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A review: Silage preparation and silo management techniques

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Abstract
Forage is stored and fed to animals in the form of silage. The steps involved in the silage making process are cutting fresh green fodder, compaction, storing and fermentation in a silo in anaerobic condition. The different types of silos used are upright, bunker, sack, or pile, bag and trench. Maize silage is frequently used as the main source of feed for ruminants throughout the world. Green maize feed is referred to as the "king of crops" and is perfect for producing great silage. The silo type affects the chemical properties of silages, including the dry matter, crude protein content, neutral detergent fibre, pH, temperature and flieg score. Silage additives are substances added to the fodder or green mass that are either natural or manufactured. Additives are used to boost the nutrient content of silage, raise its aerobic stability, decrease storage losses by promoting quick fermentation, and reduce fermentation losses by reducing the duration of fermentation. The signs of degradations of silage are an increase in temperature of silage, an increase in pH of silage, a loss of dry matter of silage, the development of surface molds, and the refusal of animals to eat the silage.

Keywords: Silage, silo, dry matter, crude protein, additives

Introduction

Animal husbandry has been a crucial component of agriculture since prehistoric times. In the past, various animals of all kinds would visit fields to graze. But with an increasing population and less pastures, feeding the animals with fresh fodder has become a challenging problem. Fodder is now primarily transported to cities from far-off regions, with prices rising dramatically in some months of the year, particularly in the summer before the onset of the rainy season. Low milk yields are a direct effect of a lack of green feed. India leads the world in milk production, yet its cattle only produce an average of 1172 kg of milk per year, or 50% of the world average. There is a critical need for the systematic production and storage of green fodder. Silage can be one of the solutions of the above problem [1].

Silage is a feed product that is produced when green forage crops with high moisture levels are acidified. Ensilage, ensiling, or silage are terms used to describe the fermentation and storage of food. It is typically prepared utilising the entire green plant from grass crops like maize, sorghum, or other cereals (not just the grain). Other field crops can also be used to make silage, and different names may be used based on the type, such as Oatlage (silage made from oats) for oat plants. The composition of silage is stable for a long period of 5 years. It can guarantee a source of good feed at a time of famine. Silage can be created to conserve extra green output for later use. Silage can be prepared in cold and cloudy conditions [1].

Forage storage as silage has a number of benefits, such as not requiring the same ideal weather conditions as hay and grain production, yielding more nutrients per acre from annual crops (such as maize and sorghum small grains), and having more flexibility with harvest times. Silage storage has some disadvantages, such as the following: 1) silage has a higher moisture content and lower nutrient density than many other feeds 2) anaerobic storage requires more sophisticated storage systems 3) the moisture content and nutrient density limit feasibility of transport (produced and stored close to home) and 4) high initial investment in facilities and equipment [2]. Maximizing the original nutrient retention in the forage crop for future feeding is the main objective of silage production. Unwanted silage fermentations and inadequate aerobic stability cause a loss of energy, dry matter, and total nutritional value, which eventually jeopardises animal performance and net farm earnings. For successful silage production, accurate forage dry matter content measurement in the field is essential. To make silage of the best quality, it is imperative to comprehend how crops are preserved in silos.

Silage of high quality is the outcome of many management techniques. The management of silages was divided into four sections such as harvesting at the correct maturity, silo types, filling the silo rapidly and covering silos with polyethylene plastic and tyres and feed out period [2].

Feed out period begins as soon as the silo is opened for animal feeding. Silage fermentation and subsequent quality can also be impacted by management parameters as packing speed, pack density, additive type, chop length, covering management, and silo management during feed-out [3]. The economics of feeding silage can be affected by each of these management techniques. In rare instances, fermentation analyses can provide a qualitative explanation for low intakes or inadequate nutritive value. The quality of silage is assessed by analysing suitable sample for both fermentative and nutritional evaluations [4]. The physical characteristics such as colour, smell, and structure along with total flieg score are influenced by silo type. Flieg score provides information on quality of silage using pH and dry matter content and it is related to the quantity of organic acids in the silage. Chemical characteristics of silages such as dry matter, crude protein content, neutral detergent fibre, pH is influenced by silo type [5].

