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UTILIZATION AND CONSTRUCTION OF PIT SILOS FOR MAKING SILAGE

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Utilization and Construction of Pit Silos for Making Silage

The Peace Corps

Knowledge and Learning Unit

September 1982 (Revised June 2015)

Background

As part of the United States government's efforts to address food security in the developing world and specifically the United States Agency for International Development's Feed the Future initiative, the Peace Corps edited and revised a number of existing manuals that were initially designed for Volunteers' use in the late 1970s and early 1980s.

Given the need of Volunteers and staff to access information on a variety of topics related to food security, subject matter experts reviewed and updated these manuals and their accompanying references. The content for some topics has not changed much since the manuals were first produced. References have been reviewed and updated where necessary and new websites identified for additional content.

The Pit Silos manual was reviewed and a section on bagged silage was added from a publication developed by USAID that is being used with permission.

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Ch 1: Introduction

This manual discusses the production and storage of silage. Silage is comprised of fermented grass and other green fodder, including grain legumes, and is used to feed livestock when they are unable to graze. Forage is a generic term for the raw plant material that serves as the basis for silage.

The plant material in silage is conserved when it is still fresh and green, making it more nutritious than hay, which has a nutritional value that declines over a short period. Plant material is preserved using a "pickling" process that produces lactic acid, a natural preservative that can hold the nutritive value of the plants for up to three years.

Silage can also be used to feed animals in situations where grazing is prohibited or discouraged, such as in urban environments. Silage can be one component of zero-grazing, a practice in which livestock are contained and food is brought to them. Keeping animals contained minimizes their exposure to disease and injury and can minimize the damage wandering livestock cause to growing trees and gardens.

Pit silos have been proposed as an economic alternative to above-ground storage, which requires investment in expensive containment systems. Since this publication was written, the use of polythene bags has emerged as another low-cost alternative. The bag system will also be discussed.

Overview

The pit silo resembles a well or cistern. The walls of a pit silo may or may not be lined. Such use is popular in semi-arid areas where the water table is low enough to prevent the silo from becoming filled with water.

Pit silos have the following advantages:

- They are never damaged by storm or fire
- They require less reinforcement
- They minimize silage loss since they have no doors
- They are less expensive and are practical

Requisites of a Good Pit Silo

- The size should be appropriate for the number and type of animals to be fed daily, length of the feeding period, and the amount of forage available for ensiling.
- The sidewalls should be level and smooth to prevent the formation of air pockets.
- The pit silo should be of adequate depth, which ensures better packing and less exposed surface area. This will help keep spoilage losses to a minimum.
- The silo should be conveniently located and accessible for both filling and feeding.
- The silo should be located in a well-drained area.
- The soil should be designed so that the sidewalls will not collapse. (It is not safe to dig a pit silo where there is deep sand.)

Selecting a Site for a Pit Silo

When selecting the site for a pit silo, the following should be considered:

- Depth of loose sand
- Depth of the water table
- Availability of forage
- Convenience of feeding the silage
- Availability of flood plains during the rainy season
- Availability of shade

When utilizing areas where the sand is deep (more than 2 feet), there is a tendency of the sidewalls to be unstable. When the pit silo is empty, the side walls generally cave in. Therefore, it is recommended that pit silos be dug where there is less than 2 feet of sand.

Ch 2: Pit Silos

Before choosing a site, one must always determine the depth of the water table. To do this, look down an open well near the proposed site or ask the villagers how deep the water is in their well. Always remember, the water table usually descends at the onset of the dry season and ascends during the rainy season. Do not put silage in a pit silo that contains water.

Select the site for pit silos where forages are readily available to ensure that less time is consumed transporting cut forages to the pit silo.

Select a site that will be convenient for feeding silage to livestock. This should be close to where livestock are usually tethered.

The site location should never be in a flood plain because usually the water table is near the surface, which, during the rainy season, will make the sidewalls susceptible to caving in.

It is preferred that the pit silo be located between two large trees or on the east side of a large tree. It is important that the shade cover the hole during the heat of the day. If no shade is available, the silage is more likely to dry out after the silo is opened. Shade is also necessary for the workers who fill the silo.

Proper Size of Pit Silo

The diameter and depth of the pit silo should depend on the number and kind of animals to be fed from it and the length of the feeding period. The silo should allow the removal of 2 to 4 inches of silage daily from the entire exposed surface to prevent spoilage.

The size of the pit silo required may be computed by determining the length of the feeding period and kinds of livestock to be fed. Knowing the number of animals, the entire amount of silage that will be consumed daily, and the length of the feeding period, the total weight of silage needed can be estimated. By referring to the following table, one can determine the proper size and dimensions for a pit silo that will suffice the needs of a farmer.

Table 2-1: Proper Size and Dimensions for a Pit Silo

Depth of settled silage (feet)	Total quantity of settled silage from the top to the depth indicated in silos having a diameter of:			
	10 feet (tons)	12 feet (tons)	14 feet (tons)	16 feet (tons)
1 foot	1	1	1	2
2 feet	2	3	4	5
3 feet	3	5	6	8
4 feet	5	7	9	12
5 feet	6	9	12	16
6 feet	8	11	15	20
7 feet	10	14	19	25
8 feet	11	16	22	29
9 feet	13	19	26	34
10 feet	15	22	29	38
11 feet	17	24	33	43
12 feet	19	27	37	48
13 feet	13	30	41	53
14 feet	23	33	44	58
15 feet	25	36	48	63

The amount of silage fed per daily to the various classes of livestock is estimated in the table below.

