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DEPARTMENT OF ANIMAL NUTRITION

Silage And Hay

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Silage- can be defined as a green material produced by controlled anaerobic fermentation of green fodder crop retaining its moisture content.

The process of conserving green fodder is called as ensilage.

Silo is the receptacle in which silage is made.

Crops Suitable for Silage Making

1. Kind of crop

(a) Crops rich in soluble sugars/carbohydrates are most suitable for ensiling, e.g. maize, sorghum, bajra.

(b) Cultivated and natural grasses can be ensiled with addition of molasses at 3 to 3.5%.

(c) Mixture of grasses/cereal fodders and legumes such as berseem, lucerne, etc. in a ratio of 3:1.

(d) Unwilted leguminous leafy fodders and dry forage in the ratio of 4:1.

2. Stage of harvesting: Crop should be harvested between flowering and milk stage. In general, crops with thick stems are conserved in the form of silage while thin stemmed crops are conserved as hay.

Preparation of Silage-

There are different types of ensiling. Apart from making silage under farm conditions, the same can be done under laboratory conditions.

Laboratory Method of Silage Making: Under laboratory conditions silage can be prepared using Polythene bag silos.

Steps in ensiling:-

1. A 45 X 60cm polythene bag is taken for the experiment.
2. The crop chosen for ensiling is chaffed to 2-4cm in length and wilted to 35% DM.
3. The crop is thoroughly mixed. Molasses can be added to ensure the availability of soluble carbohydrate for efficient bacterial fermentation to an extent of 3 to 3.5%. Salt and urea are added at 0.5 and 1% respectively, to improve palatability and nitrogen content of silage.
4. The material is then packed tightly into the bags.
5. The open end is sealed perfectly and kept in an identical bag and placed in a metal can/cement tub after sealing.
6. The remaining space is filled with sand before closing the lid, thus minimizing the possibility of the air, permeating the polythene film.
7. The silo is then stored in a room and opened for sampling after 4-6 weeks.

Preparation of Silage Under Field Conditions: Silo

A silo is an air tight structure designed for the storage and preservation of high moisture feed as silage. Pit silos are more common in India. The pits are dug 2.4 to 3.0 m deep, with variable sizes. One cubic metre of space is required for 400 kg fodder.

Requisites of a Silo

1. The walls should be impermeable so that water can't gain entry into silo pit. Walls may be made of cement or brick and mortar.
2. Silo should be sufficiently deep. It should not be shallow. The depth depends on the water table in the locality.
3. Silo must be located on an elevated ground.
4. The size of the silo should be calculated on the basis of the number of animals to be fed, the length of feeding period.

Method of Preparing Silage-

1. Select the crop that is to be ensiled when it has 30-35% dry matter. In case the crop has less than 30% dry matter, allow it to dry for 3-4 hours so that the dry matter content would increase to 30-35%.
2. Generally the crops are harvested and ensiled when the ears start coming.
3. Select the days of the week when the weather is fair and not rainy.
4. Silo can be filled with long fodder as well as with chopped fodder. It is always better to chop the fodder first since packing is better. Thus loss of nutrients is minimized with chaffed fodder. Further, filling and removal of silage is easier.
5. After chaffing and ensuring that dry matter is around 35% the silo is filled with fodder.
6. The fodder should be evenly distributed throughout the pit. Trampling should be done properly either with men or tractor or bullocks depending upon the size of the pit. At the top of the silo the fodder should be packed 3-4 feet above the ground level.
7. From all the sides it should be covered with long paddy straw or poor quality grasses and then covered with wet mud and dung to seal the material preventing the entry of air and water. The layer of straw/grasses (over the green fodder) may be about 4 to 5". The silage would be ready in two months after covering.

8. Salt at 0.5% and urea at 1% are added to cereals and grasses to improve the palatability and nitrogen content. In grass silages, molasses is added at 3 to 3.5% to improve the sugar content and thus quality of silage. In a more mature crop higher level of molasses (5%) may be added.

