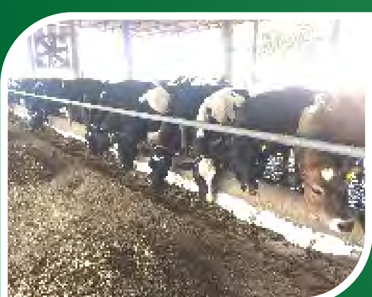
SILAGE MAKING

AN EMERGING ENTERPRISE FOR DAIRY SECTOR



ICAR-AGRICULTURAL TECHNOLOGY APPLICATION RESEARCH INSTITUTE
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AN EMERGING ENTERPRISE FOR DAIRY SECTOR

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MESSAGE

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The key to profitable milk and dairy production lies in proper feed management of dairy animals. In India, there have been significant changes in forage production, harvest, storage, and feed practices over the past 50 years, especially with the commercialization of dairy farming. Technological innovations like silage feeding have emerged as a game-changer in this sector, as it can increase productivity by extracting more nutrients from available land, lower feed costs, reduce harvest losses, and improve forage quality. Therefore, it is crucial to consider the potential of Silage technology in dairy farming for future growth and development.

Despite the benefits of silage feeding, most of the small farmers still prioritize the alternate way of feeding their animals without considering the potential advantages or disadvantages of silage. However, once they are educated on the results of using silage and how it can be balanced with other feeds, there is a notable shift in their approach and many opt for silage. For commercial silage producers there may be initial challenge of marketing and sales, but once farmers begin using this technology, it becomes a cyclic action with continuous demand. Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana is also engaged in various endless efforts through awareness programs, demonstrations, and participatory projects for promotion of this technology. In India, manual methods are typically used for silage preparation, although under the university's guidance, many farmers in Punjab have started corn silage preparation in mechanised manner. The state government is also incentivizing the promotion of machinery for silage preparation through various funding schemes.

It has been observed that many dairy entrepreneurs lack knowledge in the silage sector and often seek guidance from experts. They also lack technical support and require the best agronomic and feeding practices for silage usage for their animals. The book "Silage Making: An Emerging Enterprise for Dairy Sector" provides a genuine framework for the productive use of silage technologies in the livestock sector. I would like to appreciate all those who have contributed directly and indirectly to this useful publication.

In conclusion, the future of silage production is promising, and proper measures need to be taken to upscale production and improve the dairy sector and the silage industry as a whole.

(U.S. Gautam)

MESSAGE

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India's vast bovine population has made it the world's largest milk producer. Besides, with the growing population, increasing income levels, and changing dietary preferences, commercial dairy farming in India is rapidly evolving to meet the rising demand for milk and milk products. Regardless of being the largest producer, the per-animal productivity (1600 kg/animal) is significantly lower than the global average (2700 kg/animal). The main factors attributed to this are low genetic potential, poor farm management and atrocious nutrition. Additionally, the cost of livestock feed, which accounts for approximately 60-70% of their daily income, is also a significant factor for improper feed management. Over and above that, India is also facing a shortage of 36% in green fodder and 11% in dry fodder, with availability being particularly scarce during the summer season and periods of deficient monsoon rainfall.

Given the current situation where land is facing competing demands, expanding cash crops is challenging, making it nearly impossible to increase the area under fodder crops. As a result, a multi-faceted approach is necessary to ensure adequate availability of fodder to safeguard farmers against climatic variability. This provides an opportunity to enhance potential fodder conservation technologies, which are already widely adopted by farmers. Silage production holds significant potential as an industry and offers an avenue to meet the aspirations of today's youth in agricultural farming while maintaining their social and cultural ecosystems. Developing entrepreneurship through advanced feed technologies like silage manufacturers is a superior option to be explored.

The future growth of the livestock sector, similar to earlier agricultural reforms, will depend on the emergence of new feed technologies which must be supported by public policies, relevant institutional changes, and increased private sector investment. The publication "***Silage Making: An Emerging Enterprise for Dairy Sector***" is a much-welcomed effort to compile all these necessary information from the current scenario to the future prospects of the silage industry. I commend the Editorial Team for their initiative and effort, which will undoubtedly assist farmers and other stakeholders in comprehending the potential of this industry in a more systematic manner.

Finally, I extend my congratulations to the entire editorial team for their valuable contribution to this book. I look forward to continued efforts towards creating a favourable environment through various schemes, services, and technological options for this upcoming enterprise.

30/5/2023

(B.N. Tripathi)

PREFACE

India is an essentially agrarian economy, around 70% of its population lives in villages, where livestock plays a pivotal role in uplifting their livelihood security. The health and production levels of the dairy animals depend upon the quality nutrition supplied to them. For full exploitation of milk production in dairy animals, it is imperative that nutritionally rich lush green fodder of 40-50 kg per adult animal per day is made available throughout the year. In general, the feed and fodder requirements for animals remains below the normative or recommended levels at the farmer's level. Few studies have also highlighted the role of suboptimal feeding in restricting the utilization of full potential of animals by 26-51%. To resolve all these issues, fodder requirements can be sustained by conserving surplus fodder in the form of silage.

Silage making is equally popular among different categories of dairy farmers in Punjab state. Crops such as maize, sorghum, bajra, hybrid napier bajra, oats etc. are most suitable for silage making. Rabi crops such as oats, wheat, barley, triticale and cereal rye can all be used for silage preparation. Efforts have been put forth in this book to briefly describe the management practices for successful cultivation of different fodder crops for silage making. More importantly, it is very essential to harvest the silage crop at an optimum stage to ensure good yield, quality and ensiling characters of fodder. After harvesting, its scientific storage in silo pit/bunker is equally important step in the process of silage making. The goal of silage making is to preserve as much of the nutritional value of the parent crop as possible.

Silage industry has become one of the most booming industries in some of the states in India. With increasing competition among manufacturers and suppliers, it has shown direct benefits to farmers in the form of improved bale quality and cheaper prices. In this book, attempt has been made to present all these topics in different chapters under specific headings. Some of the successful case studies in silage making are also presented herein to highlight the challenges and opportunities towards adoption of silage technology at grass root level. The role of various institutes has also been discussed in promoting this technology. Efforts have been made in presenting all the information in a clear and concise manner. Any error/mistake, if observed, may be due to chance only. Authors will appreciate comments and suggestions for further improvement of this compilation. We expressed our sincere thanks to all the contributors directly or indirectly involved in preparation of this document.

(Authors)

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Chapter 1

CURRENT FODDER SCENARIO AND FUTURE PROSPECTS

1.1 Importance of green fodder in dairy farming

Dairy farming is an important branch of agriculture that involves the breeding, raising, and utilization of dairy animals, primarily cows and buffaloes, for the production of milk and the various dairy products processed from it. Dairy farming has been an integral part of the agricultural scenario for thousands of years. India is an essentially agrarian economy, around 70% of its population lives in villages, where livestock plays a pivotal role in socioeconomic life. The potential to reduce rural poverty can be higher with growth in the livestock sector than the crop sector. About 28.40 per cent of agricultural GDP in India is presently contributed by the livestock sector, and this contribution is 38.8 per cent in Punjab state. Livestock provides high-quality foods such as milk, cheese, butter, ghee, etc. India is not only one of the world's leading milk producers, but the largest consumer of milk and dairy products in the world. In India, in general and in Punjab, in particular, dairy farming has evolved from just an agrarian way of life to a professionally managed industry. A large number of rural families in Punjab are engaged in dairy production, for whom this is an important source of secondary income. In an era of declining farm income and a drop in employment opportunities, the livestock sector has emerged as an important sub-sector of Punjab's agriculture. For the rural economy, there is a significant role of livestock. It is one of the money-spinning alternatives to the dominating wheat-rice system and provides regular income and employment to households, particularly small and marginal farmers. This regular source of income acts as a cushion against the inclement weather-linked risks to seasonal income from the crop sector.

Now, the success of dairy farming largely depends upon the health and productivity of the animals. Further, the health and production levels of the dairy animals depend upon the nutrition supplied to them. An animal's diet must contain the optimum concentration of essential nutrients to achieve proper maintenance, growth and productivity. Feeding a balanced diet, and avoiding over or underfeeding with abundant supplies of fresh and clean water will help to optimize feed and nutrient use in an animal, which also translates on their productivity. Hence, the largest operating cost in a dairy enterprise is feed because it alone accounts for 60-70 per cent of the total cost of milk production. Therefore, the availability of adequate nutrition coming from cheaper sources assumes greater importance. While the average milk production per cow per year for USA is around 9,000 kg, the figure stands far below in our country. The indigenous cow produces less than 1000 kg per year. Although we, Indian stand high in case of total milk production, however, the productivity is quite low. Further, the genetic potential contributes significantly towards higher milk production but the genetic potential of high-yielding animals can be realized only if they are fed well with quality nutrition.

Among, the various sources of feeding for dairy animals, green fodders are an economic source of nutrients. Green fodders are rich and cheapest sources of carbohydrates, protein, vitamins and minerals for dairy animals. Forages generally contain protein (8-10 % in non-legumes and 18-22 % in legumes), vitamins (vitamin A-carotene), minerals (Ca - 1.5 to 3.0 % in legumes and 0.3 to 1.3 % in non-legumes; P - 0.28 to 0.65 % in legumes and 0.12 to 0.30 % in non-legumes), carbohydrates, micronutrients and having *in vitro* dry matter digestibility (IVDMD) between 55 to 75%. These nutrients are vital to the growth, maintenance, reproduction and production of dairy animals. The lush green forages are palatable and are preferred by the animals to fill their stomach and to satisfy the hunger. Considering their unique digestive system, ruminants need quality feeds that fill their stomach and satisfy them while meeting their nutritional requirements. In view of microbial digestion system, the feeds have to meet requirements of the animal, its production as well as the needs of microbes for promoting digestion. Forage crops meet these requirements very efficiently which indicates their importance to the ruminant production system. For full exploitation of milk production of dairy animals, it is imperative that nutritious lush green fodder is make available at the rate of 40-50 kg per adult animal per day throughout the year.

Regular supply of fodder is essential for the production and economic returns from the dairy farming sector. In most of the Asian countries, nutritional requirements of ruminants are mainly met by feeding green fodder and dry roughages, as well as post-harvest crop residues. Contribution of forage in animal feed is more than 75% and is considered a cheap source of nutrients (Sarwar *et al* 2002; Kumar *et al* 2014). Poor supply of nutrients to livestock during scarcity period is a matter of concern. The availability of nutrients from green fodder is significantly cheaper than concentrate feeds. Hence, by providing adequate quantities of fodder instead of costly concentrates and feeds to the milch animals, the cost of milk production can considerably be reduced.

Table 1.1 show that availability of green fodder round the year in

Table 1.1: Green fodder availability scenario of different states

Percent deficit			Percent surplus		
<25	25-50	> 50	<25	25-50	> 50
Uttar Pradesh, Assam, Karnataka, Nagaland and Kerala	Sikkim, Odisha, Meghalaya Manipur, West Bengal, Tamil Nadu, Goa, Chhattisgarh, Rajasthan and Bihar	Jharkhand, Andhra Pradesh, Tripura, Uttarakhand and Jammu & Kashmir	Gujarat, Arunachal Pradesh and Maharashtra	Himachal Pradesh and Madhya Pradesh	Haryana, Punjab and Mizoram

Source: Roy *et al* (2019)

northern India is scarce due to extreme seasonal severity during May to June and November to December. 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). At present about 35.6% of green fodder in India is deficient (Kumar, 2021). In conventional feeding system, farmers practise harvesting and carrying of green fodder on day-to-day basis. However, in this system it is difficult to ensure the quality fodder because with maturity and advancement of age, lignin content in fodder goes on increasing. Lignification of fodder crops decreases their quality, compromise digestibility and affects net energy balance of the animals.

1.2 Present situation of green fodder in India

Since thousands of years, livestock has been considered a mark of prosperity, affluence and power across civilizations and India is blessed to have the world's largest and most diverse livestock population. Approximately 70% of farm families in the country depend on the livestock and agriculture sector for their livelihood. According to the 20th Livestock Census – 2019, India's total livestock population is 535.8 million, an increase of 4.6% from the previous Census in 2012. Cattle, buffalo, mithun and yak make up the 302.8 million bovine populations. India is home to 57.3% of the world's buffalo population and 14.7% of the world's cattle population. In the country, there are around 74.3 million sheep and 148.8 million goats (20th Livestock Census–2019). Despite the lowest animal productivity (1538 kg/year), India is the world's leader in milk production. The major reason for the low performance of our animals is malnutrition which may be due to huge demand-supply gap of animal feed.

There is currently a net deficiency of 35.6% green fodder, 10.95% dry fodder and 44% concentrate feed materials in the country (IGFRI Vision, 2050). By 2050, the demand for green and dry feed will be 1012 and 631 million tonnes, respectively (Figure 1). In the year 2050, with the current rate of expansion in forage supplies, there will be an 18.4% deficit in green fodder and a 13.2% shortfall in dry fodder. Green forage supply must rise at a rate of 1.69% per annum to satisfy the deficit; however, the area under cultivated fodder accounts for only 4% of the total cultivated land (8.4 million ha) in the country and has remained unchanged over the last few decades. Although, different states are affected by the shortfall in different ways. While the shortage is insignificant in Punjab and Haryana, where fodder accounts for roughly 8% of total cultivable land, it is severe in dry arid areas such as Bundelkhand, where fodder is grown on less than 2% of cultivable land. With the rising livestock population, the fodder scenario in the near future seems very grim.

Forage production in India varies widely across the country and its use is determined by crop characteristics, climate, socio-economic conditions and livestock type. Forage crops are grown to feed the animals in the form of forage (cut green and freshly fed), silage (preserved anaerobically) and hay (dried green). Sorghum (2.6 M ha) and Egyptian clover (1.9 M ha) represent approximately 54% of the total forage area of the *kharif* and *rabi* seasons, respectively. Farmers are growing grasses and legumes including hybrid Napier, guinea grass, paragrass, velvet bean, stylo, etc. in many areas. Farmers with small ruminants, in particular, harvest tree fodder in times of shortage. The area under permanent pastures and other grazing land is 10.34 M ha

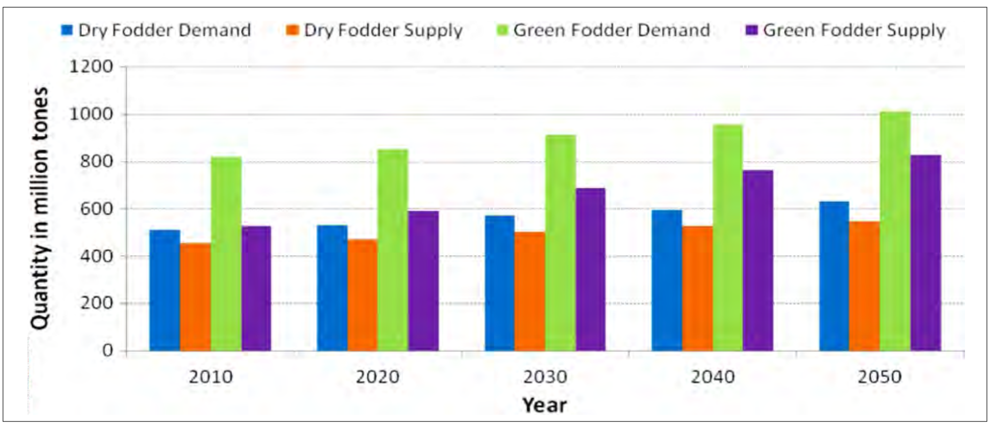


Figure 1. Year wise demand and supply of green and dry fodder in India

Source: IGFRI Vision, 2050

(Directorate of Economics & Statistics, DAC&FW, 2020) and has been declining over the years, with the trend likely to persist. The productivity of pastures has also been falling due to overgrazing (Pathak and Dagar, 2015). Crop residues are expected to provide 54% of total fodder, while rangelands provide 18% and only 28% is met from cultivated fodder crops.

Crop residues, cultivated fodder and fodder from community resources like permanent pastures and grazing lands are the three main sources of fodder in India. There is a big gap in fodder availability and demand due to multiplicity of forage crops grown in different seasons and regions, non-commercial nature of crops and production of forage with minimal inputs from degraded and marginal land. Further, since it is not cost-effective to transport forages across long distances, regional and seasonal deficits are more critical than national deficiencies. Also, because the available forages are of poor quality and lack adequate energy, protein and minerals, farmers maintain huge herds of animals to compensate for low productivity, putting further pressure on fodder and other natural resources. Feed and fodder accounts for over two-third of total animal production costs, hence, any effort to increase feed and fodder availability and economizing the feed cost will result in better remuneration to livestock farmers.The land available for cultivation of green fodder crops is getting restricted and the rising trend of cultivation of cereals will further restrict its growth. Thus, the feed and fodder requirements for animals has remained below the normative or recommended requirements. This suboptimal feeding has restricted the utilisation of the potential of animals by 26-51%.

Fodder yield per acre is also low because of number of reasons, including poor seed quality and inappropriate agronomic practices (Kumar *et al* 2016). Area under fodder cultivation is decreasing due to ever-increasing demand of cereal grains for human consumption, as well as preference to grow cash crops instead of the fodders. Low fodder production resulted fluctuation in uniform availability of quality fodder, thus affects the performance and productivity of dairy animals. Fodder production is abundant from February to April and July to September, whereas under adverse climatic conditions, there is hardly any production of quality fodder.

The changing feeding menu of cattle has an effect on milk production and there is considerable variability in production round the year. The quality of milk also varies depending upon the type of feed. The farmers are unable to harvest the full potential of milk production due to improper feeding practices. It is also cumbersome to record the individual milk production of farms and get the information analysed. Hence, the situation is reflected in the farms' poor profitability, in relative terms.