Table 2-2: Amount of Silage Commonly Fed per Head Daily to the Various Classes of Livestock

Animals	Amount
2–3 year old oxen	25–30 pounds
3–8 year old oxen	30–50 pounds
Sheep	2–3 pounds per 100 pounds live weight
Goats	2-3 pounds per 100 lbs. live weight

Example

Mr. Keita owns two oxen, 10 sheep, and 10 goats. He wants to store enough silage to feed all of his livestock during the dry season. How large must he make his silo?

- Step 1: Determine the length of the dry season or the number of days he must feed his livestock silage. In this case, it will be five months or 150 days.
- Step 2: His two oxen will eat an estimated 60 pounds of silage each day, with the sheep and goats eating a combined estimated total of 60 pounds of silage each day, making a grand total of 120 pounds of silage needed each day.

150 days X 120 pounds of silage = 18,000 pounds or 9 tons

Mr. Keita needs an estimated 9 tons of silage to meet his livestock needs for the coming dry season. Refer to Table 5-1, a pit silo with a diameter of 12 feet and a depth of 5 feet of settled silage will suffice his needs.

Digging a Pit Silo

The following observations should be considered when digging the pit:

- Shape of the pit
- Having the pit repaired for filling at the proper time
- Keeping the sidewalls straight
- Keeping the top edge of the pit free from piled soil

There are three shapes of a pit silo—round, square, or rectangular. The shape of the pit depends entirely upon the wishes of the farmer but round pit silos are recommended over square or rectangular ones. Round silos have the following advantages: silage will tend to settle more uniformly, which is desirable for quality; corners are eliminated, which have a tendency to form air pockets that cause spoilage; and the round shape is a more efficient use of given space than the other shapes.

It is recommended that the pit be prepared for filling before forages are at their best for harvesting. Pit silos should be prepared for filling immediately following the rainy season.

When making a new pit silo, it is important that the sidewalls be kept straight and smooth. Often there is a tendency for the sidewalls to slope inwards as the pit gets deeper, giving it a larger diameter at the top compared to the bottom. Having the sidewalls smooth and free of holes, roots, or stones reduces the possibilities of air being entrapped, which will help to settle the silage more uniformly.

If using a pit silo from previous years, all rotten and moldy silage should be removed. Sidewalls should be straightened if portions have fallen in during the preceding rainy season.

While digging the pit silo, it is recommended that the soil from the pit be piled at a minimum of 1–2 feet from the edge of the pit, thus eliminating the possibility of the soil being pushed into the silage by workers when filling the pit silo.

Filling the Silo

Filling a pit silo properly will pay dividends during the dry season when feed for livestock is difficult to obtain. When filling a pit silo, the following points should be considered.

Distribution of the Silage

When the silo is being filled, the crop material should not be allowed to accumulate in the center of the silo. It should be kept well distributed over the entire area and well tramped near the wall. This is particularly important when the crop is wilted slightly. Good distribution and thorough packing are necessary in the top part of the silo.

Attention to Top Layer

Only heavy, unwilted crops should be used for the last few loads so that enough weight and pressure will be provided to force the air out and keep it out. Preservatives will be needed in this wet top layer to prevent undesirable fermentations.

Rate of Filling the Silo

The rate at which the silo is filled affects the how the air is eliminated from the silo and, consequently, the temperature that the ensiled mass attains. If the silo is tight and is properly filled and sealed, the temperature will seldom exceed 100 degrees Fahrenheit (38 degrees Celsius), except at the top, and may sometimes not exceed 90 F (32 C). If the ensiled material is high in moisture, or if the weather is cool, silo temperatures will be lower than when the crop is wilted or the weather is warm. When the silo is filled with a high-moisture crop, particularly in cool, moist weather, there may be an advantage in filling at a slow or moderate rate, which will allow the ensiled material to warm up slightly. That procedure also will help to prevent an undesirable type of fermentation.

When the silo is filled during a long dry spell or with a wilted crop, it should be filled rapidly to hold the silo's temperatures down to a desirable level. Spoilage is likely to occur on the surface of the ensiled material if more than two days elapse between filling periods. When such an interval occurs, the top of the material should be kept tramped thoroughly in the meantime, and any spoiled silage should be removed before filling is resumed. During instances when

one crop only partially fills the silo and another crop is put in later, the silo should be tramped, sealed, and weighted down between fillings to keep silage temperatures and losses as low as possible.

Tramping Chopped Silage

While filling a pit silo with chopped silage, it is very important that the silage be periodically tramped. Tramping the chopped silage facilitates packing and excludes air pockets that may cause spoilage. It is especially important that the edges be well tramped since there is more of a tendency for air pockets to form. Remember, one cannot over tramp silage in a pit silo. Before entering a pit silo, precautions must be taken to ensure no dangerous silage gases are present.

Amount of Time Required to Fill a Pit Silo

Filling a pit silo as quickly as possible will further ensure high quality silage. It is recommended that a minimum of 1–2 feet of chopped forage be added daily until the pit silo is completely filled. The time required to fill a pit silo depends upon the following:

- Size of the pit
- Number of workers
- Availability of forages
- Method of transporting forages
- Local factors, such as holidays, sickness, deaths, etc.

Number of Workers

The number of workers participating will greatly influence the time necessary to completely fill a pit silo. When possible, farmers should avoid attempting to fill a pit silo alone. It is highly recommended that farmers work cooperatively in filling pit silos. The more workers available, the more quickly the silo can be filled, thus improving the overall quality of the silage.

Process of Ensiling

The ensiling process refers to changes that take place when green forage is stored in a pit silo in the absence of air. An understanding of these changes is likely to lead to the production of more high quality silage.