Crop for silage preparation

In tropical regions, there are numerous forage species with silage potential. Corn (*Zea mays*), sorghum (*Sorghum bicolor*), and sunflower (*Helianthus annuus*) are a few of them [6]. In many parts of the world, maize silage serves as the primary source of feed for ruminants, and numerous studies have discussed its significance [7-13].

The third-most significant grain crop worldwide is maize. It is utilised as food, forage, and feed. All phases of growth can be fed maize fodder without risk from oxalic acid or prussic acid, unlike sorghum or other fodders. Green maize fodder is hence known as the "king of crops" that is ideal for making fine silage [15]. Maize (*Zea mays*) has a high protein efficiency ratio (PER), relatively high digestible energy (DE), and total digestible nutrients, it is a nutrient-dense feed for small and large ruminants. Thus, maize fodder can play a significant role in supplying animal feed all year long [14]. In Indian states of Andhra Pradesh and Karnataka, the practice of feeding silage-based rations to sheep is popular among the farmers. Over the past few decades, maize silage has replaced other forages as the main part of diets of dairy cows. The nutritious content of maize silages varies greatly, and most of this variation is brought on by significant variations in harvest maturity.

Early-stage maize silages (dry matter (DM) 250 gkg^{-1}) were particularly low in starch content and starch or neutral detergent fibre (NDF) ratio, which decreased milk output and protein content as well as dry matter intake (DMI). For maize silages ensiled at dry matter contents of 300-350 gkg^{-1}, the dry matter intake (DMI), milk output, and milk protein content improved with increasing maturity, reaching an optimal level, and subsequently marginally decreased at additional maturity beyond 350gkg^{-1}. The rise in the starch/NDF ratio of the maize silages was favourably correlated with the increases in milk and protein yields with silage maturity. Higher dry matter intake and milk yield are supported by high metabolizable energy content of maize silage. Dairy cows produce more milk when maize silage is harvested at a dry matter level of between 300 and 350 gkg^{-1} combined with grass silage [16].

Preparation of silage

The step in the silage-making process is to determine how much silage is required for feeding animals. The size of the silo depends on number and type of livestock to feed, length of the feeding period, percentage of silage in the full ration**,** water content of the silage**,** Losses in percentage (on average 15% losses due to spoilage) and density of the silage (Density of 0.8 metric tonnes/m^3) [17].

The silage is prepared in silo constructions such as bunkers, trenches, pits, and horizontal silos. They are built in accordance with the needs of silage. Pit silos or horizontal silos have a 152.4 mm layer of agricultural leftovers at the bottom, and the edges of the structures are covered in polythene sheets. When storing fodder in bags, crop residue is placed directly within the bag silo and crushed. The 50.8 to 76.2 mm sized chopped fodder is added layer by layer to the pits or bunkers and carefully crushed by a tractor. The anaerobic conditions are created in silos, and the tops of silos are covered with polythene sheets and dirt(mud) (2019, Brar *et al*.) [18]. Some additives like common salt, urea made for fertiliser, and sugarcane molasses are frequently added to silage at rates of 1, 0.5, and 0.5 percent, respectively and evenly sprinkled over the fodder. In a plastic barrel, they are thoroughly combined with water (50 litres per tonne of fodder) [19].

Sealing of silo structures

In recent years, plastic films have frequently been utilised as protection for storing silage in bunkers, trenches, and stacks. The weight of destroyed silage and/or feedable silage recovered indicates different levels of air protection, ranging from nearly 100 percent protection to incredibly insufficient protection. (Gordon *et al*. 1961) [20].

In order to effectively protect the top layer of silo, the plastic sheeting must be anchored and maintain structural integrity. The plastic covering must be kept in place and must not slide off due to rain and wind [21].

The use of the high oxygen barrier (HOB) film ensures a longer shelf life of silage during consumption by reducing the negative impact of yeasts, molds, and aerobic and anaerobic spore-formers on the nutritional and microbiological quality of silage. The best barrier to oxygen is ethylene-vinyl alcohol (EVOH) film. Reducing oxygen penetration in the silage mass during the conservation and feed out phase is one of the most efficient techniques to reduce top layer spoilage of silage. A high-quality plastic film that combines improved oxygen impermeability with beneficial mechanical qualities could be used to accomplish this goal [22].