1.3 Role of silage to supplement the fodder deficit

The farmers may adopt the following techniques to provide greens to animals:

1.3.1 Fresh Greens

Fresh greens are one of the best options to feed the animals. A farmer needs to grow crops in rotation, based on requirement. In Punjab, farmers keep approximately 0.5 acre of land for fodder cultivation for 2-3 animals. The bigger dairies plan fodder cultivation on their lands or purchase fodder. The choice of crops depends on the season like:

Kharif Season- Maize, Bajra, Sorghum, Cow Pea, Guara

Rabi Season- Berseem, Lucerne, Ryegrass, Oats

Spring- Spring Maize

Summer- Summer Maize

The daily harvesting and chaffing of the crops are labour-dependent and require the use of machines which increase the cost of fodder. Therefore, situation calls for exploration of means to regularize the fodder production without sacrificing the area under grain and cash crops. So, there is urgent need for preservation of nutrients from green forages including fodder tree leaves available during the flush period to feed livestock during lean period (Mahanta and Pachauri, 2005) so that high yielding animals can be sustained for profitable dairy farming.

All above mentioned fodder production issues can be resolved by conserving surplus fodder in the form of silage, when fodder crops are at optimum level of nutrient contents. So when grains are in milky stage (for most of fodder crops), the surplus fodder if conserved as silage, will not only provide nutritionally uniform fodder but also spare land for other crop cultivation (Mandal *et al* 2003).

1.3.2 What is silage?

"SILAGE" is an age-old practice to preserve grasses for fodder. It was practiced in ancient Greece around 1000BC. The technique was limited to Europe and spread to the rest of the world in the 19th century. Silage is a technique where green fodder like maize, sorghum or jowar, bajra (Pearl millets) is cut fresh, chaffed and packed in closed containers or structures called silos to prevent the entry of oxygen. Here, fermentation is being occurred in an anaerobic environment, where the sugar is changed to acids. The acidic environment kills most of the microorganisms and preserves the fodder. Silage is the product from a series of processes by which cut forage of high moisture content is fermented to produce a stable feed that resists subsequent breakdown in anaerobic storage.

The technique is to store grass in an airtight environment until fermentation and acidification happens. The acid decreases the pH and kills most of the bacteria and microorganisms, which prevent any decomposition and fodder remains preserved for 1-1.5 years. In 1877, Goffart, a French farmer, published the first book on ensiling, detailing his experiences in making whole plant corn silage. Different kinds of green fodder can be preserved through this technique and feed to animals. The crops used for silage making are maize, sorghum, oats, pearl millets, hybrid-napier, beet etc. The best silage crops are corn/maize and sorghum, due to their high sugar content. "Maize or Corn silage" is widely used under Indian conditions.

Silage is as nutritious as green fodders as it preserves the nutrients in the original form and hence it is as good as green fodder for animal (Chaudhary *et al* 2014). One time harvesting of fodder crop for silage making is beneficial, since the crop is harvested at appropriate time. During silage making, the palatability of fodder crop increased as hard stem on fermentation in silage becomes soft, which helps in easy digestion by dairy animals. Also, anti-quality components such as nitrate are either destroyed or lowered during silage fermentation.

1.3.3 Ensiling-A potential process for preservation of 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. Ensilage has many advantages over the other methods for preservation of nutrients, particularly from forages. 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

Table 1.2: 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.

Source: Kumar *et al* (2019)

present in fresh herbage or by additives to maintain anaerobic conditions and discourage clostridial growth with minimum loss of nutrients. More recently, 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 animal feed (Machin, 1990). The end products of silage fermentation are often monitored to assess silage quality is presented in Table 1.2.

1.3.4 Advantages of silage

- The most important advantage of silage is that it is used during the scarcity of green forages called lean periods.
- Provides round the year supply of nutritious fodder and leads to uniformity of feeding round the year.
- Silage is as nutritious as green fodders as it preserves the nutrients in their original form and hence it is as good for animal feeding as green forages itself. It can be balanced with other feed ingredients
- The labour cost in dairy farming is significantly reduced by using only silage as fodder. A total of 4-5 persons can easily manage a flock of 40-50 cattle heads. In conventional feeding, maximum labour is consumed in harvesting the green forages.
- The entire crop is harvested in a single step for silage making. Thus, we can harvest the crop at the appropriate time and at the same time the field became available for the timely sowing of the next crop.
- Palatability increases as hard stems when fermented into silage become soft and better utilized by the dairy animals.
- Ensure regular supply of green fodder.
- High utilisation of greens and less wastage, control of parasites, etc.

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. One time harvesting of fodder crop for silage making is beneficial, since we can harvest the crop at appropriate time. 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).

1.4 Silage making: Case study of Punjab

Punjab is an agrarian state and is the highest producer of food grains contributing 11.78% of country's rice and 17.57% of country's wheat production. About 98.5% of states gross cropped area is irrigated and multiple cropping systems are followed by the farmers resulted in 190% cropping intensity of state. Now, agricultural production and productivity of the state is reached a plateau with growth rate of 1.38 % (2021-22).

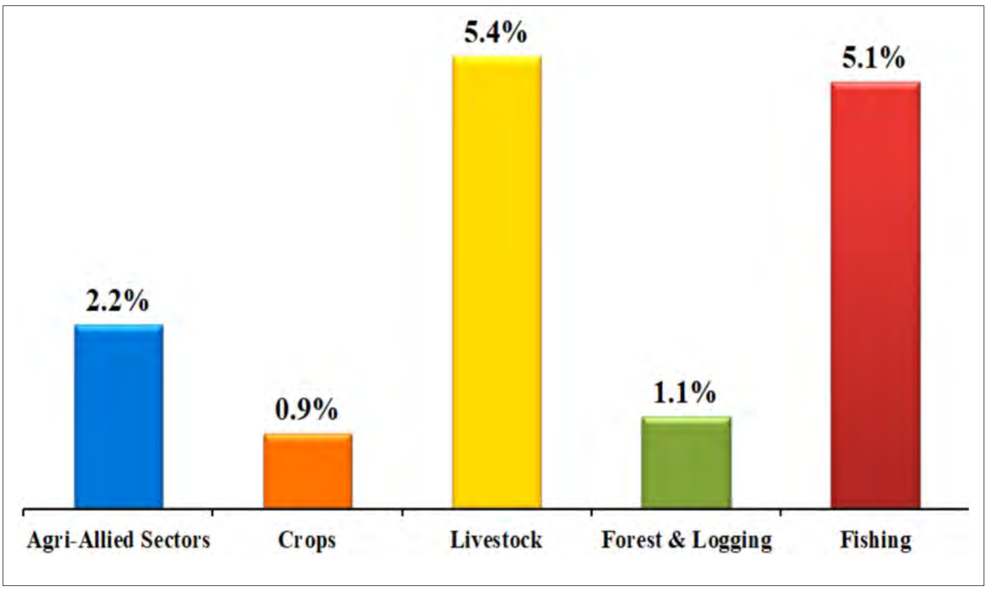


Figure 2. Growth rates and share of agriculture and allied sectors in Punjab (2012-13 to 2018-19)

The growth of livestock sector in state is at positive rate and there is a scope of growth in this sector to supplement the income of farmers. It may also help in crop diversification by shifting from traditional rice-wheat to fodder crops. Livestock sector provides an alternative source of income and also results in efficient utilization of resources. Dairy farming is major livestock sector in the state and milk production potential of the dairy animals depends upon the efficient feeding, breeding and disease management. At present, state have 32.2% crossbred cattle with average production potential of 25-30 litres per day.

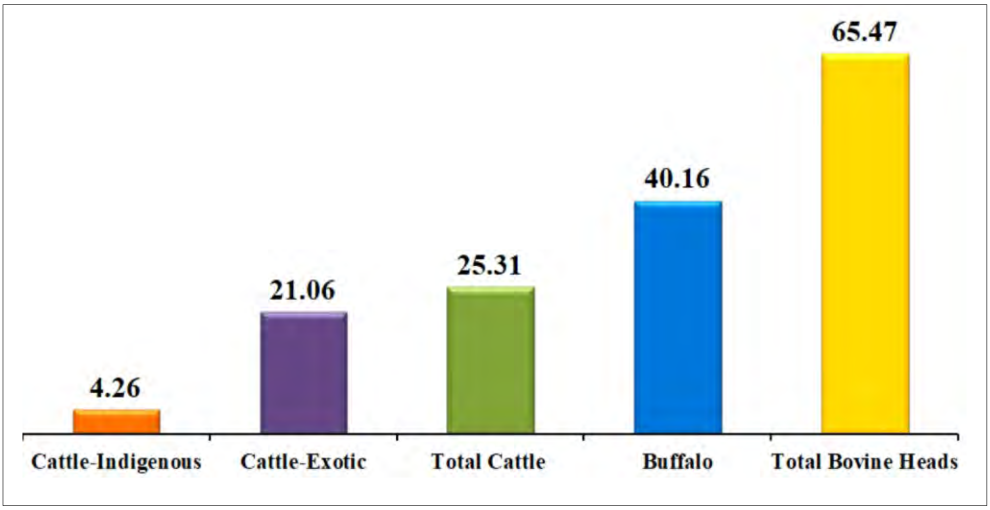


Figure 3. Trends in census of Cattles and Bovines in Punjab (Number in Lakhs)

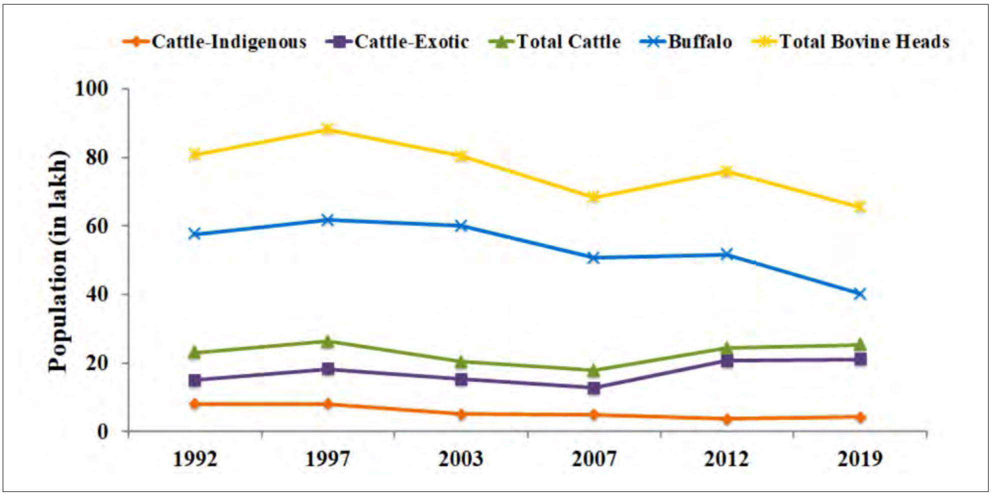


Figure 4. Trends in census of total bovines in Punjab (Nos.)

At present, milk production in state reached 13.34 MT (2019-20) in which the 70.67 % is contributed by buffalo and 26.34% by crossbred cattle (Anonymous 2022a). Due to efforts of Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana; Punjab Dairy Development Board (PDDB), Punjab; Department of Animal Husbandry, Punjab and Progressive Dairy Farming Association (PDFA) on promotion of crossbreeding with high level germplasm, selection of high-quality buffaloes and best feeding practices including quality silage feeding, there is significant increase in productivity of dairy animals in state.

The average milk production from buffaloes reached 8.65 kg day^{-1}, crossbred 13.86 kg day^{-1} and indigenous cattle 7.59 kg day^{-1} against the national average of 6.41 kg day^{-1}, 7.22 kg day^{-1} and 3.3 kg day^{-1}, respectively (Anonymous 2022a; www.statista.com)

At present, the major challenge in the further growth of livestock sector is deficit of high-quality green fodder round the year due to decrease in area under fodder crops. Rice-wheat is the major cropping system followed by the farmers and fodder crops are cultivated mainly on marginal lands with poor quality and productivity. The non-availability of quality green fodder round the year is major constraint in harvesting the full production potential of dairy animals. So dairy farmers are using concentrates along with fodder to sustain the production of dairy animals which resulted in increase in cost of production. The suboptimal feeding management resulted in under-utilization of production potential of animals.

1.4.1 Agroclimatic zones and suitable fodder crops in Punjab

In order to meet the fodder requirement of state there is need to increase the productivity, as there is very little scope to increase area under fodder cultivation. This will only possible by adopting different cropping systems including fodder crops according to agro-climatic conditions of Punjab. Punjab is divided in to 6 agro-climatic zones described in Table 1.3.

Table 1.3: Detail of agro-climatic zones of Punjab and fodder crop suitable for cultivation

S. No.	Agro-climatic zone	District covered	Area (%)	Rainfall (mm)	Suitable fodder crop
1.	Sub-mountain undulating zone	Gurdaspur and Hoshiarpur	9.5	>900	Maize, Cowpea, Berseem, oats, Shaftal, Senji, Ryegrass
2.	Undulating plain zone	Rupnagar, SBS Nagar and SAS Nagar	9	800-900	Maize, Bajra napier hybrid, Cowpea, Berseem, Oats, Shaftal, Senji, Ryegrass
3.	Central plain zone	Amritsar, Tarn Taran, Kapurthala, Jalandhar, Ludhiana, Fatehgarh Sahib, Sangrur and Patiala	36	500-800	Maize, Sorghum, Bajra napier hybrid, Guinea Grass, Cowpea, Berseem, Oats, Ryegrass
4.	Western plain zone	Firozpur, Faridkot and Fazilka	19	630-700	Pearl millet, Bajra napier hybrid, Guinea Grass, Guara, Lucern, Oats
5.	Western zone	Moga, Bathinda, Mansa, Muktsar, Sangrur & Barnala	20	500	Pearl millet, Sorghum, Bajra napier hybrid, Guinea Grass, Guara, Lucern, Oats
6.	Flood plain zone	Ghaggar, Sutlej, Beas and Ravi flood plains	7	500-800	Bajra napier hybrid, Sorghum, Berseem, Oats

Source: ICAR-IGFRI (2022)

1.4.2 Present trend of silage making in Punjab

In Punjab state, the trend in dairy farming is shifting from allied agricultural activity towards the commercial dairy farms due to involvement of youth in this sector. At present, there are approximately 8500 dairy farms in the state with milk production of 365 lakh litre per day and average milk procurement of 16 lakh litre per day. The major part of milk is handled by unorganised private sector after home consumption. The increasing demand of milk will only be fulfilled by meeting demand of quality feed and fodder in near future.

At present there is 25% deficit of green fodder in state. The small dairy farmers in the state are fulfilling the demand dairy animals by cultivation of seasonal fodder crops, weeds, agricultural by products, and dry roughage like wheat, paddy straw etc. Occasionally they prepare silage of surplus fodder on small scale or purchase it from market during the lean period. There is seasonal variability of quantity and quality of fodder on these farms which results in decrease milk production and also effect the reproduction potential of animals. Repeat breeding is common problem on these farms.

The medium to big commercial dairy farmers in the state are managing the requirement of fodder by silage making. Most of these farmers are cultivating spring maize for silage making on their owned land and also take land on lease according to their fodder requirement for silage making. They are following the rice-oats/toria/gobhi sarson/vegetable pea/potato-spring maize cropping systems. In these rice-based cropping systems, a time period of 90-120 days is left between the harvesting of *rabi* crop (oats/toria/gobhi sarson/vegetable pea/potato) and sowing of next *kharif* crop (rice). During this window, dairy farmers prefer to cultivate spring maize for silage making.

This season is considered best for the silage production as atmosphere is hot and dry at the time of harvesting of spring maize. Hence, there is no need to dry the crop after harvesting to obtain optimum moisture content. Secondly, farm labour is easily available during this pre-paddy transplanting period. Thirdly the silage is also of good nutritive quality when the corn is harvested with cobs at milk stage. The silage prepared after month of June is not of good quality due to coincide of this period with monsoon showers in state, which makes the operation of harvesting difficult and also results in humidity in atmosphere which affect the quality of silage negatively.

Most of commercial dairy farmers have purchased owned single row maize harvesters required for mechanical harvesting of corn for silage making. There are number of service providers in the state who are performing these operations on custom hiring basis having self-propelled fodder harvesters having capacity to harvest 20-25 acres in a day. Availability of these harvesters makes the process of silage making easy, as dairy farmers are able to fill their silo in a single day.

On an average, the silage prepared from spring maize cultivated on one hectare area is sufficient in fulfilling the requirement of 5-6 dairy animals round the year. So they adjust the sowing area of spring maize according to number of animals on their dairy farm.

Table 1.4: Trend of silage making at different categories of dairy farms in Punjab

Dairy farm size	No. of animals	Adoption of silage making
Small	1-4	Do not prepare silage, depends upon green fodder. Baled silage is only option
Medium	5-10	Prepare silage for feeding at time of scarcity of green fodders or lean period. Having *kaccha* silo pits. Perform operations manually or by using machinery from service providers
Commercial	11-40	Prepare own silage. Having *kaccha* silo pits or permanent *pakka* silo pits/bunkers. Hire machinery from service providers
Big	>50	Prepare own silage for round the year. Having permanent silo pits/bunkers and machinery for silage making. Also hire machinery from service providers

Apart from commercial dairy farmers, the process of silage making is also becoming popular among the small and medium farmers in Punjab. As the entire process of spring maize silage making, starting from sowing of crop to harvesting and sealing in silo, is completed in 95-105 days. So it saves the labour cost, ensure uniform supply of quality fodder round the year even during adverse weather conditions, spare land for the cultivation of other crops and increase the profitability of dairy farm. A production of 35 lakh ton of maize silage in Punjab (rough estimate) from maize cultivation on 1.75 lakh acre was mentioned in a report published by Grant Thomton Bharat LLP (Anonymous 2022b).

Chapter 2

AGRONOMIC ASPECTS OF SILAGE MAKING

2.1 Potential of different fodder crops for silage making

Consider the following points when selecting the most suitable crops for silage production:

- What best fits into my cropping system. Is buying a neighbour's standing crop an option?
- What are my yield and quality targets?
- Is my present silage system suited to the forage type chosen? Am I prepared to change my silage system?

There are desirable characteristics of fodder crops for quality silage such as:

- High level of fermentable sugars
- Low buffering capacity
- Ideal dry matter content

Crops like maize, sorghum, bajra, hybrid napier bajra, oats etc. are most suitable for silage making. Legumes were less suited to silage-making than grass, because of their higher buffering capacity and lower water-soluble carbohydrate content. *Rabi* crops such as oats, wheat, barley, triticale and cereal rye can all be made into silage. Wheat and barley possess dual-purpose characters for fodder and food availability. These crops also add flexibility to farming systems, as decisions to cut crops for hay or silage can be made mid-season in response to livestock prices or weather conditions (Table 2.1).