The ensiling process is principally governed by the interaction of three factors: the bacteria on the plant material, the composition of the plant material placed in the pit silo, and the amount of air entrapped or allowed to enter the stored forage.

The entire ensiling process requires 2–3 weeks, during which time the following aerobic bacteria (with air) and anaerobic bacteria (without air) predominate.

Aerobic Bacteria

The living plant cells of forage continue to respire or breathe, consuming the oxygen of the silage. As the cells respire in this entrapped space, where there is no air exchange, they breathe out carbon dioxide (CO2) and water (H2O), and release heat energy. Simultaneously, aerobic yeasts and molds thrive and multiply. During this period, the temperature may rise to about 100 F (38 C). When forage is freshly harvested, the bacteria that live on that plant material are largely aerobes. These bacteria, along with the facultative bacteria (bacteria that can "switch" to anaerobic respiration in anaerobic conditions), increase in number, and their activity aids in the exhaustion of oxygen (O2) from the silage mass.

Anaerobic Bacteria

When the available oxygen of the entrapped air has been completely consumed by the respiration of the plant and aerobic bacteria, a 4–5 hour transition period takes place in which anaerobic conditions prevail. In anaerobic conditions, acid-forming, proteolytic bacteria, such as lactic acid bacteria, increase in numbers and produce volatile fatty acids, which form a hostile environment for the kinds of bacteria that cause spoilage. Simultaneously, the molds and yeasts die, but continue to function as enzyme systems that produce alcohol and other products.

The combined anaerobic activity produces the following changes:

- The carbohydrates and sugars (especially the sugars) are broken down into lactic acid (e.g., the acid in sour milk), some acetic acid (e.g., the acid in vinegar), and certain other acids and alcohols. The sugars that are broken down are largely sucrose and monosacharides, glucose, and fructose.
- Some of the proteins are broken down into ammonia, amino acids, amines, and amides.
- The acidity finally reaches a point where the bacteria themselves are killed, and the silage-making process is completed. Silage in a good pit silo will remain unchanged for a long time during the dry season. The acid development "pickles" the plant material by reducing the PH to 4.0 or below. The low PH inhibits further bacterial growth and enzyme action and preserves the silage. In addition, it inhibits proteolytic and putrefactive bacteria from growing, which cause rotting and putrefaction. The presence of small amounts of ethyl and other alcohols is desirable, because they combine with the acids to form compounds that impart to silage the characteristic aroma.

Dangerous Silage Gases

Pit silos are always dangerous, even after filling

Gases formed during fermentation may become hazardous when making and feeding all types of silages unless precautions are observed. The gases are heavier than air and may accumulate near the surface of the silage in pit silos.

The suffocating effect of carbon dioxide (CO_2) gas formed in silage is well known. It is the most common and most dangerous of gases from silage, because it is invisible.

It has also been recognized that nitrogen dioxide (NO_2) gas is formed by high-nitrate silages and can cause a sometimes-fatal disease called nitrogen dioxide pneumonia in humans and livestock. Some plants, such as legumes, oats, barley, wheat, corn, sorghums, many pasture grasses, and certain weeds appear to accumulate especially high concentrations of nitrates during droughts and when grown on high-nitrate soils. When these plants are made into silage, poisonous nitrogen dioxide gas forms from a week to 10 days after filling the pit silo.

Carbon dioxide gas may be detected by lowering a lighted lantern into the level of the silage. If the flame goes out, the oxygen content of the atmosphere in the pit silo is dangerously low. Nitrogen dioxide gas can be detected by its yellow or yellowish brown color or by means of starch-iodide paper (obtained from drugstores or chemical supply houses), which turns blue in the presence of nitrogenous compounds.

Box 2-1: The Dangers of Silo Gases

Nitrogen dioxide is dangerous because it acts as a corrosive agent on the mucous membranes, and may cause lung inflammation. Very high levels of gas will quickly cause an individual severe distress and could kill them very quickly. Lower levels of gases might cause less immediate distress, such as upper respiratory congestion, watery eyes, cough, difficulty breathing, fatigue, and/or nausea. What makes this dangerous, however, is that an individual might choose to stay to "work through the pain," allowing toxic levels of the gas to enter the bloodstream, and symptoms can become worse over the course of several days. One after effect, for example, is "chemical pneumonia," which, in turn, can lead to death. For these reasons, it is very important to remain cautious and to avoid silos when gases are forming during the first two to three days of ensilage. After that, the silo should be well ventilated prior to entering and one should always be accompanied by a partner who can go for help should it be needed. In addition, making silage can be a fun and interesting draw for children, and special efforts must be taken to keep children away from silos and to inform them of the dangers.

(Sources: http://extension.psu.edu/business/ag-safety/confined-spaces/silo-safety/e16 and http://nasdonline.org/document/64/d001621/silo-gas-dangers.html)

Precautions Against Silage Gases

Before entering a pit silo, swing a piece of canvas, a tree branch, a burlap bag, or something to agitate the air and dilute gases that may be present with oxygen from the air. Adequate ventilation is essential.

Notice: A victim of silo gas should be moved into fresh air as soon as possible, artificial respiration should be applied, and he or she should be taken to a physician immediately.

Sealing Pit Silos

When the pit silo has been completely filled with chopped forages and has been well tramped, it is necessary to seal the silage mass so it can be properly preserved.

Cover the entire silage mass with a layer of long grass, banana leaves, palm tree leaves, dry grass, or anything that will prevent soil from being mixed with the chopped forage. Then cover the entire surface of the forage mass with 18–24 inches of soil.

