UNIT 6 IN SILAGE PRODUCTION FROM WASTE

Structure

6.1 INTRODUCTION

During the cold, continental winter, the major fodders available are wheat or maize straw, together with hay and concentrated feeds. As a minimum, it is essential to provide a green fodder supplement to enhance rumen function for bovine animals. For smallholder farmers with limited production capacity, finding enough feed in the winter months to maintain good milk production is always a problem. Many are forced to buy hay, concentrates or silage just to keep their animals alive and are unable to benefit due to the higher prices paid for animal feed in the winter months (Woolford et al., 1984).

Fresh forage crops such as maize, grasses, legumes, wheat and lucerne can be preserved by ensiling. In many countries ensiled forages are highly valued as animal feed. In European countries such as The Netherlands, Germany and Denmark more than 90% of the forages locally produced are stored as silage. Even in countries with generally good weather conditions for hay making such as France and Italy approx. 50% of the forages are ensiled (Wilkinson et al.1996). It is essential to have a good microbial fermentation process to produce high quality silage. A good fermentation process is not only dependent on the type and quality of the forage crop, but also on the harvesting and ensiling technique. In this paper our current knowledge on general silage microbiology is reviewed with the aim to aid with the choice of the best ensiling strategy to produce high quality silage (Auerbach et al., 1998).

6.2 OBJECTIVES

After reading this unit you should be able to:

- Define silage;
- Describe the advantages and disadvantages of silage;
- Describe the Basic principle of Silage Production;
- Describe the role of saccharolytic and proteolytic organisms in Silage Production;
- Explain Phases of Silage Production;
- Explain the Enzymology of silage production.

6.3 SILAGE PRODUCTION FROM WASTES

Forage which has been grown while still green and nutritious can be conserved through a natural 'pickling' process. Lactic acid is produced when the sugars in the forage plants are fermented by bacteria in a sealed container ('silo') with no air. Forage conserved this way is known as 'ensiled forage' or 'silage' and will keep for up to three years without deteriorating. Silage is very palatable to livestock and can be fed at any time.

Silage is the fodder which is conserved by reducing pH through natural anaerobic fermentation and is used for feeding during scarcity period, drought or floods and for utilizing surplus forage. The suitable crops are sorghum, maize and oat etc. During lean period feeding of silage acts as a green fodder and maintains livestock productivity (Wiedmann, et al., 1994)

6.4 BENEFIT OF SILAGE

Forages can be made into hay to conserve the nutrients, especially protein, before they decline in the plant. However it is often too wet to dry the successfully and special machinery, has to be used to assist the forage to dry quickly. Forage crops such as maize, are too thick-stemmed to dry successfully as hay.

Silage is considered the better way to conserve forage crops. A forage crop can be cut early and only has to have 30% dry matter to be ensiled successfully. There is no need to dry out the plant material any more than that, so wet weather is not such a constraint as it is with making hay.

Silage making is long practiced by the larger agricultural sector, but the production method relies on heavy equipment and large production, in order to dig or build storage pits and to compress the green mass, putting it beyond the reach of smallholder farmers.

Silage is storage system of green fodder which keeps all parts of fodder in appropriate condition for feeding than any other system of storage of fodder. Silage requires less space for storage as it is pressed in pit/tank than hay making. For daily cutting, transporting & chaffing of fodder in traditional way requires more labour & time but in case of silage, fodder cutting, transport, chaffing is done at one time only, so it is less labour & time consuming practice.

Land under fodder cultivation is emptied, and immediately it is used for plantation of other crops. So farmers' can take more crops in same land in a year against traditional way where land is reserved for fodder until all crops is harvested. Silage is prepared in closed & air tight condition so there is no danger of fire. Due to lactic acid in silage, it is easily digestible to animals, so energy required for digestion is used for other purposes like milk production etc. Silage is tasty & flavoured, so it increases appetite of dairy animals. Important thing behind to adopt silage is in scarcity it provide supply of fodder to dairy animals. Situations like drought, high rainfall & scarcity of fodder, farmers may use silage for feeding to dairy animals. (Rain fed area where shortage of green fodder is for March to June & in high rainy area or water logged lands, it is impossible to cultivate or harvest fodder) Due to treatment of additive for silage, farmers can supply energy, mineral & vitamins to dairy animals (Hengeveld, 1983).

6.4.1 Advantages

- Stabile composition of the feed (silage) for a longer period (up to 5 years);
- Plants can be harvested at optimal phase of development and are efficiently used by live-stock.
- Reduction of nutrient loses which in standard hay production may amount to 30% of the dry matter (in silage is usually below 10%);
- More economical use of plants with high yield of green mass;
- Better use of the land with 2-3 crops annually;
- Silage is produced in both cold and cloudy weather

6.4.2 Disadvantages

- Silage is not interesting for marketing as its value is difficult to be determined.
- It does not allow longer transportation;
- The weight increases manipulation costs;
- Has considerably lower vitamin D content compared to hay.
- The fermentation in silage reduces harmful nitrates accumulated in plants during droughts and in over-fertilized crops.
- Allows by-products (from sugar beet processing, maize straw, etc.) to be optimally used;
- Requires 10 times less storage space compared to hay;
- Maize silage has 30-50% higher nutritive value compared to maize grain and maize straw;
- 2 kg of silage (70% moisture) has the equal nutritive value of 1 kg of hay.

6.5 THE ENSILING PROCESS

Ensiling is a forage preservation method based on spontaneous lactic acid fermentation under anaerobic conditions. The epiphytic lactic acid bacteria ferment the water-soluble carbohydrates (WSC) in the crop to lactic acid, and to a lesser extent to acetic acid. Due to the production of these acids the pH of the ensiled material decreases and spoilage microorganisms are inhibited. Once the fresh material has been stacked and covered to exclude air, the ensiling process can be divided into 4 stages (Weinberg and Muck 1996; Merry et al. 1997). System for manufacturing of silage has been shown in Figure 1.