In comparison to conventional sealing, double sealing with oxygen-impermeable film and sealing systems with 200 µm thick double-sided polyethylene were effective and promoted improvements in chemical composition, ruminal digestibility of dry matter, fermentation profile, and physical losses of corn silages from the feed out face of trench silos. Due to the difficulty of compacting and sealing the site, the feed out face of trench silos presents the most difficult environment for silage preservation. It is therefore suggested that there is a greater influence of the type of sealing used, impacting on the quality of the fermentation process and, as a result, in the ruminal digestibility of the material [23].

The use of polyethylene double sealing systems in bunker silos determines improved silage aerobic stability, lower dry matter losses, and higher neutral detergent fibre (NDF) digestibility [24]. High-quality preserved fodder can be made using films in a variety of colours and thicknesses, even ones that are much thinner than those 150-200 µm. Silage is often preserved in bunker silos that are wrapped in low-density polyethylene (LD-PE) film [25]. Since the conventional polyethylene film is not oxygen-impermeable [26], the protection of silage in bunker and clamp silos given by polyethylene sheeting, normally weighted by car tyres [27, 28].

Baling is the process of wrapping compacted and inoculated fodder in polypropylene sheets. Bales are typically covered in thin (25 µm thickness) polyethylene film that has been stretched about 0.7 during wrapping, with two full rotations and an overlap of 0.5 between layers result in a covering of four film thicknesses [29].

The maize ensiled with co- extruded oxygen barrier film of 125 µm thickness reported losses of dry matter from the top 40 cm layer to the tune of 10 percent. Polyethylene film of 180 µm thickness showed losses of dry matter to the tune of 37 percent. Under challenging farm conditions, the co-extruded oxygen barrier film is better solution for limiting spoilage and dry matter losses. The stability of corn silage in the outermost parts of the silos was significantly enhanced by the co-extruded oxygen barrier coating [30]. Aerobic stability tended to be higher for silage under the oxygen barrier film than under the standard film, and there were less mould and butyric acid spore counts in the periphery of bunker silos [30, 31].

Studies on oxygen barrier films with a 45 µm thickness thinner have demonstrated benefits for both grass silages (Wilkinson and Rimini, 2002) [32] and maize silages [33]. In order to keep ensiled maize from absorbing oxygen during the storage and feed-out phases, oxygen barrier film outperformed regular polyethylene film [34].

Other researchers, however, reported no differences between oxygen barrier film and conventional film in wet grass silage stored under either two sheets of 125 µm thick black polythene film or a single layer of oxygen barrier film covered by a single protective sheet of black polythene (210 g DM kg-1 FW (Forage Weight in wagon)) [34].

Effect of additives on silage

Silage, which is green fodder that has undergone anaerobic fermentation, is prized all over the world as a source of animal feed during the off seasons. Several farms in India uses 2% carbohydrate sources such as molasses or jaggery for the preparation of silage, which raises the cost of production. Jaggery was added at a rate of 2 percent, and this had a considerable positive impact on silage intake, lactic acid composition, pH, and fermentation. The technique for making silage in barrels would be appropriate for small-scale silage production for use by small-holding farmers [35].

The use of ensilaging additives is advantageous for making silages from a mixture of dendromass (biomass made up of roots) and maize for wild ruminants since it enhances both the fermentation process and the quality of the silages. A good microbial fermentation process is necessary to produce silage of the highest quality. In addition to the type and quality of the fodder crop, a successful fermentation process also depends on the harvesting and ensiling method. To enhance the fermentation quality of manufactured silages, many additions have been applied. The highest lactic acid concentration and the lowest levels of volatile fatty acids and alcohol indicate that silages treated with the chemical addition underwent the most successful fermentation. Rajcakova assessed the effects of specific biological and chemical ensilaging additives on the nutritional value of silage made from a mixture of dendromass and maize, with 70 percent maize, as well as the quality of the fermentation process. Two mixtures were made, and their proportions of spruce and oak twigs in the dendromass varied. In the instance of mixture 1 silage, which was made using a dendromass mixture of 50 percent oak and 50 percent spruce twigs, the ensilaging additives were more successful. The chemical addition based on salts of organic acids was shown to be more successful than the other applied silage additives at enhancing the quality of silage [36].

