>
<td>109</td>
<td>4.75</td>
<td>220.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast wilt</td>
<td>224</td>
<td>4.45</td>
<td>136.2</td>
<td>92</td>
<td>4.87</td>
<td>453.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>116</td>
<td>3.93</td>
<td>171.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>116</td>
<td>3.76</td>
<td>189.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>246</td>
<td>3.85</td>
<td>93.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>239</td>
<td>5.51</td>
<td>260.4</td>
<td>91</td>
<td>4.87</td>
<td>436.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>120</td>
<td>3.74</td>
<td>158.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>257</td>
<td>4.03</td>
<td>137.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>l.s.d. (P&lt;0.05)</td>
<td>11</td>
<td>0.10</td>
<td>15.6</td>
<td>9</td>
<td>0.13</td>
<td>58.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

Well-preserved silages should have an ammonia N concentration <100 g/kg total N (Wilkinson, 1990). Without additives it is difficult to produce adequately preserved silage from low-DM Kikuyu grass, particularly when prolonged and ineffective wilting occurs due to poor weather conditions. Our other research has shown that where weather conditions favour wilting, rapid wilting will produce satisfactory silage. Where low-DM silages are produced from rapidly wilted Kikuyu, silage ammonia N can be further reduced by the application of molasses. When unfavourable weather conditions prevail, molasses can produce large improvements in silage fermentation, but the level of application will need to be higher than that used in Experiment 2. Apart from improving silage preservation, molasses addition will also increase the metabolizable energy content of the silage.

**ACKNOWLEDGEMENTS**

We are greatly indebted to the Australian Dairy Research and Development Corporation and NSW Agriculture for funding this research, and for assistance from local dairy producers who provided access to land and equipment.

**REFERENCES**

INTRODUCTION

Tropical grass biomass increases with maturity, but decreases in nutritive value. To overcome this problem, these grasses are frequently ensiled at an early growth stage. However, young plants have a high moisture content, high buffering capacity and a low level of soluble carbohydrates. According to Woolford (1984), these factors have a negative influence on the fermentation process, preventing a rapid lowering of the pH and thus allowing unwanted secondary fermentation, consequently damaging the quality of the final product.

Assuming that the above problems are the main limitations to the ensilage of Napier grass, research was undertaken with the objective of finding practical solutions to enable the production of good quality silage from Napier grass.

Amongst the existing alternatives, the addition of dehydrated sugar cane to the Napier grass to be ensiled appears to be interesting, because it has high contents of DM and WSC.

The aim of this study was to evaluate the chemical and fermentation characteristics of the Napier grass silage with different levels of added dehydrated sugar cane.

MATERIALS AND METHODS

This experiment took place at the Forage Section of the Federal University of Ceará. The chemical and fermentation characteristics were studied of Napier grass silage with the addition of 0, 5, 10 and 15% of dehydrated sugar cane on a fresh material basis. The Napier grass biomass, approximately 80 days old, was chopped and mixed with the dehydrated sugar cane. The sugar cane was ground in a mill fitted with a 3-mm sieve. A replicated, completely randomized design was used.

Polyethylene laboratory silos were used, 100 mm in diameter and 340 mm deep. Sixty days after filling, the silos were opened and homogeneous samples of approximately 300 g were taken to determine DM, CP, pH and NH₃-N. Analyses of
RESULTS AND DISCUSSION

The DM content of the silage increased linearly with the addition of dehydrated sugar cane (Table 1). Almeida et al. (1986) and Tosi et al. (1989), studying the addition of sugar cane and sugar cane bagasse, respectively, in the ensilage of Napier grass, also observed a rise in the DM levels.