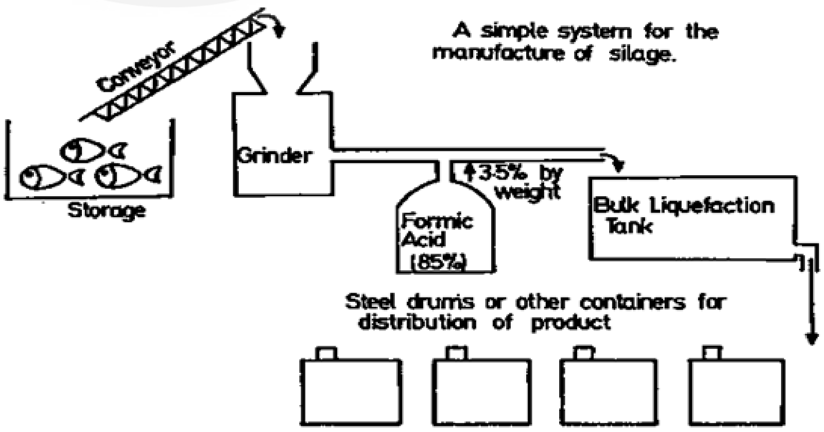

Figure: 1 System for the manufacturing of Silage

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

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

Stable phase (Phase 3): As long as air is prevented from entering the silo, relatively little occurs. Most microorganisms of phase 2 slowly decrease in numbers. Some acid tolerant microorganisms survive this period in an almost inactive state, others such as clostridia and bacilli survive as spores. Only some acid tolerant proteases and carbohydrases and some specialized microorganisms, such as *Lactobacillusbuchneri* continue to be active at a low level.

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

To avoid failures it is important to control and optimize each phase of the ensiling process. In phase 1 good silo filling techniques will help to minimize the amount of oxygen present between the plant particles in the silo. Good harvesting techniques combined with good silo filling techniques will thus minimize WSC losses through aerobic respiration in the field and in the silo, and in turn will leave more WSC available for lactic acid fermentation in phase 2. During phases 2 and 3 the farmer cannot actively control the ensiling process. Methods to optimize phases 2 and 3 are therefore based on the use of silage additives that are already applied at the time of ensiling.

Phase 4 will start as soon as oxygen is available. To minimize spoilage losses during storage an airtight silo is required, and any Silage fermentation processes and their manipulation damage to the silo covering should be repaired as soon as possible.

During feed-out spoilage by air ingress can be minimized by a sufficiently high feed-out rate. In addition, at the time of ensiling silage additives can be applied that are able to decrease spoilage losses.

6.6 BASIC PRINCIPLES

At harvest, plant cells do not immediately "die"; they continue to respire as long as they remain adequately hydrated and oxygen is available. The oxygen is necessary for the physiological process of respiration, which provides energy for functioning cells. In this process, carbohydrates (plant sugars) are consumed (oxidized) by plant cells in the presence of oxygen to yield carbon dioxide, water and heat.

Sugar + oxygen=carbon dioxide + water + heat

Once in the silo, certain yeasts, molds and bacteria that occur naturally on forage plants can also reach populations large enough to be significant sources of respiration. In the silage mass, the heat generated during respiration is not readily dissipated, and therefore the temperature of the silage rises.

Although a slight rise in temperature from 80° to 90°F is acceptable, the goal is to limit respiration by eliminating air (oxygen) trapped in the forage mass. Some air will be incorporated into any silo during the filling process. These temperature increases can clearly be limited by harvesting at the proper moisture content and by increasing the bulk density of the silage. Generally, it is desirable to limit respiration during the fermentation process by using common sense techniques that include close inspection of the silo walls prior to filling, harvesting the forage at the proper moisture content, adjusting the chopper properly (fineness of chop), rapid filling, thorough packing, prompt sealing and close inspection of plastics for holes (Honig and Woolford 1980).

Check Your Progress 1

Note: a) Use the space given below for your answers.

b) Check your answers with those given at the end of the unit

1. What is Silage?

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2. What are advantage and disadvantages of Silage Production?

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3. State Basic Principle of Silage Production?

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6.7 ROLE OF SACCHAROLYTIC AND PROTEOLYTIC ORGANISMS

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

6.7.1 Desirable Microorganisms

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

Lactic acid bacteria that are regularly associated with silage are members of the genera Lactobacillus, Pediococcus, Leuconostoc, Enterococcus, Lactococcus and Streptococcus. The majority of the silage lactic acid bacteria are mesophilic, i.e. they can grow at temperatures between 5 and 50oC, with an optimum between 25 °C and 40°C. They are able to decrease the silage pH to pH 4-5, depending on the species and the type of forage crop. All lactic acid bacteria are facultative aerobes, but some have a preference for anaerobic conditions (Holzapfel and Schillinger 1992; Hammes et al. 1992;Weiss 1992). Based on their sugar metabolism lactic acid bacteria canbe classified as obligate homofermenters, facultative heterofermenters or obligate heterofermenters. Obligate homofermenters produce more than 85% lactic acid from hexoses (C-6 sugars) such as glucose, but cannot degrade pentoses (C-5 sugars) such as xylose. Facultative heterofermenters also produce mainly lactic acid from hexoses, but in addition they also at least degrade some pentoses to lactic acid, and acetic acid and/or ethanol. Obligate heterofermenters degrade both hexoses and pentoses, but unlike homofermenters they degrade hexoses to equimolar mounts of lactic acid, CO_2, and acetic acid and/or ethanol (Hammes et al.1992; Schleifer and Ludwig 1995).

Obligate homofermenters are species such as Pediococcus damnosus and *Lactobacillus ruminis*,Facultative heterofermenters are for example *Lactobacillus plantarum* , Lactobacillus pentosus, Pediococcus acidilactici, Pediococcus pentosaceus and Enterococcus faecium . To the obligate heterofermenters belong members of the genus *Leuconostoc* and some *Lactobacillus* sp. such as Lactobacillus brevis and Lactobacillus buchneri (Weiss 1992; Holzapfel and Schillinger 1992; Hammes et al. 1992).

