9

Making quality silage

This chapter:

Explains the benefits of conserving excess forages as silage, the important principles of consistently making quality silage and how to calculate the size of the silage storage.

The main points in this chapter:

The 10 steps to making quality silage are:

- harvest the forage when excess to feed requirements and high in quality
- wilt the forage to 30% DM
- add a fermentable substrate at ensiling
- chop the forage into short lengths (1–3 cm) before ensiling
- compact the forage as tightly as possible
- complete the entire storage as quickly as possible
- seal storage air tight as soon as possible after filling
- maintain airtight seal until feeding out
- feed out a whole face of the storage to a depth of at least 20 cm each day
- if the silage is unsatisfactory, determine the reason for the next season.

Silage allows the long term storage of a variety of wet agro-industrial by-products.

Excess forages can be conserved as hay or silage. However, ensiling generally produces better quality roughage than hay because less time is required to wilt the feed, when the forage loses nutrients, causing a reduction in feed quality. Hay making requires a longer period of rain-free days, which are often rare in the tropics during the wet season when feed excesses generally occur. This manual will not discuss hay making.

The principles of silage making are the same regardless of size of operation, the major difference being in the type of storage used (Mickan 2003). However, the mechanics of silage making (labour, timing, resources) for individual small holders are completely different to those in larger communal farms, where labour and other resources can be shared or amalgamated for efficiencies of size of operation.

9.1 What is silage?

Silage is forage, crop residues or agricultural and industrial by-products preserved by acids, either artificially added or produced by natural preservation, in the absence of air. It must be emphasised that air is the biggest enemy of silage.

Ensiling is the preservation of a forage (or crop residue or by-product) based on a lactic acid (ideally) fermentation under anaerobic (no air) conditions. The lactic acid bacteria ferment the plant sugars (water soluble carbohydrates) in the crop to lactic acid, and to a lesser extent to acetic acid. The production of these acids reduces the pH (acidity) of the ensiled forage which inhibits spoilage microorganisms (due to their reduced activity). However, if ensiled under incorrect conditions, different and poorer quality fermentations can occur, producing other acids such as butyric acid, resulting in unpalatable and lower quality silages.

9.1.1 The four phases of silage making

Once the fresh material has been harvested, chopped, compacted and well sealed, the ensiling process then begins and undergoes four phases.

Phase 1 Aerobic phase

Any oxygen trapped between the forage particles is eliminated as a result of the respiration ('breathing') of the plant material and the aerobic (with air) activities of yeasts and bacteria. The plant enzymes are also active during this phase, provided the pH is still within the normal range for fresh material (pH 6.0–6.5). This phase may take a few hours only, provided the forage is well compacted and sealed as soon as possible after harvest.

Practical aspects of the aerobic phase:

- fill the storage site quickly (1–2 days)
- chop the material as short as possible (1–3 cm)
- compact the storage container as well as possible, as fingers should not be able to be inserted into the compacted forage
- seal the storage container air tight
- weight the top of the stack to maintain an airtight seal between the cover and compacted forage
- seal as soon as possible after harvesting is completed.

Phase 2 Fermentation phase

This stage begins once the oxygen is gone and the storage becomes anaerobic. Depending on the properties of the ensiled crop and the ensiling conditions, this phase may last several days to weeks. A successful fermentation will see the number of lactic acid-producing bacteria dominate, reducing the pH to 3.5 to 4.5. The lower pH level may be achieved in unwilted material whereas the higher levels are from wilted forages.

Practical aspects of the fermentation phase:

- mix molasses (at 3–5% on wet basis), a substrate source for the bacteria, to encourage lactic acid fermentation
- If possible, wilt forage to preferably about 30% Dry Matter (DM).

Phase 3 Stable phase
Once the pH level has dropped, and air and water is not permitted to enter the storage site, most microorganisms of phase 2 slowly decrease in numbers, resulting in a silage which is relatively stable. However, some acid tolerant microorganisms survive this period in an almost inactive state, along with others such as *Clostridia* and bacilli which survive as spores.

How to conduct the stable phase:

- Maintain an airtight seal around the silage
- Repair holes as soon as they are noticed.