Table 2.1: Optimum stage of harvesting of crops for silage making

S. No	Crop	Stage of harvest	Days after sowing
1.	*Kharif* Maize	Milk stage	70-80
2.	Spring Maize		90-100
3.	Summer Maize		80-90
4.	Sorghum	Boot to milk stage	80-90
5.	Bajra	Flowering	50-60
6.	Oats	Milk stage	90-105

Cultivation of maize/corn for silage making is preferred because of its relatively constant nutritive value, high yield and higher water-soluble carbohydrates for fermentation to lactic acid. Maize is the third most important cereal crop of the world and is a major forage source for ruminants around the world. In Northern India, spring maize is mainly cultivated for silage making instead of its high-water requirement and chemical fertilizer demand. Recently, more emphasis has been given to research to develop and promote technologies which help to decrease the stress on underground water resources. There are several challenges to increase area under spring maize cultivation in north-west India. The main concerns about the cultivation of spring maize in the state are given below:

1. High evapotranspiration demand of atmosphere during the growing season of spring maize (February-June). This crop requires 12-14 irrigations during its growth period, which exerts huge stress on underground water resources.

2. The pesticide load on the spring maize is very high. It requires 2 sprays for control of weeds and two sprays for control of stem borer/fall army worm. This increased the chances of pesticide residue in fodder.

3. Increase in the lease rent of land also increased the cost of silage production.

4. Dairy farmers are required to buy spring maize fodder for silage making from market at higher price which result in increased cost of production.

State government is working on these issues and providing the subsidy for the installation of drip irrigation system in the fields to save irrigation water. Punjab Agricultural University, Ludhiana is also issuing regular advisories to the farmers for better control of pests in this crop by adopting proper time, method and dose of pesticide application and also to ensure the safety of environment. Due to these problems, some commercial dairy farmers also started the cultivation of oats and wheat for silage making which enable them to fulfil their requirements and also decrease the dependency of dairy farmers on spring maize.

Cropping system research is an important area of research, and it has opened a whole range of new and hitherto unavailable avenues for augmenting production of forage crops through both horizontal as well as vertical means. The cropping system with forage crops provides potential alternative to overcome the fodder problem as it utilizes the resources more efficiently. Dairy farmers are taking three crops in a year by incorporating spring maize in rice-based and maize-based cropping systems. Enhancing the fodder productivity per unit land area and their preservation as silage are only viable options to meet the growing fodder needs of livestock sector. The integration of fodder crops in the existing cropping systems by using short duration cultivars of grain and fodder crops can help the farmers to fulfil the fodder requirement of livestock as well as production of commercial crops. Growing of winter cereals in existing rice- and maize-based cropping systems and their preservation as silage, will not only provide herbage to the livestock but will also ensure fodder availability during lean and aberrant weather situations. In addition to corn, wheat has huge potential to be used as silage for ruminants. Moreover, wheat has been used as fodder for decades in USA, Australia, Argentina and many Mediterranean countries. Wheat and barley are widely used for silage making in Israel, Turkey, United States and Korea. Wheat and barley fodder contains water-soluble carbohydrates which are fermented to lactic acid during anaerobic storage, and have potential for silage production. The use of winter cereals, mainly wheat and barley for silage making may help to decrease the dependency of dairy farmers on spring maize, which is water guzzle crop. This will provide an alternative option to dairy farmers for silage making. To bridge demand and supply gap of forage resources, silage from *rabi* cereals can be one of the alternatives to feed ruminants.

Moreover, *Phalaris minor* has emerged as a big challenge in wheat production for farmers as well as researchers especially in Punjab and Haryana. This weed has evolved resistance to some commonly used herbicides. Silage production from *P. minor* infested wheat crop (before shattering of weed seeds) from such fields will help in reducing the weed seed bank of *Phalaris minor* in the field. This may emerge as important cultural method for control of *Phalaris minor* in region. Among the winter forages, barley also occupies the largest share of the domestic forage production and feeding barley silage may help to increase animal productivity and thus, farm profitability. Therefore, it is very essential to explore the potential of wheat and barley for silage making in the region.

2.2 Scientific cultivation of fodder crops for silage making

Good agronomic management of the parent crop is important in achieving high forage yields of high nutritive value. Apply 15 tonnes ha^{-1} of farmyard manure along with inorganic fertilizers. Organic fertilizers are very important for high yield and better quality of fodder crops. Poor quality forage will never become good quality silage. The brief cultivation practices to be followed in cultivation of different fodder crops grown for silage making are discussed below.

2.2.1 Maize

Maize is the best suitable and most common silage crop due to its high and easily digestible carbohydrate content and optimum buffering capacity in addition to high herbage yield. However, growing of corn is a difficult process in regions without irrigation facilities.

1. Time of sowing: First week of March to Mid-September
2. Seed rate: 75 kg ha^{-1}
3. Sowing method: 30 cm row spacing
4. Fertilizer: 375 kg SSP and 255 kg Urea ha^{-1}

Apply whole quantity of SSP and half dose of urea at the time of sowing and remaining half one month later.

5. Weed management: Application of atrazine 2000 g ha^{-1} within 10 days after sowing.

In northern India, spring maize is mainly grown for silage making in between window period of 80-120 days which is left between harvesting of *rabi* crop and sowing of next *kharif* crop. The brief package of practice for spring maize is discussed below.

1. Cropping system: Rice/Maize- Potato/Vegetable Pea-Spring maize
2. Time of sowing: 20^{th} January to 15^{th} February
3. Seed rate: 25 kg ha^{-1}
4. Sowing method: On ridges 60 cm apart with plant to plant spacing of 20 cm
5. Fertilizer: 125 kg DAP and 225 kg Urea ha^{-1}

Apply whole quantity of DAP and $1/3^{rd}$ urea at the time of sowing and remaining in two equal splits at knee height stage and pre tussling stage.

6. Weed management: Application of atrazine 2000 g ha^{-1} within 10 days after sowing.

2.2.2 Sorghum

1. Time of sowing: From mid-March to mid-July
2. Seed rate: 50 kg ha^{-1}
3. Sowing method: In rows 22 cm apart
4. Fertilizer: 125 kg SSP and 220 kg Urea ha^{-1}

Apply whole quantity of SSP and half dose of urea at the time of sowing and remaining half urea one month later.

2.2.3 Bajra

1. Time of sowing: March to August
2. Seed rate: 20 kg ha^{-1}
3. Sowing method: In rows 22 cm apart
4. Fertilizer: 110 kg Urea ha^{-1}

Apply half dose of urea at the time of sowing and remaining half three weeks later.

2.2.4 Oats

Silage of oats may also be supplied to dairy cows to meet the dry matter needs of the animals. Such silage crops may be an alternative silage source in cold and dry regions and may provide support to meet silage needs by plating ahead of corn

1. Time of sowing: 2nd week to last week of October
2. Seed rate: 62.5 kg ha^{-1}
3. Sowing method: In lines 20 cm apart
4. Fertilizer: 125 kg SSP and 165 kg Urea ha^{-1}

Apply whole quantity of SSP and half urea at the time of sowing and remaining half at 30-40 days after sowing.

2.2.5 Wheat

1. Time of sowing: 2nd week to last week of October
2. Seed rate: 100 kg ha^{-1}
3. Sowing method: In lines 15-20 cm apart
4. Fertilizer: 387.5 kg SSP and 275 kg Urea ha^{-1}

Apply whole quantity of SSP and half urea at the time of sowing and remaining half at 30-40 days after sowing.

2.2.6 Barley

1. Time of sowing: 2nd week to last week of October
2. Seed rate: 87.5 kg ha^{-1}
3. Sowing method: In lines 20 cm apart
4. Fertilizer: 187.5 kg SSP and 137.5 kg Urea ha^{-1}

Apply whole quantity of SSP and half urea at the time of sowing and remaining half at 30-40 days after sowing.

2.2.7 Weed Control

Weeds compete with forage crops for water, minerals, light and space results in yield and quality loss. Interculture is generally not necessary in fodder crops, but the growth of weeds must be checked in the early stages of the crop by weeding, if necessary. In most of the seasonal forage crops, maximum crop weed competition occurs up to 4-5 weeks and the loss caused by the weeds varies with the season, crop and variety. Admixture of weeds with green fodder during harvest like *Coccinia grandis* with fodder maize and sorghum, *Celosia argentea* with fodder sorghum, *Trianthema* with fodder maize and sorghum, reduces palatability of green fodder and thus affects milk production of milch animals. Apart from yield loss, some poisonous weeds harvested along with fodder or grass and fed to cattle or while grazing the cattle cause ailment on livestock resulting in death and cause great loss. Weeds like *Chenopodium album* L., *Amaranthus viridis* L. and *Solanum nigrum* L., when fed to livestock, these may cause severe problems like difficulty in breathing, reduced weight gains, pre-mature abortion of foetus and even cause death.

2.2.8 Pesticide residues

In order to sustain the productivity of fodder production system, biotic stresses such as insect-pests, plant pathogens and weeds should be kept below a threshold level. There are certain constraints to use of pesticides in forage crops such as risk of pesticide residue accumulation in the food chain through milk and milk products and also chances of direct toxicity to livestock. To ensuring food safety and human health, the increase in presence of pesticide residues in the meat and milk is of great concern. The lack of pesticide recommendations specific to forage-crop protection by pesticide manufacturers and policy makers in India might be responsible for it. Chemical weed control has become imminent due to non-availability of working force, high labour cost and unfavourable climatic conditions at time of mechanical weeding operations. There is an increasing concern about residue of different pesticides in food chain. Fodder crops are harvested between 60-120 DAS, and there are chances of herbicide residue in green fodder of these crops. Herbicide residue in the green fodder may adversely affect health of dairy animals. Forage crops are harvested at milk stage as fodder, and it increases the probability of toxic residues of pre-emergence herbicides such as atrazine and pendimethalin in green fodder of these crops and also some unintended negative impacts such as its persistence in soil and pollution of ground water.

2.3 Biofortification of fodder crops to enhance fodder quality

Worldwide, nutritional or hidden hunger is a fast-emerging critical issue requiring urgent efforts to tackle it. Over the years, agriculture everywhere has witnessed incredible changes leading to more efficient cultivation of our lands. In India, there have been tremendous changes from traditional to modern agriculture of nowadays. Advances in machinery, seed, irrigation and

Table 2.2: Some of the disorders in animals due to malnutrition

Mineral and Vitamins deficient	Disease	Symptoms	Function of the nutrients
Zinc	Parakeratosis	Hard skin lesions mostly on scrotum, head, neck and legs, popularly known as parakeratosis. It was first reported in swine in 1955	Activation of over 300 enzymes, protein synthesis, nucleic acid metabolism, carbohydrate and energy metabolism, lipid synthesis, epithelial tissue integrity, cell repair and division, transportation and utilisation of Vitamin A and E, immune system function, reproductive system and hormone function and other functions in the animal body
Iron	Anaemia	Anaemia, reduced reproductive health, reduced appetite	Important constituent in the synthesis of haemoglobin and myoglobin, other essential enzymes responsible for synthesis of ATP in electron transport chain and acts as the carrier of oxygen to the tissues
Copper	Swayback or enzootic ataxia	The symptoms are not visible. The affected animal suffers from motor dysfunctional like staggering, recumbency and occasional blindness, death of embryos, necrosis.	Acts as a cofactor in enzymatic activity, important for the production of erythrocytes, transportation and absorption of iron.
Selenium	Nutritional muscular dystrophy or white muscle disease	Heart and skeletal muscles are affected	Protective functions as an anti-oxidant by eliminating the free radicals formed as a result of peroxidation.
Vitamin C	Scurvy	Development of lessions around the connective tissues	Synthesized in the liver, it performs protective function against the oxidative stress, wound healing, maintaining the health of skin, blood vessels, bones and cartilage, growth of tissue.
Vitamin B1	Beriberi	Fatigue, weight loss and loss of appetite.	Vit B1 also known as thiamine helps in converting carbohydrates into energy. It is also important for muscle contraction and conducting nerve signals.
Ca, P	Osteomalacia	Bones get soft and brittle and are fractured easily, the egg shells become soft.	Ca and P are present in the bones and teeth.
Vitamin A	Night blindness	Inability to see during night	It is necessary for maintenance of vision, synthesis of glucose for the energy metabolism, maintenance of hoof tissue and skin.
Folic acid, choline	Slipped tendon	Chickens fall down on their knees	Folic acid is required for synthesis of DNA and nucleotides, choline is a constituent of cell wall, responsible for transmission of nerve signals and essential for optimum growth and performance of animals.

Source: FAO (2012)

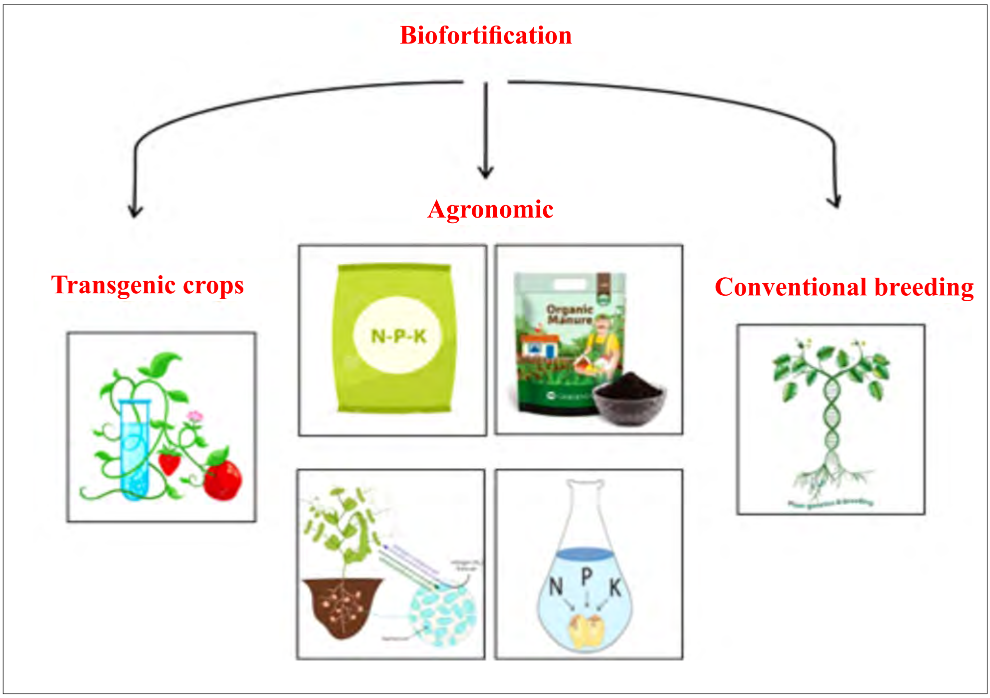
fertilizers have expanded the productivity of farms. Particularly, the usage of fertilizers in crops has increased and is still following an upward graph. However, there has been a gross imbalance in the use of fertilizers since more emphasis has been given to the use of three major nutrients such as nitrogen, phosphorus and potassium. And, the over-application of fertilizers over the years has led to major negative environmental externalities like reduction in soil fertility, stagnation of crop yields and the most striking is the deficiencies of micro-nutrients in our soils.

Since soil, plants, livestock and human are closely related trophic levels in the food chain, the deficiency of a particular nutrient in one level can subsequently cause deficiency in the other levels. Hence, because of the micro-nutrient deficient soils, hidden hunger or malnutrition is wide spread now not just in human but also in livestock. Poor and unbalanced nutrition of domestic animals has an impact on their health as well as the quality of the product that is produced from them.

This is also a major reason for the lower productivity of livestock in our country. Now, there are many ways to overcome this issue. One of the effective techniques is biofortification. Agronomic methods, breeding programs, transgenic organisms, and sophisticated genome editing techniques constitute the major biofortification approaches.

2.3.1 Biofortification as a solution to ameliorate malnutrition

Biofortification is the process of increasing the density of nutrients in food or feed either through plant breeding, biotechnological tools or agronomic practices. While, fortification means adding a nutrient during the processing, biofortification means addition and increasing a particular nutrient content during the production cycle. For example, addition of urea, molasses, salt etc. in the silage to increase its nutrient content and palatability is a form of fortification. On the other hand, oats can be said to be biofortified on application of foliar spray of recommended zinc sulphate at 15 DAS.



2.3.2 Different methods of biofortification

1. **Agronomic biofortification:** When biofortification is achieved by application of synthetic fertilizers, organic amendments, biofertilizers or seed priming, it is known as agronomic biofortification.

2. **Conventional breeding:** When an elite plant variety with morphological traits such that it could absorb and store sufficient amount of both macro and micronutrient and able to synthesis minerals and vitamins is crossed with a local variety poor in its nutrient percentage is called as conventional breeding type of biofortification. Here, light is thrown mostly on identification of suitable gene and its expression.

3. **Genetic engineering:** It is the type of biofortification where a germplasm is modified by incorporating a gene of interest.

2.3.4 Advantages of biofortification

- Biofortification is less time-consuming approach for increasing nutritional requirements and highly sustainable.
- Biofortification so far has helped to reduce 34% of anaemia and 74% goiter population wise.
- It is comparatively cost-effective bearing high benefit cost ration.
- Throughout the world, biofortification of food crops has covered all the masses of the population-both poor and the rich.
- It can treat combination of micronutrient deficiencies existing in a population with proper diet.
- It does not demand changes in the food pattern.
- Along with enhancing the nutritional content of the crop, bioforitification can increase resistance to biotic (pest, disease and weeds) and abiotic stress (drought, water logging, salinity, acidity, etc.).