Changes During Fermentation-

Enzymes, aerobic bacteria, yeast and moulds become active until all the oxygen in the packed material is used up. The respiration also uses up some of the carbohydrates in the plant material, giving off CO_2 and water. There is also a production of energy which contributes to the heat with a rise of temperature to about 27 to 38°C, particularly in the early stages of the fermentation process (aerobic phase).

The remaining carbohydrates are then broken down to their monomers glucose and fructose, which are water soluble and are the major carbohydrate sources for microbial purposes.

Proteins

Proteases are important enzymes responsible for undesirable changes in plant proteins during the first 5-7 days of ensilage. A proportion of the protein is degraded to nonprotein nitrogen compounds, mainly free amino acids, ammonia, amides and amines. The free amino acids may be metabolized further**. Aspartate is thus degraded to ἀ-alanine and glutamate to ἀ -amino butyrate.** These two reactions are particularly important, since the two amino acids are limiting factors for the growth and development of lactic acid bacteria. The activity of plant proteases is influenced by factors such as the pH and dry matter content. The optimum pH for proteolysis is around 6 for most silage crops, with activity declining linearly between pH 6 and 4 because proteases are acid labile and cease to function 5-7 days after ensilage when the acidic condition is established.

Other plant enzymes such as **polyphenol oxidases** may contribute to changes in the protein value of silage. Under improper ensilage conditions and in the presence of oxygen, the enzyme causes formation of **quinones** which combine with proteins and eventually leads to the formation of **brown colour by the Maillard reaction process**. While proteases convert proteins to soluble compounds of some value, the **polyphenol oxidases and the Maillard reaction** sequence make proteins biologically unavailable to the animal.

Types of Fermentation-Two main types of fermentations occur:

Lactic acid type and Butyric acid type. When the fodder contains 65 to 75% moisture and sufficient sugar in the plant juices, anaerobic lactic acid bacteria become active, to produce eventually a good, clean-smelling silage of high quality. If the acidity rises to about 1% at the start itself, the silage will be of good quality, as the lactic acid checks the activity of undesirable organisms (pH around 4.0). Harmful bacteria, for example, those producing butyric acid are inhibited. It is thus essential that the forage used should contain a high percentage of carbohydrates.

Two fermentation types of lactic acid bacteria are involved: homofermentative type and heterofermentative type. In case of homofermentative type, **2 moles of lactic acid are formed per mole of glucose or fructose under anaerobic conditions;** heterofermentative type forms anaerobically **1 mole of lactic acid, 1 mole of ethanol, and 1 mole of carbon dioxide per mole of glucose and mannitol, acetic acid and less lactic acid per mole of fructose.**