When the pit silo has been properly sealed, 2–4 days afterwards, the forage mass will have settled approximately 1 foot or more, depending upon how well the chopped forage was tramped before sealing. The weight of the soil cover aids in forcing out any entrapped air pockets, thus further eliminating possibilities of spoilage.

Opening Pit Silos

Keeping in mind the number of animals that will be fed daily, it is necessary, after the silo is opened, that 2–4 inches of silage or more be removed from the exposed surface daily. Therefore, the amount of silage a farmer exposes when opening a pit silo will depend a great deal upon how much silage he will need each day. Removing the daily minimum of 2–4 inches of silage reduces the time silage near the surface is exposed to the air, thus curtailing loses caused by spoilage.

When only a small number of animals will be fed daily from a pit silo, it is suggested that the pit silo be divided into three vertical sections. Thus, only a portion of the pit silo will be opened at a time. When only a portion of the silage is exposed, the minimum of 2–4 inches of silage will more likely be removed from the exposed surface when a small number of animals are to be fed.

When removing silage from the pit silo, care should be taken not to cause loose soil to fall on exposed silage. The soil should be placed at least 2 inches from the edge of the pit when opening each section. Soil mixed with the silage reduces its palatability.

After the soil cover has been removed from the silage, one will find 4–6 inches of spoiled silage on both the top and sides of the silage mass. This thin layer of spoiled silage formed a seal following the ensiling process. This small amount of spoiled silage is normal and must be thrown away and not fed to livestock.

Termites

In many areas, heavy termite infestations exist. When introducing silage to farmers, one of the first questions they ask is, "Will termites eat the silage stored in pit silos?"

Thus far, experience and studies have indicated that termites will not eat well-preserved silage. It is suspected that due to the low PH of well-preserved silage, the acidity may discourage termites from damaging silage.

Pit silos have been filled where termites were visible on the sidewalls while filling, but no detrimental effects have been observed while the silage was being removed during the dry season.

Termite infestation has been occasionally observed in the thin layer of silage that normally spoils next to the sidewalls, but no infestation or damage has been noted in the usable silage.

Silage in Bags

This method is one in which cut green mass is stored in large sacks made from polythene. It is not a complex process. Ideally, the green mass is cut into small pieces about 3 centimeters long that are used to fill the bags. The material is pressed, removing the air and thereby preventing decomposition once the bag has been filled and shut. The feed can be stored in this way, without losing the nutritive quality, for up to one year. This allows farmers to maintain feed levels through the winter.

Photo c/o creativecommons.org

The purpose of chopping and compacting forage for silage is to release as much plant sugar as possible for fermentation and to ensure that all the air is pushed out of the plant material so that when the silo is sealed, the plant material is free of air. This is when fermentation works best to produce lactic acid.

Chopping can be done by hand but this can take too much time for forage on more than 0.1 hectares, so it is preferable that a forage chopper be used.

It is important to time the cutting of the forage so the cut forage is not sitting for more than a day waiting to be chopped and ensiled, otherwise it will become moldy or too dry.

Once the forage has been chopped, it is important that it is placed in the silos and compacted as much as possible to get the air out before the silo is sealed. A key feature of silage bags 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 are harvested and chopped at one time. For example, a farmer family might conserve a couple of bags a day over the growing season, which would allow their milking animal to be fed over the 200 days of autumn and winter. The fodder might include all parts of the corn plant, leafy grass weeds, etc., which could also be partially air-dried before chopping and ensiling. It is also possible to progressively remove leaves from maize plants as they commence to deteriorate.

Ch 3: Bag Silos

Advantages

There are several advantages to using silage bags. Among them are the following:

- Plastic silage bags are an economical alternative to traditional silage storage systems, such as pits and silos.
- It is an effective way for preserving feed with minimum nutrient loss. (The anaerobic environment that is created eliminates spoilage from the growth of yeasts, molds, and adverse bacteria while maintaining essential proteins and nutrients).
- The method allows farmers to store silage anywhere they need it. A well-graded and well-drained ground surface is all that is necessary.
- The silage is completely sealed in the bag. This means that all the acid is retained in the silage, unlike that in pit silage where it seeps out through the bottom of the pit as effluent. This compensates for longer pieces of forage and poorer compaction than that found with silage machinery, making the quality of the silage just as good.
- Ensiling in a bag avoids the hard work of having to remove silage every day.
- Because the whole bag is fed to the animal, it means the rest of the silage in the other bags is not exposed to air during removal and is therefore unspoiled. Much of the silage in pits has been found to be spoiled due to poor sealing and exposure to air every day when the silage is removed for feeding.
- The bag is easily stored and easily portable so any member of the family can carry it to the feed trough for the cow.

Disadvantages

There are a few disadvantages to using silage bags. Among them are:

- Pest control is needed to prevent damage to the bags.
- Containment and disposal of the plastic is needed once silage is removed from the bag.
- The labor required to chop the green mass is greater, as chopped material tends to make much better silage and the small pieces cannot puncture the bag.

With careful planning, all of these obstacles can be overcome. Most loses of silage during the process occur due to:

- Seepage losses when dry matter is less than 32 percent
- Unnoticed bird/rodent damage to the bags resulting in spoilage loss
- Too wet (gaseous/seepage losses) or too dry silage (spoilage)

Storage

It is important to pick a suitable location for the storage bags. One should keep them relatively close, in an area that has adequate drainage and easy access. Keeping the bags away from other feed sources reduces damage from birds and rodents. Stacking them carefully in a room can protect them against rats, mice, and other pests.