Phase 4 Feed out phase or aerobic spoilage phase
This phase begins when holes are made in the storage site by mice, birdsor other agents or it becomes uncovered for feeding out. The aerobic spoilage phase occurs in two stages. Deterioration begins through degradation of the preserving organic acids by yeasts and occasionally acetic acid bacteria. This results in a rise in the pH and then the second stage of spoilage begins. This is associated with increasing temperature in the silage and activity by spoilage microorganisms such as bacilli, moulds and enterobacteria.

The rate of spoilage is highly dependent on the numbers and activity of the spoilage organisms in the silage and may be in the range of 1.5% to 4.5% DM loss/d.

Practical aspects of the aerobic spoilage phase:

- maintain an airtight seal
- feed out to ensure about 20 to 30 cm removal from the entire silage face each day
- if the silage gets hot, feed it out at a faster rate
- if silage heating occurs, consider a smaller stack face next harvest.

9.2 Why make silage?

All the major forages (grasses, forage legumes, tree legumes, by-product forages) can be stored as silage. Rice straw is sometimes mixed with very moist forages, to reduce effluent losses, but this results in a poorer quality silage. Rice straw could be used at the bottom of a silage pit, to absorb the highly polluting silage effluent.

Unfortunately tropical forages and legumes are not well suited to ensiling due to their inherent low concentrations of water soluble carbohydrates (ie sugar, or one of the storage carbohydrates mentioned in Chapter 4), compared to temperate species. However, rapidly wilting the forage or adding a fermentable substrate, such as molasses before ensiling, will usually result in well-fermented silages.

During the wet season, the tropical forage species grow very fast, with forage yields often exceeding animal requirements. If not cut and fed, it will continue to grow, producing very long and fibrous material, low in energy and protein.

If this forage was harvested and successfully stored as silage at the same stage as it is cut for producing milk, then it could be fed back during the following dry season. Although the quality of the forage will be slightly lower than its fresh state (10–15% lower in good ensiling conditions), it will still be better quality than many of the forages only available for dry season feeding. Conversely, in some locations, the silage can supplement other good quality but very slow-growing forages.

9.3 Silage storage systems

Silage can be stored in small plastic bags, 120 to 200 L plastic and steel drums (plastic lined or bagged), small or large pits dug into hillsides and in stacks above ground.

Steel and plastic drums should be stored on their lids to minimise losses if and when air enters the lid. When stored on their base, and air enters as it often will, then decomposition of the silage continues as more air enters. However, when stored upside down, the weight of the silage causes it to drop down inside the drum and minimise air entry.

The typical weights of silage in various types of storage or per unit volume in stacks are listed in Table 9.1. Weights will vary widely according to content of material, chop length, type of material ensiled and how well it was compacted.

Table 9.1 Weights of chopped silage in various types of storage

Storage type	Silage weight (kg fresh weight) or per unit volume
Small plastic bags, 30 × 30 cm	4–6
Medium size plastic bags, 105 × 85 cm	35–45
Small plastic drum (20 L)	15–20
Large plastic drums (120 L)	60–120
Steel drums (200 L)	140–190
Pits in ground	300–500 kg/m^3
Stacks above ground	200–400 kg/m^3
Cement boxes	200–400 kg/m^3

9.4 How much silage should be made?

The quantity of silage to store depends on several factors such as how many animals are to be fed, for how long, how much they are to be fed, the storage space available, the amount of excess feed to conserve, forage dry matter content, available labour and total costs. The following example shows the calculations for total silage requirements for a small holder dairy farm.

This farmer has four milking cows that must be fed for 90 days (3 months) on 20 kg/cow per day fresh silage, to supplement other forages and concentrate. If not wilted, 20 kg fresh material at 20% dry matter provides 4 kg silage DM/d.

To calculate total silage requirements:

4 cows × 20 kg/cow per day × 90 days = 7200 kg or a total of 7.2 t fresh weight required.

In most storage systems, there will be about 15% loss due to fermentation (this can be higher if air enters the storage). For a total of 7.2 t required, the fresh weight that needs to be stored is:

Tropical dairy farming : feeding management for small holder dairy farmers in the humid tropics
By John Moran, 312 pp., Landlinks Press, 2005

$$7200 \text{ kg} \div 0.85 = 8.5 \text{ t fresh weight.}$$

When compacted, pits or stacks contain say 300 kg/m^3 of fresh silage.
So the volume of storage is 8500 kg ÷ 300 kg/m^3 = 28 m^3.
If the stack is 1.5 m wide by 1.0 m high, then its length should be:

$$28 \text{ m}^3 \div (1.5 \text{ m} \times 1.0 \text{ m}) = 18.7 \text{ m long.}$$

This may be too long and the small holder would be better advised to have two pits each about 9 m long or three pits each 6 m long. More pits will also increase the flexibility of the storage system, for example if one pit is holed, if crops are of different ages or are different types.

