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NUTRITIOUS FEED FOR FARM ANIMALS DURING LEAN PERIOD : SILAGE AND HAY-A REVIEW

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SUMMARY

Green forages are considered to be the backbone of dairy sector as they play a vital role in transforming dairy farming into a profitable business. So, there is urgent need for preservation of nutrients from green forages including fodder tree leaves available during the flush period for feeding livestock during lean period so that high yielding animals can be sustained for profitable dairy farming. Silage is as nutritious as green fodders as it preserves the nutrients in the original form and hence it is as good for animal feeding as green fodder itself. From a practical view, the three most important things that must occur in order to make good silage are 1) the rapid removal of air, 2) the rapid production of lactic acid that results in a rapid drop in pH, and 3) continued exclusion of air from the silage mass during storage and feed out. In certain forage crops such as maize has relatively low buffering capacity and high concentrations of fermentable carbohydrates; therefore, pH decline is rapid and final pH is usually low, approximately 3.5, thus are more suitable for silage making. In general, the pH of silage at the final stage should be within the range of 3.5-4.3. Berseem and alfalfa has a high buffering capacity in comparison to maize leading to difficulty in lowering pH and making silage from berseem. Proper dry matter in forage should be there so that it can be packed well and more lactic acid is produced. Longer filling time of chaffed fodder in silo might have not maintained anaerobic conditions properly leading to increased aflatoxins in silage. The container in which silage is made is of greatest importance and will determine to the large extent the nature and quality of final product. The most common silo is the trench silo. One cubic meter space can store 5-6 quintals of green chopped fodder. Various types of additives can be used to improve or inhibit the fermentation or supplement nutrients needed by ruminants to be fed as silage. Silage quality is determined by mainly the odour, physical state, pH, ammonia nitrogen, volatile acids and lactic acid. It should be of pleasant smell and semi dry in nature. It should be of green colour. Another way of preserving nutrients is practiced in the form of hay. The principle of hay making is to preserve nutritional value of forages through drying it to a level at which the activity of microbial decomposers is inhibited. Forages can he harvested at the stage of proper nutritive value and be preserved as hay for feeding it during lean period. A moisture content of 10- 12 % is optimum level for halting the microbial activity. It assures the supply of high digestible feed with high protein and caloric values all the year round. Hay making is profitable when the production of fodder is in excess of consumption. Food quality of dried forage (hay) is as nutritious as the green forage (if available) during the period of June-December when high protein forage is scarce. It fetches higher price and helps to increase milk production.

Key Words : Silage, Hay, Lean, Silo pit, Dry matter, Protein

Green forages are considered to be the backbone of dairy farming as they play a vital role in transforming dairy farming into a profitable business. India is basically an agrarian country with large livestock population making dairy and livestock industry an important subsidiary occupation of farmers. It contributes to the economy of the country by providing milk, meat, wool etc. India has recently emerged as largest producer of milk in the world but livestock productivity is very low as compared to the developed countries. Low productivity of the animals is ascribed chiefly due to inadequate supply of nutrients. Poor supply of nutrients to livestock during scarcity period is a matter of concern. Both quantitatively and qualitatively, there exists a huge gap in availability and supply of feed nutrients which is further compounded during lean and scarcity period (Singh and Mojumdar, 1992; Kumar *et al.*, 2016). Inadequate supply of quality fodder has been identified as one of the reasons for poor livestock productivity (Anjum *et al*, 2012; Kumar *et al*, 2016).

Contribution of forage in animal feed is more than 75% and is considered a cheap source of nutrients (Kumar *et al.*, 2014). At present there is 63 % deficiency of green fodder and 23.5 % deficiency of dry fodder in India (Singh, 2009) whereas in Punjab there is 26.7 % deficiency of green fodder (Mahal and Bhatti, 2018) where as dry fodder in the form of wheat *bhusa* and rice straw is available in sufficient quantity. During the lean period (May-June and November-December) the farmer have to feed straws and stover's along with the costly concentrates to fulfill the daily dietary requirement of milking animals. The straw and stovers are not nutritious feed and is often deficient in some vital nutrients and hence may produce some deficiency disease in farm animals whereas concentrates are not economically viable. So, there is urgent need for preservation of nutrients from green forages including fodder tree leaves available during the flush period for feeding livestock during lean period (Mahanta and Pachauri, 2005) so that high yielding animals can be sustained for profitable dairy farming.

Forage conservation is a key element for productive and efficient ruminant livestock farms. Forage conservation permits a better supply of quality feed when forage production is low or dormant. Forage conservation also provides farmers with a means of preserving forage when production is faster than can be adequately utilized by grazing animals. This prevents lush growth from becoming too mature. Consequently, forage conservation provides a more uniform level of high quality forage for ruminant livestock throughout the year.

India being a tropical monsoon bound country, here large quantity of surplus *Kharif* forages are produced which are frequently excess of need. It is therefore essential to preserve the nutrients available from excess forage both during *Kharif* as s well as *Rabi* season at proper stage of maturity to provide nutrients during lean period. As the climate is changing very fast and there is unpredictability in rain fall in recent years due to which drought like conditions has arisen. Under such conditions not only major crop like rice, maize, bajra and pulses suffered loss but, also there was drastic reduction in the yield of forage crops which ultimately has negative effect on the growth of animals, milk production and dairy industry as whole in the state and at national level due to inadequate nutritional supply during scarcity of fodder. Poor nutritional support during scarcity also caused adverse effects on dairy animals which included, weight loss, poor fertility and reproductive function, breeding cover, bovine population and draft energy.