The ensiling process completes in the following steps: harvesting the crop (30-35%DM), chopping, and loading into a silo, compacting and sealing to exclude air, storing and feed out phase (unloading for animal feeding). Biochemical and microbiological incidents can ariseduring the different stages of ensiling which may affect the silage quality. At first step of ensiling is the enzymatic activity of intact plant cells whenresidual respiration occurs. The intact cellsuse glucose and fructose as carbohydrate source and consume oxygen entrapped in the silage. Early consumption of carbohydrates is detrimental for the subsequent anaerobic lactic acid fermentation. In initial phase of ensiling epiphytic aerobic flora such as Enterobacteria, yeasts and molds develop until oxygen has been entirely consumed or acidification is sufficient to stop their metabolism. At ensiling, the facultative anaerobic bacteria carry out a heterolactic fermentation which slightly decreases the pH of the silage.

As the conditions become anaerobic in silage pit, fermentation phase starts. This phase continue for several days or weeks, during which different groups of facultative aerobic or anaerobic microorganisms naturally found in plants compete for available nutrients. With gradual acidification, acid tolerant bacterial development start; convert water soluble carbohydrates into lactic acid. In well-processed silage, LAB dominates the fermentation, rapidly producing the low pH conditions that help to preserve the silage. In case of accidental soil incorporation in ensiled material, a long aerobic phase or slow acidification, the microbial communities in the silage will be dominated by Clostridia, yeasts, molds and accidentally incorporated pathogenic microorganisms such as Listeria sp.

As long as the pH is sufficiently low and anaerobiosis is maintained, storage phase lasts and few changes occur. Numbers of LAB and other viable microorganisms decline over time, except for some specialized species such as *L. buchneri* with continues to be active at low population densities. Some acid-tolerant microorganisms can survive this storage period in an almost inactive state (e.g. acid-tolerant yeasts) or as spores (e.g. butyric acid bacteria). Homofermentative lactobacilli such as *L. plantarum* and *Lactobacillus curvatus* tend to predominate in well preserved silage until the final stage of fermentation, when they are invariably replaced by heterofermentative species such as L. brevis and L. buchneri.

The fourth phase is the unloading or feedout phase. On opening of silos air penetrates into the silage depending on the density and porosity of the plant material and the rate of silage removal. This causes the growth of undesirable aerobic microorganisms initially present in the silage, such as yeasts and molds and an increase in pH.

6.7.2 Undesirable Microorganisms and their Metabolites

Several undesirable microorganisms can grow during ensiling process which can affect silage quality and thus affect animal performance or both animal and human health. These microorganisms are known as spoilage microorganisms; responsible for silage degradation mainly induce economic losses.

Yeasts and molds: Yeasts are considered to be the most important groupamong the undesirable microorganisms of silage because they are involved in aerobic spoilage either during the aerobic phase at the beginning of ensiling or during the unloading phase. The organic acid metabolism pathways (succinic, citric and lactic acids) of yeasts restarts on exposure of silage to air; inducing a pH increase and allowing the growth of less acid-tolerant microorganisms. Yeasts present in silage convert WSC into CO2 and alcohols; impair silage quality and lead to a decrease in feed intake. The alcohol production also has negative effect on milk taste.

Moulds are eukaryotic micro-organisms and develop in part of silage where oxygen is present. Many mould species produce the large filamentous structures and coloured spores in silage. Penicillium (70%), Fusarium (47%) and Aspergillus (34%) are the most frequent mycotoxin-producing fungi isolated from corn silage. There metabolites remain in the silage even after the fungus has disappeared. More than 20 mycotoxins can be produced by Fusarium sp., mainly dioxynivalenol (DON), zearalenone (ZEN) and fumonisin (FB).

Chronic exposure to mycotoxins produce non-specific symptoms such as immune system impairment, increased infections and metabolic and hormonal imbalances. Ruminants are better protected than other animals against many mycotoxins but fumonisin B1 is only poorly metabolized in the rumen.In high producing dairy animals fed on silage-based diets with high levels of concentrates; the consequent acidification of the rumen environment may increase the animal's sensitivity to mycotoxins.

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

Bacilli: Bacilli are like clostridia endospore-forming rod shaped bacteria. Nevertheless, they can easily be distinguished from clostridia due to the fact that they are (facultative) aerobes, whereas all clostridia are obligate anaerobes. Facultative aerobic bacilli ferment a wide range of carbohydrates to compounds such as organic acids (e.g., acetate, lactate, and butyrate) or ethanol, 2,3-butanediol, and glycerol. Some specific Bacillus sp. are able to produce antifungal substances, and have been used to inhibit aerobic spoilage of silage. Except for these specific strains, the proliferation of bacilli in silage is generally considered undesirable. Not only are bacilli less efficient lactic and acetic acid producers than lactic acid bacteria (McDonald et al. 1991), they can also enhance (later stages of) aerobic deterioration. Furthermore, high numbers of Bacillus spores in raw milk have been associated with high spore numbers in fresh cow feces. In seems very plausible that bacillus spores are transferred from silage to milk via feces similar to clostridial spores.

Butyric acid bacteria (BAB): Soil accidentally included with the plant material during silo filling is the source of Butyric acid bacterial contamination of silage. Endospore-forming bacteria of the genera Clostridium, especially C. tyrobutyricum and C. butyricum and Bacillus are main BAB found in silage.At a relatively low ph,BABconvert lactic acid into butyric acid, hydrogen and carbon dioxide. A typical "clostridial silage" is characterized by a high butyric acid content of more than 5 g/kg DM, a high pH (over pH 5 in low DM silages), and a high ammonia and amine content. Excess butyric acid from feeding butyric silages results in higher levels of plasma Ketones. Daily doses of over 50 – 100g of butyric acid can cause ketosis. Feeding butyric silage has long term negative effects on production, fertility and health, thus economy of the farm business.