2.3.5 Disadvantages of biofortification

- The access to acquire the biofortified crops by the poor is less.
- Loss of traditional crop genes and varieties.
- Take sufficient time for implementation
- Lack of awareness and spread of rumours.
- Need for efficient trails for confirming the results of biofortification

Chapter 3

POST-HARVEST MANAGEMENT PRACTICES FOR CORN SILAGE MAKING

Maize is an excellent crop for ensiling. For optimum fermentation, the crop might possess sufficient quantities of moisture as well as soluble carbohydrates which are converted to lactic acid during the process of fermentation. Maize cultivated for green fodder and baby corn purpose possesses the required moisture and soluble sugars, digestibility and, therefore, is most suitable for ensiling (Chaudhary *et al* 2014). Cows fed with corn silage produced more milk and consumed more silage dry matter in both trials than those fed sorghum silage (Lance *et al* 1964). Corn silage is used extensively for lactating dairy cows that require high-energy feed for maximum milk production (Marsalis *et al* 2010). Maize silage is an excellent high energy supplement for grazing dairy cows. A typical response of 0.9 and 0.6 kg higher milk yield kg^{-1} silage DM have been observed in early and late lactation, respectively (Kaiser *et al* 2004).

3.1 Methodology of silage making

In addition to the crop and its variety used for silage making the stage of harvesting, method of storage and period of ensiling also affect the quality of silage. Stage of harvesting of crop at the time of silage making is a key factor which determines the quality of silage. It is very essential to harvest the crop at an optimum stage to ensure good yield, quality and ensiling characters of fodder. 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 form 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) or when the milk line is halfway down the grain.

Table 3.1: Optimum stage of harvesting of crops for silage making

Grain description	Milky	Milky doughy	Doughy milky	Doughy	Hard dough, top is hard and glassy	Hard and glassy
						
Milk line	None	Beginning to show from top	¼ way down grain	⅓ way down grain	½ way down grain	At bottom
Husk	Green	Green	Green	Yellowing	Yellowing	Desiccated
Whole plant DM (%)	Less than 25	25-28	28-30	30-32	32-35	Over 35
Status	Not ready	Not ready	Not ready	Ready	Ready	Too late

Source: Kumar *et al* (2019)

Detection proper stage of harvesting

Manual harvesting of crop

Mechanical harvesting of crop

Kaccha Trench silo pit

Kaccha Bunker Silo

Pakka Trench Silo Pit

Pakka Bunker Silo

Filling of silo pit

Pressing of chaffed fodder

Fodder pressed in silo pit

Fodder stored in silo pit

In the tropics, the right stage of harvesting is usually found in 70–90 days after sowing. Further, time of sowing and cultivar grown may also affects the harvesting time. The dry matter content of whole plant should be around 25–30%. Harvesting at this recommended time will ensure optimum compaction properties, reduced tendency to heating up, and mould formation.

After harvesting of fodder crop, its scientific storage in silo pit/bunker is the most important step in the process of silage making. Any negligence during this process may leads to production of inferior quality of silage due to production of aflatoxins and reduced quality in it. The major things keep in consideration during post-harvest handling of green fodder are discussed below.

Types of silos: The structure used to make silage is called silo and it is a major factor to determine the nature and quality of final product. The size of silo is determined by the herd size, amount of daily silage fed, number of feeding days and packed density of the raw materials. The different kinds of silo designs are given below.

1. Stack/Clamp silo 2. Bag silo 3. Pit/Trench silo

4. Bunker silo 5. Tower silo

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

3.1.1 Dimensions of silo pits/bunkers

First of all, a rectangular pit is to be dug near the cattle shed whose size depends upon the number of animals along with the availability of fodder. If the fodder is sufficiently available, then the duration of feeding could be considered in deciding the size of the pit. Usually, one cubic feet of area can accommodate roughly 18-20 kg of green fodder.

Selection of site for the construction of silo pit is very important for quality silage making. The site should be at higher elevation with respect to surrounding area in order to prevent the seepage of rain/irrigation water from the surrounding fields to the silo. It should be near the dairy farm in order to decrease the labour cost and also reduce the losses while taking silage from silo pit to animal mangers during feed out

The selection of dimensions of silo pit/bunker is very important to ensure the proper pressing of green fodder in silo pit to provide proper conditions for anaerobic fermentation. As the most of commercial dairy farmers are using tractor for pressing the green fodder in silo pit/bunker, so select the dimensions of silo pit/bunker in such a way that it will allow free movement of tractor in

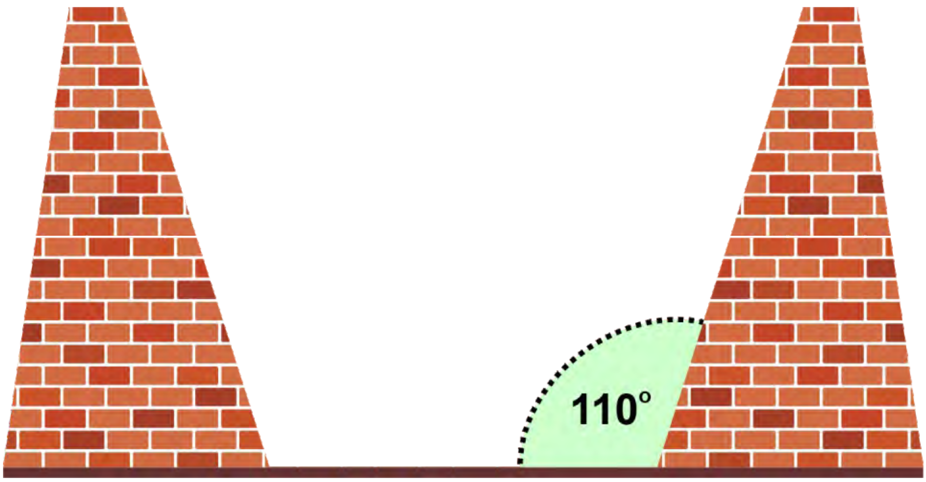


Figure 5. Inclined support wall (110°) enable an ideal compaction of the silo edges

order to ensure proper pressing of the fodder. The breadth of the silo pit/bunker should be more than double the width of tractor (minimum 12-15 feet), so that there will be no space left un-pressed during side wise movement of tractor in the silo. The length of pit is adjusted according of the amount of fodder to be stored and the depth of pit or height of bunker should be 5.5 feet. A silo pit/bunker of dimension 40 feet×15 feet×5.5feet can store approximately 600 quintals of green fodder produced from approximately 1.0 ha area.

While construction of silo pit/bunker, it is noted that the walls should be inclined at the angle of 110° instead of straight walls, to enables the ideal compaction of silo edges. The side walls of bunker silo should be double with gap between them filled with soil. This will provide the support to inner wall to tolerate the pressure and prevent the cracks in inner wall while pressing of fodder in the silo.

3.1.2 Packing density of fodder in silo pit

Packing of fodder in to the silo/bunker at proper density is very important to expel the air from the silo to provide proper atmosphere for anaerobic fermentation. If the fodder is packed loose, it prolongs the aerobic respiration in the silo pit resulting in the deterioration of quality of silage, may increase the concentration of butyric acid and undesirable organisms in the silage. To obtain the proper storage conditions and increase the shelf life of silage, green fodder should be packed at least the density of 20 kg feet^{-3} or 700 kg m^{-3}.

Before filling of pit/bunker, the side walls should be covered with the plastic sheets to prevent the entry of rainwater/moisture from the sides of silo in to the silage. The bottom of silo should be kept *kaccha* covered with wheat straw to facilitate the seepage the silage effluents produced during the pressing of fodder in to the soil and to prevent the capillary movement of moisture from soil in to the silo. In pukka floor there should be slope of 1inch for every 10 feet length to ensure the seepage. Fodder should be chaffed in to small pieces preferably 2-3 cm length to ensure proper packing density which favours the growth of lactic acid bacteria. Chaffed material should be spread evenly over entire surface of silo in 0.5 m thick layers and pressed evenly with the help of tractor. Tractor should be move to and fro as well as side by side in such a way that no space in the silo remained unpressed. This helps in rapid evacuation of air from silo, thus helps in preventing aerobic respiration and nutrient loss.

To obtain proper anaerobic conditions, the silo should be filled within 1-2 days as the prolonged filling deteriorates the quality of fodder due to aerobic respiration. The top of silo pit/bunker is pressed in such a way to make a dome having 1.5 to 2 feet above the ground area in case of pit or above side walls of bunker. Sealing of the silo pit is done in such a way that neither air enters in to the silo nor the gasses come out from the silo. After covering the top of the silo with the polythene sheet, its sides will be sealed with the mud. The surface of the polythene sheet should be covered with the straw up to the thickness of 20 cm to prevent it from damaged animals or rodents.

3.1.3 Process of silage making

The process of making silage is called ensiling which involves

1. Harvesting of green fodder at optimum stage

2. In case of high moisture content fodder should be wilted to 65-70 % moisture.

3. Chop the fodder into shorter lengths i.e. 1-3 cm to facilitate required compaction.

   However, at least 20% of the particles should exceed 2.5 cm in length to insure enough effective fiber in the silage. Further, chop length depends upon the dry matter content of the crop (Table 3.2).

4. The walls of the silo pit should be plastered or lined with polythene sheet. The chopping should be done near the silo so that the chopping of fodder and filling of silo pit is done simultaneously.

5. Filling should be done in layers of one foot as soon as possible.

6. Pressing of the fodder in the pit should be done regularly to exclude the air.

7. Compact the forage as tightly as possible to reduce increase in temperature due to respiration. The standard packing density for silage is 700 kg in 1 m^3 space.

8. The silo should be filled 1 meter above the ground level and arranged it in the semicircle with dome shaped at top.

9. 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

Table 3.2: Ideal chopping length for silage making

Dry matter	Ideal chop length
28-35%	½ -¾ inches
20-28%	¾ - 1 inches
<20%	>1 inches

but weighing down plastic adequately (> 20 tires/100 square feet (Bolsen and Bolsen, 2004).

10. 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.

11. Open the silo pit from one side for animal feeding.

A sufficiently high feed out rate should maintain to avoid heating at the silage face and minimum disturbance of the feeding face, to minimize air penetration.

3.1.4 Stages of fermentation

In order to make good quality silage, it is very essential to rapid removal of air during pressing of fodder to prevent the growth of unwanted bacteria and rapid production of lactic acid leads to drop in pH. The process of silage making is divided in to four phases.

1. Aerobic phase

Under this phase, atmospheric oxygen present between the plant particles is reduced due to the respiration of the plant material. During the pressing of fodder in silo pit/bunker, even with the best harvest management in place, some oxygen will remain in the silage. In the process of cell respiration, this remaining oxygen will be used up, as the cells in the forage take in the oxygen and turn it into carbon dioxide. Aerobic bacteria also use the remaining oxygen in this phase, combined with plant sugars, to create carbon dioxide, water and heat.

This phase lasts for 1-2 days depending upon the situation. This aerobic phase is longer for poorly packed silage and shorter for well-packed silage. The longer aerobic phase results in very high silage temperature (42 to 44°C), more dry matter losses, mold growth, production of aflatoxins and browning of forage.

2. Anaerobic fermentation:

This phase starts when the silage becomes anaerobic and it continues for several days to several weeks, depending on the properties of the ensiled forage crop and the ensiling conditions. If fermentation proceeds successfully, lactic acid bacteria develop and become the predominant population during this phase. Due to the production of lactic and other acids, the pH decreases to 3.8-5.0. In this phase, after the remaining oxygen is used up, plant cells are broken down and used as a food source by bacteria. Plant enzymes break down complex carbohydrates, starch and fiber into simpler sugars that are easily used by bacteria. Enzymes also break down plant proteins at this time, making protein more soluble.

The lactic acid bacteria are most important bacteria and involved in preservation of forages as silage by production of lactic acid. When cell juices are available, oxygen has been eliminated and silage pH has declined to a level at which lactic acid bacteria can grow (below 5.7 pH). With decline in pH, the lactic acid bacteria begin to grow, multiply, make lactic acid and also some amount of acetic acid, resulted in increase in acidity of silage. Two types of lactic acid bacteria namely, homofermentative and heterofermentative were reported in silage. The homofermentative bacteria produce primarily lactic acid, are more desirable as they work faster, saving more nutrients for the animals to use and for silage to be better preserved. Of the total acid in well-preserved silage, at least 70% should be lactic acid. The heterofermentative bacteria produce lactic acid, acetic acid, ethanol and carbon dioxide. The initial amount of lactic acid bacteria in the silage will be higher with warmer temperatures and higher silage moisture. The anaerobic fermentation phase usually takes about two weeks, and the silage cools to near ambient temperature.

3. Stable phase

The microorganisms of phase 2 slowly decrease in numbers during the stable phase. Only some acid tolerant proteases and carbohydrates and some specialized microorganisms, such as Lactobacillus buchneri continue to be active at a low level. With active growth of lactic acid bacteria during ensiling, the ensiled material enters the stable phase. Very little biological activity occurs in this phase, as the pH has been reduced to a low level. Chemical breakdown of hemicellulose at very slow rate resulted in release of sugars during this phase.

Permeability of air to silo to air is the major factor affecting the quality of silage during this phase. Oxygen entering the silo is used by aerobic microorganisms causing increases in yeast and mould populations, losses of silage dry matter and heating of the ensiled mass. Proper sealing of silo is very essential to prevent these losses. Holes in polyethylene sheet used to cover the fodder in silo and cracks developed in silo walls should be checked to stop the entry of air in the silo.

5. Feedout phase

This phase starts with the exposure of silage to air. Aerobic spoilage during feedout is unavoidable, but under poor management conditions, it starts earlier due to damage of the silage covering by rodents, birds, animals, adverse weather conditions. The process of spoilage during this phase is divided into two stages. The initiation of deterioration is due to the degradation of preserving organic acids by yeasts and occasionally acetic acid bacteria. This will cause a rise in pH leads to initiation of second spoilage stage. This stage is associated with increasing temperature and activity of spoilage microorganisms such as bacilli. This spoilage occurs in almost all silages after the opening of silo and exposed to air. The rate of spoilage is highly dependent on the numbers and activity of the spoilage organisms in the silage.

The feeding rate and packing density determine the exposure of silage to oxygen. Silage should be fed as soon as possible and after feeding, feed bunks must be cleaned to prevent contamination of the next feed out. After the opening of silo bunker, at least 15 to 20 cm layer of silage from the face of the bunker is removed every day to prevent the aerobic deterioration.

Chapter 4

SILAGE QUALITY DETERMINANTS

4.1 Importance of silage quality

Quality fodder production is also considered to be important criteria for sustainable and economical livestock production. An inadequate supply of quality fodder has been identified as one of the reasons for poor livestock productivity in India (Anjum *et al* 2012; Kumar *et al* 2016). Silage production has been seen to suffice all those factors which can help in the sustenance of provision for round the year fodder for dairy sector. Quality of silage is also an important issue that needs prime attention. Farmer's knowledge regarding the stage of harvesting of crop for silage making is very important as it determines the moisture content of the crop. Silage is preserved through a fermentation process that produces acids to inhibit spoilage (Chahine *et al* 2009). Once silage is ready, it is important to estimate its quality, as improper storage could result in the development of detrimental bacteria resulting in reduced quality. 'Quality'- encompassing all the attributes that influence silage's nutritive value which determines the potential animal production per tonne of silage and is an important indicator for the profitability of silage produced. The goal of silage making is to preserve as much of the nutritional value of the parent crop as possible.

4.2 Quality determinants of silage

4.2.1 Dry matter and moisture

Dry matter content of silage strongly influences the type of fermentation that takes place in silo. Calculation of dry matter content of silage is important as it indicates the adequacy of wilting. Ideal dry matter content of forage should be 30-35% at the time of ensiling. Forages ensiled below 30% DM will produce effluents that 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 30-40% 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 silage to prepare at farmers field under different management practices between 16.5 to 31.8 %.

4.2.2 Water soluble sugar

The water-soluble sugar content of parent fodder is also one of the major determinants of silage quality as it converts into lactic acid (most desirable acid) during ensiling process and facilitate preservation of silage. The water-soluble sugar content of forage should be 2-3% on fresh basis or 8-10% on DM basis. Further, water soluble sugar content of forage depends upon type of crop, stage of maturity, time of harvesting during day and environmental conditions. The water-soluble sugar of maize, grasses and lucerne are 80-300 g, 35-300 g and 20-150 g kg^{-1} DM, respectively.

4.2.3 Fibres

Fibre content is an important indicator of feed quality and digestibility for various classes of feeds, including silage (Kumar *et al* 2016). Increased fibre content of forage is associated with decreased digestibility and intake, and subsequently lower animal production (Kumar *et al* 2016; Chaudhary *et al* 2016). Out of total fibre content, Neutral Detergent Fibre (NDF) provides an estimate of total cell wall content of forage and reflects the amount of forage the animal can consume (Kumar *et al* 2016). The optimum range of NDF in corn silage is 35-55% (Chahine *et al* 2009) ADF fraction consists of highly indigestible plant material in forage comprised of cellulose, lignin, cutin, silica, pectin and unavailable protein. The ADF fraction also contains some unavailable (bond) nitrogen. ADF content of silage inversely relates with the digestibility of silage in animal body. The higher is the ADF content, lower will be the digestibility of silage. The optimum range of ADF in corn silage is 20-33%.

ADL is non-digestible portion of cell wall, having optimum range of 2.8-4.1% in corn silage. In nutshell, an increase in fibre content of silage is associated with the decrease in intake, digestibility and subsequently animal production.

4.2.4 Crude Protein

Protein content of the silage is a key nutrient and its estimation is essential to optimise nutrient management and production in animals. A large proportion of the crude protein (often 90%) is known as rumen 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). Crude protein content of forage is a vital criterion for quality evaluation (Kumar *et al* 2016). A range of 7.0-9.0% crude protein is optimum for corn silage as reported by Chahine *et al* (2009) and Chaudhary *et al* (2016).

4.2.5 pH

The pH of silage indicates silage fermentation quality for silages with a DM content below 35%. Silage pH is influenced by dry matter and sugar content of the fodder ensiled and type of silage fermentation (Kaiser and Piltz, 2004). Roth and Heinrichs (2001) reported the optimum range of pH values for corn silages in between 3.8 to 4.3. In case of acidic silage (pH<3.8) there is need to supplement buffers to avoid stomach upsets.

The higher pH may be due to the high dry matter content, poor fermentation, excessive ammonia or urea, soiling, growth of clostridia or molds in silages. However, the pH of legume silage may vary from 4.2 to 4.8 which attributed due to its higher ash contents (> 15% of DM) and (or) high protein content (> 18% CP).