If silage is to be fed at 80 kg/herd per day, and the whole feeding face is used each day at a minimum of 20 cm/d (0.2 m), the amount of silage removed each day would then be:

$$1.5 \text{ m} \times 1.0 \text{ m} \times 300 \text{ kg/m}^3 \times 0.2 \text{ m} = 90 \text{ kg}$$

(that is slightly more than the 80 kg silage required).

Therefore, to feed his four cows for three months, this farmer needs to source 8.5 t of fresh forage and store it in two or three pits each 1.5 m wide and totalling 19 m in length.

9.5 The ten steps to making silage

The success or failure in making quality silage is affected greatly by practices and requires a strict set of guidelines. There are no short cuts! Below are 10 steps to making good quality silage (Sections 9.5.1 to 9.5.10).

9.5.1 Harvest the forage

Forages should be harvested when excess to feed requirements but also when high in quality. In the wet season, tropical forages, such as Napier grass and sorghums, can grow rapidly to heights in excess of 2 to 3 m. Following this rapid growth, preferably even before it produces more forage than the small holder needs, this excess should be ensiled. This will allow the entire supply of forage to be maintained as high quality, into the dry season, rather than it becoming long with reduced leaf content, hence low in quality.

Forage harvested for silage should be at the same stage of maturity (ie its optimum), as if feeding fresh. For example, Napier grass should be harvested following 30 to 40 days regrowth in the wet season, at about 75 to 150 cm in height, for optimum quality and for ease of transporting to livestock in small holdings. At this stage, the Napier grass will have about two to three nodes showing on the stem.

Native roadside forages should be harvested when leafy and contain no prickly species. Tree legumes should be cut while leaves are still green and contain minimal twigs or branches.

9.5.2 Wilt the forage to 30% DM

Tropical species are difficult to ensile because of their high buffering ability (ie their resistance to changes in pH). To enable them to undergo a more satisfactory fermentation, two techniques are available to small holders, wilting the forage prior to and adding a fermentable substrate at ensiling.

Napier grass will be about 12% to 15% DM at harvest and should, if possible, be wilted to at least 30% DM. Wilting involves laying the cut forage on racks or against walls, to allow the sun's heat to evaporate some moisture from the plants. If rain is likely to fall, the material must then be covered (with plastic, palm leaves) or moved under shelter.

When harvested in the morning, wilting may only require the heat of the afternoon of that day, but when cut later in the day or on cloudy days, it may need wilting till midday of the following day. The layer of material to be wilted should be no thicker than 10 cm, and should be turned over two to three times to encourage wilting. If too thick, the forage will heat and begin to decompose and encourage the wrong types of bacteria to grow. Forage quality and dry matter will be lost.

Since leaves dry more quickly than stems, smashing or conditioning the nodes on the stems and the stems themselves will increase the wilting rate. Table 9.2 shows the effect of wilting on the final dry matter content of leaves and stems of Napier grass, as we measured in two locations in Indonesia.

Wilting Napier grass prior to making silage at workshops in West Java, Indonesia.

Table 9.2 Effect of wilting on the dry matter content (%) of leaves and stems of Napier grass (*Pennisetum purpureum*)
(Source: Moran and Mickan 2004)

	Fresh plant (at cutting)	Location 1 (after 24 h)	Location 2 (after 28 h)
Leaves	22	27	46
Stems	10	12	17

In these two locations, native roadside forages, harvested at 15% DM in the early morning was wilted to 29% DM after 4 hours and to 37% DM after 26 hours.

The dry matter content of forage can be assessed as follows:

1 cut a representative sample (including leaf and stem) into 1 to 2 cm lengths
2 squeeze tightly in hand for 30 to 60 seconds
3 open the hand quickly and observe the material and amount of moisture.

It will be approximately 30% DM if:

- your palm becomes moist but not wet
- no water drips from your hand
- the squeezed forage does not spring quickly back to its original form.

9.5.3 Add a fermentable substrate at ensiling

If the fresh forage cannot be wilted, the fermentation of the silage will be improved by mixing the chopped material with 3% to 5% molasses (on a fresh weight basis) just prior to ensiling. Although this is a time consuming and messy job, the rewards are well worth it. Adding water to the molasses is not recommended as the forage is already too moist and extra water will just reduce the fermentation quality.