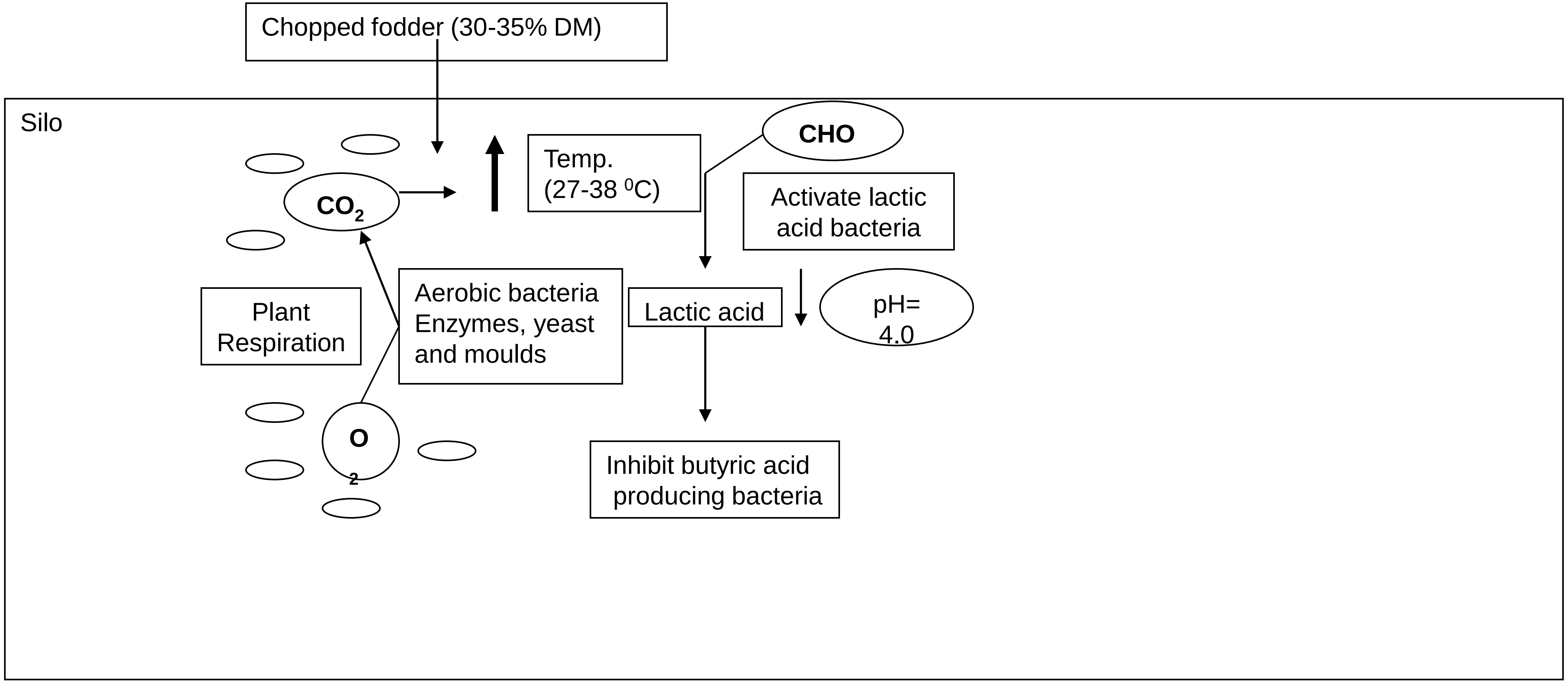
Heterofermentative type is **less efficient** than the homofermentative one in terms of lactic acid production. The homofermentative lactic acid bacteria remain active only in the first few days (10-14) of ensilage, during which time they account for 85% of the total bacterial population. As fermentation of silage proceeds, the heterofermentative bacteria become dominant because the homofermentative bacteria are less tolerant to acidity than the heterofermentative types. In well-made silages, the overall amount of lactic acid should be 60% of the total acids by the end of ensilage so that homofermentation of silage is encouraged.

If the forage is too rich in proteinaceous substances, the butyric acid type of fermentation will predominate. Butyric acid has a sharp, disagreeable odour and the silage is not relished by the animals. **Clostridia are the principal anaerobic microorganisms which are detrimental to silage quality. They are classified into saccharolytic and proteolytic groups, both of which require wet conditions for an active growth. The result of the saccharolytic clostridial fermentation is mainly butyric acid, with some byproducts such as carbon dioxide and hydrogen.**

Proteolytic fermentation results in a variety of products such as ammonia and volatile amines. The presence of ammonia in silage may contribute to the high silage pH and often leads to a reduced intake of silage by ruminant animals. Hence optimum moisture content of the fodder ensiled is important.

Under optimal conditions, lactic acid forms rapidly and lowers the pH to 4.0 or below, where it remains constant. This normally inhibits clostridial growth but, with excessive moisture, clostridial growth can occur at a pH as low as 4.0. Clostridia attack already formed lactic acid and residual soluble carbohydrates and thereby raises the pH and set the stage for putrefactive organisms to operate. Clostridia also act on the amino acids normally resulting from proteolysis in the silage to produce amines, ammonia and fatty acids and CO_2

A rapid fall in pH inhibits such degradation of amino acids and its effect on the quality of the silage.