The surface area selected for the storage of silage bags has a large impact on silage quality and ease of feeding from the bag. Based on experience, the surfaces' ratings are as follows:

- **Concrete pad**. These provide excellent surface for silage bag, allowing easy removal of feed with little or no damage, and achieving exceptional drainage of water away from the bags. They also discourage pests and make inspecting damaged bags very easy.
- **Asphalt surface**. This is less expensive than concrete and provides many of the same advantages as concrete. Care is needed to maintain the surface during the hottest hours on summer days.
- **Gravel**. This is a good surface for placing silage bags. Weed and pest control are quite good. However, the crushed rock surface does not support traffic very well.
- **Dirt surface**. This can work if there is adequate drainage away from bags. Weed control must be practiced on this surface and it is very helpful to have a second location of silage for use when it is extremely wet, especially during the spring.

Packing

Packing the silage bag correctly is the most important factor in affecting silage quality. Therefore, the following recommendations should be followed when selecting the packing materials:

- Select a good bag. Strong high density plastic bags (from fertilizer bags to shopping bags) with a capacity of 110–120 pounds are best. Bags with no obvious holes can be purchased in packs of 10 to 100.
- The quality of the bags is important. High-density plastic reduces the potential for tearing. The seal must be without holes. 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 (if more bags are used) also tend to get damaged, but thicker bags are always less damaged, to the extent that two rather than three layers of bags are sufficient.
- Plastic fertilizer bags make very good silos. The fertilizer bag will last for at least three seasons.

Maintenance

Damage to the bags can happen due to animals and even children puncturing the plastic. This lets air in the bag and can result in spoilage. Following are recommendations for maintaining the stored bags:

- Inspect the bags on a regular basis and, if possible, mend holes.
- Do not allow dogs, cats, and other animals to climb the bags.
- Number and date the bags for easy identification and recall of materials bagged.
- Do not leave the silage bags opened overnight.
- Inspect frequently and seal holes immediately.
- If the damage is extensive, the silage needs to be re-bagged as soon as possible.
- After emptying, the bags must be carefully washed, dried, and stored in a safe place for use the following year.

Filling

While filling your silage bags:

- Do not allow the feed to become contaminated with dirt.
- Ensile at proper maturity and moisture (58–68 percent).
- If moisture levels are higher, reduce the packing pressure to avoid creating mushy, silage. Better yet, wait until the forage is drier; if moisture levels slip below 65 percent, increasing the packing pressure can help.
- Pack no later than 24 hours after harvest.
- Fill rapidly and pack uniformly. Each bag should be filled in 1–2 hours at maximum. This is needed to maintain forage consistency.
- Pack the silage as densely as possible to avoid air pockets that can interfere with proper fermentation. Air pockets can develop more frequently when longer chop lengths are used.
- Monitor particle length. A shorter chop length of 3/8 inch will pack better, but may not retain enough physical fiber for the ration.
- Hand chop or chop the fodder through a cutter.
- Carefully pack to avoid making any holes in the bag.
- Gently but firmly squeeze the bag by hand to expel air, and while compressed, close the bag.

Rodent Control

Silage bags attract rodents, especially those bags with fodder maize. Once in, rodents can easily hide between bags, chewing through the plastic bags and resulting in aerobic spoilage. Following are recommendations for controlling rodents:

- Monitor the silage bags on a regular basis for any rodent, bird, or livestock damage.
- Do not use elemental sulfur or chemical means for rodent/pest control, as life expectancy of the plastic is reduced when exposed to chemicals.
- Frequently some form of construction may be required. This might be within an existing store, such as large cement or clay storage jars.
- Alternatively, storage (shelves) can be constructed with legs to keep the store off the ground, shaped in a way to prevent rats and mice climbing (such as mushroom-shaped legs used for grain stores, or protected legs with metal horizontal discs or downward facing cones).

Sealing the Bag

If bags are used, leaning heavily on the forage material in the bag then tying the remaining plastic as close and tight to the material as possible will compact the silage and then seal it from air. Make sure there is enough plastic to tie up so it does not come free from the twine.

Tobacco twine or hay-baling twine is best for tying up the bag and it should be twined around the top of the bag several times to ensure the bag is completely sealed. Remember to seal tightly. Several methods can be used to seal the bags:

- For larger bags, stretch the remaining plastic as far as it will reach, then place a wooden board on the plastic and wrap it around the board back toward the bag, much like re-sealing a bag of potato chips.
- For smaller bags, twist the neck of the bag, then turn it over and tie with twine.
- You can also practice nailing a wooden board to the one used to wrap the end of the plastic bag. Just roll the board and plastic two or three times and place a second board on the top. Nail the two boards together, slightly alternating the angle of the nails.

Advantages and Disadvantages of Silage

Silage has numerous advantages, particularly when compared to hay.

Advantages

- Silage has a stable composition for a long period (up to five years).
- Plants are harvested at an optimal phase of development for silage and are thus efficiently used by livestock.
- Nutrient loses are low in silage production (10 percent). (In standard hay production, these may amount to 30 percent of the dry matter.)
- Silage makes economical use of plants, with a high yield of green mass.
- Silage makes good use of the land, with 2–3 crops annually.
- Silage is produced in both cold and cloudy weather.
- The fermentation in silage reduces harmful nitrates accumulated in plants during droughts and in over-fertilized crops.
- Silage allows by-products (from sugar beet processing, maize straw, etc.) to be optimally used.
- Silage requires 10 times less storage space compared to hay.
- Maize silage has 30–50 percent higher nutritive value compared to maize grain and maize straw.
- 2 kilograms (4.6 pounds) of silage (70 percent moisture) has the equal nutritive value of 1 kilogram (2.3 pounds) of hay.