Listeria: The presence of *L. monocytogenes* in silage, feces or both increases the risk of its presence in milk and hence of its transmission to humans. pH of silage over 4.5 increases the risk of presence of *Listeria sp*. In ruminants it could cause encephalitis, absorption or septicemia, even death.

E. coli **(STEC):***E. coli* and higher prevalence of E. coli O157 or *E. coli* O157:H7 has been found in herds fed corn silage. At ensiling, insufficient anaerobiosis could delay the establishment of lactic acid fermentation, slowing the pH decrease andincreasing the survival of pathogenic E. coli, which is a food born pathogen.

Biogenic amines (BA): Putrescine, cadaverine and tyramine are main biogenic amines found in silage; derived from arginine, lysine and tyrosine, respectively. These are produced due to amino acid decarboxylation by enzymes of several lactic acid bacteria. Species of many genera present in silage such as *Clostridia*, *Bacillus*, *Klebsiella*, *Escherichia* and *Pseudomonas* can also cause biogenic amine production. Several factors such as temperature, oxygen availability and rapidity of pH decrease during the initial stage of fermentation results inthe formation of BA. Feeding of silage having BA acts as causative factors in ketonemia. BA presence in silage decreases the palatability and reduces Dry Matter Intake (DMI) and cattle performance.

6.8 PRESERVING TECHNIQUE

After the fermentation process is done and once all of the oxygen is used up, lactic acid bacteria start to multiply. These are the bacteria that are needed to make the silage. They play a key role in turning the plant sugars into lactic acid causing the pH to drop (mixture becomes more acidic). Once the pH is around 4-5, the sugars stop breaking down and the grass is preserved until the silage is opened and exposed to oxygen.

If the pH isn’t low enough, a different kind of bacteria will start fermenting the silage, producing by-products (like ammonia) that taste bad to cows and sheep. Thus, the latter situation needs to be avoided at all costs.

6.9 PREVENTIVE MEASURES TO CONTROL SILAGE SPOILAGE

Preservation of surplus fodder as silage makes it possible to have the green fodder availability throughout the year. Lactic acid fermentation is important for good silage production, but some undesirable bacteria can make entry during ensiling, which can degrade the quality of silage and cause economic losses to the farmer. Safety control measures and additives may be helpful used in producing quality silage.

In developing countries including India, livestock sector is one of the fastest growing segment of the agricultural economy. The supply of the green forage throughout the year is an economic priority to the farmers, in order to maintain the production from the ruminant stock. But forage production is mostly seasonal in many parts of the world, with surplus availability in harvesting season and shortage of fodder during dry season. Silage making is an option to preserve the green fodder to make the greens available throughout the year. Ensiling is based on natural lactic acid fermentation under anaerobic conditions. The most important fodder crops for ensiling are corn, sorghum, barley and various other grasses. Beside these crops various moist "by-products" of the food industry, such as apple pomace, beet pulp and brewer's mash can also be used for silage preparation. Ensiling process has many steps which should be timed and controlled carefully to ensure successful ensiling.

6.10 PREPARATION OF SILAGE

During the silage making process, the pasture is cut when the grasses contain the highest nutrient levels. This level is attained just before they are fully mature. The reason why it is cut just before they are fully mature is that all forms of preserved grass, such as hay and silage, will have lower amounts of nutrients than fresh pasture, so everything must be done to make the end product be as nutritious as possible. During Silage preparation, the grass is allowed to wilt in the field for a few hours to reduce the moisture content to around 60-75% as this is the optimum level. If the grass is left out longer, it may get too dry, or it may get rained on and both these will reduce the efficiency of the fermentation (Hoogkamp,1999).

6.11 PROCESS IN SILAGE MAKING

1. **Selection of forage crops and their maturity stage**

   The optimum dry matter for crop harvesting for silage depends on the stage of harvesting (Table 1). Most of crops are harvested at 50% flowering to dough stage when the moisture content varies between 18-22%. After overnight wilting the dry matter content become 30-35% which is proper dry matter content for ensiling. Table 1: Optimum stage for crop harvesting Common forage crops Stage of harvest Maize 50% flowering to dough stage Sorghum 50% flowering to dough stage Bajra 50% flowering to dough stage Oat Boot to dough stage

2. **Steps in silage making**

   Silage making involves four major steps viz., harvesting and transportation, chaffing, filling and compaction and covering of silo.

1. **Pit making:**

   Firstly, a silage pit has to be dug for storing silage. The pit size may be determined based on the amount of silage to be stored. A pit with a dimension of 1 metre wide X 1 metre length X 1 metre depth can store 500 kilograms of silage. The location of pit should be free from water stagnation. The pit should be surrounded on all sides with thick plastic sheet. Pit can also be constructed using bricks and cement.

2. **Preparation of fermentation mixture:**

   For preparing 1 ton silage, the following materials are required.

   - Jaggery or Molasses – 1 Kg
   - Salt – 1 Kg
   - Mineral Mixture – 1 Kg
   - DCP (Di-Calcium Phosphate) – 1 Kg
   - LAB (Lactic Acid Bacteria)
   - Urea – 1 Kg

   Mix all of the above into a drum by adding water

3. **Harvesting and transportation of crop (ensiling):**

   Harvesting at proper stage but delay in transportation may lead to loss of excess moisture results in haylage (DM 70-80%) 4. Chaffing:

   It has to be chaffed into small pieces preferably 2-4 cm length using a chaff cutter. This improves the packing density which favours the growth of lactic acid bacteria, naturally present in crops. Add the fermentation mixture in small quantities as the fodder is loaded to chaff cutter. Position the chaff cutter so the chaffed fodder directly falls into the silage pit. Level the chaffed pieces evenly and press it hard so that all air comes out. Pressing and removing air is very important.