In order to combat these situations, the nutrients from forage can be preserved either as silage or hay in order to meet the fodder requirement in lean period (Ozata *et al.*, 2018). Ensilage and hay making are the two popular methods of forage preservation widely used. Silage consists of chopping of green forage and storing them in a specially constructed underground or above ground structure, ensuring that no air or moisture enters into it. Silage particularly corn silages is a major forage source for dairy animals (Wei *et al.*, 2018; Goyal and Tiwana, 2016).

Hay making, the other method of forage preservation, consists of drying the harvested forage crops at appropriate stage of growth to a safe level of around 15 per cent moisture content without much bleaching, wetting, or shattering of leaves. The forage preserved in this manner is called 'hay". Haylage sometimes also called low-moisture silage, hay crop silage or drylage, can be defined as the hay put up at 40 to 60 per cent moisture as compared with less than 15 per cent for dried hay and 60 to 75 per cent for silage. There is high energy out put in high temperature dehydration and therefore can not be termed as economically feasible. Forage can be profitably preserved either as silage or hay for providing nutrients during scarcity.

Silage

Silage is the product from a series of processes by which cut forage of high moisture content is fermented to produce a stable feed which resists further breakdown in anaerobic storage.

Silage is as nutritious as green fodders as it preserves the nutrients in the original form and hence it is as good for animal feeding as green fodder itself. Production of high-quality silage is dependent on both controllable and uncontrollable factors (Bernardes *et al*, 2018). One time harvesting of fodder crop for silage making is beneficial, since we can harvest the crop at appropriate time when the nutrient content in them are at peak. During silage making, the palatability of fodder crop increased as hard stem on fermentation in silage becomes soft, this helps in easy digestion by dairy animals and the anti quality components are either destroyed or lowered during silage fermentation (Chaudhary *et al.*, 2012).

Ensiling-A potential method for conserving nutrients

Ensiling is a process by which fodder or feed is stored in a silo in order to be converted into silage, a more succulent feed for livestock. The principle of ensiling involves the conversion of water-soluble carbohydrates (WSCs) into organic acids (mainly lactic acid) by lactic acid bacteria (LAB) under an anaerobic environment to rapidly reduce the silage pH. As a result, decomposition of the nutrients is inhibited and the storage time of the forage is extended through its preservation from spoilage microorganisms (Zhang *et al.*, 2019). Ensilage has many advantages over the other methods for preservation of nutrients, particularly from forages. Silage is the material produced by controlled fermentation of nutrients under an anaerobic condition. Ensiling of forage requires precautions for proper preservation of nutrients as lack of understanding of the factors associated with ensiling process may produce silage of poor quality leading to the poor animal performances. The fermentation process is governed by microorganism present in fresh herbage or by additives to maintain anaerobic conditions and discourage clostridial growth with minimum loss of nutrients. This process has been used to preserve carbohydrate rich materials, either alone or through fermentation with other materials, as well as storage of protein rich materials used as animals feeds (Machin, 1990).

Ensiling procedure

From a practical view, the three most important things that must occur in order to make good silage are 1) the rapid removal of air, 2) the rapid production of lactic acid that results in a rapid drop in pH, and 3) continued exclusion of air from the silage mass during storage and feed out. Lactic acid producing bacteria (*Lactobacillus plantarum*) present on fresh forage and on silage equipment, are responsible for most of the acid production during fermentation. There is a positive correlation between the number of bacteria present at the time of ensiling and the rate of pH decline (Thomas, 2008). In short, for a rapid and extensive fermentation to occur, the forage must have high concentrations of fermentable carbohydrates, low buffering capacity, relatively low dry matter content (30-40 %) and adequate lactic acid bacteria present prior to ensiling. Certain forage crops such as maize has relatively low buffering capacity and high concentrations of fermentable carbohydrates; therefore, pH decline is rapid and final pH is usually low, approximately 3.5. In general, the pH of silage at the final stage should be within the range of 3.5-4.3 (Roth and Heinrichs, 2001). Because of the biochemical changes involved in silage making, the colour of chlorophyll changes to greenish brown due to a pigment called phaeophytin (a magnesium free derivative of chlorophyll).

After chopping, plant respiration continues for several hours (and perhaps days if silage is poorly packed) and plant enzymes (e.g., proteases) are active until air is used up. Rapid removal of air is important because it prevents the growth of unwanted aerobic bacteria, yeasts, and molds that compete with beneficial bacteria for substrate. If air is not removed quickly, high temperatures and prolonged heating are commonly observed. Air can be eliminated by wilting plant material to recommended dry matters (DM) for the specific crop and storage structure, chopping forage to a correct length, quick packing, good compacting, even distribution of forage in the storage structure, and immediately sealing the silo. When air is removed lactic acid bacteria utilize water-soluble carbohydrates to produce lactic acid, the primary acid, responsible for decreasing the pH in silage. A quick reduction in silage pH will help to limit the breakdown of protein in the silo by inactivating plant proteases. In addition, a rapid decrease in pH will inhibit the growth of undesirable anaerobic microorganisms such as enterobacteria and clostridia. Airtight silos and removal of sufficient silage during feed-out can help to prevent aerobic spoilage due to limitation of yeast.