Table 1. Average value of the levels DM, CP, ammoniacal nitrogen (NH$_3$-N), pH and regression equations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sugar cane</th>
<th>Mean</th>
<th>Regression equations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0% 5% 10% 15%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% DM</td>
<td>21.2 25.2 27.5 29.9</td>
<td>25.9</td>
<td>Y = 25.9465+2.8442x R$^2$ = 98.05%</td>
</tr>
<tr>
<td>% CP</td>
<td>7.3 5.7 5.6 4.9</td>
<td>5.9</td>
<td>Y = 5.8895-0.6954x R$^2$ = 99.25%</td>
</tr>
<tr>
<td>NH$_3$-N</td>
<td>4.6 3.9 4.9 4.4</td>
<td>4.5</td>
<td>NS</td>
</tr>
<tr>
<td>pH</td>
<td>3.6 3.6 3.6 3.7</td>
<td>3.6</td>
<td>NS</td>
</tr>
</tbody>
</table>

CP levels decreased linearly with the addition of dehydrated sugar cane. Similar results were obtain by Almeida et al. (1986). Tosi et al. (1989), using sugar cane bagasse as an additive in Napier grass ensilage, observed that the CP level of the silages fell below 4%. This drop is due to the very low CP concentration in sugar cane bagasse (ca 2%).

We have not observed significant differences in NH$_3$-N and pH value between the silages. The quality of the silage without sugar cane was as good as that with. Almeida et al. (1986) and Tosi et al. (1989) also found that wilted Napier grass made well-preserved silage without sugar cane or bagasse.

CONCLUSIONS

From the data obtained in this study we can conclude that the addition of dehydrated sugar cane did not change the characteristics of the fermentation of the silages, but reduced its CP levels.

As the CP reached very low levels with the addition of the sugar cane, further studies are needed to evaluate the benefit of inclusion of a nitrogen source together with sugar cane.

REFERENCES


INTRODUCTION

Over a period of more than three months (September to mid-December, 1999) the participation in the Electronic Conference on *Silage Making in the Tropics* was good and sustained. There were 355 participants from 68 countries, 148 of whom were from Latin America, although only a limited number of contributions came from there. Ten invited main papers were supported by 26 submitted posters, and several comments stimulated a reasonable and sometimes lively discussion. It was an eye-opener to me and probably to many other participants in this conference to what extent silage making in the tropics has been advocated and tried. But a question remains: “To what extent is silage production being adopted by small-scale farmers?” At this stage, we cannot gauge how many small-scale producers are actually practising silage making.

ADOPTION BY SMALL-SCALE FARMERS

The contents of the papers and the posters show that silage making is generally known by scientists in the tropics, but that actual small-scale silage making activity is low, except in Malaysia (Chin and Idris) and China (Li Dajue and Song Guangwei). The reasons for non-adoption of this technology were presented for Pakistan (Hassan Raza), India (Rangnekar) and Thailand (Nakamanee).

The main reasons mentioned were:

- lack of know-how;
- lack of finance;
- silage making was considered cumbersome and labour intensive;
- benefits were not commensurate with effort and time;
- animals have a low genetic potential for production;
- cost and trouble of silage making did not provide adequate returns;
- lack of farm planning; and
- lack of available feedstuffs of good quality

It was also mentioned that farmers might be prepared to buy ready-made silage, which indicates willingness to feed it, but lack of time to prepare it.

It is clear that it is necessary to have trained extension staff and in order to involve farmers from an early stage in any pilot project for silage making. Only a participatory approach will lead to adoption of new technology that fits in with their system of farming; and availability of funds and labour. If farmers would like to feed silage but cannot adopt the technology, it may then be necessary to modify it in
close cooperation with the farmers to suit their needs and resources.

**MATERIALS TO ENSILE**

Anything that has feeding value can be ensiled. What actually is ensiled depends on availability and quality, but only good quality material should be ensiled, to ensure that costs will be reimbursed. Materials mentioned in this conference include:

- grasses;
- legumes (both herbaceous and edible material of woody species);
- fodder crops;
- crop residues;
- oil palm fronds;
- tomato pomace; and
- poultry litter.

**METHODS OF SILAGE MAKING**

For large farms, the temperate approach of mechanized methods and the use of large silos is also applied in Australia (Cowan) the Philippines (Montemayor, Enad and Galarrita) and Cuba (Ojeda). Small farms use plastic bags, containers or small bale wrapping.

**ADDITIVES**

Although a large range of additives is available, there is little evidence of their use on small farms in the tropics. If anything, molasses is used with materials having low sugar levels.