5. **Filling of silo and compaction:**

   Chaffed material should be spread evenly over entire surface of silo (the structure) and then compacted through trampling (in case of small silo). In case of large silo (trenches) the compaction can be done using tractor. It helps in rapid evacuation of air from the silo, thus checks the aerobic respiration and nutrient loss.

6. **Properly sealing and covering of silo pit:**

   It should be done in such a way that neither air enters in to the silo nor the gas comes out from the silo. It is better to use polythene sheet but care should be taken that entire surface of polythene sheet should be covered with straw or any other dried material up to 6-8 inch thickness to avoid the damage of polythene sheet by dog, cat or other animals. Make sure water does not enter the pit during rains. The silage will be ready in 45 to 60 days, depending on the types of material used. The silage of thin stem crop like oat becomes ready in 45 days while thick stem crops like maize, sorghum and bajra become ready in 60 days. Ideal silage is golden yellowish green colour with good aroma. After completion of incubation period the silo is opened for feeding. The whole silo should not be disturbed and it should be opened from one place/corner to avoid the loss of moisture and nutrients. Depending on the type of animal, stage of production and availability of silage it can be supplemented in the ration (5-25 kg per animal) of animal during lean period. After opening the pit, silage should be used within 30 days.

6.12 PLANNING FOR SILAGE MAKING

There are two methods for silage making which are vastly used i.e. Pit method or tank method. These two methods are economically viable for dairy farmers.

- **Pit/tank method for silage making**

For pit method, select location for making pit at higher level on ground so that rain waer may not percolate in to pit. In rectangular pit, corner edges should be making round so that while filling & pressing chaffed fodder, air will not remain inside in the corners of pit or tank. Wall of pit/tank should be air proof to avoid air too come inside in pit /tank through cracks or crevices .To avoid this situation, plaster wall of silo pit or tank with cement or moistened soil.

- **Treatment for Silage**

For making best quality & balanced silage, needs proper treatment of additives like Per ton of chaffed green fodder requires 1 kg Urea, 2 kg jaggary, 1 kg common salt, 1 kg mineral mixture & 1 litre of Whey.

- **Procedure for filling silo pit/tank**

When fodder crop is in cob stage or Tussling stage, harvest it for preparation of silage. Very mature stage is not good for preparing silage as its sugar content is decreased as well as fibre percentage in increased; this kind of fodder is less suitable for silage making.

After harvesting fodder crops, let it dry for 5-6 hours in shed so that moisture content of fodder will decreases from 80% to 65-70%.Care to be taken to avoid silage making in rainy days or crops containing dew drops in winter season because moisture is more in this situation so there may be chances for development of mould in silo pit during storage period.

Following steps to be taken while filling silo pit-

- Prior to filling silo pit / tank, clean·& dry it.
- Cover with plastic film inside pit/tank in such way that it will cover all sides of pit/tank.·
- For making silage, chaffing of fodder is essential component. With the help of chaff cutter machine, make pieces of 1.5c.m. to 2 c.m. length of green maize.sorghum,sugarcane tops,marwel,Fodder bajara etc for filling silo pit.·
- Prepare separate solution in 15 to 20 litres of water for Urea, Jaggary, Mineral mixture· & common salt in separate pots/buckets & then spread

it on layer of pressed chaffed green fodder while filling silo pit/tank.

- Start to fill chaffed green fodder in pit or tank.
- After making 4” thick layer of chaffed green fodder, press it with wooden plank(Like Mortar) in such a way that air will not entangled in chaffed fodder. Then sprinkle it with prepared solution of Jaggary, Mineral mixture, Urea, Common salt· & whey.
- Follow the same procedure until filling of pit/tank 1 to 1.5 feet above the ground level(In pit).Then covet it from plastic film from all side carefully.·
- Covet it with Trash, Wheat straw, Soil· & dry hay to protect it from entering rain water in to it. If possible to temporary arrangement of shed above the silo pit/tank.
- It will require 45 to 60 days to make good quality of silage (Hengeveld 1983).

6.13 USE OF SILAGE

After 8-10 weeks, silage is ready as feed for animals. Open pit/tank initially from one side of for use. If it is not in use, then cover it carefully with plastic film so that air will not go inside in silage. Initially animals should be fed with 5-6 kg silage by adding it with chaffed green fodder to develop taste to animals. Once animal likes sweet-sour taste of silage; it will eat it with good liking.

6.14 QUALITY OF SILAGE

- Mould- If silage while filling pit/tank, not well pressed; there will be growth of mould.
- Odour- Good quality silage has sweet & sour taste.
- Colour- Good quality silage has faint green or brownish colour. Rotten silage has black colour.
- pH- Good quality silage has pH of 3.5 to 4.2.

6.15 STRATEGIES TO LIMIT SILAGE DEGRADATION BY UNDESIRABLE MICROORGANISMS

Spoiled silage has to be thrown out because till now no any measure has been develop to improve the quality of spoiled silage. Main factors which affect the quality during silage processing are the use of poor quality or immature plant material, insufficiently rapid filling (causes delay in establishment of anaerobiosis leading to weak silage acidification), and contamination by pathogenic or spoilage microorganisms. Preventive measures which should be taken care for quality silage production are discussed below.

Promoting acidification: Silage preservation is mainly based on acidification which depends on anaerobiosis (promoting LAB fermentation), buffering capacity and DM of the crop. Soil incorporation in silage increases its buffering capacity, encourages the growth of aerobic microorganisms, which reduce the quantity of hexoses and pentoses available for further LAB fermentation. This all leads to delay in silageacidification during which lactic acid is converted to butyric acid, followed by pH increase and further spoilage due to secondary fermentation by Clostridia. Mineral acids such as sulfuric and chlorhydric acids has been used to promote silage acidification and to limit the pathogenic microorganism growth.