Berseem and alfalfa has a high buffering capacity in comparison to maize leading to difficulty in lowering pH and making silage from berseem. The dry matter content of the forage can also have major effects on the ensiling process. Proper dry matter in forage should be there so that it can be packed well and more lactic acid is produced. Undesirable bacteria called clostridia tend to thrive in very wet silages and can result in excessive protein degradation, DM loss, and production of toxins. Where weather permits, wilting forage above 30-35% DM prior to ensiling can reduce the incidence of clostridia. Delayed filling of silo pit results in excessive amounts of air trapped in the forage mass can have detrimental effects on the ensiling process. Longer filling time of chaffed fodder in silo might have not maintained anaerobic conditions properly leading to increased aflatoxins in silage (Brar *et al.*, 2017). Wittenberg (2004) also reported that with rapid elimination of oxygen, as the corn herbage enters the silo, is critical for the prevention of storage moulds, as subsequent aeration of silage can cause fungi to proliferate and if conditions are suitable, mycotoxin may be produced. Another factor that can affect the ensiling process is the amount of water-soluble carbohydrates present for good fermentation to take place. WSC decreases and DM losses increased when forage was not immediately packed into silos after chopping. The end products of silage fermentation are often monitored to assess silage quality and the composition of "normal silages" is presented in Table 1.

Harvest time for making good quality silage

To prepare best quality silage, cereal green fodder like green fodder maize, fodder sorghum, bajra, Hybrid Napier, sugar cane tops and oat, etc are required. Preference for cereal green fodder (monocotyledons) is due to because of more sugar content than protein, as sugar is utilized in fermentation process to make lactic acid by microorganisms. These cereal fodder crops have hard stem, which takes more time for drying in making hay of these crops, so it is better to use these kinds of crops for making silage than hay. Silage quality and yield are affected by sowing method, cultivar and applied cultural practices (Ileri *et. al*, 2018).

Time of harvest has a major impact on the nutritive value of silage. With advancing crop maturity, protein content, available energy, daily nutrient intake and digestibility decrease while later cutting represents lower carbohydrate and more lignin. Since dry matter yield per unit area are lowered by early harvest, time of harvest is a compromise between nutritive value and yield. High prices for energy and protein tend to favour early harvest despite of lower dry matter yield.

Griffiths *et al.* (2004) used Milk line score (MLS) to determine the proper stage of harvesting of maize crop. The MLS varies from 0 (no visible milk line at the tip of kernel) to 5 (the milk line reaches the base of the kernel and a black or brown layer forms across it). Maize is best suited to be ensiled when the grains are in the milking stage or at 2.5 milk line score (MLS) i.e. the milk line is halfway down the grain, is considered best stage to harvest maize for silage (Fig. 1). Brar *et al*, (2017) reported that, for making of good quality silage, harvest the crop at proper stage, when the nutrient contents are at peak i.e. when the grains are in dent stage or near 2.5 MLS.

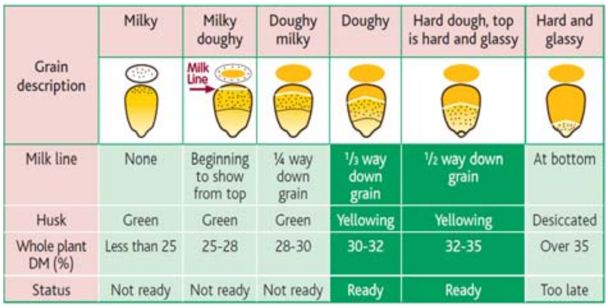

Fig. 1. Right stage for harvesting maize for grain based silage making.

Some important management practices that will help in making high quality silage are listed in Table 2.

Advantages / Disadvantages of Ensiling :

Silage has many advantages over hay and other methods of preservations, chiefly because of less loss of essential nutrients.

- For daily cutting, transporting & chaffing of fodder in traditional way requires more labour and time but in case of silage, fodder cutting, transport, chaffing is done at one time only,

TABLE 1
Common end products of silage fermentation.

Item	Positive or Negative	Action (s)
pH	+	Low pH inhibits bacterial activity
Lactic acid	+	Inhibits bacterial activity by lowering pH.
Acetic acid	-	Associated with undesirable fermentations.
	+	Inhibits yeasts responsible for aerobic spoilage.
Butyric acid	-	Associated with protein degradation, toxin formation, and large losses of DM and energy.
Ethanol	-	Indicator of undesirable yeast fermentation and high DM losses.
Ammonia	-	High levels indicate excessive protein breakdown
Acid detergent insoluble nitrogen (ADIN)	-	High levels indicate heat-damaged protein and low energy content.