4.2.6 Buffering Capacity

Buffering capacity (BC) means to what degree, a forage sample will resist a change in pH. The BC of forages depends upon level of protein and mineral content of fodder which may varies due to crop species, stage of growth, soil types, fertilizer application etc. All forages contain chemical compounds called buffers which resist changes in pH. Buffering capacity of forages depends upon the content of organic acids and their salts, with proteins contributing to about 10-20% of BC. There is an increase in risk of poor fermentation when ensiling forages with a high BC (Piltz and Kaiser, 2004). Therefore, it is said that BC indicates about the aptitude of a forage for silage preservation.

Forage type	Buffering capacity (mEq/kg DM)	Aptitude for silage preservation
Maize	150-300	High
Grasses	250-550	Intermediate
Lucerne	350-650	Low

4.2.7 Ammonia-N

Ammonia-N (% of total nitrogen) in silage is a best indicator of silage fermentation quality. It shows the proportion of N (including protein) that has been broken down during ensilage. High ammonia-N is seen in poorly preserved silages and indicates extensive degradation of the forage protein during ensiling process (Kaiser and Piltz, 2004) caused by a slow drop in pH or clostridial action. Higher ammonia-N in silage decreases the silage intake by ruminants and also results in poor utilization of silage nitrogen/protein due to rapid degradation of nitrogen in the rumen. 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.

4.2.8 Mycotoxins

Mycotoxins produce in silage due to aerobic exposure during conservation, during storage or the feedout phase. About 300 mycotoxins had been detected in maize silage and among these aflatoxins are the most harmful for feed and food safety (Cavallarin *et al* 2011). However, the food and drug administration limit the amount of aflatoxins allowable in lactating cow feed to 20 ppb. Mycotoxins can be prevented in silage as follows

- Harvest the forage crop at the recommended maturity and moisture level for ensiling
- Quickly eliminate oxygen as the forage enters the silo is critical to prevention of molds
- Using sharp knives at harvest to enhance packing, aiming for a fill rate of 1 minute $tonne^{-1}$ and a packing density of at least 700 kg m^{-3}
- Cleaning bunkers prior to use and quick sealing of silos
- Weighing down plastic adequately (> 20 tires /100 square feet)
- Silage additives (acids, enzymes, inoculants) usage helps to ensure acidic conditions essentially required to eliminate mycotoxins.
- Regular inspection bag or bunker plastic for holes and seal it promptly
- Maintain feedout rate of at least 6 inches of silage per day to minimize exposed faces that are undisturbed for days
- Maintaining a straight silo face with shavers or block cutters

4.2.9 Silage additives

The silage fermentation quality depends upon the production of lactic acid during ensiling process which in turn dictated by the number of lactic acid bacteria present at the time of ensiling, fermentable sugar content and absence of oxygen in the silage. The number of lactic acid bacteria present at ensiling time can vary from less than 1,000 to about 20,000,000 g^{-1} of fresh forage (Muck 1989), however, the recommended dose is 1,00,000 g^{-1} of fresh forage.

In case, the forage is higher in dry matter or low in nutrients, the following group of silage additives can be used to improve silage fermentation quality.

1. Fermentation stimulants: Lactic acid bacteria, molasses, enzymes
2. Fermentation inhibitors: Acids, HCHO
3. Aerobic spoilage inhibitors: Propionate, benzoic acid, sorbic acid
4. Nutrients: Urea, grains

The enzymes like cellulase at dose rate of 200U kg^{-1} fresh biomass of maize with having CMC activity 2000U g^{-1} enzyme are helpful as silage additives to improve fermentation quality.

4.3 Testing of silage quality

Silage is an end product of fermenting a high-moisture forage crop. The quality of silage depends upon the quality of the parent crop. The testing of silage not only establishes the quality of silage but also tells the success of the ensiling process. Further, testing can be used as objective basis for costing silage, to assist in budgeting and formulation of diets. Testing of silage include mainly sensory (colour, aroma) and chemical evaluation.

4.3.1 Sensory evaluation of silage

The colour of good quality silage for maize, cereals and other grass silages is light green to green (Table 3.3). If colour of silage is very dark olive to dark olive, it indicates wilted legumes, silage with limited fermentation whereas if brown to dark brown it means overheating and inadequate compaction or aerobic spoilage. The aroma of good quality silage will be mild, pleasantly acidic, sour milk or natural yogurt smell (Table 4.1). However, sometimes sweet, fruity alcoholic aroma (Yeasts fermentation), sour vinegar smell (poor fermentation), rancid butter, putrid aroma (clostridial fermentation) or strong tobacco or caramel smell with flavour of burnt sugar (heat-damaged silage) may be observed which is unpleasant.

Table 4.1: Sensory evaluation of silage and its interpretation

Parameter	Interpretation
A. Colour of silage	
Very dark olive to dark olive	Wilted legumes, silage with limited fermentation
Light green to green	Colour of good quality silage for maize, cereals and other grass silages
Light amber brown	Typical colour for more mature grasses and cereals or low DM silages
Brown to dark brown	Overheating, inadequate compaction or aerobic spoilage
B. Aroma of silage	
Mild, pleasantly acidic, sour milk or natural yogurt smell	Normal lactic acid fermentation Desirable
Sweet, fruity alcoholic aroma	Yeasts played role in the fermentation, Ethanol levels high. Silages are often unstable during feedout.
Sour vinegar smell	Poor fermentation dominated by bacteria producing acetic acid. Common with low DM, low-sugar forages. Intake likely to be depressed.
Rancid butter, putrid aroma	Poor fermentation dominated by clostridia bacteria that produce high levels of butyric acid. Intake likely to be depressed
Strong tobacco or caramel smell with flavour of burnt sugar	Heat-damaged silage, dark brown in colour. Often palatable to stock but have low in nutritive value

4.3.2 Laboratory analysis of silage

Laboratory analysis of silage is more reliable method to establish silage quality. The pH of silage should be 3.8-4.2, lactic acid >4%, acetic acid 1-3% and butyric acid <0.13% on DM basis. The higher acetic acid content may result from the extremely wet silages (<25% DM), prolonged fermentations (due to high buffering capacity), loose packing, or slow silo filling whereas the higher value of butyric acid (>0.5%) may indicates Clostridial fermentation. However, the use of microbial inoculant like Lactobacillus buchneri results in higher acetic acid content in silage which may not be mistaken as an indicator of poor fermentation. The ammonical nitrogen, which is the best indicator of silage fermentation, should be less than 10% of percent total nitrogen. A good quality silage should have

- pH: 3.8 to 4.2 %
- DM: 30 to 35 %
- Crude protein: 7 to 9 %
- Ether extract: 2.8 to 3.8 %
- NDF: 35 to 55 %
- ADF:20 to 33 %
- ADL:2.8 to 4.1 %
- Ammonia nitrogen (% of total N): less than 10%
- Lactic acid: Above 4 %
- Acetic acid: 1 to 3%
- Butyric acid: <0.13%

Further, silage should be free from molds, yeasts, clostridial bacteria and other unwanted organisms. Otherwise, it will compromise animal performance. Further, the quality of parent forage and optimum management is required to determine silage quality. Sensory and lab evaluation are important to assess silage quality and to formulate total mixed ration for animals to maximize performance.

4.4 Nutrient losses during ensilage and ways to reduce it

The losses of nutrients arise from field losses during harvesting, oxidation losses, fermentation losses and effluent losses. Generally, loss of dry matter, carotenes, carbohydrate and proteins occur due to respiration, fermentation and aerobic deterioration.

4.4.1 Field losses

The field losses may occur due to shattering of leaves and other nutritious portions because of poor harvesting managements. It includes the dry matter loss during harvesting, chopping and transportation of fodder from field to silo. The losses will be more (>10 %) if the crop is harvested manually and leave in the field for wilting. These losses will increase under adverse weather conditions. The major loss is of water-soluble carbohydrates and proteins. The losses will be negligible (1-2%) if the crop was harvested and chopped mechanically at optimum dry matter content and ensiled on the same day.

4.4.2 Oxidation losses

After ensiling, air present between the fodder particles continues to respire. It uses sugars and oxygen to produces CO_2, water and heat. There is continuous metabolism (mainly respiration and proteolysis) of plant cells from the activity of plant enzymes before the depletion of air from the silage, (McDonald *et al* 1991). The aerobic microorganisms such as yeasts, molds and some bacteria will remain active until oxygen is depleted and the pH begins to decrease. During first phase, the prolonged aerobic respiration can induce substantial respiratory heating and DM loss, which may have negative impact on fermentation. These losses are minimum in the silo of proper size, filled and sealed rapidly after proper pressing of fodder. The oxygen trapped within the plant tissue cause dry matter loss of only 1%.

4.4.3 Fermentation losses

Clostridia and Enterobacteria are the major group of microorganisms causing silage deterioration. They are active in moist silages (<30% DM) with high BC. Then butyric acid produced by proliferation of clostridia leads to rising in pH. In clostridial and enterobacterial fermentations, nutrient losses will be much higher than the lactic acid bacterial fermentations because of production of carbon dioxide, hydrogen and ammonia. 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 ensiling material and type of micro-organism growing during course of 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 fermentation losses chiefly depend upon the moisture content and will be minimised by ensiling of fodders at optimum dry matter. 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 30-40 % 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.

4.4.4 Effluent losses

Forages with low dry matter content (less than 25 %) leads to effluent production tha results in a loss of nutrients. Therefore, for making high quality silage, the dry matter content concentration of fodder should be at desired level (usually 300 g kg^{-1}) that ultimately ensures an achievement of good fermentation and elimination or reduction of effluent losses.

4.4.5 Losses during feedout

During feedout, silage is re-exposed to air enabling undesirable aerobic microorganisms, particularly yeasts, moulds, and acetic acid bacteria to become active and spoil the silage. The presence of air allows these organisms to multiply, resulting heating of silage. During aerobic degradation, the temperature and pH rises while lactic acid content reduces. Loss of dry matter 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). These losses could be minimized by management practices such as use of cover, propionic acid etc (Wyss, 2000). Table 4.2 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 resulted in loss of valuable dry matter and energy. Air exposure during preservation tends to progress towards mould formation and leading to rotten 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.

Dry matter concentration of the forages plays a vital role in minimizing

Table 4.2: Losses during process of silage making

Biological process	Judgement	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)

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, 1971). 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 foul 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 (Rodriguez *et al* 1985). Higher temperature also increases aerobic spoilage and reduces stability of silage.

4.5 Non-leguminous v/s leguminous fodder

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 (4.2) 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 reputed to produce stable and good quality silage chiefly because of low lactic acid production mostly below 3% of dry matter (Singh and Rekib 1986). 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).

4.6 Anti-quality factors in silage

4.6.1 Yeasts

Yeasts activity is considered undesirable in silages under anaerobic as well as aerobic conditions. Under anaerobic silage conditions yeasts ferment sugars to ethanol and CO_2 (Schlegel 1987; McDonald *et al* 1991), resulted in decrease in amount of sugar available for lactic acid fermentation and also have a negative effect on milk taste (Randby *et al* 1998). Under aerobic conditions many yeast species degrade the lactic acid to CO_2 and H_2O, causes a rise in silage pH and triggers the growth of many other spoilage organisms (McDonald *et al* 1991).

4.6.2 Enterobacteria

Enterobacteria in silage compete with the lactic acid bacteria for the available sugars and can degrade protein. This protein degradation causes a reduction in feeding value and leads to the production of toxic compounds such as biogenic amines and branched fatty acids. They have a negative effect on silage palatability (Woolford 1984; McDonald *et al* 1991) especially in animals that are not yet adapted to the taste. The formation of ammonia during proteolysis increases the buffer capacity of the ensiled crop, thus counteracting a rapid decrease of silage pH. Enterobacteria will not proliferate at low pH. Ensiling methods that induce a rapid and sufficient drop in silage pH will therefore help to decrease enterobacterial growth (McDonald *et al* 1991).

4.6.3 Clostridia

Many clostridia ferment carbohydrates as well as proteins. This leads to problems such as the reduction in feeding value, the production of biogenic amines and this clostridia in silage impair milk quality. This is due to the fact that clostridial spores can survive the passage through the alimentary tract of a dairy cow. Clostridial spores present in silage are transferred to milk, via feces and fecal contamination of the udder. In addition to carbohydrate fermentation *C. tyrobutyricum* can degrade lactic acid to butyric acid, H_2O and CO_2. Some clostridia can cause serious health problems.

A typical "clostridial silage" is characterized by a high butyric acid content of more than 5 g kg^{-1} dry matter, a high pH (over pH 5 in low dry matter silages), and a high ammonia and amine content (Vos 1966; McPherson and Violante 1966). Ensiling methods that cause a rapid and sufficient drop in silage pH will help to prevent the development of a "clostridial silage",

4.6.4 Acetic acid bacteria

The activity of acetic acid bacteria genus *Acetobacter* spp. in silage is undesirable because they can initiate aerobic deterioration, as they are able to oxidize lactate and acetate to carbon dioxide and water.

4.6.5 Bacilli

The proliferation of bacilli in silage is generally considered undesirable. Bacilli are less efficient lactic and acetic acid producers than lactic acid bacteria (McDonald *et al* 1991) and enhance aerobic deterioration (Lindgren *et al* 1985). To decrease bacillus growth in silage, storage temperatures should not be too high (Gibson *et al* 1958) and contamination of fresh plant material with soil or manure should be prevented (McDonald *et al* 1991; Rammer *et al* 1994).

4.6.6 Molds

The identification of mold-infested silage is large filamentous structures and colored spores that many species produce. Molds develop in parts of the silage where (a trace of) oxygen is present. During storage, moulds are usually present in the surface layers of the silage, but during aerobic spoilage the whole silage can become moldy. Molds cause a reduction of feed value, palatability of the silage along with negative effect on human and animal health. The spore of mold may resulted in lung damage and also cause allergy (May 1993). Other health problems are associated with mycotoxins that can be produced by molds

(Auerbach 1996). Ensiling methods that minimize air entrapped or entered in silo during ensiling (e.g. good compaction and covering of the silo), and additives that prevent initiation of aerobic spoilage, will help to prevent or limit mold growth.

4.6.7 Listeria

Fatal cases of listeriosis in sheep and goats by silage contaminated with *Listeria monocytogenes* has been reported (Vazquez-Boland *et al* 1992; Wiedmann *et al* 1994). Contamination of raw milk by *L. monocytogenes* due to poor quality silage was reported by Sanaa *et al* (1993). If small amount of oxygen is present, it can tolerate a low pH of 3.8-4.2 for long periods of time and under strictly anaerobic conditions it is rapidly killed at low pH (Donald *et al* 1995). Keeping silage anaerobic is most effective method to prevent growth of *L. monocytogenes* and does not develop in well fermented silages with a low pH (McDonald *et al* 1991).

Poorly managed silage pit

Moldy silage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Chapter 5

SILAGE FEEDING

5.1 Feeding of silage to milch animals

Silage is high in energy (70% TDN), moderate in protein (9%) and low in minerals like calcium, phosphorus, and magnesium (0.2%) on dry matter basis. The digestibility of organic matter, energy and nitrogen in ruminants is 70.3, 67.7 and 54.9%, respectively for maize silage. Metabolizable content of maize silage varies from 7.2 to 10.9 MJ kg^{-1} DM. A good quality silage can be ingested at levels similar to fresh forage. However, low protein content of silage can affect dry matter intake if not supplemented with a good quality protein source.

Silage can be fed to all types of animals on the farm: lactating, growing and dry animals. The majority of the farmers use maize as silage for their animals. Ration should be formulated for silage-based diets depending upon the type of animal, production level, physiological state and lactation number. However, as a thumb rule one can feed adults cows with silage at the rate of 6% of their body weight which is equals to 30 kg for a 500 kg cow. However, there is need to balance the nutrients in ration depending upon the quality of silage. For an instance, if cows are fed with corn silage, about 20% less concentrate is required (8 kg instead of 10 kg day^{-1}). The calves (< 6 month of age) should not be fed maize silage. The unbred heifers could be fed maize silage only if they are fed high protein feeds, otherwise fat deposited in their developing udder led to compromise their milk production efficiency.

The dry matter requirement of an adult animal is 2% of its body weight plus 1/3rd of the milk production of the animal. For example, a cow weighing 500 kg and yielding milk at 30 litre day^{-1} requires dry matter as follows

DM requirement = $500 \times 2\% + 30 \times 1/3 = 10 + 10 = 20$ kg

The required DM can be provided by maintaining optimum roughage to concentrate ratio depending upon nutrient requirements of animal and fiber content, particle size, starch, energy level etc. of the available silage or forage. To optimise production above animal, it will be fed with 30 kg silage (32% DM), 1.5 kg wheat straw and 9 kg concentrate. However, always keep in mind, feeding of silage starts gradually and after a week it can be fed up to 20-30 kg day^{-1} $animal^{-1}$. Feed the silage at least 4 hours before milking or feed it after completion of milking.

During feeding of silage to livestock, following precautions must be taken:

1. Precaution should be taken to avoid pulling or cutting the top sheet back too far once the silo is opened and to keep the front edge weighted down
2. Spoiled silage present at the top surface, along the walls of silo and chunks in the main body should be removed and discarded.

Removing of silage during feed out

Well managed silo during feed out

3. While removing silage from the pit/bunker, keep the silage face vertical and tight.

4. Do not make the pile of silage before feeding and remove only required quantity to avoid any heating.

5. Before feeding of silage, pre-mix the silage removed from entire face and make sure that minimum loose silage is left after end of feeding.

6. Silage should be removed at the rate of at least 6-8 inches to prevent aerobic deterioration. This rate varies depending on packing density and daily requirement.

7. Mouldy silage or dirt in front of the silo pit will contaminate the silage with undesirable bugs, reducing quality and reducing intake.

8. If there is spoiled silage, discard it immediately to prevent it from mixing with good quality silage. Because the feeding of poor-quality silage has negative impact on rumen fermentation.

9. While removing the silage, the face should be kept smooth to lower its surface area to ensure the minimum entry of air to prevent aerobic spoilage.

The aerobic reactions due to non-uniform removal of silage increases the risk of aerobic spoilage leads to production of mycotoxins and resulted in deterioration of nutritional quality of silage. It is very important to get a quality analysis of silage to ensure its quality.