Establishment of anaerobiosis during ensiling: For good silage production anaerobic conditions should be established as soon as possible in the silo. This can be achieved by rapid filling of silo and compaction of the silo to exclude the trapped air. Compaction of silage is easy with small particle size of crops. So chopping length plays an important role in good silage production, while every small particle size may impair the rumen function. For grass silage optimum chopping length is 4-6 cm. The corn silage prepared for dairy cow feeding should contain less than 1% of large particles (>2 cm), 8–12% of medium particles from 1 to 2 cm and less than 50% of very short particles (<6 mm). Harvesting of crop at appropriate dry matter is helpful to reduce effluent losses, which may impair anaerobiosis.

Prevention of air ingression during storage of silage: Silo should be sealed properly to avoid air ingression during storage, which can lead silage spoilage. A barrier made up of plastic sheets is helpful to prevent air ingression and give protection against damage by birds, rodents and UV rays. To reduce spoilage of silage due to exposure during feed-out phase,silage requirement and silo pit dimensions should be calculated prior to silage making.

Improving the aerobic stability of silage: Chemical additives like formic acid, silage additives containing partially neutralized acids in salt form (nitrites, sulfates) in association with formol-based preservatives can be used to improve aerobic stability of silage. Bacterial additives like *Lactobacillus buchneri* and *Lactobacillus plantarum*, *Pediococcus acidilactici*, *Pediococcus cerevisiae* and *Propionibacterium acidipropionici* can also be used during ensiling to improve the silage quality. Bacterial inoculants also limit pathogen development andproduce substances which may have antimicrobial potential (H_2O_2, ethanol, diacetyl, exopolysaccharides) and antibacterial peptides such as bacteriocins.

Prevention of pathogen introduction during harvesting and ensiling of crop: Entry of soil in the silage is the source of butyric acid bacterial/ pathogen contamination. Crops should be harvested 4 weeks after manure application taking care to prevent contamination by soil (Woods et al., 1981).

6.16 SILAGE ADDITIVES

In the past decade it has become increasingly common to use silage additives to improve the ensiling process. The choice of additives appears to be sheer limitless if one looks at the large number of chemical and biological silage additives that are commercially available. (Table 1).

Table 1: Category of additives

Additive category	**Selection of Active ingredients**	**Remarks**
Fermentation stimulants	Lactic acid bacteria Sugars (molasses) Enzymes	May impair aerobic stability
Fermentation inhibitors	Formic acid Lactic acid Mineral acids Nitrite salts Sulfite salts Sodium chloride	Inhibition of clostridia
Aerobic deterioration inhibitors	Lactic acid bacteria Propionic acid Benzoic acid Sorbic acid	
Nutrients	Urea Ammonia Minerals	Can improve aerobic stability
Absorbents	Dried sugar beet pulp Straw	

6.17 ENZYMOLOGY OF SILAGE PRODUCTION

Enzyme addition to silages has received considerable attention over the past decade. Their primary function is to break down forage fiber during fermentation, rendering the silage more digestible during feedout. The breakdown of fiber into soluble sugars also helps bacteria produce lactic acid, which helps to lower silage pH. An enzyme is a naturally occurring protein that catalyzes chemical reactions in biological systems. Enzymes promote the breakdown of complex feed molecules into smaller chemical fractions such as glucose or amino acids that are digestible by the ruminant animal. As an example, the enzyme cellulase initiates the breakdown of cellulose (fiber) into sugars. Common enzyme-based silage additives contain cellulases, hemicellulases, xylanases, amylases, and pectinases. Cellulases, hemicellulases, and pectinases are enzymes that degrade the fiber portion of forages. Amylase breaks down starch (amylose) therefore its use would be directed towards starch containing silages such as corn silage.

A number of studies have reported reductions in neutral detergent fiber (NDF) by using enzyme-based silage additives. Observed NDF reductions have been more consistent in grass silages as compared to alfalfa silage. Research data also suggests that hemicellulases and pectinases are more effective than cellulases at reducing fiber content. Unfortunately, hemicellulases and pectinases break down fiber fractions (hemicellulose, pectin) that are more easily digested by ruminants. Consequently, these enzymes reduce the concentration of digestible NDF fractions rather than the indigestible NDF fraction cellulose.

Enzymes can improve silage fermentation when the substrate (e.g., sugars) is limiting. Soluble sugars are required to help bacteria produce lactic acid, which is required to lower silage pH for proper fermentation. Generally, enzyme addition to silages has a small positive effect on fermentation.

Interestingly, current trends in enzyme technology involve incorporating enzymes directly into total mixed rations (TMRs) or silages prior to feeding. Initial research has observed some positive effects using this method. The economics of this practice have yet to be determined.

Enzyme technology continues to improve. New products designed for ruminants and for specific types of feed will increase the potential for profitable use of enzymes with silages.

Check Your Progress 2

Note: a) Use the space given below for your answers.

b) Check your answers with those given at the end of the unit

1. Explain process of silage making.

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2. Describe uses of Silage?

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3. Name the enzymes involved in silage production?

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6.18 LET US SUM UP

We have studied the Silage with its advantages and disadvantages. We have studied the principle of silage production with well define role of proteolytic and cellulolytic organisms. We have studied the enzymes required for silage production.

6.19 KEY WORDS

Silage: Silage, also called ensilage, forage plants such as corn (maize), legumes, and grasses that have been chopped and stored in tower silos, pits, or trenches for use as animal feed.

Additives: A substance added to something in small quantities to improve or preserve it.

Enzyme: Enzymes are proteins that help speed up metabolism, or the chemical reactions in our bodies. They build some substances and break others down. All living things have enzymes.

Fungi:A fungus (plural: fungi or funguses) is any member of the group of eukaryotic organisms that includes microorganisms such as yeasts and molds, as well as the more familiar mushrooms.

Bacteria: Bacteria are small single-celled organisms. Bacteria are found almost everywhere on Earth and are vital to the planet's ecosystems.

Cellulose: Cellulose is a polysaccharide composed of a linear chain of β-1,4 linked d-glucose units with a degree of polymerization ranged from several hundreds to over ten thousands, which is the most abundant organic polymer on the earth.