TABLE 2
Some good silage management practices

Silage practice	Reasoning
Harvest crop at correct maturity and DM	
Maize : Grains in 2.5 milk line stage (65-75 DAS) 35% DM	➢ Optimizes nutritive value (protein, fiber, energy, etc.)
Bajra : Boot stage (45-55 DAS)	
Sorghum : Flowering stage (75-85 DAS)	➢ In some cases optimizes DM content
Napier bajra hybrid : up to 1 meter height	➢ Ensures good packing, elimination of excess oxygen
Guinea grass : Flowering stage (60-75 DAS)	
Oats : Grains in milk stage (95-115 DAS)	➢ Minimizes seepage losses
(Thakur and Sharma, 1998)	➢ Prevents clostridial (butyric acid) fermentation
Check that all equipment which are required for silage making are in good working order	➢ Sharpen knives of the chaffer ➢ Be sure that silos are free from leaks, breakage and holes.
Chop material to correct length: about 5 to 7 cm	➢ Promotes good packing and elimination of oxygen ➢ Promotes cud chewing by animals
Wilt and chop during wet weather	➢ Prevents extensive DM losses from forage ➢ Helps in inhibiting the clostridia bacteria
Harvest, fill, and seal quickly	➢ Quick elimination of oxygen reduces DM losses from respiration and prevents growth of undesirable aerobic organisms ➢ Sealing minimizes exposure to air ➢ Pack to proper density to eliminate air
Allow silage to ferment for at least 45 days	➢ Properly ensiled silage will minimize production losses during silage changeover

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. (In hay making, dry fodder is stocked & exposed for fire like situation)
- 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. An increase in milk yield of HF crossbred cows by 15.47% (on an average) when green fodder was replaced by maize silage was reported by Brar *et al* (2016) (Table 3).
- Silage is tasty & flavored, so it increases appetite of dairy animals.
- Lower field losses particularly of leafy portion which is relatively rich in protein and minerals.
- Lower probability of rain damage and thus leaching of nutrients
- Storage over longer period, if properly packed under optimal ensiling conditions
- Provide more succulent feed to livestock
- Ideal technology for preserving nutrients in temperate conditions
- Less dependence over weather conditions, particularly availability of sun lights

Disadvantages of Silage Making:

- Being mechanized technology, requires considerable capital investment.
- Limits the preservation of high CP containing forages such as leguminous fodders e.g. cowpea, berseem, lucerne etc.
- Losses of nutrients can be high if not properly preserved with exclusion of air and water. Clostridial fermentation spoils the quality of silage and its feeding value. Formation of butyric acid makes silage unpalatable.
- High moisture silage leads to greater seepage losses.
- Less marketable.
- Voluntary intake by animal is a limiting factor if acid production is high (Demarquilly, 1973).
- Must be fed as soon as possible after removal from silo to avoid secondary fermentation.
- Chopping of forage is must otherwise good packing of silo is not possible and allows the air to be trapped which in turn allows mould and yeast formation.
- Poor technical knowledge of storage.

Silos and method of silage making :

Types of silos : The container in which silage is made is of greatest importance and will determine to the large extent the nature and quality of final product. The size of container will generally depends on the number and kind of animals to be fed from it

TABLE 3

Milk production (kg/animal/day) of HF crossbred dairy cows pre and post maize silage feeding

Village	Size of silopit (m^3)	Fodder stored (tonnes)	No. of animals	No. of animals in early lactation	Silage fed	Average milk yield before silage feeding	Average milk after silage feeding	Increase milk production (%)
	-----	-----	-----	-----	(Kg/animal/day)	-----	-----	-----
Mari Kamboke	285	200	35	12	30.0	20.0	23.0	15.0
Mari Boharwali	596	420	65	13	28.0	22.0	26.0	18.2
Saidpur	294	190	35	15	30.0	27.0	30.0	11.1
Kairon	656	460	70	25	35.0	28.0	33.0	17.9
Kairon	544	380	60	20	35.0	27.0	31.0	14.8
Thattian khurd	351	230	50	15	32.0	25.0	29.0	16.0
Mean	--	--	--		31.7	24.8	28.7	15.5

Source : Brar *et al.*, 2016.

and the length of the feeding period. The different kinds of silo designs are.

1. Stacks
2. Clamp silo
3. Pit silo
4. Trench silo
5. Bunker silo and
6. Tower silo

The most common silo is the trench silo. One cubic meter space can store 5-6 quintals of green chopped fodder. Generally a trench of 10 m x 4 m x 1.5 m near the cattle shed can store 350-400 quintals of chopped green fodder or one cubic feet pit can accommodate roughly 15 Kg of green fodder. The length and width of trench can vary depending on the number of animals and fodder available for making the silage. The pressing of the material may be carried out manually or mechanically by using a tractor. In case of pressing with tractor, the width of pit should be at least double the width of tractor i.e. 12-15 feet. Depth of pit should be 6-8 feet. Care should be taken that material on the sides and edges are properly compressed.

The trench should be high spot so that rain water cannot stagnate near the silo pit. Trench silo has advantages like less air infiltration, less power required for filling the trench, loading and carrying silage is easier.

Silo pit should have slanting walls with narrow base and broad opening as such shape helps in maximum exclusion of the air.

The silage is made by 1) Direct cut method 2) Wilting method. Wilting method is preferred over direct cut method which as under:

1. Harvested green fodder should be wilted to 65-70 % moisture. Or when harvested at pnper harvesting stage contains this much moisture.
2. Chop the fodder to make pieces of 2-3 inches so that material is packed well.
3. The walls of the silo pit should be plastered or lined with straw. The chopping should be done near the silo so that the chopping of fodder and filling of silo pit is done simultaneously.
4. Filling should be done in layers of one feet as soon as possible.
5. Pressing of the fodder in the pit should be done regularly to exclude the air.
6. The silo should be filled 1 meter above the ground level and arranged it in the semicircle with dome shaped at top.
7. Cover the pit with one feet thick layer of straw and plaster it with the mud mixed with wheat *bhusa* to make it air tight and protect it from rains. Alternatively plastic sheet can be used to cover the cut forage.
8. Check the filled pit once a week to avoid cracking of the plaster because any crack in the plastered layer will affect the fermentation process. Silage will be ready within 45 days.
9. Open the silo pit from one side only and take out 25-30 kg silage per animal/day for feeding. The remaining silage kept covered stays good till used.