Changes during ensiling

- Grasses, legumes are more difficult to ensile. Grasses are low in soluble carbohydrates. Legumes have higher moisture levels, higher proteins and minerals which raise the buffering capacity of plants and thereby their ability to resist pH change and these must be overcome to make satisfactory silage.
- **Preservatives:- Sodium metabisulphite** causes partial sterilization. Dose is 4 to 8 kg per 1000 kg of forage. It checks bacterial growth, and reduces the final acidity.
- Bacterial cultures and other microorganisms: Mixed culture of lactic acid producing bacteria.
- Bioactive forage legumes as a strategy to improve silage quality and minimize nitrogenous losses

The use of forage legumes as a source of protein for ruminants is a sustainable strategy to reduce the use of inorganic-nitrogen fertilizer. Further, some legumes species contain naturally bioactive secondary compounds, such as condensed **tannins or polyphenol oxidase,** which could improve silage quality. Study revealed that all silages that contained bioactive legumes were better conserved than the pure grass silo (Ginane et al., 2014). In addition, bioactive legumes were able to preserve protein from degradation during the silage process.

Important Conditions for Success in Silage Making:-

1. Storing the plant material at a moisture content of 65%
2. Excluding air
3. Encouraging a rise of temperature to 30 to 38°C. When it is not possible to secure these optimum conditions, it is helpful to add some preservatives or 'silage conditioners'. Molasses, salt, cereal grains, citrus pulp act as preservatives and enhance feeding value. Sodium metabisulphite modify fermentation process and reduce the smell.

Colour of the Silage-

When the temperature in the silo is moderate the silage tends to be yellowish or brownish green and sometimes even golden in colour. This is due to the action of the organic acids on the chlorophyll, and converts chlorophyll into the brown magnesium-free pigment, **phaeophytin**. Silage is dark brown or black, when temperature in the silo is **high.**

A.I.V. Method of Silage Making-

Silage was popularised in America in 1917, when lucerne was successfully ensiled. The method of making silage by using acid additives was developed principally by Professor A.I. Virtanen in 1925 in Finland, and the process has come to be known as A.I.V. method of silage making. He recommended the addition of equal quantities of dilute **(2N) H_2SO_4 and HCl** to the green fodder when ensiling clover and clover-grass mixtures. Later it was recognised that the addition of other materials rich in carbohydrates kept the silage good for longer periods. The use of germinated maize and molasses improved the quality further.

Silage Quality Shephered et al. (1948) have classified the silage into the following categories-

1. Very good silage: Silage having acidic taste and odour, being free from butyric acid, moulds, sliminess, showing a **pH range of 3.5-4.2, an**d with ammoniacal nitrogen less than 10% of the total nitrogen. Lactic acid content is 1-2%.
2. Good silage: Silage possessing acidic taste and odour, traces of butyric acid (less than 0.2%)**, pH 4.2-4.5** and ammoniacal nitrogen 10- 15% of the total nitrogen.
3. Fair silage: Ensiled material with some butyric acid, a slight proteolysis, some moulds, **pH 4.8 and above** and ammoniacal nitrogen 20% of the total nitrogen.

Flieg Index - Flieg index is a commonly used method for evaluation of silage quality. The index is calculated by determining the relative amounts of lactic, acetic, and butyric acids, expressed as % of the total acids in the silage. Scores are given to each value of these acids, and the higher the total score the better quality of fermentation.

The Flieg index is also correlated positively to the feeding value of silage according to the following equation:

$Y=55.95 +0.07 X$

Y = TDN expressed as % of dry matter X = Flieg score

Flieg index takes into account butyric acid, the main product of saccharolytic clostridia and it makes no reference to the ammonia produced by the proteolytic species.

Haylage- When grasses and legumes generally meant for hay are ensiled, the term 'haylage' is used. Material wilted to 40-45% dry matter before ensiling is often referred to haylage. The dry straws are improved by the addition of suitable additives namely urea, mineral mixture and water. The straws are chaffed into fine pieces (2-3 cm). One kg of urea and 1.5 kg of mineral mixture are dissolved in 20 kg of water and mixed with 97.5 kg of the chaffed material. This is stored in silo pits like silage and is allowed to ferment under anaerobic conditions. The soluble carbohydrates present in the dry straws act as a source of energy for the bacteria to grow well. After about 2 months the pits are opened, and fed to livestock. It is termed as "haylage".