6.20 SUGGESTED FURTHER READING/REFERENCES

- Wilkins, R.J., L. Syrjälä-Qvist, and K.K. Bolsen1999. p. 23-35. In: T. Pauly (ed.) Proc. 12th Int. Silage Conference, Uppsala, Sweden, 5-7 July. 1999.
- Weinberg, Z.G., and R.E.Muck 1996. New trends and opportunities in

the development and use of inoculants for silage. FEMS Microbiol. Rev. 19, 53-68.

- Merry, R.J., K.F. Lowes, and A. Winters 1997. Current and future approaches to biocontrol in silage. p. 17-27. In:V. Jambor, L. Klapil, P.Chromec, and P. Prochazka. (ed.) Proc. 8th Int. Symposium Forage Conservation, Brno, Czech Republic. 29 Sept.-1 Oct. 1997. Research Institute of Animal Nutrition, Pohorelice, Czech Republic.
- Honig, H., and M K.Woolford1980. Changes in silage on exposure to air. p. 76-87. In: C. Thomas (ed.) Forage Conservation in the 80s . Occasional Symposium No. 11 . British Grassland Society, Hurley, Berkshire, UK.
- Hengeveld, A.G. 1983. Sporen van boterzuurbacteriën in kuilvoer. Report 88. Proefstation voorde Rundveehouderij, schapenhouderijen paardenhouderij, Lelystad, The Netherlands.
- Holzapfel, W.H., and U. Schillinger1992. The Genus Leuconostoc . p. 1508-1534. In: Balows, A., H.G. Trüper, M. Dworkin, W. Harder, K.-H. Schleifer (ed.) The Prokaryotes. 2nd ed. Springer Verlag, New York, USA.
- Hoogkamp, W. 1999. Koeien smullen van kuilgras met bacteriemengsels. Boerderij- Veehouderij 84,32-33.
- Weiss, N. 1992. The Genera Pediococcus and Aerococcus . p. 1502-1507. In: Balows, A., H.G. rüper, M. Dworkin, W. Harder, K.-H. Schleifer (ed.) The Prokaryotes. 2nd ed. Springer Verlag, New York, USA.
- Weissbach, F., and H. Honig1996. Über die Vorhersage und Steuerung des Gärungsverlaufs bei der Silierung von Grünfutter aus extensivem Anbau. Landbauforschung Völkenrode, Heft 1,10-17, Germany.
- Wiedmann, M., J. Czajka, N. Bsat, M. Bodis, M.C. Smith, T.J. Divers, and C.A. Batt1994. Diagnosis and epidemiological association of Listeria monocytogenes strains in two outbreaks of listerial encephalitis in small ruminants. J. Clin. Microbiol. 32, 991-996.
- Wieringa, G.W. 1958. The effect of wilting on butyric acid fermentation in silage. Neth. J. Agr. Sci. 6, 204-210. Swedish University of Agricultural Sciences, Uppsala, Sweden.
- Wilkinson, J.M., F. Wadephul, and J. Hill 1996. Silage in Europe, a survey of 33 countries. ChalcombePublications, Welton, UK.
- Woods, L.F.J., J.M. Wood, and P.A. Gibbs1981. The involvement of nitric oxide in the inhibition of the phosphoriclasticsystem in Clostridium sporogenes by sodium nitrite. J. Gen. Microbiol. 125, 339-406.
- Woolford, M.K. 1975a. Microbiological screening of the straight chain

fatty acids (C1-C12) as potential silage additives. J. Sci. Food Agr. 26, 219-228.

- Woolford, M.K. 1975b. Microbiological screening of food preservatives, cold sterilants and specific antimicrobial agents as potential silage additives. J. Sci. Food Agr. 26, 229-237.
- Woolford, M.K. 1984. The Silage Fermentation. Microbiological Series, 14, Marcel Dekker, Inc., New York and Basel.
- McDonald P., A.R.Henderson, and S.J.E. Heron 1991. The Biochemistry of Silage. 2nd edition. ChalcombePublications, Marlow, Bucks, UK.
- Hammes, W.P., N. Weiss, and W. Holzapfel1992. The Genera Lactobacillus and Carnobacterium . p. 1535-1594. In: Balows, A., H.G. Trüper, M. Dworkin, W. Harder, K.-H. Schleifer (ed.) The Prokaryotes. 2nd ed. Springer Verlag, New York, USA.
- Schleifer (ed.) The Prokaryotes. 2nd ed. Springer Verlag, New York,USA.
- Spoelstra, S.F. 1983. Inhibition of clostridialgrowth by nitrate during the early phase of silage fermentation. J. Sci. Food Agr. 34, 145-152.
- Spoelstra, S.F. 1985. Nitrate in silage. A review. Grass Forage Sci. 40, 1-11. Spoelstra, S.F. 1987. Degradation of nitrate by enterobacteriaduring silage fermentation of grass. Neth. J. Agr. Sci. 35, 43-54.
- Spoelstra, S.F, M.G. Courtin, and J.A.C. van Beers 1988. Acetic acid bacteria can initiate aerobic deterioration of whole crop maize silage. J. Agr. Sci.Camb. 111, 127-132.
- Auerbach, H., E. Oldenburg, and F. Weissbach1998. Incidence of Penicillium roqueforti and roquefortinC in silages. J. Sci. Food Agr. 76,565-572.

6.22 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Forage which has been grown while still green and nutritious can be conserved through a natural 'pickling' process. Lactic acid is produced when the sugars in the forage plants are fermented by bacteria in a sealed container ('silo') with no air. Forage conserved this way is known as 'ensiled forage' or 'silage' and will keep for up to three years without deteriorating. Silage is very palatable to livestock and can be fed at any time.