Nutrient losses during ensilage and steps to Reduce Nutrient Losses:

Generally loss of dry matter, carotenes, carbohydrate and proteins occur due to respiration, fermentation and aerobic deterioration.

The other losses of nutrients arise from field, harvesting and affluent losses. The field losses may occur due to shattering of leaves and other nutritious portions because of poor harvesting managements. The extent of loss in dry matter depends on the time at which the forage is ensiled. Over the period of 48 hours, losses of DM may occur which may be as high as 6.4 percent after 5 days. Loss of carbohydrates and protein also occur due to respiration and proteolysis by plant enzymes. Studies have been revealed that the loss of nutrients during ensilage was drastically minimized with increasing dry matter content of ensiling material (Chaudhary *et al.*, 2014). The fermentation losses chiefly depend upon the moisture content. The clostridial type fermentation is deleterious for most of the nutrients. The clostridia are responsible for the loss of protein. Losses thus are dependent upon pH, moisture content of siling material and type of micro-organism growing during course of fermentation. Forages of low dry matter content (less than 22.9%) leads to effluent production with a considerable loss of nutrients (Castle and Watson, 1993). After the silo is opened for feeding to livestock, the silage surface is exposed to air and thus leading to aerobic secondary fermentation. During aerobic degradation, the temperature and pH rises while lactic acid content reduces. Loss of DM and nitrogenous substances occur due to escape of volatile fatty acid, lactic acid and ammonia. Aerobic deterioration of silage can cause problems for human due to transfer of pathogens and mycotoxins from the silage to other feeds and animal products such as milk (Ogunade *et al*, 2016). Loss of nutrients arising out of secondary fermentation could be 0-15 % and could be minimized by management practices such as use of cover, propionic acid etc (Wyss, 2000). The Table 4 below summaries the losses of nutrients during preservation of herbages as silage.

Reduction in the nutritive value of silage fermentation with respiratory losses, silage heating and clostridial fermentation is minimized by limiting air and moisture contact with silage (Bolsen *et al*, 1996). Minimizing oxygen exposure to silage is essential for obtaining good quality silage. Air allows the respiration process to continue using soluble carbohydrates essential for acid production, which generates heat and increases the temperature. Process of respiration results in loss of valuable dry matter and energy. Air exposure during preservation tends to progress towards mould formation and leading to rottened silage. The increase in the temperature of silage as a result of heating also reduces its palatability when fed to livestock (Pelz and Hoffman, 1997). Uniformly compacted silage and properly sealing aid in air exclusion.

TABLE 4
Nutritive Losses During Silage making

Biological process	Judgment	Approx loss (%)
Respiration	Unavoidable	1-2
Fermentation	Unavoidable	1-4
Effluent	Mutual	5-7
Pre-wilting	Unavoidable	2-5
Secondary fermentation	Avoidable	0-5
Aerobic transformation	Avoidable	0-15
Total losses		7-35

Source : Mojumdar (2009).

Dry matter concentration of the forages plays a vital role in minimizing the nutrient losses during ensilage. High moisture silage leads to clostridial fermentation, which cause excessive dry matter loss, high butyric acid concentration and lower nutrient intake (Henderson and Mc Donald, l971). Proper stage of harvesting and dry mater content maximizes the nutritive value of silage (Mojumdar and Rekib, 1980; Brar *et al*, 2017). Chahine *et al*. (2009) reported that 30.0-40.0% dry matter content is optimum for corn silage for better quality and for the production of livestock. Wilting of high moisture forage to 30% dry matter is a safe way, which inhibits the clostridial fermentation. Clostridia bacteria degrade sugars and also convert lactic acid to butyric acid and elevate ammonia concentration and thus causing pH to rise. They also break down protein to amines. Thus, clostridial fermentation has an undesirable effect on the nutrient leading to their decomposition to undesirable end products, dry matter loss and reduced palatability (Nikolic and Jovanovic, 1986).

The heat caused during fermentation plays vital role in preservation of nutrients. Higher temperature silage (100ºF) has been found to be poor in quality. The over heated silage produced at a temperature above 120ºF have been found to be resulting into heat damaged protein having brown to dark brown colour with a tobacco type fowl smell. Protein of heat-damaged silage forms a complex with carbohydrates and is not digestible. The part of protein and energy is not available to livestock and resulting into lower DCP and TDN values (Redriguez *et al*, 1985). Higher temperature also increases aerobic spoilage and reduces stability of silage.

Water soluble carbohydrate content of forages constitutes the primary nutrient that is fermented to lactic acid and acetic acid by *Lactobacillus* bacteria to produce a low pH (4.5) and stable silage. Maize, sorghum, oat and other cereal fodders usually have higher soluble sugar concentration and a good stable silage having lactic acid as percent of total acid to the tune of 60 is obtained, while legume forages having low soluble sugar content are not repeated to produce stable and good quality silage chiefly because of low lactic acid production mostly below 3% of dry matter (Singh and Rekib, l986a). Carbohydrates in the forages may be naturally occurring or may be added as a separate ingredient such as molasses obtained as sugar industry by-products (Evers and Carrell, 1998), which act as a fermentable substrate. Relatively more lactic acid is produced from glucose present in the ensiling forage than fructose. Hemi-cellulose after acid hydrolysis produces pentoses, which is then fermented to lactic acid and acetic acid. Besides carbohydrates, the protein content of the ensiling forage plays an important role in determining the quality and feeding value of silage. High CP content in the leguminous forages leads to ammonia production during fermentation leading to rise in pH (5 and above), buffering action and temperature. The high moisture content (more than 75%) causes more protein loss due to proteolysis by clostridia. Nitrates present in the plant are reduced to nitrites which in turn release ammonia (Singh *et al*, 1983).