It is supplemented with 2 kg of green fodder per day per animal to take care of the requirement of vitamin A.

Wastelage- Silage containing animal organic waste (poultry droppings, poultry litter, swine excreta, and bovine dung) is called wastelage. Wastelage is anaerobically fermented animal waste containing other feed ingredients with the help of lactic acid producing bacteria.

Nitrate in Silage-

Spoelstra (1985) reviewed the effect of nitrate content on ensilability of grasses and other related things. High rates of N fertilizer diminish the ensilability of grass by lowering the concentration of fermentable carbohydrates and increasing the protein concentration and buffering capacity. The nitrate content of the grass is also increased by N fertilizer. All or part of the nitrate present in the fresh crop is broken down during silage fermentation. Degradation is complete in poor quality silages. It is reported that high pH values, high ratios of NH_3-N to total N and low ratings in Flieg's evaluation system correlate with nitrate reduction. Within few hours after ensiling nitrate reduction starts and **nitrite (NO^-_2) and nitric oxide (NO) are** temporarily accumulated to disappear again within 1 or 2 weeks. Further end products of nitrate in silage are ammonia (NH_3) and nitrous oxide (N_2O). The formation of nitrous oxide gas started 2 days after ensiling and continued for about a week. **Enterobacteria** appear to be mainly responsible for the degradation of nitrate in silage. In well-preserved silages volatile nitrosamines are absent or present in very low amounts. Higher amounts have been found in badly preserved silages and in silages that have been exposed to air.

Silo-filler's Disease-

Silo-filler's disease is an illness of farm workers that is caused by inhalation of oxides of nitrogen (NO) during ensiling or after entering a silo after filling. In the anaerobic environment of silage, nitric oxide (NO) is the predominant nitrogenous gas formed. Minor amounts of nitrogen dioxide (NO_2) and nitrous oxide (N_2O) may also be present. Nitric oxide is a colourless gas. Upon contact with oxygen it is oxidized to a mixture of NO_2 (red), N_2O_3 (brown) and N_2O_4 (yellow). This mixture is responsible for the frequently reported brownish fumes in and near silos. High amounts of NO can be expected when nitrate-rich, rapidly fermenting material is ensiled. Upon inhalation, NO, gases are oxidized in the lung to mixture of nitrous and nitric acids. These strongly oxidizing acids damage lung tissue and can cause chemical pneumonia. In addition, reactions with haemoglobin (nitrosylhaemoglobin and methaemoglobin) occur, causing impaired oxygen transfer. Animals are also affected.

Hay Making-

The forage, crop is cut before it is fully ripe and dried for storage as hay. Hay is the product obtained by cutting and curing the entire herbage of fine stemmed grasses or legumes so that the moisture content of the product is not more than 12-14%.

Crops Suitable for Hay Making-

All thin-stemmed grasses and legumes can be conveniently and quickly dried unlike thick-stemmed fodders, which take more time for drying, e.g. grasses (Cyanodon, Cenchrus, Marvel, etc.), M.P. chari (*Sorghum bicolor*), oats, legumes (Stylosanthes, siratro, sunhemp, cowpea, berseem, lucerne, horse gram, pillipesara). In case of spear grass, the sharp pointed 'spears' or awns on the inflorescences make the hay unpalatable. Thin **napier grass, sudan grass and Johnson grass** can make fairly good quality hay only if they are cut at early flowering stage, before the heads set seed. However, if the thick-stemmed fodders are required to be dried quickly they should necessarily be chopped into small pieces or crushed by passing the material in between rollers.