2. **Advantages:**

    - Stabile composition of the feed (silage) for a longer period (up to 5 years);

- Plants can be harvested at optimal phase of development and are efficiently used by live-stock.
- Reduction of nutrient loses which in standard hay production may amount to 30% of the dry matter (in silage is usually below 10%);
- More economical use of plants with high yield of green mass;
- Better use of the land with 2-3 crops annually;
- Silage is produced in both cold and cloudy weather

Disadvantages:

- Silage is not interesting for marketing as its value is difficult to be determined.
- It does not allow longer transportation;
- The weight increases manipulation costs;
- Has considerably lower vitamin D content compared to hay.
- The fermentation in silage reduces harmful nitrates accumulated in plants during droughts and in over-fertilized crops.
- Allows by-products (from sugar beat processing, maize straw, etc.) to be optimally used;
- Requires 10 times less storage space compared to hay;
- Maize silage has 30-50% higher nutritive value compared to maize grain and maize straw;
- 2 kg of silage (70% moisture) has the equal nutritive value of 1 kg of hay.

3. At harvest, plant cells do not immediately "die"; they continue to respire as long as they remain adequately hydrated and oxygen is available. The oxygen is necessary for the physiological process of respiration, which provides energy for functioning cells. In this process, carbohydrates (plant sugars) are consumed (oxidized) by plant cells in the presence of oxygen to yield carbon dioxide, water and heat.

   Sugar + oxygen=carbon dioxide + water + heat

   Once in the silo, certain yeasts, molds and bacteria that occur naturally on forage plants can also reach populations large enough to be significant sources of respiration. In the silage mass, the heat generated during respiration is not readily dissipated, and therefore the temperature of the silage rises.

   Although a slight rise in temperature from 80° to 90°F is acceptable, the goal is to limit respiration by eliminating air (oxygen) trapped in the forage mass. Some air will be incorporated into any silo during the filling process. These temperature increases can clearly be limited by harvesting at the proper moisture content and by increasing the bulk density of the silage. Generally, it is desirable to limit respiration during the fermentation process by using common sense techniques that include close inspection of the silo walls prior to filling, harvesting the forage at the proper moisture content, adjusting the chopper properly (fineness of chop), rapid filling, thorough packing, prompt sealing and close inspection of plastics for holes.

Check Your Progress 2

1. **Selection of forage crops and their maturity stage**

   The optimum dry matter for crop harvesting for silage depends on the stage of harvesting (Table 1). Most of crops are harvested at 50% flowering to dough stage when the moisture content varies between 18-22%. After overnight wilting the dry matter content become 30-35% which is proper dry matter content for ensiling. Table 1: Optimum stage for crop harvesting Common forage crops Stage of harvest Maize 50% flowering to dough stage Sorghum 50% flowering to dough stage Bajra 50% flowering to dough stage Oat Boot to dough stage

2. **Steps in silage making**

   Silage making involves four major steps viz., harvesting and transportation, chaffing, filling and compaction and covering of silo.

1. **Pit making:**

   Firstly, a silage pit has to be dug for storing silage. The pit size may be determined based on the amount of silage to be stored. A pit with a dimension of 1 metre wide X 1 metre length X 1 metre depth can store 500 kilograms of silage. The location of pit should be free from water stagnation. The pit should be surrounded on all sides with thick plastic sheet. Pit can also be constructed using bricks and cement.

2. **Preparation of fermentation mixture:**

   For preparing 1 ton silage, the following materials are required.

   - Jaggery or Molasses – 1 Kg
   - Salt – 1 Kg
   - Mineral Mixture – 1 Kg
   - DCP (Di-Calcium Phosphate) – 1 Kg
   - LAB (Lactic Acid Bacteria)
   - Urea – 1 Kg

   Mix all of the above into a drum by adding water

3. **Harvesting and transportation of crop (ensiling):**

   Harvesting at proper stage but delay in transportation may lead to loss of excess moisture results in haylage (DM 70-80%) 4. Chaffing:

   It has to be chaffed into small pieces preferably 2-4 cm length using a chaff cutter. This improves the packing density which favours the growth of lactic acid bacteria, naturally present in crops. Add the fermentation mixture in small quantities as the fodder is loaded to chaff cutter. Position the chaff cutter so the chaffed fodder directly falls into the silage pit. Level the chaffed pieces evenly and press it hard so that all air comes out. Pressing and removing air is very important.

5. **Filling of silo and compaction:**

   Chaffed material should be spread evenly over entire surface of silo (the structure) and then compacted through trampling (in case of small silo). In case of large silo (trenches) the compaction can be done using tractor. It helps in rapid evacuation of air from the silo, thus checks the aerobic respiration and nutrient loss.

6. **Properly sealing and covering of silo pit:**

   It should be done in such a way that neither air enters in to the silo nor the gas comes out from the silo. It is better to use polythene sheet but care should be taken that entire surface of polythene sheet should be covered with straw or any other dried material up to 6-8 inch thickness to avoid the damage of polythene sheet by dog, cat or other animals. Make sure water does not enter the pit during rains. The silage will be ready in 45 to 60 days, depending on the types of material used. The silage of thin stem crop like oat becomes ready in 45 days while thick stem crops like maize, sorghum and bajra become ready in 60 days. Ideal silage is golden yellowish green colour with good aroma. After completion of incubation period the silo is opened for feeding. The whole silo should not be disturbed and it should be opened from one place/corner to avoid the loss of moisture and nutrients. Depending on the type of animal, stage of production and availability of silage it can be supplemented in the ration (5-25 kg per animal) of animal during lean period. After opening the pit, silage should be used within 30 days.

2. After 8-10 weeks, silage is ready as feed for animals. Open pit/tank initially from one side of for use. If it is not in use, then cover it carefully with plastic film so that air will not go inside in silage. Initially animals should be fed with 5-6 kg silage by adding it with chaffed green fodder to develop taste to animals. Once animal likes sweet-sour taste of silage; it will eat it with good liking.

3. Common enzyme-based silage additives contain cellulases, hemicellulases, xylanases, amylases, and pectinases. Cellulases, hemicellulases, and pectinases are enzymes that degrade the fiber portion of forages. Amylase breaks down starch (amylose) therefore its use would be directed towards starch containing silages such as corn silage.