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Forage Conservation and Utilization

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Forage conservation allows the intensification of dairy farming with a higher stocking rate than using nutrients from grasslands and harvested forages only. Different methods of foraging and their problems, especially losses in dry matter and energy, are presented. Nutritive value of conserved forages has a direct relation to animal production and land productivity. The author also reports preliminary experiments in small-scale silage making of maize in Uganda.

The supply of nutrients from grasslands and harvested forages is seasonal in Uganda because of the rainfall pattern. During the rainy season, there is luxuriant growth of pastures and during the dry season, pasture is very scarce with a resultant decline in animal performance. Hence the need to conserve forage to bridge the nutrient gap during periods of scarcity. Forage conservation allows for intensive dairy farming with a higher stocking rate than would otherwise be possible. The principles of drying (hay) and fermentation (silage) have been used by many farmers in developed countries to conserve feed.

Hay Making

The objective of hay making is to achieve a rapid moisture loss after cutting so that the forage can be removed from the field with minimum losses from weathering and microbial degradation. The degree of success in hayfield operations also has a tremendous effect on storage characteristics of the hay and the proportion of original forage nutrients available for feeding.

The rate at which a forage dries in the field depends mainly on vapour pressure differences between the ambient air and the swath environment and forage tissue characteristics. Thus water loss is rapid initially but slows as drying progresses. Three-quarters of the water may be lost in the first one fifth of drying time with the final drying rate being less than one hundredth of the initial rate (Pitt and Shaver, 1990). Conditioning equipment that abrades, crushes or lacerates the forage has been used to reduce crop resistance to water loss. Swath dimensions, structure and density, and frequency of tending and turning affect the water content and its location within the swath. Physical redistribution of the forage in the swath is more beneficial to drying rate when dry matter is below 70%, rather than above. There are large differences in drying rate among grass species with leaf: stem ratio accounting for a significant amount of variation.

Losses of nutrients in the field result in substantial changes in forage quantity and quality. These losses are associated with the following processes:

1. Plant respiration: Respiration converts sugars to water and carbon dioxide, decreasing the energy content and increasing the cell-wall content. Respiration intensity decreases with increasing forage DM (dry matter) and increasing ambient temperature (Pitt and Shaver, 1990). During field drying in daylight, some of the respiration loss is offset by the photosynthetic activity of the forage. However, this compensation is likely to be insignificant compared to field loss. A rapid attainment of baling moisture is desirable in order to limit respiration losses.

2. Mowing/conditioning, raking/tending and baling: Mechanical loss represents forage not picked up during the harvesting operation. It increases with the degree of fragmentation during mowing or conditioning, turning, final winnowing and loading. In contrast to respiration losses, fragmentation is most severe during the final stages of drying. Loading loss is also

affected by the setting and ground speed of the baler. Normally, mechanical losses are higher for legumes than grasses because in the case of legumes the leaf dries faster than the stem, resulting in greater leaf shattering. These losses are especially detrimental to forage quality because the leaves contain most of the crop nutrients.

3. Rain damage: Rainfall during the field drying period not only prolongs the drying time but also results in a direct loss of soluble nutrients through leaching. It also prolongs respiration and can cause losses by shattering leaves, especially in legumes. The extent of leaching loss is influenced by several factors including forage moisture content at the start of the rainfall, amount of rainfall, number of rains and mowing or conditioning treatments. Estimates of total field losses during hay making can range between 4 percent and 60 percent of the forage dry matter. Weather is the most important factor influencing drying losses.

Losses during hay storage are caused by continued plant respiration, the activity of micro-organisms and chemical oxidation. The magnitude of storage losses are also influenced by a multitude of factors including initial storage moisture, storage facility or site (barn, stack, plastic cover etc.), artificial ventilation (drying) bale size and density and length of storage. Losses in the order of between 3 percent to 7 percent of the DM entering storage have been reported (Bolsen, 1985). Under the worst circumstances, heat produced by continued respiration after baling, in the presence of sufficient hay moisture and oxygen, may encourage thermophilic microbial activity, chemical oxidation of plant tissues and spontaneous combustion.

Hay making will always depend on the uncontrollable factor of weather and there has been little progress in reducing this dependency. However, preservation techniques could minimise this risk by allowing hay to be baled at higher moisture levels, thus reducing field and storage losses and increasing nutritive value. Employing preservatives with moist hay could lengthen the hours for optimum baling and reduce fragmentation from overdried swaths. Propionic acid, ammonia and urea are among the many chemicals which have successfully reduced field and storage losses in moist hay under research conditions.

The moisture levels for safe and efficient storage of hay are not well defined. Such factors as forage species, bale type, size and density, method of storage and time between baling and placing the hay in storage all affect the optimum storage moisture.