Disadvantages

- Silage is not interesting for marketing, as its value is difficult to determine.
- The weight of silage increases manipulation costs.
- Silage has considerably lower vitamin D content compared to hay.

Source: http://pdf.usaid.gov/pdf_docs/PNADQ897.pdf

Types of Silage

A great variety of crops can be made into silage. A rule of thumb is that crops and forages that are palatable and nutritious to animals as pasture, green feed, or as dry forage also make palatable and nutritious silage. Likewise, crops and forages that are unpalatable and innutritious as pasture, green feed, or dry forage also make unpalatable and innutritious silage.

The varieties of grasses and legumes that can be used depend on those that are available in each locality. Some of the more common forages found on African savannas which make good silage include hyparrhenta sp., andropogon gayanus, roettebbia exaltata, peanut greens, millet, sorghum, bean vines.

Farmers are frequently confronted with choosing between corn or sorghum silage and grass silage. Under these circumstances, the following facts are pertinent:

- Where adapted, corn or sorghum will generally produce a greater tonnage of feed per acre than grass silage.
- Good quality corn or sorghum silage can be made more consistently and with greater ease than good quality grass silage.
- Corn or sorghum silage is generally more palatable than grass silage, even when the latter is carefully preserved.
- Grass silage is generally higher in protein and carotene but lower in total digestible nutrients (TDN) than corn or sorghum silage (generally, grass silage contains about 90 percent as much TDN as corn silage, but it will equal corn silage in TDN where 150 pounds of grain per ton have been added as a preservative). Thus, grass silage generally requires the addition to the ration of less protein supplement but more total concentrates than corn or sorghum silage. This would indicate that corn or sorghum silage would be slightly preferable to grass silage in high roughage finishing rations for beef cattle and sheep, whereas grass silage would be preferable in high roughage rations for dairy animals and young beef cattle and sheep.
- Grass silage is higher in carotene content but lower in vitamin D, unless made by the wilting process, than corn or sorghum silage.
- Grass silage can be produced in those areas where the climate is too cool and the growing season too short for corn or sorghum silage.
- The production of grass silage will result in less soil washing than the production of corn or sorghum silage on lands subject to erosion.

Characteristics of Good Silage

In order to make good quality silage, farmers need to know what constitutes silage quality. They need to be acquainted with those recognizable characteristics of silage that indicate high palatability and nutrient content. The easily recognized characteristics of silage of high feeding value are:

- Odor—It has a "clean" rather pleasing acid odor, in contrast to the foul or objectionable odor of poor silage.
- Taste—The taste is pleasing, but not bitter or sharp.
- Absence of mold and rot—There is no visible mold, and it is not musty or slimy.

- Uniformity—It is uniform in moisture and color. Generally green or brownish silage is good. Tobacco brown or dark brown silage indicates excessive heat, and black silage is rotten and should not be fed.
- Animals' acceptance—Animals like and thrive on good silage.

Factors Affecting Silage Production

Several factors influence the type of fermentation produced, the nature and extent of the losses occurring during silage fermentation and storage, and the quality of the silage produced:

- Maturity and chemical composition of the crop
- Ratio of soluble carbohydrates to the mineral base content of the crop
- Percentage of moisture when stored
- Rapidity and completeness with which air is excluded from the silo
- Atmospherical temperatures when the crop is ensiled

Silage Making Practices

One of the basic problems in making high-quality silage is the variability of the product, even under apparently similar conditions. Generally, the following practices have resulted in making good grass-legume silage:

- Use a crop of high quality.
- Harvest forage at the proper stage of growth.
- Fine-chop unwilted material 6–25 centimeters in length and wilted material 6–12 centimeters in length.
- Field-dry to 65 percent or less to produce either a wilted or low-moisture silage, or use an additive.
- Use a silo that excludes air and water.
- Fill the silo rapidly and pack thoroughly.
- Use a suitable seal to exclude air.
- Leave the silo until ready to use the feed.

Optimum Moisture Content of Silage

The moisture content of the crop at the time of ensiling is the most important factor in determining the character of the silage fermentation, the extent and character of the losses through seepage and fermentation, and the quality of the silage produced.

Excessively high moisture content leads to large losses of liquid. Too little moisture (less than 60 percent) results in molding and spoiling of the silage.

When crops are ensiled with a moisture content of more than 70 percent, fermentation takes place at a rapid rate, there is considerable seepage from the silo, and losses of most feed nutrients, except carotene, are large. Dry matter is the most important component of good silage and will range from 30–35 percent moisture.

You can estimate moisture content by a squeeze test. Squeeze a handful of the chopped forage into a ball and hold it 20 to 30 seconds, then quickly release your grip. The condition of the ball shows an estimate of how much moisture it contains. Following is a guide for estimating moisture content:

Table 4-1: Estimating Moisture of Silage

Condition of the Forage Ball	Approximate Moisture Content
Ball holds its shape and there is considerable free juice	Over 75%
Ball holds its shape but there is very little free juice	70 to 75%
Ball falls apart slowly and there is no free juice	60 to 70%
Ball falls apart rapidly	Below 60%

(Source: http://pdf.usaid.gov/pdf_docs/PNADQ897.pdf, p. 4)

When the moisture content of the crop is reduced to 68 percent or less, the fermentation rate is reduced and seepage from the silo is eliminated. The best silage is made when the moisture of the material is not above 68 percent or less than 60 percent. However, occasional loads may contain as much as 70 percent or as little as 55 percent of moisture without materially affecting the quality.

Cutting Forages for Silage

Most grasses should be cut after the heads have emerged but before the plants have started to bloom. Delays in harvesting beyond the early heading stage in grasses decreases the palatability and digestibility of the forage. Each day of delay decreases digestibility about 0.5 percent, which in turn results in a decline in production for animals that are fed silage from grass that is too mature.