Rather than mixing it in thoroughly, the molasses can be spread as layers in the forage, say every 10 to 15 cm. Where the molasses is applied, the silage ferments better and is sweeter smelling, but the overall silage quality is still good. Other suitable fermentable substrates include rice bran or formulated concentrates (mixed at 10%) in layers with molasses (5%) poured on top of the rice bran. We found the silage surrounding the rice bran was drier and more acidic (pH 4.1) compared to silage with no additive (pH 4.5).

9.5.4 Chop the forage into short lengths

The shorter the chop length, the better the compaction, hence less air is trapped in the forage, resulting in better silage quality. Chop lengths should be from 1 to 3 cm. Mechanised forage choppers will chop quickly to very short lengths. However, small holders can manually achieve similar chop lengths using knives but at a high labour input and more slowly.

If chop lengths are longer, additional molasses (5–6% on a fresh forage basis) may improve the fermentation. However, the stems should be chopped to small lengths because they are harder to compact. Leaves can be left at 3 to 8 cm length.

Where the forage has become too long but is still in a vegetative state (not yet in head), only chop and ensile the leaves and the top end of the stems to produce a higher quality silage.

9.5.5 Compact the forage as tightly as possible

Regardless of the system of silage storage, the forage must be compacted as densely as possible, so compact it until it is difficult to insert your fingers into the stack. The shorter the material is chopped, the more dense it can be packed and the less air that will be trapped inside the stack.

If compaction is by human trampling, be wary of trapping pockets of air inside the stack. The edges of the storage must be well packed. Poles or feet may be used to compress the edges in drums and material must be pushed into corners of plastic bags by hand. Be careful not to puncture the plastic bags with fingers, wooden poles or any other implement.

Larger stacks of silage in cement boxes or in pits in the ground will require continual trampling while the forage is being delivered. It should be spread evenly and thinly (no more than 5–7 cm thick) over the stack to enable it to pack more densely.

9.5.6 Complete the entire storage quickly

The entire silage storage should be filled and sealed in one day, and at a maximum, two days. This is easily achieved with bags, drums and small concrete boxes.

In larger stacks, where the forage may require several days to be delivered, the forage from one day should cover that from the previous day to a depth of at least 1 m. The current day's forage then acts as a 'seal' for the previous day. If some of the previous day's forage is not covered sufficiently, it will suffer from aerobic deterioration causing the stack to heat up, with subsequent losses in both quantity and quality.

Each night until it is filled, the stack should be covered with a sheet of plastic or a thick layer of banana or palm leaves. This will minimise the amount of warm air leaving the stack, which sets up convection currents, thus encouraging more air to enter. This is particularly important with wilted tropical forage, as it is more prone to aerobic deterioration than are temperate forage species.

9.5.7 Seal storage air tight

Silages in well-sealed storages that prevent the entry of air or water will maintain their quality for much longer than will silage in poorly sealed storages.

Plastic bags: Forages ensiled inside small bags should be stored inside a second bag as the thin plastic is easily punctured. Furthermore, non-punctured stretched plastic can allow entry of air. To ensure a tight seal, the neck should be twisted and then tied or taped, then doubled over and retied or retaped.

Forage maize ensiled in large plastic bags in Guizhou province, China.

Bags must be stored under cover and protected from any animal (eg vermin, rodents, birds, poultry), children or other agents which may cause punctures. They should also be protected from direct sunlight, to prevent the plastic breaking down, and to minimise direct heating of the bags.

Plastic and steel drums: The tops of the drums should be covered with a sheet of plastic before the lid is placed on top. To ensure an airtight seal once clamped or screwed in place, plastic tape should be placed around the top. The drums should then be stored upside down, preferably under cover or protected from direct sunlight to minimise heating.

Concrete silo or boxes: To reduce losses through aerobic deterioration once opened, it is useful to divide large concrete silos into smaller compartments. This can be done with straw, mud, cement bricks or using a rectangular timber frame. At least one side of the stack should be sealed with plastic, to prevent air entry during feed out (Figure 9.1). Straw placed above stones in the base of the pit allows moisture to seep to the bottom, but does not allow air entry into the stack. The stones should be about 2 to 4 cm high depending on stack size.