Silage Making

The objective of silage making is to preserve the harvested crop by anaerobic fermentation with minimum loss of nutrients. The process involves converting soluble carbohydrates to lactic acid which drops the pH to a level sufficient to inhibit any further biological activity in the ensiled forage mass.

Silage is popular because: it is much less weather-dependent than hay making, it is more suitable than hay for large-scale livestock production and it is adaptable to a wider range of crops, i.e. maize, sorghum, grasses and legumes.

The ensiling process is often described as one of minimising nutrient losses and changes in nutrient value. Good silage is achieved by discouraging the activities of plant enzymes and undesirable micro-organisms and encouraging the dominance of lactic acid bacterial. In the initial stages of ensiling, plant respiratory enzymes oxidize water-soluble carbohydrates (WSC) resulting in heat production and decreasing sugars available for fermentation. Plant proteases hydrolyse proteins to non-protein nitrogen (NPN) forms such as peptides and free amino acids. Silage's containing high amounts of NPN usually do not support optimum animal production.

The undesirable micro-organisms are primarily clostridia, coliforms and yeasts. They compete with lactic acid bacterial for WSC and many of the have no preservative action. The clostridia are responsible for secondary fermentation which can convert lactic acid to butyric acid and degrade amino acids to amines and ammonia. This fermentation results in both dry matter (DM) and energy losses and decreased silage intake by animals. Yeasts are also linked to aerobic deterioration, particularly during the silage feedout period. Growth of certain moulds, e.g. Fusarium and Aspergillus sp., on silages can produce mycotoxins, which are harmful to cattle. (McDonald, 1981).

The ensiling process is influenced by a multitude of factors, both biological and technological. Many of these factors are interrelated and it is difficult to present their significance individually. However, there are two dominant features of every silage: the nature of the crop and the technology (management and knowhow) imposed by the farmers. If a stable pH is to be achieved without using additives, then the chemical composition of the crop is of particular importance. The fermentable sugar or WSC content has been used to predict the suitability of a crop for silage (McDonald, 1981); when crop DM is high enough, good silage can be produced irrespective of WSC but when DM and WSC are both low, the silage is usually poor. Maize has been regarded as the "near-perfect" silage crop. Its nutrient digestibility and DM yield/ha. plateau during the soft dough to hard dough stages are good, and its DM content is in an ideal range of 25–40 percent for 3 to 4 weeks during the harvest season. Sorghum and elephant grass are also good silage crops. Legumes have low WSC and this coupled with a high buffering capacity makes them difficult to ensile. Hence it is advisable to ensile legumes in mixtures with grass.

The control of silage fermentation within predictable boundaries at the farm level is the biggest challenge to improving nutrient conservation and utilisation. Major efforts have been made to control silage fermentation with additives. The use of chemicals such as formic acid, formaldehyde or sulphuric acid to prevent clostridial fermentation and to achieve a satisfactory silage has been a common practice in Europe. There is renewed interest in the use of bacterial inoculates to improve the efficiency of the ensiling process (Muck, 1988). However, these chemicals are too costly to be used in developing countries.

The DM losses from silage making can be divided into two categories: unavoidable and avoidable. Unavoidable losses include the loss in the field, plant respiration and primary fermentation. Avoidable losses include effluent from the silo, secondary fermentation and aerobic detorialation. Estimates of unavoidable losses range from 8 percent to 30 percent. Avoidable losses from 2 percent to 40 percent or higher. The importance of quickly achieving and maintaining oxygen-free conditions has led to improved equipment and techniques for precision chopping, better consolidation, rapid filling and complete sealing. Delayed silo filling inadequate sealing (i.e. in bunker, pit and clamp silos) predispose silage to high respiration losses, surface wastes and aerobic losses during the feedout period.

The DM content of the crop and silo type have the greatest effects on insilo losses. Solid construction of silos to minimise air entry, in combination with harvesting crops at higher DM will reduce both insilo losses and variation in silage quality

Under farm conditions, aerobic losses which occur after a silo is opened for feedout may exceed the combined losses from other sources. To minimise these losses, silos should be sized so that a sufficient depth (1030 cm) is removed from the silo each day and a compact silage face is maintained. Propionic acid and ammonia have been used to stop or reduce aerobic microbial activity but they are expensive. Maintaining an anaerobic environment is still the cheapest and most efficient means of reducing this problem.

Silage Making Without Technical Equipment

Advanced technical equipment for silage making, such as forage harvesters and chaff cutters, is expensive and not readily available to most farmers in Uganda. For these farmers to benefit from the advantages of silage feeding other cheaper and simpler methods must be found.