In handling the crop for silage, the farmer should cut the forage when it has a high content of protein and carotene and when the yield of total digestible nutrients per acre is high. The

farmer should ensile it in a way that will produce good palatable silage with the least loss of feed nutrients and minimal wear and tear on the silo.

In doing so, the farmer must give proper consideration to the stage of maturity at which to cut; the moisture content at which to store; the need for and use of preservatives; the length of cut to use; the distribution and packing of the crop in the silo; and the sealing from air when the silo is full.

If no treatment other than chopping is provided, the type of fermentation will be desirable and the silage will be of good quality as long as the crop ensiled consists principally or entirely of grasses or cereals that are cut after heading out and that they contain a medium or low amount of protein. On the other hand, the type of fermentation will be undesirable and the silage will be of poor quality and have a strong offensive odor if the ensiled crop consists principally or entirely of legumes or of grasses and cereals that are cut before heading out and that have a high-protein content.

Cutting the forages in the late afternoon and placing at the edge of the pit for chopping the following morning has proven to be a satisfactory system for these reasons:

- Cutting the forages in late afternoon for chopping the following morning allows the plants to wilt somewhat before putting into the pit silo. Water evaporated from the plant juices before putting into the silo decreases the amount of nutrients that will escape from the silage in the plant juices and water that normally drains from the silage mass. Wilted forage increases the amount of sugar per pound of forage because part of the water is removed, thus improving the quality of chopped silage.
- Workers usually do not like to cut forage during early morning hours when plants are heavily covered with dew. Cutting forages in late morning hours or late afternoon when forages are dry improves work efficiency.

Cutting forages and chopping without wilting is a proven practice when making silage. The system used depends upon the wishes of the farmer.

When cutting forages, if the grasses or legumes tend to be "stemmy," cut plants higher from the ground using only the succulent and leafy part of the plant, eliminating the coarse, woody stem of more mature plants. For high quality silage, cut only leafy succulent forages.

Tools

Tools used to cut forages depend on what is available locally. Locally made knives and machetes have been found to be satisfactory for cutting and chopping forages. Factory-made machetes, military machetes, and scythes work very well for cutting forages, when available.

It is recommended that a file be kept available for workers to sharpen knives and machetes, when necessary. It has been found that work efficiency is greatly improved when tools are kept sharp.

Chopping the Forage

Except for short and very immature crops put up under special conditions, it is necessary to chop the crop as it is siloed.

Chopping cut forages into 2- to 4-inch lengths improves the quality of silage and makes forages more palatable. Very coarse, mature forages cause the silage to pack more tightly, excluding the air, and increases the volume of forages that can be put into a given pit silo.

Where forage-chopping machinery is not available, manual methods can be successfully utilized by placing logs at the edge of the pit silo. With workers sitting by the log, placing forages on the log toward the pit silo, using machetes or locally made knives, silage can be chopped into 2- to 4-inch lengths that fall directly into the pit silo. This method has proven to be practical and well accepted by local farmers who are making silage for the first time.

Transporting Forages to Pit Silo

Transporting cut forages to the pit silo depends on what the farmer has available and how far forages are located from the pit silo. Ox-drawn carts have proven to be very satisfactory in transporting cut forages to pits. Where ox-drown carts are not available, workers may carry bundles of cut forages on their heads. Attaching bundles of cut forage on the backs of horses and/or donkeys has been used for long-distance transporting. Regardless of the method used, transporting cut forages to pit silos must be economical and practical for the farmer. Transporting cut forages long distances could prove to be both uneconomical and unpractical.

Wilting Silage

Harvesting silage crops can be classified as "direct cutting," where the forage is ensiled directly after being field cut, or "wilting," where the forage is partially field dried so that it contains 60–70 percent moisture when stored.

Wilting high-moisture crops for silage not only produces a mild, palatable silage that will be consumed in normal roughage amounts, but wilting also reduces the losses of nutrients (except carotene) that usually occur when the silo is filled with comparable unwilted materials. It also increases the amount of sugar per pound of forage.

However, care should be taken not to wilt the crop too much, and the part that is wilted most should be placed in the lower part of the silo. The walls of silos used for wilted silage should be air-tight and smooth.

A means of quickly judging the degree of wilting achieved is visual. If the leaves become dry and curled, the wilting may have proceeded too far. The crop will have wilted sufficiently when the leaves and stems become limp or the stems can be readily twisted in two and the broken ends will have a dark, moist, but not excessively juicy appearance.

Once in the silo, wilting silage is at a disadvantage because it is more difficult, as compared to direct cut silage, to exclude air. The lighter, wilted silage will not pack as tightly in the silo. For this reason, if the wilting process is followed, the last few layers of silage put in the silo should not be left to wilt. In this way, additional weight will be placed on the top of the silage, pushing down to help force out any air within the silo.

Wilted silage made without preservatives usually has an acidity within the PH range of 4.0 to 5.0, depending on the crop.

Remember that in a dry season, or with rather mature crops, the forage does not need to be wilted.

Salt has little effect on the fermentation process and is of little practical value in silage making.

Grasses and cereals cut after heading out or a mixture of such crops with legumes can be made into mild, good-quality feeding silage without preservatives when ensiled in the fresh green state. The fermentation rate will be slowed down, fermentation and storage losses will be reduced, and the palatability of the silage will be increased by wilting the crop slightly before ensiling.

Immature grasses and cereals cut before heading out, or crops consisting principally or entirely of legumes, can be made into good silage by wilting them down to a moisture content of 68 percent or slightly less.