**CONCLUSIONS**

Silage making is possible and can solve nutritional problems on small as well as larger farms, but as with many innovations to overcome animal production constraints in developing countries, socio-economic problems frustrate general adoption. The main exception is Malaysia, where silage making has become part of a scheme of small-scale milk production and collection, providing a regular income to farmers. This may be a lesson in itself: technology of any kind will only be adopted if it can be part of production systems that generate income.

This conference has been useful because it has brought together and made available the knowledge and shown the constraints concerning silage making in the tropics.

**ACKNOWLEDGEMENTS**

The readiness of authors for a quick turn-round of edited papers and posters has made it possible to adhere to the time schedule. I thank them for their cooperation and enthusiasm.

Special thanks to Héctor Osorio, who has given excellent assistance in technical editing and preparing the material for distribution by e-mail and posting on the Website.

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During the conference there were some welcome comments from participants, which can be summarized under three main headings.

**PROBLEMS OF ADOPTION OF SILAGE MAKING IN THE TROPICS**

In the Introductory Paper, 't Mannetje (Paper 1) raised some doubts about silage making in the tropics, which stirred several participants to agree or to disagree.

Peter Wollesen (<darudec@darudec.dk>), writing from experience in Zanzibar, Somalia and Indonesia, mentioned that smallholders in these countries have excessive amounts of forage available in the wet season in the form of grass and foliage as well as various crop residues and by-products at the end of the growing season. In order to preserve these feedstuffs, ensiling or urea treatment would be necessary, but smallholders are not doing this to any extent because of problems of airtight and watertight storage, with plastic sheeting being too expensive. The use of plastic bags or plastic-lined empty oil drums would offer a solution, but these and the machinery for chopping are also expensive. Furthermore, the effect of the improved feeding strategy is not readily seen in the production of milk and meat, and that discourages the smallholders from continuing. Gilles Stockton (<gilles@midrivers.com>), also having worked in Somalia, found that there are a variety of forages during the rainy season, but a shortage during the dry season, despite the fact that the price of milk increased substantially at that time. He does not understand why fodder conservation is not practised.

Miguel Velez (<mvelez@zamorano.edu.hn>) agreed that silage is the best choice for conserving forage in the tropics, but disagreed on other points regarding the need for silage making in the tropics. He wrote that for the intensification of livestock production in the tropics, forage conservation is a must in most areas. Not only to improve milk production, but also for the fertility of the cows. Without good feeding, livestock improvement is impossible. In tropical regions with an extended dry season, supplementary feeding is necessary. According to him, farmers should not only conserve excess forage or crop residues, but they should plan to ensile forage early in the growing season.

't Mannetje (Paper 1) advocated ensiling sorghum or maize rather than tropical grasses with their low feeding value and low soluble carbohydrate contents, but Velez remarked that the crops require annual planting, pesticides, heavy machinery for harvesting and chopping and level land to avoid erosion. Boonman agreed with this. He considered the promotion of “special-purpose-fodder-crops” as a major impediment to silage making. These are full-season crops that compete directly with the land needed for cropping. Many farmers find the ensiling of staple food crops objectionable. Most important, however, mechanized maize silage making can be so
expensive that it is cheaper at times to harvest and feed the grain.

Wolfgang Bayer (<wb.waters@link-goe.de>) found that the smallholders he has dealt with (Africa, India, Eastern Europe) make hay quite often, even in very laborious ways, such as drying on a roof. Hay can be stored and transported more easily than silage. Boonman also made a strong plea for haymaking, which, he found, is not as problematic in the tropics as many believe. He considered that conservation of surplus grass provides fodder in the dry season and maintains a young, green sward in periods of excess growth.

Bayer pointed out that animals kept for manure basically have to survive, whilst draft animals, sometimes used only for several weeks or months need not be fat. These types of animals can also afford to lose weight in the dry season. When resources are scarce, silage making may not be a good proposition, because of the costs and losses involved.

Choi Chee Wong (<ccwong@mardi.my>) agreed with the introductory paper, but pointed out that there is much low-value fodder in the form of rice straw and oil palm fronds (see Poster 6.3 by Wan Zahari et al.), which will either be lost or can be ensiled or treated with urea to preserve them for later use and improve their quality. However, there is no adoption of the technology. He wonders whether the technologies generated are not relevant to the livestock farmers, or that the target group should be the more progressive farmers who are willing to put in some investment?