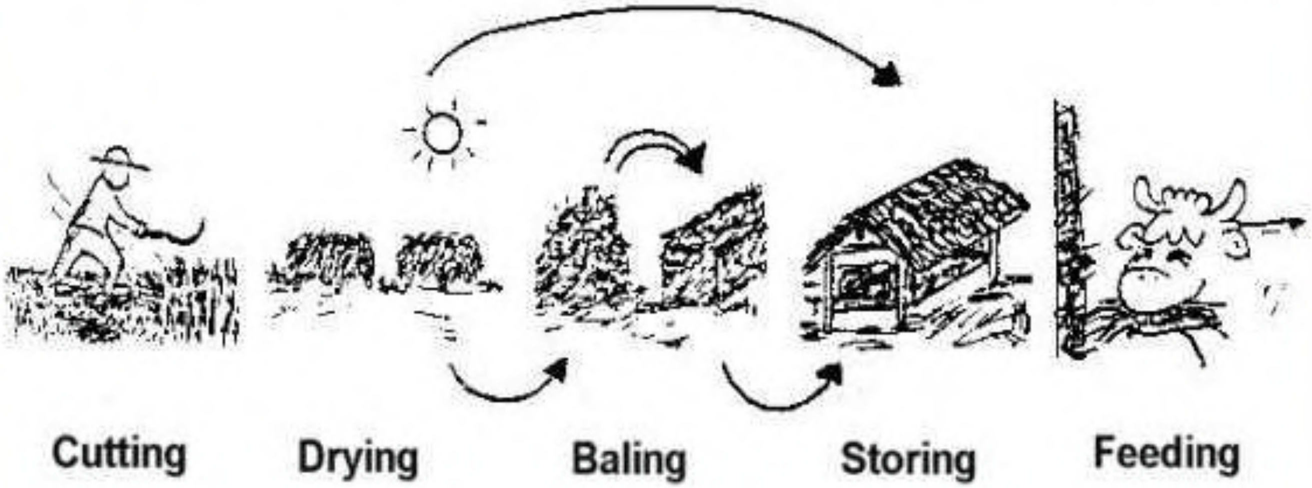
Kinds of Hay-

1. **Legume hay-** They are rich in digestible nutrients, digestible protein, vitamin content, carotene and may contain vitamin D. Rich in vitamin E and calcium and they are palatable.

2. **Non-legume hay-** Non-legume hays are made from grasses and cereals. They are, as a rule, less palatable and contain less protein, minerals and vitamins than the legume hays but rich in carbohydrates. Non-legume hays have the advantage over legume hays because their outturn per hectare is more than that of legume hays and the former can be grown easily. Hays made from crops like oats, barley, etc. Compare very favourably with the other grass hays.

3. **Mixed hay-** Hay prepared from mixed crops of legumes and non-legumes is known as mixed hay. The chemical composition of such a kind of hay will depend on the proportion of the different species grown as a mixed crop. If harvested early, the cereals are generally richer in proteins.

What are the steps in making and handling hay?



Different Methods of Hay Making

There are three methods of hay making. They are field curing, barn drying, and artificial drying.

1. **Field curing-**

As the name indicates, cut plants are cured in the field itself to make hay. The various steps in this process are:

(i) Cutting the crop: Any type of power or hand cutting may be used. It is highly desirable to cut in the same direction. The crop is left there itself in the swath to dry partially.

(ii) Swath curing: Hay is dried much more rapidly in the swath than in the windrow. Therefore maximum advantage of swath curing may be taken to speed up the operations. But after a certain degree of curing, there will be shattering and bleaching of leaves reducing the nutritive value of hay considerably. The forage should be left to cure in the swath until it is wilted sufficiently but before there is danger of shattering and loss of carotene due to bleaching action of sun. No definite time can be assigned to swath curing but at this time the moisture is roughly 40**%.**

(iii) Raking: After wilting forage to about 40% moisture in the swath, it is rolled into small loose fluffy cylindrical bundles known as windrow. It is better to do raking in the morning as dew makes the hay a little more tough and prevent shattering.

(iv) Cocking: This is the process of making bigger heaps after hay has been cured partially in windrows. Cocks were protected with rain caps where rain is expected. If there is labour shortage this step may be discarded. Under such circumstances hay is completely cured in the windrow. However, cocking is advisable as it will give better hay with more carotene content.

(v) Baling and storing: Pick-up baling directly from windrow is the most automated system where the baler attached to tractor picks up hay in the form of windrows and bale it. Where such machines are not available hay may be stored as loose bundles in hay stacks.