The box in Figure 9.1 holds 24 m^3 of silage, too much to open and possibly expose to the air, all at the one time.

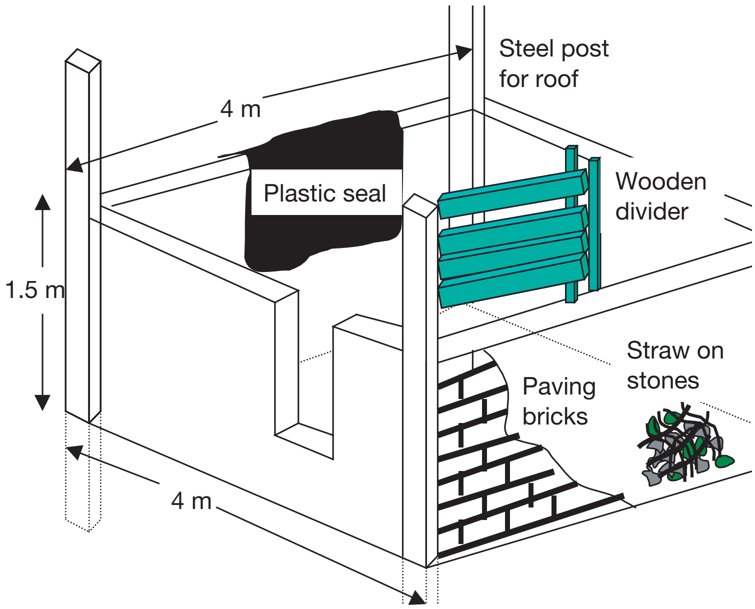


Figure 9.1 Concrete silo or box with a wooden divider.

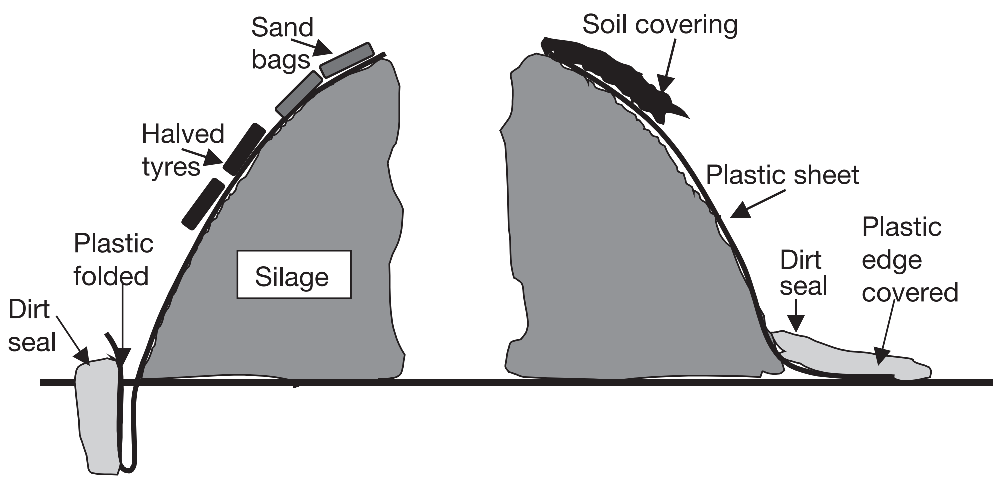


Figure 9.2 Stacks of silage showing sealing techniques at edges and on top.

Silage pits or bunkers: Immediately the filling is complete and the stack well compacted, it should be sealed air tight using plastic, preferably plastic treated with a ultraviolet (UV) light inhibitor. If such plastic is not available (eg if only builder's plastic is available), it should be entirely covered with about 10 to 15 cm of soil to protect it from direct sunlight.

When using UV treated plastic, it must be weighted with tyres cut in half or sand/dirt-filled bags, to maintain the plastic close to the silage, preventing air entry and movement under the seal. Covering the plastic with soil would be ideal. The plastic edges, when folded over then buried, as shown in Figure 9.2, provide an excellent airtight seal.

9.5.8 Maintain airtight seal

All storage types must be sealed then kept air tight throughout the entire storage. If the plastic is holed, or stacks start to shrink too much, the cause of air entry into the silage must be determined and repaired as soon as possible.