Investigations into small-scale silage making were carried out. In one trial, maize was harvested at dough stage (25–27 percent DM) and ensiled in six 1-ton pit silos. Two pits were filled with the maize chaffed by machine. In each of these treatments one pit was ensiled without additives and the other with 5 percent molasses added. The labour input for cutting the maize by hand and filling the silos was recorded. Labour involved in transporting the maize from field to silo was not included as this will vary from farm to farm. Cutting in the field needed 4 man-hours per ton. Chopping with a panga needed 25 man-hours per ton making a total labour input of 29 man-hours per ton. Excluding transport it thus took 4 man-days to ensile one ton of green maize. This input is not prohibitive especially if unutilised family labour could be employed. Chopping of elephant grass with a pangas is much slower than chopping maize and requires about 6 man-days per ton of green grass.

The quality of the silages when opened after 3 months of ensiling is given in Table 1.

The DM losses were fairly high in all silages, partly due to rain-water seepage into the silos. Addition of molasses had little effect on whole plant silage and most of the silage was mouldy and inedible. Cutting with the panga improved the silage considerably, especially with the addition of molasses. The silage made from chopped material was very good with molasses and fairly good without molasses.

In another trial, maize cut with a panga was ensiled using four different additives: 5% molasses, 10% molasses, 10% molasses-wheatbran (50:50) and 0.25% formic acid. The results (Table 2) showed good silages in all cases. An additive is necessary as panga-chopped material does not compact as well as finely chopped material. The results also indicate that if molasses is used as the only additive, as much as 10 percent (wet basis) should be used. The molasses wheatbran mixture was included as it is easier to handle than liquid molasses. The mixture proved to have the same effect as 10 percent molasses. Formic acid gave the best results but this is too expensive and unavailable to most farmers.

Nutritional Value of Conserved Forages

The nutritive value of hay and silage is ultimately determined by animal production (live weight gain, milk production, or wool yield) which is a function of voluntary intake, digestibility and nutrient adequacy of the forage or ration. The best available crops should be used for silage and they should be harvested and ensiled to conserve them at their optimum stage of maturity in terms of DM digestibility. When nutritive value is combined with net harvested forage yield and net hay or silage after conservation, it is possible to measure land productivity as the amount of product marketed/ha.. Feeding of a supplement is essential to maximise silage utilisation.

Conclusion

A well organised, efficient forage system should include a knowledge of the nutrient requirements of the livestock, harvesting the crop at its optimum stage, the necessary capacity and combination of equipment and suitable storage conditions. The animal production potential of a highly nutritious crop can be compromised lost entirely to poor conservation techniques. In addition to preserving the forage with minimum DM and energy losses, practices which reduce the amount of soluble nitrogen in silage and heat-damaged protein in hay must be encouraged. Hay making must be made less dependent on the weather and the risks of poor silage fermentation must be minimised.

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Appendix

Table 1. *Silages made from maize whole plant, cut with a panga or chopped by machine with and without additional molasses*

Technique Green material	Additive*	Material ensiled Green kg	Material ensiled DM kg	Material ensiled CP kg	Edible silage Silage kg	Edible silage DM kg	Edible silage CP kg	Recovery DM %	Recovery CP %	pH of Silage
Whole plant	-	650	185.3	17.2	456	99.0	9.8	53.4	57.0	4.80
	+	650	201.9	17.5	581	124.9	11.9	61.9	64.4	4.00
Cut with panga	-	650	172.9	16.0	500	111.0	10.4	64.2	64.9	4.70
	+	700	203.0	17.9	630	143.0	13.2	70.4	74.0	3.85
Chaffed	-	740	196.8	18.4	702	148.1	13.8	75.3	75.0	3.85
	+	1000	295.0	25.4	1010	236	21.1	80.1	83.2	3.80

DM=dry matter
CP=crude protein

Table 2. *Silages made from maize cut with a panga and ensiled with different additives*

Additive	Material ensiled Green kg	Material ensiled DM* kg	Material ensiled CP* kg	Edible silage Rec. kg	Edible silage % of total	Edible silage DM kg	Edible silage CP kg	Recovery DM %	Recovery CP %	pH
None	486	131.1	11.25	378.5	80.3	89.7	6.80	68.4	60.4	4.20
5% molasses	460	152.2	12.39	455.6	92.2	121.6	9.73	79.9	78.5	4.20
10% molasses	520	189.8	14.73	576.7	96.4	155.7	12.53	82.0	85.1	3.90
10% molasses/ wheat bran	520	194.5	16.62	567.5	97.6	161.2	14.12	82.9	85.0	3.95
0.25% formic acid	500	139.5	11.75	518.0	96.6	130.0	10.47	93.1	89.1	3.85

*DM and CP from additives included