Suttie (<106162.757@compuserve.com>) remarked that the technology is available, at least for mechanized farms, so why is tropical silage not more widely used?

The problems of adoption of silage making technology were extensively dealt with in posters from Pakistan (Syed Hassan Raza - Poster 1.3) and from India by Rangnekar (Poster 1.4) and in comments by Andy Safalaoh (<ASafalao@nsnper1.up.ac.za>), working in Malawi. The main constraints are listed in the closing paper by 't Mannetje (Paper 10).

Boonman reminded us that farmers have done more for the development of new technology in livestock farming than scientists have. He blames the lack of cutting tropical pastures as a management tool in forage production on the reluctance of legume-oriented scientists to cut grass-legume pastures. In his opinion legumes cannot stand either cutting or grazing and therefore the proponents of legumes do not recommend silage making.

Elaine Lanting (<efl@ultra.pccarrd.dost.gov.ph>) from the Philippines observed that the benefits of silage cannot be overemphasized. This is particularly true in commercial cattle feedlot operations and in dairying, where it has great economic benefits. However, in smallholder farms where livestock fodder such as crop residues and weeds abound and can be used conveniently without costs involved, silage production/utilization has not found a place. In some areas, though, where green corn is the major product and farmers raise two or more ruminants or in small-scale dairying, silage may find its niche on smallholder farms.

Poornima Vyasulu (<danwytep@bgl.vsnl.net.in>), working with a farm women project in Bangalore, presented a very good case in point about the introduction of silage making to smallholders. In the first instance, she sought advice from the conference on silage making, as she is not familiar with farming practice. The main activities of her project are training women in agricultural techniques, extension services, organizing them into groups to support each other, buy farm inputs and obtain help from other government departments. Most women have holdings of 2-5 acres; most are in rainfed areas and practice 'complex, diverse and risk-prone' agriculture as a family livelihood. They are economically in the lower stratum, mostly illiterate and vulnerable. She wondered if silage making would have a place in this situation. She
received plenty of advice. Choi Chee Wong commented that smallholder farmers in Philippines did not adopt silage making because it involves cost and that she should first find out if silage making would be an option for these women. Rangnekar (<dattavr@wilnetonline.net>) pointed out that she should see if the level of milk production of the animals was adequate to respond to better feeding and if there is surplus green fodder available. Unless the women have better producing animals, they are unlikely to spend time and money on such technology.

Poornima Vyasulu replied that the conference had given her a steady stream of very professionally presented material on silage. She has begun to see some of the issues involved in silage making: the scale of operation, utility, suitable materials, processes, nutritional value, location-specific variations, etc. She can now understand why farm women of smallholdings have not taken to it so readily. Rural women apply very calculative cost-benefit analysis to everything they do and the way they perceive costs and benefits are not so easily discernible to us! She does not believe in ‘pushing’ any technology on farm women. Her approach would be to offer them information on a potential technology, assist them in adoption if needed but let them choose to do so.

**SILAGE FROM TROPICAL GRASSES AND LEGUMES**

Marion Titterton and Felix Bareeba (Paper 4.0) introduced silage making from tropical grasses and legumes, which also elicited comments from Chris Regan (<chris.regan@dpif.nt.gov.au>) who has had much experience with silage making of mixed legume-grass pastures in northern Australia. His general practice is to wilt to between 40-55% DM before baling and wrapping.

Alejandro Uribe-Peralta and Javier Bernal E. (<agronet@impsat.net.co>) from Colombia pointed out the heterogeneity of climatological conditions within the equatorial zones of the world, caused by differences in altitude. Colombia has three distinct equatorial zones: the high altitude (the Andes mountains), the shelf (the Andean mountains shelf), and the lower equatorial zones. However, even the high altitude zones of the world cannot be regarded as comparable. For example: the hours of sunlight in the high equatorial zones of Kenya, where Kikuyu grass originated, are 150% greater than those found at similar altitudes in the Colombian equatorial zones, where Kikuyu is also grown. This lower period of sunlight has lead to an abnormal distribution of the nitrogen fractions in Colombian Kikuyu grass, which has in some instances caused nitrate poisoning in cattle, a phenomenon not reported under Kenyan conditions.