Effluent flowing out of the storage for longer than 2 to 4 weeks is indicative that the silage is slowly deteriorating (rotting) due to entry of air. The air entry should be identified and stopped. If it cannot be stopped, ensure that the same mistake is not made in the future. (A mistake is something wrong that happens more than once!)

Wilted silage should produce little or no effluent unless the stack is poorly sealed. Unwilted silage will produce some effluent, which may leak out of drums and stacks into the soil. Silage effluent should be prevented from entering waterways and drinking water as it causes pollution. It can kill plants or fish if in large quantities.

Only small amounts of silage effluent will leak from well-sealed drums and plastic bags, and may even leak slowly from upturned drums. It is important not to remove drum lids, untie bag tops or hole their bottoms to let moisture out, or to 'see how they are going!' This will allow far too much air to enter, leading to very poorly fermented silages, and even just compost.

9.5.9 Feed out a whole face of the storage

As soon as the storage is opened for feeding, air will enter and the silage will begin to deteriorate. Silage in small storages should be fed out completely within 1 to 3 days of opening. If drums are being fed out over longer than three days, plastic and weights should be placed over the open face to minimise air entry to the silage.

Unless the forage has been chopped very short (1–3 cm) and well compacted, air enters silage stacks of tropical species very easily. For large silage storages, the whole face of the stack should be removed every day to a depth of at least 20 cm. If the silage is fed out only every two days, at least 30 to 40 cm should be removed every second day. Stack widths should be designed to ensure it takes no longer than two or three days to feed out the entire feeding face.

Only remove the weighting material on top of the stack as required to prevent air moving back into the stack under the top seal. If the silage is warming once opened, it is starting to deteriorate and lose yield and quality. If steam is rising from the stack or if the silage becomes very hot, aerobic deterioration is extreme and the feeding rate must be increased rapidly, unless the problem is due to air entry via other means.

9.5.10 If silage is unsatisfactory, determine the reason

It is important to learn from mistakes and to ensure that the silage is consistently of good quality from year to year.

Silage that has undergone an unsatisfactory fermentation will be unpalatable, and in some cases even poisonous to animals. Once opened, such silage may be recognised by the following characteristics, as it:

- has a strong, pungent, very unpleasant smell
- has a strong ammonia smell
- contains excess moisture when squeezed or continually oozes from the base
- is mouldy or slimy
- has undergone much deterioration (>20% DM loss)
- is slightly damp and dark brown
- the plastic sheet or lid has not stopped air entry for many days.

Even though animals may not eat the silage initially, they should once the silage has been left in feed troughs for an hour or so, thus allowing some of the pungent smells to escape. However, animal production will suffer as a result. To avoid any possible animal health problems, be very wary of feeding mouldy silage to pregnant and lactating animals.

Silage has a characteristic odour unfamiliar to most livestock. Therefore, they may not immediately consume the silage offered without some incentive, such as molasses or fresh forage mixed in with the material. It is very unusual for stock to refuse silage after a slow introductory period.

Even when they make good quality silages, farmer adoption rates of silage making have not always been high. As with other feeding technologies such as chemically treated rice straw, farmers do not like to double handle forages. Often, they need to see the benefits of feeding better quality roughages in higher milk yields, before they accept the higher work loads in silage making compared to purchasing other forages, generally of poor quality, for dry season feeding. Another problem is the shortage of excess wet season forage with which to make silage because of high stock numbers on limited areas.

9.6 Silage from by-products

Fruit, fish waste, vegetables and root crops are increasingly integrated into tropical farming systems and provide a wide range of valuable wet by-products and residues which are often underutilised or wasted. The ensiling of such by-products is a simple conservation method and a most effective way to improve animal feed resources.

The major problems usually encountered are the seasonality of supply and their high moisture content. High moisture by-products often have high nutritive value. It is difficult and expensive to dry them so all too frequently such by-products often become contaminating wastes that quickly go sour, mouldy and lose much of their soluble nutrients as effluent. The advantages of ensiling such material include:

- for feeding when such by-products are not being produced
- increasing feed resources and an insurance for high nutrient demands, such as milking cows

- reducing demands on homegrown forages
- if low cost, reducing total feed costs
- can improve their palatability
- can reduce toxicity to safe levels (in vegetables or cassava leaves)
- can destroy harmful bacteria (in poultry litter or fish wastes)
- can constitute a major proportion of diets.

9.6.1 Sources of by-products

There are a wide variety of wet by-products or residues and their nutritive values are presented in Table 9.3. This list does not include cereal by-products (rice bran) or drier by-products (coconut meal) which can be stored fresh. These are discussed in Chapter 10.