5.2 Effect of silage feeding on production potential of dairy animals

The evaluation of silage feeding effects on the production potential of dairy animals is very important to motivate the rural farmers in dairy farming as well interest in growing high yielding fodders for silage making. Moreover, these farmers need to be motivated to adopt the advanced silage making technology and feeding it round the year to get better production from dairy animals.

Table 3.5: Milk production (kg animal^{-1}day^{-1}) of HF crossbred dairy cows pre and post maize silage feeding.

Village	No. of animals	No. of animals in early lactation	Silage fed to the animals	Average milk yield before silage feeding	Average milk yield after silage feeding	Increase in milk production (%)
			(kg animal^{-1} day^{-1})			
Mari Kamboke	35	12	30.0	20.0	23.0	15.0
Mari Boharwali	65	13	28.0	22.0	26.0	18.2
Saidpur	35	15	30.0	27.0	30.0	11.1
Kairon	70	25	35.0	28.0	33.0	17.9
Kairon	60	20	35.0	27.0	31.0	14.8
Thattian khurd	50	15	32.0	25.0	29.0	16.0
Mean	**--**		**31.7**	**24.8**	**28.7**	**15.5**

Source: Brar *et al* (2016)

Recent findings of research work on silage production and feeding indicate that it could replace the conventional fodder without any negative effect on intake, digestibility, milk yield and its composition in dairy animals (Chaudhary *et al* 2014). In a well-managed system, where losses are low, the silage dry matter content, digestibility and ME content will be similar or slightly lower and crude protein content might be similar or slightly higher than that in parent fodder (Kaiser and Piltz 2002). Conserved fodder may be used throughout the year especially during fodder scarcity periods (Azim *et al* 2000) for consistent growth and production of dairy animals (Tauqir *et al* 2007).

Brar *et al* (2016) reported that in the animals fed with green fodder (40-45 kg day^{-1}), the average milk yield ranged from 20.0 kg animal^{-1} day^{-1} to 28.0 kg animal^{-1} day^{-1}. The overall average was of 24.8 kg animal^{-1} day^{-1}. They replaced green fodder with silage and reported that after five months of silage feeding, average milk yield animal^{-1} day^{-1} of same animals at different dairy farms ranged from 23.0 kg animal^{-1} day^{-1} to 33.0 kg animal^{-1} day^{-1} with an overall average of 28.6 kg animal^{-1} day^{-1} (Table 3.5). They further reported that the average milk yield of HF crossbred cows increased by 15.5% when green fodder was replaced by corn silage.

Phillips (1988) reported an increase in milk production when high quality silage is used as supplement to pasture. Similarly, Chamberlain *et al* (1996) also reported increase in milk production with feeding varying quality of silage to cows at various stages of lactation. Quality silage supports high production of milk and milk solids at each stage of lactation (McDonald *et al* 2000). Higher nutrients digestibility and economic return with feeding of millet silage over millet hay in buffalo calves had also been reported by (Anjum *et al* 2016). Maize silage is an excellent high energy supplement for grazing dairy cows. Animals fed sorghum silage produced significantly more milk as compared to those fed green fodder .

Increase in milk yield of all animals fed with silages than those fed with green fodder was reported by Haque *et al* (2018). Among the silage, the animals fed maize silage gave significantly higher milk yield than those fed napier whole grass silage. They further reported that the average milk production (litre per day) of the 90 days feeding trial period for maize silage, napier chopped silage, napier whole grass silage and green fodder were found as 18.94, 17.82, 16.79 and 14.73, respectively. The groups of animals fed with silage gave significantly higher milk yield than that of the animals fed with green fodder. The animals fed with maize, napier chopped and napier whole silage resulted in increase in milk yield by 28.59%, 20.96% and 13.97% over the group fed with green fodder.

Silage feeding to animals

Chapter 6

TRANSFORMING SILAGE SECTOR: ENTREPRENEURSHIP DEVELOPMENT

Despite being the largest producer of milk in the world, cattle productivity in India is very less than global average. Poor nutrition and improper feed management are the reasons for low yield along with low genetic potential and poor farm management. In order to bridge the gap between demand and supply of cattle feed, alternatives for green and dry fodder need to be discovered. One such solution to the challenge is the use of good quality silage. Mechanization for silage preparation is still at very nascent stage. Some farmers in Punjab have started end-to-end mechanized silage preparation. Government also provides incentives for promotion of this machinery for silage preparation. Seed companies also provide trainings on package of practice for silage preparation. Hence, end-to-end mechanization for silage making units can further be promoted for overall improving the dairy sector and in turn corn industry will boom.

6.1 Silage industry

Silage industry has become one of the most booming industries in some of the states in India. In industrial silage making in northern India, spring and summer maize/corn is mostly used for silage making. Beside this, silage is also prepared from wheat, barley, oat, rye, etc. Corn silage is much more edible and have higher digestibility. Corn silage have better dry matter content, energy and have greater shelf life as compared to other forages. In commercial silage making, inoculants containing lactic acid- producing bacteria helps in improving fermentation process, retain valuable nutrients, reduce losses, increase milk production and also improves quality of milk by increasing fat percentage and protein in milk.

Silage industry is involved in storing chopped forage into compressed air tight bales and keeps fodder under anaerobic conditions for at least 45 days to complete fermentation. These bales are then transported to different parts of the state or country. With increasing competition among manufacturers and suppliers, it has shown direct benefits to farmers in the form of improved bale quality and cheaper prices.

With increasing livestock population and feed prices, there is continuous decrease in pasture land and/or area under fodder crops which has led to change in global trends towards ensiling. However, high initial fixed cost to start the project and fluctuation in demand due to unawareness among the consumers regarding the benefits of silage are a few restraining factors for this market.

6.2 Potential of silage industry in India

States like Punjab, Haryana and some regions of Uttar Pradesh have a large cultivable area with assured irrigation facilities. There is ample amount of green fodder available during flush/production period of winter and summer fodder crops and a very less portion of available green fodder is used for silage preparation. However, considering the overall availability of green or dry fodder in India as a whole, a net deficit in green fodder and dry fodder to the tune of 35.6% and 10.95%, respectively is being reported (IGFRI vision, 2050). To manage this deficit, judicious use of green forage during flush period by its conservation as silage is very important. The present fodder supply of 18 kg animal^{-1} day^{-1} is far from satisfactory. For optimum feeding, about 40 kg green fodder per animal should be supplied daily.

Due to industrialization and urbanization, pasture lands and area under forage cultivation is continuously decreasing which has led to increased dependency of farmers upon alternative sources of fodder which is silage. With increasing population to feed, it becomes even more important to curb the deficit as soon as possible, thereby increasing the dependency on silage. Silage is better in many ways as compared to hay as it has much more nutritive value and can be stored for longer period of time.

In India, around 70% of population depends upon crops and livestock for their livelihood. At present, our agriculture is in transition phase, moving from crop cultivation to mixed farming involving both crop cultivation and dairy farming. Animal husbandry and livestock sector is a major part of rural economy, critically involving marginal farmers (Ghosh *et al* 2013). The one interesting fact about Indian agriculture is that a low poverty percentage was observed in areas with larger livestock sector (Taneja 2003). After white revolution, dairy farming has proved itself much more economically reliable as compared to agriculture alone as it involves less external environmental constrains. In Indian state, per capita milk production varies widely and it has been a major concern. The per capita milk production of states like Orissa, Andhra Pradesh, Jharkhand etc. is very low as compared to Punjab, Haryana and Gujarat.

Animal husbandry stands tall on four basic pillars namely genetics, nutrition, reproduction and management. Nutrition involves 60% of the total production or livestock rearing cost. Though we have improved the genetic potential of the animals but nutrition remains one of the important factors for phenotypic expression of the genotype. It is one of the most important limiting factors for sustainable livestock production. Balanced animal feed including feed and fodder is the most important factor to sustain the production in intensive type of animal rearing. Proper ruminal motility and its functions solely rely upon quality and quantity of available green fodder. As per feeding of livestock is concerned, green fodder is 5-14 times cheaper source of digestible crude protein (DCP) and total digestible nutrients (TDN) as compared to concentrates. In addition to DCP and TDN, forages are also sources of essential vitamins and minerals to the animals. Fodder production not only reduces the concentrate requirements of the animals but also helps to cutting the cost of production. The major challenge in success of dairy sector is round the year availability of green fodder. It has been observed that green fodder availability is not uniform throughout the year. In northern India, scarcity of green fodder is observed during lean months such as May-June and

November-December. On the other side, surplus amount of green fodder is available during rest of the year in large number of Indian states. With the use of advance scientific technology, we can conserve the green fodder as silage, and make it available round the year which will result in sustainable milk production.

Fodder crops are cultivated and harvested to be fed fresh, as silage and hay. Sorghum/ maize/bajra (*Kharif* crop) and berseem/oats (*Rabi* crop) are the major fodder crops cultivated in northern India. Area under fodder crops has been constant from last four decades. Recently, the area under fodder crops in peri-urban areas has increased due to intensive livestock farming to cope up with increasing milk demand of urban population. Thus, conservation of fodder becomes much more important to manage increasing fodder demand and reducing CP and TDN deficit by cutting down the wastage and promoting its judicious use. Promotion of silage industry is only a viable option to meet the increasing demand of quality fodder at cheaper cost. The main aim of silage making is to conserve nutritive values in anaerobic environment with formation of organic acids primarily lactic acid (Saarisalo *et al* 2007). Milk production in ruminants is directly affected by fermentation quality of the silage leading to better feed intake and silage utilization (Huhtanen *et al* 2002, 2003).

States like Rajasthan, Andhra Pradesh, Orissa, Jharkhand etc. are facing much more deficit related to forage requirement and have a large potential for silage industry. In states like Punjab and Haryana, silage making has become an industry. A lot of people are being engaged in production and utilize available resources and then, supplying the silage bales to different part of the states/country. Though transportation to different locations led to increased cost of production per quintal of silage, yet silage industry is a booming industry.

Different types of advance machineries such as seed drills/Pneumatic planters, single row/ multi row harvesters, balers etc. are being used in silage industry. Increasing silage demand has also boosted opportunities for seed production industries. However right now, very few such industries have launched themselves on commercial scale The Ministry of Agriculture and Farmers Welfare in 5th edition of India Maize Summit, 2018 has proposed Public-Private Partnership (PPP) opportunities for establishment of maize-based silage making units, as prospective avenues for investment. The honorable Minister of Agriculture and Farmers Welfare, Shri Radha Mohan Singh asked for a mix of strategies and interventions around technological innovations, promoting producer aggregation and linkages, enabling supporting infrastructure, forging public-private partnerships and appropriate policy measures to enhance its growth and tap the immense potential.

There is a rise in export quality requirements for agricultural products. Moreover, sustainable agriculture practices in countries such as China, Australia, New Zealand, India, Brazil and Argentina are being increasingly adopted. It is expected to drive the demand for silage additives among the silage growers in the Asia-Pacific and South American regions during the forecast period. This would increase the inflow of various international manufacturers to set up their business units and distribution networks, thereby leading to a strong market competition.

6.3 Silage industry in Punjab

Lack of awareness regarding importance of silage has led to slower growth of silage industry of India. However, the silage industry has well established in Punjab. Apart from Punjab Agro Industries Corporation Ltd. (organization of Punjab government), a number of private firms are already engaged in production and marketing of baled silage.

Silage feeding is well adapted at most of the commercial dairy farms of Punjab. Now, even the small dairy farmers prefer to feed silage to their animals as it provides nutrients with comparable digestibility and palatability to green fodder. There is a great scope for silage industry in Punjab as the raw material for silage making i.e. green fodder is available due to assured irrigation facilities. Rural youth is coming forward to start silage making at commercial scale. The market is also available due to shortage of fodder in neighboring states of Punjab and also there are export opportunities. Many commercial silage industries in the state are preparing and selling silage @Rs 6-7 kg^{-1} to the dairy farmers.

Spring maize is mainly grown for silage making in Punjab and the major concern about its cultivation is high water demand of this crop. With an aim to save groundwater, Punjab Agricultural University and Punjab government is promoting the adoption of micro irrigation for cultivation of this crop. Punjab Government is providing subsidies to farmers up to 80 to 90% on drip irrigation projects. Under the Micro Irrigation policy, farmers will be able to get subsidies on first-come, first-serve basis. Farmers belonging to Scheduled Castes and marginal categories, besides women farmers, will get up to 90% subsidy, and others up to 80%. This Micro Irrigation systems gives irrigation efficiency as high as 80-90% in case of drip irrigation and 60-70% in case of sprinkler irrigation in comparison of normal irrigation efficiency of 30-40%.

Apart from this, the state government is also providing the subsidy on the resource conservation technology required for the cultivation and harvesting of fodder crops. The subsidized machinery includes laser land leveler, pneumatic maize planter, raised bed planter, single row forage harvester etc., in the list of implements/equipment. There is a system setup in which the subsidy is provided to individual farmers and to custom hiring centers.

Punjab state government has launched a new subsidy scheme for silage baler cum wrapper machines. In this scheme, farmers is granted 40 percent subsidy for the purchase of automatic silage baler cum wrapper machines. The scheme is carried out by the Punjab Dairy Development Board. According to the state government, the scheme should not only help to increase the area for growing green fodder but also reduce the cultivation of crops such as wheat and rice, which will further increase the water table in the state. Under the scheme, the farmer who purchases the silage baler cum wrapper machine, can receive a grant of rupees 5.60 lakh from the government. To promote new business opportunities for farmers by selling packaged silage to landless and needy dairy farmers across the country.

Table 6.1: List of some private firms involved in Silage marketing in Punjab

S.No.	Name of firm	Location
1.	Silage Agro Private Limited- Punjab	Rajpura (Patiala)
2.	Daintech Farm Services	Ludhiana
3.	Excellent Enterprises Pvt. Ltd.	Khanna (Ludhiana)
4.	Shiv Shakti Industries	Barnala
5.	Punjab Silage company	Ludhiana
6.	Cowbell agro industries	Rampura Phul (Bathinda)
7.	Kissan Corn Silage	Rajpura (Patiala)
8.	G.N. Agro Industries	Samrala (Ludhiana)
9.	Harinder Farms	Jalandhar
10.	Janta corn silage	Ludhiana

Source: https://fliarbi.com/market.ai/india/list/corn-silage/s/punjab/

6.4 Mechanical harvesting of fodder crops

The process of harvesting of fodder for silage making and its pressing in silo pit/baling is labour intensive, time consuming and high energy intensive operation. The delay in harvesting to sealing of fodder in silo often causes loss of moisture content and deterioration of fodder quality rapidly. The prolonged period of filling silo more than 2 days increases the aerobic deterioration of fodder in silo. Hence, it is very important to complete this operation as soon as possible. During process of silage making, large volume and mass handling requires suitable machinery according to amount of biomass to be preserved depending upon the size of dairy farm.

Earlier, farmers were performing these operations manually, in which 8-10 labourers per acre per day were required for harvesting, loading, chopping, and storage of fodder in silo pit. This leads to a prolonged filling time of silo which in turn results in an increase infield losses and cost of silage production. Now advanced machinery (Table 6.2) performs the operation of harvesting, chopping and loading simultaneously which enables the farmers to complete the operation of silage making in a single day.

Table 6.2: Advanced machinery for fodder harvesting

Machine	Harvesting efficiency	Present companies	Approximate cost
Single-row forage harvester	4-5 acres day^{-1}	Shaktiman, CLAAS, Fimarks, Celikel	2.5 to 4.5 lakh
Multi-row Self propelled fodder harvester	20-25 acres day^{-1}	CLAAS, New Holland	80 to 300 lakh

Mannual harvesting, chopping and filling of silo

Single row fodder harvester

Self-propelled forage harvester

6.5 Baled silage industry

The production of pit/bunker silage is limited to dairy farms where it is produced and consumed according to their own requirement. The silage deteriorates rapidly once it is exposed to air. Therefore, it is not possible to transport it to other places for its commercial sale. This problem is solved by the introduction of baling technology in silage production. With this technology, it is very easy to preserve, store and transport silage to distance places according to its demand. Baled silage is easy to store, as bales may be kept in the open and easily transported distant places. It also makes it within the reach of small farmers or landless farmers having two to three animals. Most of farmers living in the vicinity of urban areas raring milch animals for their own milk requirement or for sale of milk in the city are most benefitted with this technology.

As per the situation of Punjab is concerned, there is an acute shortage of fodder in neighbouring states of Punjab i.e. in J&K, Himachal Pradesh, Rajasthan and Uttarakhand, due to the limited availability of irrigation facilities. There is a huge scope for marketing of baled silage in these states. Most of the big dairy farmers in the state are engaged in the preparation of pit silage, and are very limited dependent on the baled silage due to its higher cost, as the cost involved in production and transportation of baled silage to the doorstep of the farmer is 12-15 % more. Therefore, the target group of this industry is small to medium farmers having 1-10 animals with limited land for cultivation of fodder crops and the dairy farmers of neighbouring states. The baled silage industry is developing at a positive pace and are using own social media network for marketing of their product, but the major concerned is uncertainty associated with the sale of their product.

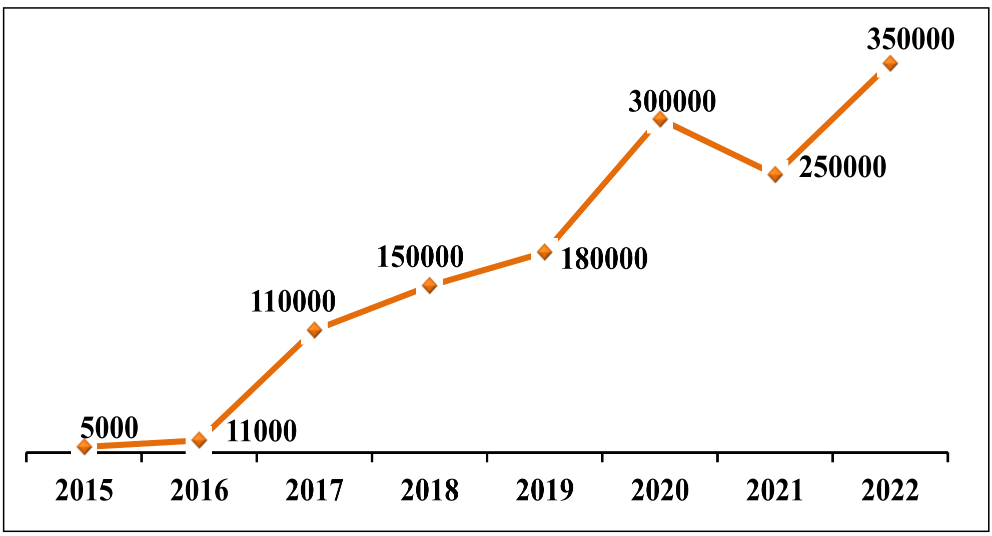


Figure 6: Growth of Baled Silage production in Punjab (In tonne)

6.6 Equipment required for baled silage production

In baled silage industry, along with the machinery for harvesting and chopping of fodder crop, additional equipment is required for its packing, handling and transportation (Table 6.3). Along with the machinery imported from Turkey, Germany, Norway and China, Indian entrepreneurs have also started manufacturing of such machinery.

