Harvesting and Ensiling Techniques

Dr. Félix Ojeda García

Estación Experimental de Pastos y Forrajes "Indio Hatuey"
Central España Republicana
Apartado Postal: 44280
Matanzas, Cuba.
E-mail: ihatuey@atenas.inf.cu

1. 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 farmers may produce good silage under tropical conditions with minimum resources. In this paper different options for the preparation of silage will be examined, based on its principles and differentiating the implicit characteristics of small and large farmers.

Many of the ideas and concepts presented are not only the fruit of research, they are a summary of years of experience in silage production on 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 characteristics, and the aim of this paper is not to supply rigid recipes.

2. Production of silage

The production process of silage may be divided in four stages:

1. Forage harvesting
2. Transport to the silo
3. Compaction
4. Sealing (air-tightness).

The execution of these stages has a big impact on the success or failure of the fermentation and the quality of the silage.

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 receiving silage.
- Length of the feeding period
- Percentage silage of the full ration
- Material resources available (equipment, labour, financial means, technical assistance, etc.).

This is illustrated by the following example:

An adult bovine, consuming 50% of the ration in the form of silage would receive 5 kg of (DM) per day. For a feeding period of 180 days, 900 kg of DM/animal would be required, that is, 3.6 t of fresh forage, containing 25% DM. Considering 15% silage loss 540 kg of fresh forage should be added, to arrive at a total of 4.14 t per head. 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 DM silage at a rate of 0.6 kg per 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, to avoid its re-entry and prevent 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 not to have all the silage required 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. 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.

2. 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, such as barrels of steel or plastic, concrete water pipes of 2 m diameter and height, 2 mm thick plastic packing bags, such as those used for fertilisers.

On large farms, which are highly mechanised, 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 l 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.

2.1 Vertical silos

The 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 to be 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.

2.2 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 air-tightness.

2.2.1 Trench silos

These 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 in the shape of a 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 eliminate surface runoff from penetrating the silo.

2.2.2 Surface silos

2.2.2.1 Silos without walls.

Silos without walls are the simplest because they do not require permanent construction. However, they are the most

subject 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. Air-tightness 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, thatthe 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.

2.2.2.2 Silos with walls

The most commonly used silos have 2, 3 or 4 walls. In the latter case 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 rectangles against an existing wall.

In general, walled silos are less critical on the forage's DM content, because drainage systems for effluent can be incorporated, including a slightly sloping floor

3. Forage collection

3.1 Type of forage

In the tropics, grasses have been, by tradition and for practical reasons, the main forage used for conservation. However, recently 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 mechanised 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 the latter generally dries more rapidly.

3.2 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 specialised 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 when it is collected in the field.

Chopping to between 2-4 cm lengths 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 microorganisms 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 loose 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 extracted. Tedding the cut forage immediately after cutting and one more time afterwards will reduce drying time. The shorter the field drying time the lower will be the risk of rain damage.

3.3 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 to 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.

3.4 Cutting systems for large farms

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

Factors as: 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, are deciding factors in organising the production process.

3.4.1 Harvesting machines

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

- *impact.* These tractor-drawn machines have a group of knives mounted on a rotor blade that cut 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 to 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 not to affect the re-growth, producing clean cuts without harming the stalks. The size of the pieces is also superior (2-4 cm). They are not suitable for uneven terrain because of a greater chance of breakages.
- *plate shears* are fitted in. the most modern self-propelled machines with a large cutting capacity (15-20 t/hour). The cutting system protects the re-growth. 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 to between 0,5 to 2 cm.

3.4.2 Pick-up trailers

Pick-up trailers must have a mechanism that can raise the forage off the ground, chop it and send it towards the collection

bin with a capacity of 8 m^3 or more. The unloading mechanism can be lateral, at the back or with a moving floor. Trailers with a lateral 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.

3.4.3 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 wheel or caterpillar tractors. 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.

3.4.4 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 homogenisation 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 pressurised sprayer or a small centrifugal fertiliser-spreader, if the silo has walls.

4. Organisation of the silage-making process

The golden rules that guarantee an efficient production process are:

1. The available silo capacity must be adequate for the amount of material to be ensiled.
2. The rate of silo filling should be in accordance with 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 air-tightness 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.

4.1 Small farms

The characteristic of small-scale silage production is that the only specialised machinery used is a stationary chopper. Manpower and animal force replace the 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
Air-tight 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 that can be transported during a day's work in order to minimise the respiration loss and development of aerobic micro-organisms.

Polyethylene covering for air-tightness does not necessarily need to be in one piece, sheets form 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 tires 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.

4.1.1 Vertical silos and barrels (3 to 6 m ^{3})

Once the receptacle has been completely covered with polyethylene on the inside, it is filled with successive layers of forage, no thicker than 20cm, 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 going towards the centre.

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

4.1.2 Horizontal silos

A small horizontal silo (2 m high, 1 m wide) is 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 heights below 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 is obtained when the loose green material under the person’s foot or animal’s hoof does not exceed 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.

4.1.3 Plastic bags

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

4.2 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)
- One tractor for each pick-up trailer (minimum two).

The quantity of forage, which can be deposited in a silo per day of work, will depend on the minimum compaction time required. In accordance with past experience these are: 15t for forage chopped longer than 6 cm, 10 t for wilted and 5 t forunwilted forage chopped to 2 cm or less. This means that during a 12 hr 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 usually accept the residues of each year to recycle the plastic and grant discounts on the newly purchased.

5. Conclusions

It is better to prepare a smaller amount of good silage than large volumes of low quality, which 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 solved are:

- the incorporation of legumes in large-scale silages
- when it is most convenient to use additives with respect to pre-drying technology;
- to analyse energy balances, 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.

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