Additives for Effective Ensiling

Various types of additives can be used to improve or inhibit the fermentation or supplement nutrients needed by ruminants to be fed as silage. Adding acids such as sulfuric acid, formic acid and other acids decreases the pH of the forage ensiled and helps to preserve it. But corrosiveness of these acids is the limiting factor for their use. Propionic acid reduces aerobic deterioration, heating and mould formation at the top of silage layers. The use of acids has also financial implications for the economic viability of their use. Formaldehyde has been used for effective preservation in silage. Addition of formaldehyde @ 5.0 litre per ton of fresh maize fodder has been found to produce good quality silage with higher feeding value when fed to cross-bred calves (Verma and Mojumdar, 1984), Addition of formaldehyde has also been reported to improve the DMI when fed to ruminants (Barry *et al.*, 1973). Forages with marginal concentration of soluble carbohydrate may benefit from enzymes such as cellulase, pectinase and amylase that can break down complex plant structural carbohydrates such as cellulose, pectin and starch present in forage to simple sugar which then can be fermented to lactic acid. An increase in soluble sugar content resulted in more lactic acid (10%) and lower ammonia- N (less than 6 % of total nitrogen) and pH 4.5 in enzyme treated silage (Van Vauran *et al.*, 1989). Commercial bacterial inoculants have also been used in developed countries which increase the rate of lactic acid fermentation and produce stable silage but such system may not be profitable.

Carbohydrate sources such as mo1asses, whey, yeast and other energy rich ingredients, have also been used as additives to increase the fermentation and feeding value of silage. Most commonly used carbohydrate sources are molasses which is used to add fermentable sugars to forage low in sugar. It can be added 5-10% depending upon the sugar content of ensilage forage. Urea is the most important source of non-protein nitrogen used to elevate CP content of cereal forage silage low in protein. Addition of urea @ 0.5-1.0 % has been found to increase CP content and lactic acid content of silage (Verma *et al* 1982, Singh and Rekib, 1986b). Nutritive value, particularly CP content of graminaceous forage silage can be improved by mixing legumes forages such as cowpea, berseem and *Leucaena leucocephala* leaves (Table 5) (Verma and Mojumdar,1985; Mojumdar 2009).

Silage Quality

Silage quality is determined by mainly the odour, physical state, pH, ammonia nitrogen, volatile acids and lactic acid. It should be pleasant smell and semi dry in nature. It should be of green colour.

There are number of factors which affect the quality of silage i. e. crop used for silage making, variety of crop, stage of harvesting, method of storage and period of ensiling etc. It is very essential to harvest the crop at a proper stage to ensure good yield, quality and ensiling characters of fodder. Farmer's knowledge regarding stage of harvesting of crop for silage making is very important as it determines the moisture content of the crop. Dry matter content of silage is important as it indicates the adequacy of wilting. Forages ensiled below 30% DM will produce effluents which can result in a significant loss of nutrients. On the contrary, when forages are too dry, it is difficult to achieve anaerobic conditions and the silage will be more susceptible to heating and mould growth (Chaudhary *et al*., 2016). Chahine *et al*. (2009) reported that 30.0-40.0% dry matter content is optimum for corn silage for better quality for the production of livestock. Chaudhary *et al*. (2016) observed variable dry matter content (22.0-35.5) of silages prepared from different maize hybrids and composite due to their morphological variation and plant characteristics. Brar *et al.* (2017) also reported the value of dry matter content in silages prepared at farmers field under different management practices between 16.5 to 31.8%.

Protein content of the silage is very important and its estimation is very essential for sound nutrient management and animal production. A large proportion of the crude protein, often 90% known as degradable protein (RDP). Ruminants need adequate RDP in the diet to sustain normal microbial activity and digestive function in the rumen (Kaiser and Piltz, 2004). A range of 7.0-9.0% crude protein is optimum for corn silage as reported by Chahine *et al.* (2009); Brar *et al.* (2017) and Kumar *et al.* (2016).

Fibre content in forage is also very important. Fibers (measured by NDF, ADF & ADL) are a strong predictor of forage quality, since it is the poorly digested portion of the cell wall. Neutral Detergent Fibre (NDF) values are important in ration formulation for the livestock because they reflect the amount of forage the animal can consume (Kumar *et al*., 2016). NDF is an inverse predictor of intake (high NDF values low intake of feed and vice versa). The optimum range of NDF in corn silage is 35-55 % (Chahine *et al*., 2009). Acid Detergent Fibre (ADF) values relate to the ability of an animal to digest the forage (Kumar *et al*., 2016). High ADF content is an issue for the same reason as like high NDF content. ADF is negatively correlated to digestibility and energy (Chahine *et al*, 2009; Kumar *et al*., 2016; Chaudhary *et al*., 2016). ADL is non digestible portion of cell wall, having optimum range of 2.8-4.1% in corn silage. Increased fibre content of forage is associated with decreased digestibility and intake, and subsequently lower animal production.