The machinery required for baled silage production is static type and needs electricity for its operation. The growth of baled silage industry will increase the demand of equipment and machinery required for it. This will also lead to the establishment of custom hiring centres of machinery and will encourage the dairy farmers to opt baled silage making by taking services of custom hiring centres in near future.

Table 6.3: Machinery required for baled silage production

Machine	Specification	Capacity	Manufacturers
Baler	400 kg	50 bales/hr	Shaktiman, Orkel
	100 kg	300 bales/day	Orkel
Accessories	Grabbers, Loaders, Trailers etc.		Local agricultural industries

Precautions to be taken for preparing silage bales:

1. To ensure good fermentation, bales are dense and well-sealed to prevent the entry of oxygen in the bale and to ensure good fermentation.
2. Area to be harvested for baled silage making is decided in advance in order to ensure that the entire quantity of material sealed in one day.
3. Avoid soil and manure contamination to prevent the entry of undesirable bacteria in the the system.
4. Fodder should be harvested at proper stage as the sugar content in

mature fodder is low resulted in poor fermentation. Stem become hard at maturity are difficult to pack and puncture the wrapping sheet.

Constraints in the development of baled silage industry:

1. High cost of equipment and machinery: The cost of equipment needed and the operating expenses are higher, which results in an increase in the cost of silage.

2. The bales are packed with stretchable film. It prevents the entry of oxygen in bale, prevents any leakage of effluents or gas and protects silage from UV radiations. The raw material of the film is petroleum based mostly imported. The fluctuation of the price of the petroleum industry effects the wrap film price.

3. Long-distance transportation of bales to neighbouring states results in an increase in its price.

Bale silage entrepreneurs also face marketing problem due to seasonal fluctuation in the demand for silage.

Harvesting with Self-propelled forage harvester

Baled silage making

6.7 Challenges and future for silage industry

There is a huge scope of silage industry in India. However, most of farmers (86.2%) in our country are small and marginal ones. Due to gradual decrease in land holding, they prefer to grow food grains and cash crops. Therefore, there is a decrease in the area under fodder cultivation that has resulted in deficit of green fodder in country. Pasture lands are not being properly managed and are over-grazed leading to poor productivity. The availability of pasture land and capacity of grazing land to sustain animal population varies greatly from one state to other. In Rajasthan, around 70% of grazing land comes under poor to very poor condition having productivity below 500 kg ha^{-1} with a carrying capacity of 0.13 ACU ha^{-1}.

Most of the marginal and land-less farmers and farm labourers are rearing cattle but could not fulfill the fodder requirement of their animals. Thus, exploration of alternative options becomes much more important to meet the fodder demand. There is a need to promote the cultivation and marketing of fodder at commercial scale. In present situation, promotion of silage industry is a better choice to meet the fodder deficit and to fill up the huge gap between the average milk productivity of India and world. The major challenges with silage industry in India are:

1. The land under cultivated fodder crops is almost static and there is a little scope of expansion due to reducing availability of per capita land.
2. Non-commercial status of forage crops and un-organized small market for fodder crops.
3. Lack of government policy back up such as minimum support price is putting forage production as a low priority agricultural activity.
4. A major part of population at grass root level are uneducated or holds very less education which makes adoption of techniques much more difficult.

5. Most of farmers in India are using traditional techniques for fodder cultivation and livestock rearing.

6. The perishable nature of silage and its transportation adds up the cost and considering that most of the farmers have less than one hectare and a smaller number of animals, the usage of silage increase the cost of livestock production.

7. Cost of machinery used in silage production may also affect silage industry upto certain extent.

To enhance entrepreneurial options in silage sector, following points need to be taken care of.

6.7.1 Finance

Initial cost to start baled silage industry is higher, as it requires heavy machinery and space for installation of unit. In addition, technical experts and skilled labour are also required with a handsome salary. Therefore, the availability of term loans and working capital at low interest rates is very essential.

6.7.2 Technology

Advances technology is required from the sowing of crop to the final preparation of bales (Pneumatic planters, pesticide application machinery, micro irrigation, harvesters etc.). The instruments are required for the estimation moisture, starch, fibre, protein, fats, microbial population etc. Most of the firms engaged in manufacturing of this technology are from other advanced countries. There is need to encourage the local manufacturers to supply these implements/instruments at cheaper rates.

6.7.3 Fodder testing facility

In order to ensure the quality of silage, the silage testing facilities must be available in every district at the block level. It will give insurance to the purchaser/farmer regarding the quality of silage as they are having lack of trust on balers/sellers. The most of firms involved in the silage industry in Punjab are not giving any information regarding the quality of silage. Many a times, their silage is not fulfilling the quality standard, especially when harvested before or after milk stage or when corn silage is prepared without cobs.

Early harvesting of crops resulted in decrease in dry matter and delay in harvesting leads to an increase in fibre content in silage. The testing facility built the trust of the consumer on the seller and also forces the baler to improve the quality of silage.

The important parameters need to be tested are pH, Lactic acid, Ammonia nitrogen, Buffering capacity, DM, CP, EE, NDF, ADF, ADL, Ash, Aflatoxins. At present, this facility in Punjab state is available at GADVASU, Ludhiana.

6.7.4 Accreditation of silage

As silage is directly related to health of dairy animals and in turn milk consumers. The silage industry is in the initial stage and at this time, the accreditation of silage will help in building trust among the farmers and will increase its acceptability.

6.7.5 Establishment of fodder banks

In many states of India with poor irrigation facilities, dairy sector is not growing due to uncertainty in production of quality fodder. The establishment of silage banks in those states give assurance to dairy farmers regarding availability of fodder and helps to boost the growth of dairy sector. This will also facilitate the movement of fodder from surplus to deficit region in country.

6.7.6 Farmer producer organizations (FPO)

The development of FPO in silage making and marketing will help in managing the surplus fodder and make them available to the other farmers in demand. This will help in the proper management if fodder at local level and also leads to a decrease in its cost.

6.7.7 Role of village level cooperative societies

The involvement of village level cooperative societies in silage making and marketing will boost the business in the country. There is need to invest in the infrastructure required for silage making (sowing machinery, harvesters, balers etc.) in cooperative societies. This will help in the preservation of the excess fodder as silage and supply it to the farmers at the time of deficit and make villages self-sustained in meet out the fodder requirements at local level.

6.8 Key reflections and policy recommendations

6.8.1 Conservation of forages to meet the demand in deficit

Fodder scarcity is mostly observed in dry periods and during floods. Conserved forages which are nutritionally rich and can be prepared by low-cost methods like silage are to be promoted among the farmers.

6.8.2 Promotion of scientific cultivation of fodder crops

There is need to promote scientific fodder crop production through improved agronomic practices and quality seed production. There is need of promotion of winter cereals (wheat, barley, oat) for silage making in order to decrease the sole dependency on spring maize. Green fodder is the raw material used for silage making and it is primary determinant of silage quality. Spring maize is the major crop used for silage making in Northern India and it is very important to adopt scientific practices for its cultivation. There is need to aware farmers about adoption of proper cropping systems to ensure the sowing of spring maize on time. There is also concern of huge water consumption by the maize crop that can be managed through the use of smart irrigation practices.

6.8.3 Research and development initiatives

Presently research initiative has been mainly focused towards cultivation of green fodder in irrigated areas only but there is need to promote the research and development programme emphasize to dry land or partially irrigated area. For this, coordination among industry-farmers-institutes for better outputs starting from seed-sowing to post-harvesting, processing, value-addition, matching-machinery, R&D services, marketing aids etc. is the need of time.

6.8.4 Quality silage production

The quality of silage is a real concern for the farmers as there is a lack of trust of balers among the farmers. It has been found that poor quality maize; maize stalks without pods, early cutting, or late-cut maize are also ensiled. The testing facilities at various levels will ensure the production of quality silage, which will ultimately benefit the stakeholders in the value chain. It can also be taken up as an entrepreneurial activity by providing desirable funding through various governments schemes and programmes.

6.8.5 Capacity building of farmers and extension functionaries

There is need to strengthen and develop trained manpower in latest technologies in terms of both animal health as well as management aspects. Need based capacity building programmes must also be organized for fodder growers to keep them abreast with latest technical know-how.

6.8.6 Promotion of fodder production as an entrepreneurial activity

The Government should provide technologies and financial support to fodder-based enterprises such as fodder bank, seed production, equipment and machinery development. The movement of quality fodder in various forms along the different borders and geographies will create employment opportunities both directly and indirectly. Thus, creation of such kind of businesses will create buffer storage and build confidence among farmers to expand or scale up their enterprises.

6.8.7 Government initiatives and policy framework

Capital subsidy for establishment of Hay/Silage/Fodder Block/TMR plants on machinery and equipment for fodder processing and storage should be introduced at larger scale. There should be provision of subsidy to the farmers for the development of infrastructure required for silage making and also on inputs required for the raising of fodder crop for silage making.

6.8.8 Marketing and storage of silage bales

Production of silage bales is limited to months of May-June, and the silage balers have to wait till January for selling purpose. It is observed that the availability of bales at nearby places or low transport cost is deciding factors for marketing and availability. There is a need for the availability of bales at the multiple location or options of selling through the conventional dealer network to boost the local consumption of bales.

Silage Bales

Chapter 7

CASE STUDIES/FARMER'S EXPERIENCES

CASE STUDY 1

A comparative study was conducted at commercial dairy farms in villages Thatian Khurd, Sabrah, Mari Kamboke and Algo kothe of Tarn Taran district of Punjab for qualitative assessment of silage prepared from maize alone and maize + sugar graze. The farmers were guided regarding the scientific cultivation of corn and its silage making. The data was recorded with respect to hybrid of maize grown, stage of harvesting (days after sowing), days taken to fill the pit and days of ensiling. The representative samples of silage were collected from all dairy farms after opening of silo pit after 45 days of ensiling. The samples were analysed with respect to moisture (%), dry matter (%), crude protein (%), fibres (ADF and NDF), pH, buffering capacity, ammonia-N and aflatoxins. It was observed that prepared from Maize Hybrid P-1844 harvested between 67-69 & 70-71 DAS, filled in pit within 2 and 3 days and ensiled for 43 and 63 days respectively recorded moisture content of 72.6 % and 68.3 %, dry matter content of 27.4 % and 31.8 % and CP content 7.9 % and 7.5 % respectively (Table 7.1). NDF content values recorded for Silage-1 and Silage-2 were 45.3 and 43.4 %, ADF content 32.9 and 28.9% respectively representing the better quality of these silages. Buffering capacity for different silages ranged between 3.9-4.2 meq. g^{-1}. Lowest value of ammonia-N 2.0% was recorded for Silage-1 while highest (3.3%) was recorded in Silage-4. Aflatoxin values for the different silages were below 8 ppb respectively. pH of different silages ranged between 3.8 to 4.0. From present study, it is concluded that for making of good quality silage, the crop should be harvested when the grains are in dent stage or near 2.5 MLS. Delay in harvesting increased the NDF and ADF content above optimum range. The silage prepared from variety

P-1844 recorded all the quality parameters in ideal range whereas other silage samples showed values beyond desirable limits.

Table 7.1: Qualitative parameters of silage prepared at commercial dairy farms in Tarn Taran district of Punjab

Sample	Village	Variety	Harvesting (DAS)	Days to fill the pit	Days of ensiling	Moisture	Dry matter	Crude protein	NDF	ADF	pH	BC	Ammonia N	Aflatoxin
						g/100g (%)						meq./gm	%	Ppb
Silage-1	Thattian Khurd	P-1844	67-69	3	43	72.3	27.4	8.0	45.3	32.9	3.8	3.9	2.0	<8
Silage-2	Sabrah	P-1844	70-71	2	63	68.3	31.8	7.5	43.4	28.9	4.0	4.1	3.0	<8
Silage-3	Sabrah	P-1844	85	1	120	77.9	22.2	8.9	63.6	45.1	3.6	3.9	2.6	<8
Silage-4	Mari Kamboke	PAC-746	68	1	40	79.1	20.9	7.6	64.8	40.8	3.5	3.9	3.3	<8
Silage-5	Mari Kamboke	PAC-746+ Sugargraze	69-70	2	62	81.3	18.7	7.9	53.4	28.8	3.7	4.2	2.5	<8
Silage-6	Algokothe	31Y45 + Sugargraze	65-71	7	45	83.5	16.5	7.5	45.5	30.9	3.8	4.0	3.1	8

Source: Brar *et al* (2017)

CASE STUDY 2

This field investigation programme was carried out in border area of Tarn Taran district of Punjab, India to promote silage making at dairy farms, under front line demonstrations of silage making under subtropical conditions. The study was carried out at 21 commercial dairy farmers selected from three blocks in the district. The corn was cultivated for fodder by following recommended package of practices and ensiled for 45 days.

At 20 dairy farms, crop was sown during first week of March to first week of April, whereas at one farm, it was sown in last week of January. At six locations, corn hybrid P1844, at eight locations, hybrid DOW2244 and at seven locations, hybrid P31Y45 was grown for silage making. Seed rate was kept 20 kg ha^{-1}, was treated with Gaucho (Imidacloprid) 600 FS @ 6 ml per kg seed before sowing. The crop was sown on the ridges 60 cm apart by dibbling seed manually keeping plant to plant distance at 20 cm. Fertilizers were managed by application of 250 kg of urea ha^{-1} and 125 kg DAP ha^{-1}. Half dose of urea and whole DAP was applied at time of sowing and remaining half dose of urea was applied when crop was at knee height stage. Weeds were controlled by application of 1500 g atrazine + 2.5 L pendimethalin ha^{-1} within 2 days after sowing. Cyprus rotundus and broad leaf weeds germinated after sowing were controlled by application of 1.0 L of 2,4-D (Amine salt) ha^{-1} at 20-25 DAS. Crop was harvested at milk stage for silage making either manually or by using single row maize harvester (SRMH).

The silage was prepared in silo pits/ bunkers having varying dimensions. The sides of pits/bunkers were covered by polythene sheet and at the bottom of pits/bunkers, a 6-inch layer of wheat straw was spread. The chopped fodder was pressed in the pits/bunkers layer by layer with the help of tractor. After filling of pits/bunkers, it was covered by polythene sheet and mud in order to create anaerobic conditions. The data was recorded with respect to maize hybrid grown, stage of harvesting (days after sowing), days taken to fill the silo pit and days of ensiling (Table 7.2). After the opening of silo pit, representative samples of silage were collected from silo pits of all dairy farms and analysed in laboratory for quality analysis. It was reported that the corn harvested by using single row maize harvester at milk stage, packed in silo pit within two days and ensiled for minimum 45 days resulted in values of pH, dry matter, crude protein, NDF, ADF, ADL, ammonia-N (% of total N) and buffering capacity, which were within the optimum range (Table 7.3 & 7.4). It was

Table 7.2: Crop variety grown, harvesting (days after sowing), days to fill the pit and days of ensiling

Silage	Variety	Harvesting (DAS)	Method of harvesting	Days to fill the pit	Days of ensiling
S1	P-1844	72	SRMH	2	45
S2	P-1844	72	SRMH	2	45
S3	Dow 2244	60	SRMH	2	37
S4	Dow 2244	60	M	3	45
S5	Dow 2244	60	M	3	41
S6	Dow 2244	55	SRMH	2	45
S7	Dow 2244	60	M	4	42
S8	Dow 2244	60	M	3	40
S9	Dow 2244	60	SRMH	2	35
S10	Dow 2244	75	M	3	40
S11	P31Y45	85	SRMH	2	45
S12	P-1844	60	SRMH	2	40
S13	P-1844	60	M	4	50
S14	P-3396	75	SRMH	1	35
S15	P-1844	70	SRMH	5	45
S16	P31Y45	94	SRMH	2	45
S17	P31Y45	98	SRMH	2	55
S18	P31Y45	82	SRMH	2	50
S19	P31Y45	75	M	3	55
S20	P31Y45	70	SRMH	2	50
S21	P31Y45	109	SRMH	2	76
Mean		**72**		**3**	**46**

Source: Brar *et al* (2019)

observed that silages prepared from the crop harvested with single row maize harvester at 72, 70, 82 and 109 days after sowing, respectively, silo pit was filled within two days and the fodder was ensiled for 45, 45, 50 and 76 days, respectively showed the values of almost all quality parameters within the optimum range. This study concluded that for quality silage making, the corn should be harvested at milk stage, which depends upon the genetic makeup of the cultivar and time of sowing of crop. It should be harvested mechanically using single row maize harvester to ensure filling of silo pit within two days and the fodder should be ensiled for minimum 45 days.