2. Mow curing (barn drying)This refers to the practice of curing partially dried hay inside the barns in mows. Heated or unheated air is blown on to the mows until the moisture is reduced to 20-25%, Swath curing is completed in the field itself and when the moisture is 35-40%, it is taken into the barns and placed on the mows. It takes 7-14 days on the mows with unheated air to cure the hay fully. With heated air it takes less time. Generally the hay produced in this manner will be greener and leafier and of a higher quality than field cured hay.

3. Dehydration or artificial drying

This is the process of chopping freshly cut or wilted fodder and drying it in artificial driers. This is limited to large commercial operations where alfalfa meal or alfalfa leaf meal for use chiefly as a vitamin supplement for poultry and swine are produced. Such hay is consistently of superior quality.

Losses of Nutrients in Hay Making

1. Losses of leaves by shattering
2. Losses of vitamins due to bleaching and fermentation
3. Losses of soluble nutrients by leaching in heavy rain.

1.**Losses by shattering-** The loss due to shattering of leaves and finer parts in hay making is of importance, especially in the case of legumes. The leaves are much richer in digestible nutrients than the stem and hence losses by shattering decrease the nutritive value of hay. To avoid these losses, hay should never be overdried or handled during warm periods of the day. Handling of hay, while field curing, is preferably done in the morning hours of the day.

2. **Losses of vitamins due to oxidation-** In the process of drying, much of the green colouring matter containing carotene (provitamin A) is bleached. Exposure of the green plants to Sun rays decreases vitamin A content of the hay. Sun cured hays are rich in vitamin D_2 (ergocalciferol).

3. **Losses due to fermentation-** After the crop is harvested the plant enzymes act on the soluble carbohydrates forming thereby CO_2 and water. Therefore, in a normal hay making process some of the nutrients are lost. This loss results in the higher crude fibre content of dry matter of hay as compared to the green fodder. In addition to carbohydrates, protein is affected. Proteins are hydrolysed to amino acids which will be lost if there is rain on the hay due to leaching. In normal curing there is a loss, about 5-9% of dry matter.

4. Losses due to leaching- If hay is almost cured and is exposed to heavy and prolonged rains, especially when it is in the field, severe losses may occur through leaching. Unless the rain is so heavy as to soak the material, losses by leaching will not occur and the losses will be much less even in heavy rains if the hay is in good sized windrows. Leaching causes loss of protein, soluble carbohydrates and other soluble nutrients.