**TECHNIQUES OF SILAGE MAKING FOR SMALLHOLDERS**

Smallholders do not favour pit or trench silos and stacks on top of the ground because it is difficult to cover them so that they are airtight and waterproof. To avoid these problems, bags, containers and wrapping of small bales are being advocated.

Ian Lane, who worked in northern Pakistan and in Nepal, presented a Poster (5.1) on Little Bag Silage and Shariffah Noorhani from Malaysia a Poster (8.1) on wrapping 30 kg bales of grass for smallholder livestock. Although this “sila-wrapping” is very convenient, the problem is the cost of the machinery, and rats tend to chew the bales, spoiling the silage. Chris Regan commented that this would be a good case for cooperation between smallholders or for someone to wrap bales at a small cost. In northern Australia the cost came to Aus$ 0.85 per bale. Bales are also handy for selling them to farmers, who do not make silage themselves.
THE CONFERENCE

The Electronic Conference on Tropical Silage ran for just over three months, from early September into December 1999. Altogether there were some 355 subscribers from 68 countries [Participants by FAO Region - Africa: 28; Asia 40; Europe: 72; Latin America and the Caribbean: 148; Near East: 7; North America: 20; Southwest Pacific: 25; and Unspecified: 15]. Details of the countries (by FAO region) of subscribers and contributors (papers and posters) are given in the table at the end of this section. There were 10 main papers and a paper summarizing the discussion, as well as 26 posters.

THE QUESTIONNAIRE

Sixty-one completed questionnaires were returned by the cut-off date. Assuming all participants received the questionnaire, this represents a return rate of just over 17%. Details of the countries (33) from which completed questionnaires were returned are given in the table below. The returned questionnaires have been analysed and results are presented below.

DETAILS OF PARTICIPANTS

Participants were mainly male (90%), in the 31 to 50 year old age group (61%) and predominantly academics (34%), researchers (26%) and consultants (16%). Only 3% were farmers and 3% extension officers.

THE CONFERENCE

Most participants were happy with the duration of the conference and the interval at which papers were posted (84% and 94% respectively). Although 97% indicated that the main papers covered their main interests in silage making, several respondents would have liked more information on smallholder silage production, with the focus on practical case studies, its integration into the farm system and economics. While 18% did not answer this question, 43% mentioned that they learned something from all or most of the papers, and others listed a number of specific papers that they found particularly interesting. Regarding the mechanics of such a conference, 98% of respondents were satisfied with the sending of papers by e-mail and their posting on the website.
Asked which papers or posters the participants found the most interesting, the five most frequently listed were: *The future of silage making in the tropics*, by ‘t Mannetje; *Grass and legume silage in the tropics*, by Titterton and Bareeba; *Silage fermentation processes and their manipulation*, by Oude Elferink *et al.*; *Little bag silage*, by Lane; and *Use of ensiled forages in large-scale animal production systems*, by Cowan.

Although the Proceedings are initially available in English, the language preference - if the Proceedings are translated in future - remained English (72%), followed by Spanish (22%) and then French (5%). This may, however, not represent the actual need on a worldwide basis.

**SILAGE MAKING**

Three-quarters (77%) of the respondents answered that silage making was practised in their area. In most of the developed countries silage making was widely practised on both large, medium and small farms (round bales and plastic wrap technology in addition to pit and tower silos) and both in the dairy (mainly) and beef sectors. In developing countries, silage making was mainly restricted to some of the larger (dairy) farms, except in Malaysia. In Thailand it was noted that in year 2000 it is hoped to demonstrate silage making to 600 smallholders. In Kenya, where 80% of the milk is produced by smallholders, it was recognized that there is a need to encourage greater adoption of silage (and hay) making.