The use of cereal grains, molasses, and ecomass would lower the pH of guar bean silage fermentation by boosting the formation of lactic acid while positively enhancing the crude protein content and silage quality. The quality and feed value of guar bean silage have been greatly improved by the addition of molasses and molasses + ecomass. It was found that the additives used in this study boosted the dry matter contents of silage. Ecomass in the silage increases crude protein content and feed value of silage [37].

The best growth rate in Nellore ram lambs can be obtained by providing maize silage supplemented with either lucerne hay, groundnut haulms (to meet 25 percent of dry matter need) or concentrate combination at 1.5 percent of body weight [19].

The pH of the alfalfa was dramatically decreased by adding pear waste to the alfalfa silage. Additionally, as the proportion of pear waste in the silage grew, so did its digestibility and potassium (K), sodium (Na), calcium (Ca), and magnesium (Mg) levels. As a result, adding pear fruit waste to alfalfa silage enhances the concentration of several nutrients as well as the digestibility of the silage. Silage can benefit from the addition of fruit wastes to maximize animal output while simultaneously reducing environmental pollution [46].

Properties of silage in silos

The different properties of silage are dry matter, pH, crude protein, temperature. The amount of dry matter, sugar, and type of fermentation in the ensiled feed all affect the pH of the resulting silage. When dry matter is minimal, well-preserved silages often have pH values between 3.5 and 4.2. Ammonia-N (percent of total nitrogen) in silage is a crucial indicator of the ability of silage to ferment. Poorly maintained silages have high ammonia-N levels, which show that the forage protein was extensively degraded during the ensiling process. There is a strong likelihood that the silage had been improperly kept if the pH of the silage exceeds these limitations (Kaiser and Piltz 2004) [38]. The ideal pH range for corn silages was between 3.5 and 4.3 [39].

The ideal crude protein range for corn silage is between 7.0 to 9.0 percent [40]. The crude protein and nitrogen losses are more in jumbo bag than aspirator bottle [1]. Trench silages had much higher protein content than bunker and bag silos. Trench silos were found to be superior for manufacturing cereal-based silages. The physical quality, chemical composition, and fermentation characteristics of the fodders ensiled in trench silos are improved. Trench silos appeared to be more temperature-resistant, which would improve the quality of the silage in subtropical region of Pakistan [5]. The type of sealing had an impact on the daily pH of silage because the conventional seal had a higher pH than the double-sided system [23]. When compared to double sealing, the lower stratum from normally sealed silos displayed a higher pH (3.76 vs 3.69). However, there was no discernible difference between the groups in the upper stratum or the average pH [24].

During the initial days of ensiling, aerobic bacteria consume the oxygen present in the bag and produces CO_2 due to which pH decreases and after the whole oxygen present utilized by aerobic bacteria, anaerobic phase starts in which anaerobic bacteria utilize the carbohydrates present and convert it to lactic acid which further reduces the pH. After a certain time, pH drops to such an extent that can't sustain the growth of anaerobic bacteria due to which further production of lactic acid stops and pH comes to a stabilized value. The quality of silage is found good but the material in touch with the plastic bag side is found affected with fungus. No fungus was found in bottle silage while about 17 percent material was fungus affected in bag silage. Compared to aspirator bottle silage, animals preferred bag silage. Compared to bottle silage, bag silage has a fruitier aroma. Overall, a bag silo is cost-effective [1].

Silage temperature and oxygen concentration are critical parameters for controlling the silage process. anaerobic conditions with a lower and steady temperature are required for the production of high-quality silage. However, the anaerobic environment changes to an aerobic state when the silo is opened or if there are any faults (such as at the cover or the walls). That intensified the decomposition process and raised the temperature in the problematic silage layers in the affected silage layers [41]. Borreani and Tabacco evaluated 54 dairy farms and observed variations in silo temperature. A reference temperature of bunker silos was measured in their central portion, and differences between that and temperatures measured in peripheral and mouldy spots areas were related to aerobic deterioration. This process was positively correlated with pH increase; water activity; filamentous fungi, yeast and clostridial spore's count; and negatively correlated with the presence of lactic and acetic acid, and nitrate concentration. Silage temperatures in the core ranged from 12.0 to 22.9 °C, with an average of 18.6 °C. Temperatures as high as 54.5 °C were recorded in the outer regions of bunker silo and in its mold-covered portions [42]. The increase in temperature is a strong indicator of multiplication of microorganisms, which is only possible in the presence of oxygen, allowing several aerobic spoilage microorganisms to become active and multiply, resulting in substantial economic losses. The degradation of silage is indicated by an increase in temperature, an increase in pH, loss of dry matter, growth of surface moulds and the refusal of this food by the animals, conditions observed in silage from the conventional sealing [43].