Brewer's spent grains: The extracted malt or spent grain contains 75 to 80% water and can be stored under cover for up to 2 weeks. It needs airtight storage for longer periods, either in trenches or large plastic bags. Including other by-products such as molasses or chopped cassava provides additional carbohydrates for improved fermentation while absorbing some of the moisture.

Banana by-products: These include reject bananas, leaves and trunks. Mixing bananas with high protein wastes such as poultry litter, fish waste or cassava leaves, produces a high quality milking feed. Banana trunks, although poor quality, produce good quality silage when ensiled with high carbohydrate feeds such as molasses or root vegetables.

Root crops: These include cassava, taro, sweet potato and yams. Cassava roots are a high energy, but low protein feed, ideal for high yielding cows (up to 25% of their total DM intake) provided they are supplemented with additional protein and minerals. Fresh cassava leaves are also a good quality forage for cows provided they are ensiled or sun dried to remove the toxic hydrocyanic acid they contain. Taro and yam roots contain unpalatable substances that are reduced by ensiling.

Wet pulps from fruit and vegetables: Citrus pulp represents 50% of weight of the fruit prior to juice extraction. Tomato pulp (peel, seeds) constitutes 20% of the fresh weight. Being so moist, they should be ensiled in alternative layers with dry by-products, such as chopped straw, cereal bran or poultry litter, to absorb the effluent. Sweet corn waste is a high energy by-product because of the large amounts of soluble sugars remaining following canning of sweet corn. Grape marc constitutes 5% to 10% of fresh grapes but is low in nutritive value because tannins reduce the availability of other nutrients, particularly the protein.

Miscellaneous: Fish by-products are very high quality protein sources for lactating cattle, because being animal in origin, their amino acid profiles are the most similar to those required by rumen microbes and cows themselves. They should be ensiled in association with high carbohydrate feeds (eg molasses or cassava roots) with maximum amounts of 50% with dry sources and only 10% with other wet by-products.

Poultry litter and manure is also rich in protein and minerals and can be incorporated into cow diets either as a dried or ensiled product, with the latter method destroying harmful microorganisms, such as *Salmonella*. Cassava and soybean wastes are readily available in many areas for 12 months each year so can be fed fresh.

Other less common by-products available in some tropical regions include condensed molasses fermentation solubles, the organic residues of microbial fermentation to produce monosodium glutamate and fermented soybean paste residue, produced after soy sauce has been extracted from soybean paste under pressure. Many Asian countries have by-products from medicinal herbs, such as ginseng, which may have potential for feeding to livestock. However, before using them, it would be advisable to obtain a full chemical profile of such residues to ensure they have no detrimental effect on cow performance or milk quality.

Table 9.3 Nutritive value of tropical by-products suitable for ensiling and inclusion rate for feeding to milking cows

Crude Fibre (CF); Crude Protein (CP); dry matter (DM); Metabolisable Energy (ME). (Source: Chedly and Lee 2000)

By-product	DM (%)	CP (%)	CF (%)	ME (MJ/ kg DM)	ME (MJ kg fresh)	Inclusion rate (kg fresh/d)
Fruits						
Reject bananas	30	5.4	2.2	11.5	3.5	2–5
Banana skins	15	4.2	7.7	6.7	1.0	2–5
Bread fruit (ripe)	30	5.7	4.9	10.8	3.2	4–8
Tomato pulp	22	21.5	35.0	8.0	1.8	1–15
Sweet corn waste	18	2.6	21.0	11.0	2.0	1–10
Grape marc	37	13.8	41.0	4.9	1.8	1–3
Citrus pulp	23	7.5	20.0	10.3	2.4	1–15
Leaves and stems						
Banana stems	9	2.0	21.0	5.5	0.5	5–10
Sweet potato leaves	12	20.0	14.5	5.8	0.7	10–20
Cassava leaves	16	23.5	19.0	6.7	1.1	3–6
Taro leaves	16	22.3	11.4	6.2	1.0	1–2
Maize stover	23	5.7	26.4	8.7	2.0	5–20
Yam leaves	24	12.0	25.0	7.3	1.8	2–5
Roots						
Cassava roots	28	1.6	5.2	12.5	3.6	5–15
Taro roots	25	4.5	2.0	13.2	3.3	2–5
Yam roots	34	8.0	2.5	13.5	4.6	2–5
Sweet potato tubers	30	7.0	2.5	13.5	4.1	5–10
Sugar beet pulp	19	9.1	31.6	9.8	1.9	1–20
Miscellaneous						
Poultry litter	82	26.5	14.5	8.2	6.7	0.5–2
Cassava waste	20	2.5	1.5	7.2	1.4	1–10
Soybean curd	14	39.0	11.3	14.9	2.1	1–5
Brewer's grain	22	26.0	13	8.2	1.8	5–20
Molasses	78	1.5	0	11.5	9.0	0.5–2