Wilted silages made without preservatives usually have an acidity within the PH range of 4.0 to 5.0, depending on the crop.

The aim should be to wilt the crop slightly, to a moisture content between 65–70 percent but not below 60 percent. If the leaves become dry and curled, the wilting may have progressed too far unless the crop is heavy and the underside of the swath is in an unwilted state. The crop will have wilted sufficiently when the leaves and stems become limp. Some stems can be readily twisted in two and the broken ends will have a dark, moist, but not excessively juicy, appearance. Upon rubbing the chopped crop between the hands, the material will feel cool

and moist, but no free water will appear when a ball of the chopped crop is squeezed in the hands.

Drying Silage

One or two hours on a dry day may be sufficient to wilt the crop to the desired moisture level unless the crop is very heavy or very high in moisture. On a dry day, therefore, the crop should not be cut too far ahead of loading and silo filling. During prolonged dry weather, crops cut at the usual stage will be ready to ensile within a few minutes after mowing. On very humid days, a half day to a day may be required to wilt the crop sufficiently. During rainy spells, the mowed crop may sometimes be in the field two or three days before it wilts enough to be siloed.

Dealing with Rain

When rain interferes with silo-filling operations, the rain/wet portion can be siloed without wilting by filling the silo at the slow rate of 3 to 4 feet a day so that some heat will be generated; or it can be siloed at a normal rate by adding dry hay (10 to 20 percent), ground dry grain (5 to 12 percent), or molasses (3 to 5 percent) to the wet crop.

Silage Preservatives

Due to technical problems in silage making, numerous substances have been investigated and used as silage preservatives. No additive is needed for making excellent silage from the whole corn plant. The use of additives to improve silage has been largely restricted to grass or forage crops with low-fermentable carbohydrates. Adding molasses or ground feed grains will improve the fermentation and silage quality. Before adding these products, acids, or other amendments, current literature should be reviewed and additional costs considered.

Effect of Silage on Milk Odor and Flavor

Silage sometimes affects the flavor and odor of milk. This effect may be somewhat more pronounced with some silages than with others. Thus, the dairy farmer will fare well by feeding all silages after, rather than before, milking.

Losses

Some losses are incurred in the ensiling process regardless of the procedures used. Field losses vary with the degree of field drying. Losses in the silo can be grouped under three main headings: surface spoilage, seepage, and gaseous or fermentation losses.

Surface Spoilage

The amount of surface spoilage is a function of the degree of exposure to air and water. Losses of 20 percent or more can occur in stack silos. Each centimeter of surface spoilage represents approximately 3 centimeters of silage lost. The most effective way to reduce loss from surface spoilage is to reduce the surface area exposed or to provide suitable protection, such as a plastic cover.

Seepage

Storage losses tend to be higher with direct-cut materials, due to squeezing out water and movement of feed nutrients out of the silo with the water. In a high-moisture silage, 50 percent or more of the dry matter losses may be due to seepage. These losses usually increase with the percent moisture of the ensiled forage and height of the silo. A horizontal silo will have less seepage loss because of lower vertical pressures. In general, silages with less than 70 percent moisture will have little or no seepage loss.

Gaseous Loss

Gaseous or fermentation loss is due to respiration by the plant in the silo and the subsequent bacterial fermentation. Both of these factors result in loss of dry matter in the silo. Some of this is unavoidable; but unnecessary loss can result because of entry of air into the silo, failure of PH to decline rapidly, and existence of unfavorable fermentations. Adherence to principles of good silage-making will keep this loss at a minimum.

Additional Resources

Fodder from Trees and Shrubs: http://www.fao.org/docrep/011/t1265e/t1275e03.htm#TopOfPage. Discusses advantages and disadvantages of fodder from trees and shrubs.

Making and Storing Quality Hay: http://extension.missouri.edu/p/G4575. Provides information on the most important factors affecting the quality of hay, as well as on hay preservatives.

Silage Making for Small Scale Farmers: http://pdf.usaid.gov/pdf_docs/PNADQ897.pdf. Focuses primarily on corn silage, but provides more detailed information about using storage bags.

Small Scale Hay Making: http://www.fao.org/docrep/011/t1265e/t1275e04.htm#TopOfPage. Provides information on different hay storage configurations, how to provide hay to livestock, and the steps for making and handling hay.

Small Scale Silage Making: http://www.fao.org/docrep/011/t1265e/t1275e05.htm#TopOfPage and http://www.fao.org/docrep/011/t1265e/t1275e06.htm. Provides information on different kinds of silos, on preparing the crop for silage, silage additives, and sealing a silo.

Tube Silage: http://betuco.be/dieren/Tube%20silage%20uganda.pdf. Provides some case studies of farmers in Uganda using polythene bags ('tubes') for silage making.

Several videos show how to make silage in the East African context:

- **Shamba Shape Up (English) - Push-Pull, Goat Care, Making Silage**: http://www.africaknowledgezone.org/content/youtube/XhIhS4fQNQk
- **Shamba Shape Up (Swahili) - Push-Pull, Goat Care, Making Silage**: http://www.africaknowledgezone.org/content/youtube/d3XMiAGDPyE
- **Makutano Junction S03Ep02**: http://www.africaknowledgezone.org/content/youtube/XzMiDNdT9Kk
- **Shamba Shape Up (English) - Silage, Bananas, Sweet Potatoes**: http://www.africaknowledgezone.org/content/youtube/gIc_qoUHUNU
- **Shamba Shape Up (Swahili) - Silage, Bananas, Sweet Potatoes**: http://www.africaknowledgezone.org/content/youtube/6zW1MIPhFyg