Silage attributes (pH and concentration of lactate and ammonia nitrogen) reflects adequate fermentation during ensiling (Belanger *et al*., 2012, 2016). Roth and Heinrichs (2001) reported the optimum range of pH values for corn silages in between 3.5 to 4.3. Kaiser and Piltz (2004) reported that, when dry matter is low, pH values of well preserved silages are usually in the range of 3.5-4.2. They further stated that if the silage pH exceeds these limits, there is a high probability that the silage had been poorly preserved.The preferred lactic acid fermentation will produce silage with a low pH. All forages contain chemical compounds, called buffers which resist changes in pH. There is an increase in risk of poor fermentation when ensiling forages with a high BC (Piltz and Kaiser, 2004).

Ammonia-N (% of total nitrogen) in silage is an important guide to fermentation quality of silage. High ammonia-N is seen in poorly preserved silages and indicates extensive degradation of the forage protein during ensiling process (Kaiser and Piltz, 2004). Wilkinson (1990) reported that silage having ammonia-N (% total silage N) < 5% is excellent, 5-10% is good, 10-15% is moderate and 15< is poor, fermentation quality.

Good quality silage should have

- pH: 3.5 to 4.2
- Ammonical nitrogen of total N: less than 10%
- Lactic acid: Above 3 %
- Acetic acid : up to 5 %
- Butyric acid: less than 0. 2%

Voluntary intakes of silage has been a limiting factor and lower than that of green forage (Pachauri and Mojumdar, 1994) which is more prevalent with high moisture silage. The main reason of low intake could he ascribed to low pH and high lactic acid content. Wilting has been reported to increase intake of silage considerably (Singh and Rekib, 1986b). Use of formic acid as additive has been reported to increase intake, body weight gain as well as milk production (Waldo and Derbyshire, 1971). Quality of oat silage was decreased considerably when silage was reused after one year from the once opened silo pit as compared to freshly made silage of oat (Kumar *et al*, 2009).

Preservation of green fodder as hay

Another way of preserving nutrients is practiced in the form of hay. The principle of hay making is to preserve nutritional value of forages through drying it to a level at which the activity of microbial decomposers is inhibited. Forages can he harvested at the stage of proper nutritive value and be preserved as hay for feeding it during lean period. A moisture content of 10- 12 % is optimum level for halting the microbial activity (Mojumdar, 2009). The hay stored at 20°c moisture level, may favour mould growth. It also increases hay temperature and may lead to spontaneous combustion which leads to loss of nutrients.

The drying and storing of high quality forage offers many advantages. It assures the supply of high digestible feed with high protein and caloric values all the year round. It reduces the amount of the concentrates that must be fed the cattle. The storage losses are less than in silage. It reduces the labour

TABLE 5
Nutritive values of promising silages

Forage material	Ratio (%)	CP (%)	DM (%)	DCP (%)	TDN (%)	DMI (% b. wt.)
Sorghum	-	4.94	35.0	5.98	56.6	2.25
Napier bajra hybrid (NBH)	-	4.30	51.5	0.9	54.1	2.67
NBH + Sesbania	3:1	7.10	53.2	3.9	54.7	2.76
Maize + 1 % urea		12.5	43.7	7.7	45.4	1.30
Maize + cowpeas	1:1	12.6	69.4	8.4	64.1	2.86
Berseem + oat	1:1	14.3	51.8	6.7	56.4	2.88

Source : Mojumdar (2009).

involved in handling and transporting of the green fodder because green forage has 80-90% water, whereas hay has less than 15 %. It makes movement to the market as well as feed manger easier. The labour and botheration of cutting of green forage daily is eliminated. Even the intensity of cropping can he increased and more cutting can be taken from the multiple cut crops. In India where ample sunlight is available, hay making is popular and economical way of preservation. The thin stemmed forage crops such as oat, lucerne, berseem, cowpea, clovers and grasses are highly suitable for hay making. In making hay from high quality forage, the biggest hazard is the loss of the leaves in handling. With the loss of leaves a large fraction of the protein in the crop is lost particularly in case of legumes such as berseem, cowpeas and guar.

Nutrient Losses During Hay Making

The field losses during hay making include respiration, leaching, shattering of leaves and mould growth. About 15-40 % of dry matter loss, mostly as leaves was reported when stylo is sun dried for hay production (Amodu, 2004). A precautionary handling of forages particularly legumes is necessary to prevent the shattering of leaves. The leaves are rich in CP content, carotenes and minerals. The loss of nutrient is much high during field curing in which the forage is spread on fields. The respiratory enzymes continue to function till moisture in the plant is available and the soluble sugar is degraded to carbon dioxide. Similarly proteases act on the protein of the forage after harvesting and cause the loss of nitrogen. Carotenes are most adversely affected during hay making. Dry matter losses are detailed in the Table 6.

Thus, the loss of nutrient is variable in various processes of hay making. There is more loss in dry matter if hay is stored in open and humid conditions while very little (around 5 %) if stored indoor and dry conditions. Digestibility of protein of hay prepared at high temperature is lowered owing to deleterious effect of heat brought about by reaction of amino acids with carbohydrates (Mojumdar, 2009).