Dry matter content is important criterion for judging the quality of silage. Dry matter content of silage is important as it indicates the adequacy of wilting (Brar *et al*. 2019) [18]. The dry matter losses were 3.7 times higher in the upper portion of conventionally sealed silos in relation to doubled sealed silos, suggesting the influence of plastic film on dry matter recovery index [30]. It was noted that the type of sealing influenced the dry matter contents, and the silo with the conventional seal had lower dry matter values (412.20 g kg-1 DM) than those obtained by double sided and double seal with values of 425.80 g kg^{-1} DM and 428.30 g kg^{-1} DM, respectively [23]. The dry matter content of silages was significantly higher in trench followed by bunker and bag silos [5]. Fermentation characteristics and ensiling losses were significantly correlated with dry matter content of maize plant at harvesting. All the fermentation parameters were significantly affected by the type of silo, except for butyric acid. The largest differences were found between experimental silos such as plastic dustbin silo, pilot-scale silo and glass jar on the whole and bunker silo. Bunker silo showed a lower pH than the average of experimental silos [44].

The silo pit was filled with fodder, and the fodder was stored. It was noted that the silage made from maize variety P-1844, P-1844, P31Y45 and P31Y45 which ensiled for 45, 40, 50 and 76 days respectively showed the values of practically all quality criteria within the optimum range. Silage made from maize variety P-1844(ensiled for 45 days) has 32.42 percent dry matter, 9.32 percent crude protein content and 3.7 ph. Silage made from maize variety P-1844 (ensiled for 40 days) has 30.05 percent dry matter, 9.72 percent crude protein content and 3.8 ph. Silage made from maize variety P31Y45 (ensiled for 50 days) has 31.27 percent dry matter, 10.88 percent crude protein content and 3.7 ph. Silage made from maize variety P31Y45 (ensiled for 76 days) S21 has 30.59 percent dry matter, 8.50 percent crude protein content and 3.8 ph [18].

After the 132nd days of storage, whereas maize silage crude protein, ether extract, ash and crude fibre contents decreased, nitrogen free extract content increased. Lactic acid concentration of corn silage increased until the 118th day but decreased between the 118th and the 160th days. Storage time had significant influence on Flieg scores. It was observed that there was a change in silage nutrient contents and fermentation characteristics with increasing storage time [45].

Conclusions

Silage is the easiest way to preserve fresh green feed with the minimum losses. Minimum 45 days are required for proper fermentation of fodder for making silage. An anaerobic environment must be created in the silo for proper fermentation of the feed. The silo can be sealed with a variety of polythene sheets, including low-density polyethylene film, ethylene vinyl alcohol film, and high oxygen barrier film. The use of films in a variety of colours and thicknesses, even ones considerably thinner than those 150-200 µm, can be used to produce preserved food of a high standard. The corn silage sealed with the conventional polyethylene film was less stable than the silage sealed with the oxygen barrier film. Unproper sealing of silos with plastic or polythene sheet tends to produce bad quality of silage. Silage under the oxygen barrier film seemed to have stronger aerobic stability than silage under the regular film.

Common salt, urea, sugarcane molasses and green fodder are essential additives of silage. Many additives such as spruce, oak twigs and pear fruit can also be applied to enhance the fermentation quality of manufactured silages. Additives increases nutritional content of silage and improves the quantity of milk or decrease heating and molding during storage and feedout. A good suggestion is to constantly utilise additives to produce best silage. In comparison to aspirator bottles, jumbo bags lose more crude protein and nitrogen. Trench silages contain significantly more protein than bunker and bag silos. Dry matter concentration is much higher in trench than in bunker, bag silos, or any other storage structure. Silage temperature in the core region of bunker silo is comparatively less than outer region of bunker silo.

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