Suggestions for increasing the uptake of silage making technology by smallholders in the tropics were:

- find least-cost, simple technologies;
- reduce costs and labour demands;
- make greater use of crop residues;
- reduce the negative impact of bad silage making by ensuring that basic principles of good silage making are understood and applied;
- reduce the moisture percentage before ensiling materials,
- use high quality materials and focus on grass/legume silage because inputs are likely to be much lower cost than maize/sorghum and other silages;
- the simple and cost-free process of wilting the source material prior to ensiling greatly enhances the quality of the silage and rate of success;
- farmers have often had poor experience because the material has been too wet;
- promote the use of molasses with tropical grass silage;
- focus on by-product silage production with simple technology (and variable formula depending on resources available) to ensure continuity of feed supply in the dry season (with benefits through more income, food security and less environmental pollution);
- intensify participatory research with farmers, especially in silage additives and machinery;
- develop techniques for production of small quantities of silage (e.g. little bag silage) which are practical and easy for small farmers to use and which can be developed in cooperation with the farmers to suit both
their environments and resources;

- in some countries, there may be scope for the development of silage making by smallholders for selling on to other farmers, peri-urban dairies, etc.;

- in Pakistan, it was suggested that silage making needs to be commercialized;

- several respondents suggested that because of the costs involved there was a need for government-sponsored silage-making projects;

- in the Northern Territory of Australia, there might be scope for smallholders to produce and sell small bale silage;

- silage contractor services with the necessary machinery would also fill a need;

- some countries identified specific research needs, such as Malaysia, where focus is needed on the promotion of oil palm frond silage for beef and milk production.

DISSEMINATION OF KNOWLEDGE.

More extension and demonstration activities and better training of extensionists in silage technology are needed since they are the key to better diffusion of the technology.

- There is a need for greater focus on participatory methodologies when introducing such technologies on farms;

- research-extension-farmer linkages should be strengthened;

- success stories should be publicized and demonstrated. Farmers can learn from other farmers and other countries by seeing success stories, for example, on video;

- constraints and economic benefits should be made more comprehensible to smallholders so they can see that the input of the extra labour and other inputs are justified. There is a need to demonstrate to farmers that well made silage pays off in increased returns;

- it was suggested to only target medium- to large-scale enterprises where economic conditions are favourable and farmers are more likely to adopt technology than small scale mixed farmers;

- farmers must first recognize a need (e.g. long dry season) and have on-farm evidence that feeding silage to livestock will result in benefits (i.e. economic returns);

- some respondents suggested that the technology is available, but there is need to apply and adapt it to various situations (by farmers themselves);

- case studies should be collected of where silage making techniques have been adopted by smallholder farmers and why; and

- a list of pre-conditions for successful silage making and the most appropriate techniques that can be expected to be adopted by smallholder farmers should be prepared.
SUGGESTIONS FOR PRIORITY ACTIONS

It was advocated that research organizations should evaluate technologies and the benefits of silage making/utilization under appropriate farmer conditions before widely recommending technologies; in particular simpler and less expensive methods of silage making for smallholders should be considered as costs are main factors restricting silage use and there is need to identify where silage making is profitable. In this respect one should be aware that silage making and use is likely to be tied to the accessibility to farmers of high value markets for animal products to compensate for the cost of inputs required.

It should be demonstrated that silage making can be an income generating activity for non-farm groups; local government officers/extension service should take the initiative to demonstrate the methodologies and benefits of silage making and establish pilot projects to demonstrate to farmers; practical programmes of on farm research and extension should demonstrate a range of model feeding systems based on ensiled by-product utilization; machinery should be developed for small-scale operations to facilitate wilting and fine-chopping. Research is needed to clarify which of the many additives are actually useful.

FINAL GENERAL COMMENTS ON THE CONFERENCE

Although in-depth analysis was lacking, the conference has been very useful for extension workers; this should be repeated in 2002 (and conferences on other topics held). There was excellent information in this conference on principles of silage making, but it really needs another conference to focus on the “practicalities” of getting smallholders to try out the technology. Conference material will be used in teaching at university and in preparing handouts for farmers; the idea of using posters was good as most were brief and very informative; a number of respondents noted that in addition to the formal papers, posters and discussion they had informal exchanges with other participants on various subjects.