TABLE 6
Dry matter losses during hay making

Particulars	DM loss (%)
Respiration during wilting	4-15
Leaf shattering (legumes)	5-15
Leaf shattering (grasses)	2-5
Rainfall and damage	10-17
Heating	4.5-5.5

Source : Mc Donald and Clarke, 1987.

Crop should be cut neither too early nor too late and shound be harvested at proper stage for hay making. If cut too early or too late then following losses may occur.

Losses from pre mature harvesting :

1. Low yield of food constituents due to low dry matter production, no doubt the percentage of protein, fat and ash is higher in early stages.
2. Low yield of dry matter.
3. Greater difficulty in curing due to higher percentage of moisture in the fodder.

Losses from delayed harvesting:

1. Shattering of leaves due to drying.
2. Lodging spoils fodder because of contact with the moist soil and hinders harvesting.
3. Reduction in palatability due to woody and stiff stem.
4. Decrease in nutritive value at maturity.
5. The subsequent cutting yields less.

Proper stage of harvesting:

Crop	**Stage**
Berseem	In full bloom

Lucerne	1/10 to 1/4 in bloom
Cowpeas	when first pod ripe
Oats, barley	For cattle: in milk stage and For horses: in dough stage

Testing for the moisture : Take some hay in hands, holding it from both the ends go on twisting and observe as under :

1. If some juice is squeezed easily from the stem = 45% moisture
2. If it is hard to squeeze the juice = 35% ,,
3. If the stem does not break on twisting and no juice = 25% ,,
4. If some culms break = 18-23% ,,
5. If breaks on twisting = 15-18% ,,

A simple method of making hay with the minimum loss of leaves is described below. It can he easily adopted by the farmers without extra investment in equipment.

1. Cut the berseem or lucerne in the pre-blossom stage in order to ensure conservation of protein and available energy to the great extent.
2. Chop the forage while still moist (fresh or wilted) with a chaff cutter. Chopping need not be fine. The best length of the cut is about 5-8 cm.
3. Spread the wet chopped forage in the sun on a smooth hard surface in a thin layer not exceeding l2-15 cm in depth. The usual threshing floors, rooftops etc. can be used for drying floors.
4. Stir the drying forage every 2-3 hours during the day to speed up the drying process under exposure to the sun and the air.
5. When thoroughly dry (usually) after 2-3 days depending on the frequency of stirring, intensity of sun light and movement of air, gather the mixture of dried stems and leaves to store or market. When hay balers are available, the chopped and dried forage can be baled. Baling will reduce the storage space and facilitate the transport of forage to the market.
6. The chopped and dried forage can he stored at the village farm in the same way as wheat *bhusa* is done in thatched or mud covered stacks or in the building normally used for storing wheat *bhusa* or rice straw.

Hay making is profitable when the production of fodder is in excess of consumption. Food quality dried forage (hay) is as nutritious as the green forage (if available) during the period of June-December when high protein forage is scarce. It fetches higher price and helps to increase milk production.

How to make good hay :

1. The crop should neither overripe nor under ripe.
2. The crop should be cut when it is free from due.
3. The crop should be sown thick which give thin stem and more leaves.
4. Over drying as well as under drying should be avoided.

Properties of good quality hay :

1. Good quality hay is of always green in colour.
2. It should be leafy.
3. Hay should be dark green in colour. Sun dried hay is rich in vitamin D.
4. It should have maximum nutrients, soft, more palatable and digestible.
5. It should be free from weeds.
6. It should be free from dust and moulds.
7. It should have smell and aroma of the crop from which it is made.

CONCLUSION

There is urgent need for preservation of nutrients from green forages including fodder tree leaves available during the flush period for feeding livestock during lean period so that high yielding animals can be sustained for profitable dairy farming. Silage is as nutritious as green fodders as it preserves the nutrients in the original form and hence it is as good for animal feeding as green fodder itself. Out of all non leguminous fodder crops, maize has relatively low buffering capacity and high concentrations of fermentable carbohydrates; therefore, pH decline is rapid and final pH is usually low, approximately 3.5, thus more suitable for silage making. For quality silage, the pH of silage at the final stage should he within the range of 3.5-4.3. But in case of leguminous fodders such as Berseem, shaftal and alfalfa, has high buffering capacity in comparison to maize leading to difficulty in lowering pH and making silage from berseem. At time of harvesting of fodder, proper dry matter in forage should be there so that it can be packed well and more lactic acid is produced. It is also very important to fill the silo pit as soon as possible, as delayed filling of silo pit results in excessive amounts of air trapped in the forage mass can have detrimental effects on the ensiling process. The container in which silage is made is of greatest importance and will determine to the large extent the nature and quality of final product. The most common silo used for silage making is the trench silo. In one cubic meter space, we can store 5-6 quintals of green chopped fodder. Quality of silage is also very important, is determined by mainly the odour, physical state, pH, ammonia nitrogen, volatile acids and lactic acid. It should have pleasant smell, semi dry in nature and should be of green colour. Another way of preserving fodder is practiced in the form of hay. In hay making, nutritional value of forages is preserved through drying it to a level at which the activity of microbial decomposers is inhibited. A moisture content of 10-12% is optimum level for halting the microbial activity. It assures the supply of high digestible feed with high protein and caloric values all the year round. Hay making is profitable when the production of fodder is in excess of consumption. The food quality of dried forage (hay) is as nutritious as the green forage.

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