9.6.2 Principles of ensiling by-products

The basic principles are the same as those for fresh forages, so attention must be paid to ensuring anaerobic conditions and there should be sufficient acid in the silage to restrict the activities of undesirable bacteria. To achieve a successful silage, attention should be given to:

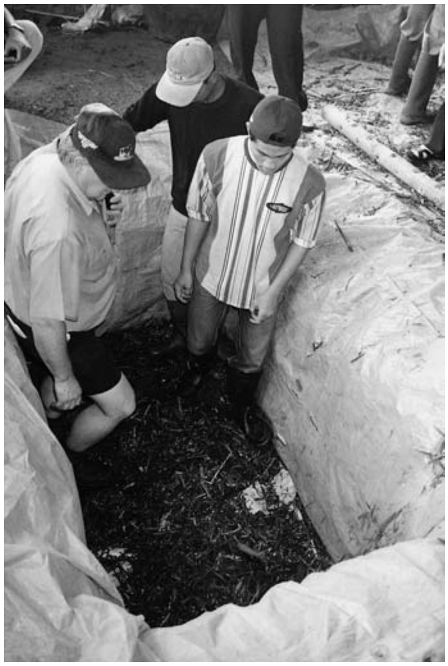
- Moisture content – this should be at least 50% for ease of compacting to eliminate air. Excessive moisture, more than 75%, can lead to an undesirable fermentation, producing a sour silage reducing palatability and hence intake. Adding water or using absorbent materials will allow the manipulation of moisture content.
- Length of chopping – the finer the chopping, the better the compaction.
- Time to fill the stack – the quicker the better, and it should be covered each night during filling to reduce invasion of air.
- Fermentable energy – these silages require a stable low pH to minimise biological activity. The final pH depends on the carbohydrate content, which may be sufficient in the material being ensiled or from added sources. For example, protein-rich by-products with low sugar or starch contents are difficult to ensile so should be mixed with energy-rich by-products such as waste bananas, molasses or root crops.
- Once opened, every effort must be made to reduce aerobic deterioration. Ensiling in layers separated by plastic sheets can reduce the size of each package of silage. Plastic bags are easy to handle as well as making excellent mini silos.
- Well-made silage can be opened within one month or can be stored for six months or more, provided the cover does not break down and allow air to enter the stack.

Workshops allow small holder farmers to quickly understand the benefits of silage in conserving excess forages.

9.6.3 Silage from maize crops and maize by-products

Maize is probably one of the most versatile of all crops. Many varieties of maize have been bred, differing in their rate of maturing, to produce a diversity of crops for different end products, such as sweet corn, forage maize and maize grain (Moran 2001b). The types of maize and by-products used for livestock feeding are:

- Sweet corn, which is consumed fresh either directly off the cob or already removed from the cob or preserved as frozen or canned sweet corn.
- High moisture maize and ground ear maize, which are both wet products from maize harvesting, the first being grain only and the second a mixture of grain and cobs.
- Maize stover, which is the leaves and stems of maize plants following its harvest for sweet corn. The stover remaining from crops grown for maize grain is very poor in quality because of its mature stage at harvest.
- Maize grain and its many by-products (see Chapter 10).
- Sweet corn trash, which is the by-product from canned sweet corn, namely cobs, leaves around the cob and some of the soluble maize from the kernels.
- Whole crop forage maize, which is the entire crop harvested in a less mature stage than when harvested for grain. It is fed as green chop or is more commonly ensiled for later feeding.



Farmers can utilise this theoretical knowledge and construct silage pits on their own farm.

Most of the forage maize harvested, and often ensiled, for small holder dairy farming is maize stover, although some farmers grow or purchase whole crop forage maize. Nutritive values of these feeds are presented in Tables 9.3, 10.2 and 10.4.