Table 1. Geographical distribution of Contributors, Subscribers and Questionnaire Respondents, by FAO Region

<table>
<thead>
<tr>
<th>FAO Region</th>
<th>Contributors (Papers and Posters)</th>
<th>Subscribers</th>
<th>Questionnaire Respondents</th>
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<td>India, Malaysia, Pakistan, the Philippines, Thailand, Viet Nam</td>
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<td>Austria, Belgium, Denmark, France (incl. La Reunion), Finland, Germany, Malta, the Netherlands, Portugal, Spain, United Kingdom, Yugoslavia</td>
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<td>Latin America and the Caribbean</td>
<td>Brazil, Chile, Costa Rica, Cuba, Uruguay</td>
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<td>Argentina, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Honduras, Mexico, Peru, Venezuela</td>
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<td>Canada, USA</td>
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<td>Southwest Pacific</td>
<td>Australia, Fiji, New Zealand, Papua New Guinea</td>
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FAO PLANT PRODUCTION AND PROTECTION PAPERS

1. Horticulture: a select bibliography, 1976 (E)
2. Cotton specialists and research institutions in selected countries, 1976 (E)
3. Food legumes: distribution, adaptability and biology of yield, 1977 (E F S)
4. Soybean production in the tropics, 1977 (C E F S)
4. Soybean production in the tropics (first revision), 1982 (E)
5. Les systèmes pastoraux sahéliens, 1977 (F)
6. Pest resistance to pesticides and crop loss assessment - Vol. 1, 1977 (E F S)
8. Tropical pasture seed production, 1979 (E F** S**)
9. Food legume crops: improvement and production, 1977 (E)
11. Pesticide residues in food 1965-78 - Index and summary, 1978 (E F S)
12. Crop calendars, 1978 (E/F/S)
13. The use of FAO specifications for plant protection products, 1979(E F S)
14. Guidelines for integrated control of rice insect pests, 1979 (Ar C E F S)
15. Pesticide residues in food 1978 - Evaluations, 1979 (E)
16. Rodenticides: analyses, specifications, formulations, 1979 (E F S)
17. Agrometeorological crop monitoring and forecasting, 1979 (C E F S)
18. Guidelines for integrated control of maize pests, 1979 (C E)
19. Elements of integrated control of sorghum pests, 1979 (E F S)
20. Pesticide residues in food 1979 - Report, 1980 (E F S)
20. Pesticide residues in food 1979 - Evaluations, 1980 (E)
21. Recommended methods for measurement of pest resistance to pesticides, 1980 (E F)
22. China: multiple cropping and related crop production technology, 1980 (E)
23. China: development of olive production, 1980 (E)
24/1. Improvement and production of maize, sorghum and millet - Vol. 1. General principles, 1980 (E F)
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108  Carambola cultivation, 1993 (E S)
109  Soil solarization, 1991 (E)
110  Potato production and consumption in developing countries, 1991 (E)
112  Cocoa pest and disease management in Southeast Asia and Australasia, 1992 (E)
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114  Integrated pest management for protected vegetable cultivation in the Near East, 1992 (E)
115  Olive pests and their control in the Near East, 1992 (E)
117  Quality declared seed, 1993 (E F S)
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120  Weed management for developing countries, 1993 (E S)
121  Rambutan cultivation, 1993 (E)
122  Pesticide residues in food 1993 - Report, 1993 (E F S)
123  Rodent pest management in eastern Africa, 1994 (E)
124  Pesticide residues in food 1993 - Evaluations - Part I: Residues, 1994 (E)
125  Plant quarantine: theory and practice, 1994 (Ar)
126  Tropical root and tuber crops - Production, perspectives and future prospects, 1994 (E)
127  Pesticide residues in food 1994 - Report, 1994 (E)
129  Mangosteen cultivation, 1995 (E)
130  Post-harvest deterioration of cassava - A biotechnology perspective, 1995 (E)
131/1 Pesticide residues in food 1994 - Evaluations - Part I: Residues, Volume 1, 1995 (E)
132  Agro-ecology, cultivation and uses of cactus pear, 1995 (E)
133  Pesticide residues in food 1995 - Report, 1996 (E)
134  (Number not assigned)
135  Citrus pest problems and their control in the Near East, 1996 (E)
136  El pepino dulce y su cultivo, 1996 (S)
137  Pesticide residues in food 1995 - Evaluations - Part I: Residues, 1996 (E)
138  Sunn pests and their control in the Near East, 1996 (E)
139  Weed management in rice, 1996 (E)
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