Total losses in hay making-

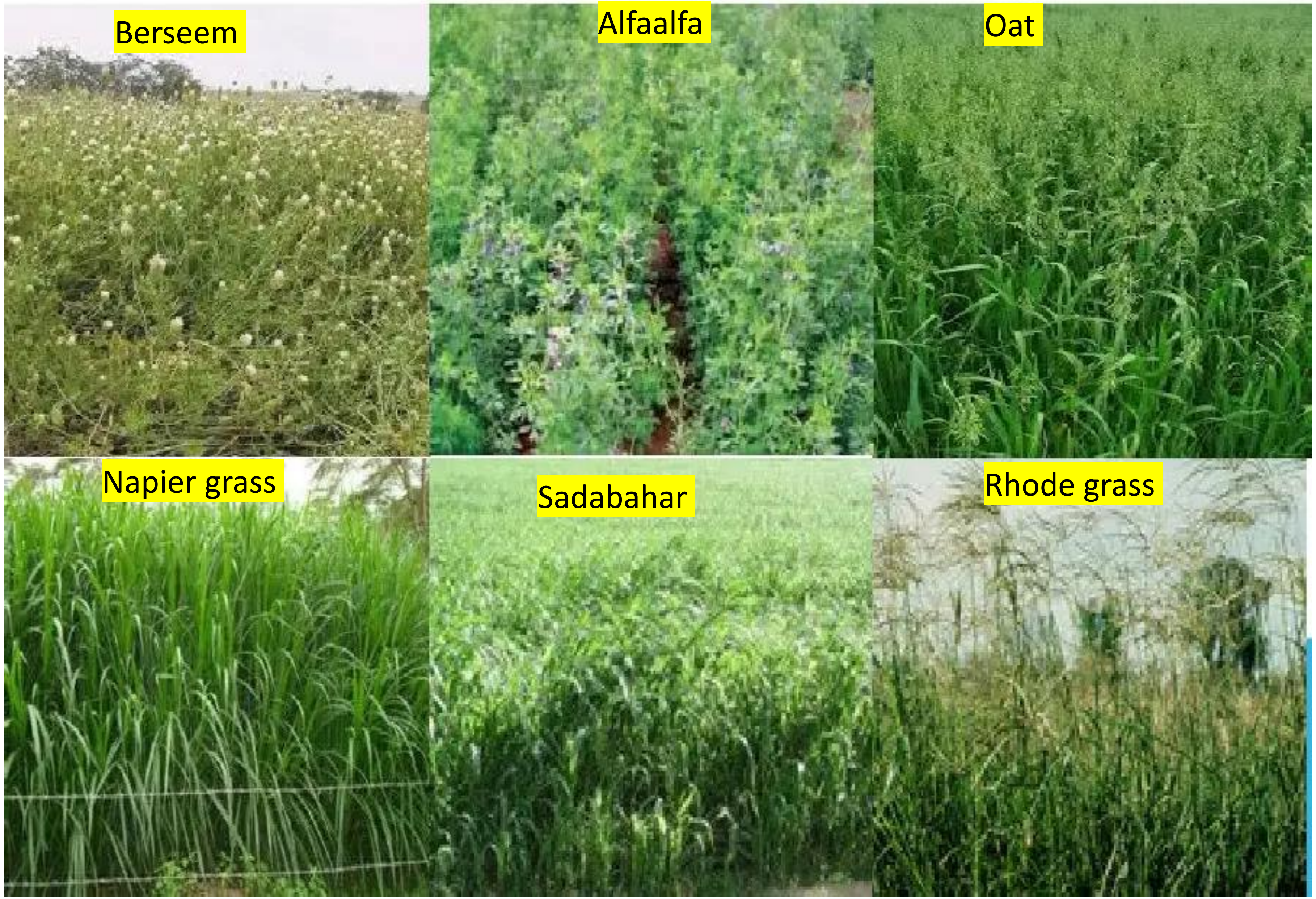
Loss of dry matter	20-30% in legumes
	10-15% in grasses
Loss of protein	28%
Loss of carotene	90%
Loss of energy	25%

Brown Hay-

The optimum moisture level for safe storage of hay is 12-14% under tropical Indian conditions. If hay is stored with moisture more than this fermentation takes place and the hay may become very hot and turn brown. Such hay is often quite unpalatable and less nutritious. Starches are broken down to sugars and alcohol and a type of hay called **'Mow- burnt hay'** is obtained. Sometimes hay stacks may catch fire spontaneously due to excess fermentation and heat. Therefore a moisture level of 12-14% is important before stacking.






Berseem
Alfaalfa
Oat
Napier grass
Sadabahar
Rhode grass

STAKING

FANCING

MOWER IS USED TO HARVEST THE CROP

RAKING

Bunker silo

Approximate * Silage Bunker Capacities **		
Silo Dimensions height X width X length (feet)	Well Packed Silage Tones	Low Packed Silage⁻ Tones
8 X 50 X 100	979	795
8 X 50 X 150	1,551	1,260
8 X 50 X 200	2,397	1,947
12 X 75 X 100	1,980	1,609
12 X 75 X 150	3,238	2,631
12 X 75 X 200	4,495	3,653
12 X 100 X 200	6,244	5,073
12 X 100 X 250	7,497	6,498
12 X 100 X 300	9,750	7,922
16 X150 X 300	18,601	15,113
16 X150 X 400	25,460	20,686
16 X150 X 500	32,319	26,259
20 X 150 X 300	21,810	17,121
20 X 150 X 400	30,040	24,408
20 X 150 X 500	38,721	31,095

Tower silo

Tube silo

Drum silo

Bag silo

Silage bale