Table 7.3: Composition of silage samples

Silage	Dry matter	Crude protein	NDF	ADF	ADL
	(%)				
S1	$27.70^{g}\pm0.03$	$9.10^{ef}\pm0.15$	$67.27^{g}\pm0.65$	$37.69^{de}\pm0.41$	$4.89^{def}\pm0.27$
S2	$32.42^{l}\pm0.04$	$9.32^{ef}\pm0.09$	$65.52^{f}\pm0.67$	$32.33^{c}\pm0.59$	$3.76^{abc}\pm0.38$
S3	$21.22^{a}\pm0.42$	$10.77^{kl}\pm0.14$	$69.65^{h}\pm0.64$	$44.68^{g}\pm0.64$	$6.37^{gh}\pm0.32$
S4	$22.66^{b}\pm0.03$	$10.99^{l}\pm0.27$	$54.70^{a}\pm0.61$	$46.94^{h}\pm0.91$	$6.96^{hi}\pm0.25$
S5	$25.39^{ef}\pm0.22$	$9.45^{fg}\pm0.13$	$68.98^{h}\pm0.94$	$41.77^{f}\pm0.78$	$5.58^{fg}\pm0.47$
S6	$22.27^{ab}\pm0.70$	$8.99^{de}\pm0.30$	$69.30^{h}\pm0.46$	$38.44^{e}\pm0.68$	$4.88^{def}\pm0.32$
S7	$25.85^{ef}\pm0.09$	$9.41^{fg}\pm0.03$	$60.74^{d}\pm0.64$	$37.13^{de}\pm0.52$	$5.26^{ef}\pm0.14$
S8	$35.25^{n}\pm0.26$	$8.73^{cd}\pm0.03$	$62.59^{e}\pm0.36$	$49.06^{i}\pm0.79$	$7.80^{ij}\pm0.25$
S9	$34.23^{m}\pm0.04$	$8.10^{a}\pm0.10$	$65.39^{f}\pm0.42$	$45.65^{gh}\pm0.71$	$6.58^{h}\pm0.30$
S10	$25.00^{de}\pm0.55$	$10.74^{kl}\pm0.05$	$56.64^{b}\pm0.62$	$31.37^{c}\pm0.69$	$3.72^{abc}\pm0.17$
S11	$28.28^{g}\pm0.26$	$10.35^{ij}\pm0.05$	$58.81^{c}\pm0.54$	$29.25^{b}\pm0.58$	$5.07^{ef}\pm0.35$
S12	$23.77^{c}\pm0.10$	$9.24^{ef}\pm0.05$	$65.34^{f}\pm0.61$	$46.57^{h}\pm0.34$	$7.75^{ij}\pm0.26$
S13	$25.53^{ef}\pm0.26$	$9.23^{ef}\pm0.04$	$68.37^{gh}\pm0.52$	$47.36^{h}\pm0.58$	$7.99^{j}\pm0.10$
S14	$22.22^{ab}\pm0.38$	$10.01^{hi}\pm0.07$	$61.30^{de}\pm0.67$	$36.53^{d}\pm0.47$	$6.65^{h}\pm0.21$
S15	$30.05^{hi}\pm0.36$	$9.72^{gh}\pm0.04$	$62.52^{e}\pm0.35$	$26.66^{a}\pm0.52$	$3.07^{a}\pm0.10$
S16	$26.40^{f}\pm0.31$	$10.01^{hi}\pm0.09$	$58.10^{bc}\pm0.38$	$32.21^{c}\pm0.40$	$4.45^{cde}\pm0.28$
S17	$25.11^{de}\pm0.20$	$8.17^{ab}\pm0.13$	$54.82^{a}\pm0.20$	$36.96^{de}\pm0.55$	$5.49^{fg}\pm0.51$
S18	$31.27^{k}\pm0.82$	$10.88^{kl}\pm0.07$	$56.57^{b}\pm0.64$	$28.97^{b}\pm0.38$	$3.98^{abcd}\pm0.24$
S19	$29.52^{h}\pm0.32$	$10.51^{jk}\pm0.08$	$64.93^{f}\pm0.32$	$35.86^{d}\pm0.56$	$4.05^{bcd}\pm0.37$
S20	$24.13^{cd}\pm0.17$	$10.56^{jk}\pm0.02$	$65.47^{f}\pm0.64$	$36.08^{d}\pm0.49$	$3.84^{abc}\pm0.25$
S21	$30.59^{jk}\pm0.46$	$8.50^{bc}\pm0.03$	$60.88^{de}\pm0.51$	$29.45^{b}\pm0.56$	$3.42^{ab}\pm0.31$
Mean	**27.09±0.51**	**9.66±0.11**	**62.76±0.61**	**37.67±0.87**	**5.31±0.20**

Source: Brar *et al* (2019)

Table 7.4: Fermentation pattern of silages

Silage	pH	Ammonia-N	Buffering Capacity
		% of total N	meq/100g
S1	3.7	$8.83^{l}\pm0.15$	$44.18^{r}\pm0.02$
S2	3.7	$5.95^{b}\pm0.06$	$43.20^{q}\pm0.01$
S3	4.0	$7.00^{d}\pm0.09$	$39.21^{e}\pm0.01$
S4	3.7	$6.33^{c}\pm0.15$	$43.19^{q}\pm0.03$
S5	3.9	$7.30^{efgh}\pm0.10$	$41.51^{j}\pm0.03$
S6	4.0	$7.50^{ghij}\pm0.26$	$38.06^{d}\pm0.04$
S7	3.6	$7.59^{hij}\pm0.03$	$45.52^{t}\pm0.04$
S8	3.7	$4.62^{a}\pm0.03$	$45.31^{s}\pm0.03$
S9	4.3	$7.21^{defg}\pm0.09$	$35.91^{a}\pm0.03$
S10	3.8	$9.03^{l}\pm0.04$	$41.35^{i}\pm0.01$
S11	3.8	$7.35^{fghi}\pm0.04$	$40.62^{h}\pm0.01$
S12	3.8	$8.76^{l}\pm0.04$	$43.12^{p}\pm0.01$
S13	4.1	$8.49^{k}\pm0.04$	$36.93^{b}\pm0.02$
S14	4.0	$9.05^{l}\pm0.06$	$37.85^{c}\pm0.02$
S15	3.8	$7.62^{ij}\pm0.03$	$41.97^{l}\pm0.01$
S16	3.8	$8.42^{k}\pm0.07$	$42.80^{n}\pm0.03$
S17	3.9	$7.04^{de}\pm0.11$	$39.89^{g}\pm0.02$
S18	3.7	$7.32^{efgh}\pm0.05$	$42.96^{o}\pm0.02$
S19	3.8	$6.21^{bc}\pm0.05$	$39.51^{f}\pm0.03$
S20	3.8	$7.08^{def}\pm0.02$	$41.84^{k}\pm0.03$
S21	3.8	$7.69^{j}\pm0.03$	$42.31^{m}\pm0.03$
Mean	**3.8**	**7.45±0.14**	**41.30±0.33**

Source: Brar *et al* (2019)

1 FARMER'S EXPERIENCE

Name	:	**S. Satpal Singh Toor**
Address	:	**Village: Swadi Kalan** **District: Ludhiana** **State: Punjab**
Silage Production	:	**3000 Quintals Per Year**

S. Satpal Singh Toor is a landless farmer of the village Swadi Kalan. He is recipient of Parvasi Bharti Award from PAU, Ludhiana during 2022 and also appreciation award for silage making in 'An International Exhibition on Agriculture Machinery and Dairy Technology', 2023 (Ludhiana). He is having dairy farm of 62 milch animals in which the fodder requirement is fulfilled by spring maize silage making. Earlier he was meeting the requirement of his cattle with green fodder. He was facing the problem of fodder deficit during lean period and also the fluctuation in quality of fodder due to seasonal climatic variations. It resulted in decrease in production potential of dairy animals.

Pneumatic maize planter

Maize sown on broad beds

Spring maize for silage making

Later, he got knowledge regarding silage making from GADVASU Ludhiana and Punjab Dairy Development Board, Punjab. Looking at the success of the technology and foresee opportunity, he started silage making in 2017 by sowing spring maize in 20 acres of land taken on leased. To save irrigation water, he is using pneumatic planter for sowing of spring maize and following PAU recommendation. The spring maize is harvested mechanically and the fodder is ensiled in pit for minimum 45 days. He experienced that silage making ensured round the year quality fodder availability and decrease the cost of production. By adopting this technology, there is saving of labour cost

Silo

involve in daily harvesting, transportation and chopping of fodder. Due to this technology, only 3-4 labours are able to manage his dairy farm. In the present agriculture scenario of region, silage making is the only option by which the dairy farmers will able to meet fodder requirement of their cattle at lower cost. In order to decrease the cost of production of milk, he urged the government to provide subsidy to the farmers for the development of infrastructure required for silage making and also on inputs required for the raising of fodder crop for silage making.

2 FARMER'S EXPERIENCE

Name	:	**S. Gurpreet Singh**
Address	:	**Village: Kahlwan** **District: Tarn Taran** **State: Punjab**
Silage Production	:	**11000 Quintals Per Year**

S. Gurpreet Singh, a progressive dairy farmer, is a recipient of 'Chief Minister Award' in Dairy Farming from GADVASU, Ludhiana during 2019 and also won 'Progressive Dairy Farmer Award' in 2015 at 10th International Dairy and Agri Expo by Progressive Dairy Farming Association (PDFA). He got 50-days training on A.I. & V.F.A. at Regional Demonstration and Training Centre Jalandhar and one-month Dairy Farming training course from Dairy Development Board, Tarn Taran. He started dairy farming in 2005 and having dairy farm of 120 milch animals in which the fodder requirement is fulfilled by

Silage prepared at farm of Gurpreet Singh spring maize silage making. The milk production of his dairy farm is 1200 litre per day. He is cultivation spring maize for silage making on 55 acres (15 acres owned + 40 acres leased land) to fulfil the fodder requirement of his farm round the year. He is having four silo pits, each having dimensions of 110×24×6 feet. The total production of silage at dairy farm was approximately 11000 quintals per year. He reported the increase in production potential of dairy animals by 15-20 % by replacing the conventional green fodder with corn silage. To save irrigation water, he is using pneumatic planter for sowing of spring maize and following PAU recommendation. The spring maize is harvested mechanically and the fodder is ensiled in pit for minimum 45 days. With to this technology, only 8 labours are able to manage his 120 dairy animals. According to his opinion, in present scenario of increasing cost of concentrate feed, corn silage making is the only option by which the dairy farmers will able to meet the requirement of their cattle at lower cost.

Silage kept in front of mangers for feeding at farm of Gurpreet Singh

3 FARMER'S EXPERIENCE

Name	:	**S. Daljit Singh Gill**
Address	:	**Village: Mari Bohar Wali** **District: Tarn Taran** **State: Punjab**
Silage Production	:	**7000 Quintals Per Year**

S. Daljit Singh is a progressive dairy farmer of the village. His father started dairy farm in year 1986 and now he is looking after the farm. He won 40 awards in different categories of animal competitions from GADVASU, Ludhiana; PDDB, Punjab; PDFA *etc*. He did 20-days training on dairy farming organized by Deptt. of Trade Development Center Ludhiana, 40-days dairy

Scientists from IGFRI Jhansi and GADVASU Ludhiana inspecting the silage at dairy farm of Daljit Singh Gill

Daljit Singh receiving award from Minister of Animal Husbandry and Dairy Development, Punjab

training from Dairy Development Board, Amritsar and one-month dairy farming training course from Dairy Development Board, Tarn Taran.

He is having dairy farm of 80 milch animals in which the fodder requirement is fulfilled by spring maize and oat silage. The milk production of his dairy farm is 900 litre per day. He is small farmer having only 2 acres of owned land and 10 acres leased land. He is cultivation spring maize for silage making on 10 acre and oats on 7 acres. Along with this he is also purchasing spring maize fodder of 25 acres from other farmers for silage making to fulfil the fodder requirement of his farm round the year. Therefore, the spring maize and oat fodder from 42 acres is used for silage making. He is having 7 silo pits, each having dimensions of 50×15×6 feet. The total production of silage at dairy farm is approximately 7000 quintals per year. He reported the increase in production potential of dairy animals by 15 % by replacing the conventional green fodder with corn silage.

4 FARMER'S EXPERIENCE

Name : **S. Harchand Singh Sandhu**

Address : **Village: Mari Kamboki**
District: Tarn Taran
State: Punjab

Silage Production : **4000 Quintals Per Year**

S. Harchand Singh, a progressive dairy farmer, started dairy farm in year 2009. He won 10 awards in different categories of animal competitions from GADVASU, Ludhiana; PDDB, Punjab; PDFA *etc*. He did 90-days training on A.I. & V.F.A. at Regional Demonstration and Training Centre Jalandhar, 15-days dairy training from Dairy Development Board, Tarn Taran and 7 days dairy farming training course from KVK, Tarn Taran

Farmer awareness camp of KVK Tarn Taran on silage making at farm of Harchand Singh

He is having dairy farm of 50 milch animals in which the fodder requirement is fulfilled by spring maize along with green fodder. The milk production of his dairy farm is 800 litre per day. He is having only 14 acres of family land on which he is cultivating spring maize and oats for silage making. He is having four silo pits, each having dimensions of 75×15×6 feet. The total production of silage at dairy farm is approximately 4000 quintals per year. He reported the increase in production potential of dairy animals by 20-25 % by replacing the conventional green fodder with corn silage.

Official from KVK inspecting the silage at farm of Harchand Singh

4 FARMER'S EXPERIENCE

Name : **S. Dilbagh Singh Gill**

Address : **Village: Jhander Mahapurkhan**
District: Tarn Taran
State: Punjab

Silage Production : **15000 Silage bales (100 kg each)**

S. Dilbag Singh Gill, a village farmer, owns small dairy farm of 12 cattle. With the guidance of KVK Tarn Taran, he started corn silage production to fulfil the fodder demand of his own dairy farm in 2014 and got positive results. The cost of production was reduced while production potential of dairy cattle

Dilbagh Singh with his Baling Machine

was sustained. In the next year, he purchased a single row fodder harvester cum chopper machine for mechanical harvesting of spring maize. This machine reduced the labour requirement and also increased the operational efficiency. Spring maize fodder from 6-8 acres was harvested and chopped in a day with this machine.

Preparation of Silage Bales

In the next year (2016), he established a custom hiring centre and started providing the fodder harvester cum chopper machine along with tractor and trailer to other dairy farmers. On an average, he is harvesting 100-120 acres of spring maize on custom hiring basis every year for silage making. In 2018, he also purchased pneumatic planter to facilitate the sowing of spring maize on raised beds. This machine resulted in saving of irrigation water and also increased the yield of spring maize. Now, he is also providing the services of pneumatic planter to other farmers on custom hiring basis. Looking in the popularity and adoption of silage among the dairy farmers in area and increasing demand of silage, he purchased a baling machine to start silage making at commercial scale in the

Baled silage kept for sale

name of Gill Farm in 2020. The cost of machine was Rs. 15, 50,000/-. He started making silage bales and selling it to the local small dairy farmers. Now every year, he is producing and selling approximately 15000 silage bales having weight of 100 kg each. For this work, he is purchasing the fodder of spring maize from approximately 80 to 100 acres at rate of Rs 230-250/- per quintals. Maize is purchased when it reach milk stage (85 to 90 days after sowing). After harvesting, fodder is transported to farm where it is chopped and baled with low density polythene sheet. This sheet is usually purchased at a price of Rs 210 to 240/- per kg and about 400 g of sheet is used for wrapping a single bale.

The selling price of these bales varies from Rs 650 to 700/- per bale and it depends upon the purchase rate of maize fodder required for its production, and the demand of baled silage in area. He said that there is continuous demand of fodder among the small dairy farmers of area round the year.

Silage prepared at farm of Dilbagh Singh

Chapter 8

PROMOTION OF SILAGE MAKING TECHNOLOGY

PROMOTION OF SILAGE MAKING TECHNOLOGY: ROLE OF AGRICULTURAL UNIVERSITIES, KRISHI VIGYAN KENDRAS, STATE DEPARTMENTS AND FARMER ORGANIZATIONS

In order to make this technology popular in country, the role of state agricultural universities and Krishi Vigyan Kendras is very important. There is need to disseminate this technology in country by using extension network of 54 state agricultural universities, 731 KVKs and state agriculture department. The refresher courses must be organised for the agronomists and animal scientists working in these KVK's at state agricultural universities in order to update them with recent advances in this technology.

In Punjab, Guru Angad Dev Veterinary and Animal Sciences University, Punjab Agricultural University, KVK's, Punjab Dairy Development Board (PDDB), State department of Animal Husbandry and Fisheries and Progressive Dairy Farmers Association (PDFA) did exemplary work in dissemination and popularization of this technology among the farmers. There are different research project on silage making going on in these two state universities through with the recommendations were issued from the sowing of crop to silage feeding for dairy farmers. Punjab Dairy Development Board, State Department of Animal Husbandry and Fisheries are providing subsidies to the farmers under various schemes for purchase of machinery required for silage making and for construction of silo.

ICAR-ATARI Zone-I, Ludhiana through the network of its KVK's in state is promoting this technology in the state on scientific lines. OFT's were conducted at the farmers field to find out the solutions of various concerns/problems faced by farmers at local level in adopting this technology.

Sh. Narendra Singh Tomar, Hon'ble Minister of Agriculture, GOI, inspecting the technology of silage making displayed in kisan mela

After getting the results of these OFT's, front line demonstrations of silage making were organised at farmer's field. Field days were organised to show the results of these demonstration to other farmers of area to encourage the adoption of this technology.

Farmers training at KVK

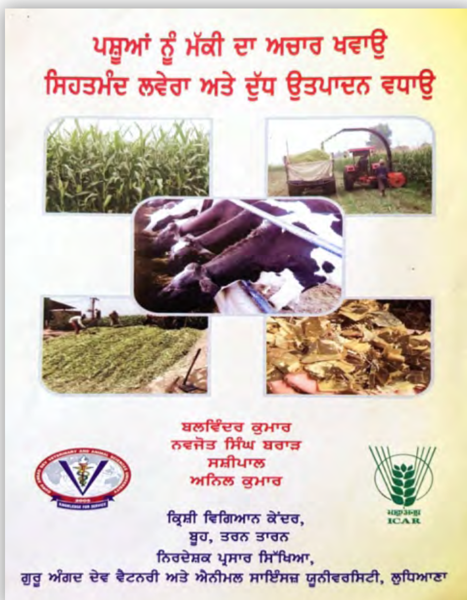
Field day on silage making

The technology is also displayed to farmers in *Kisan Melas* and *Pashu Palan Melas* organised twice every year by PAU Ludhiana and GADVASU Ludhiana every year to demonstrate the technology to the farmers. PDFA, an association of progressive dairy farmers in Punjab is also promoting the silage making by making contracts with different firms to provide inputs to the dairy farmers at discounted rate. An International Dairy and Agri Expo is organised by this association every year at Jagraon, Distt. Ludhiana in which dairy farmers from northern India participated. In this expo, the advanced technology is displayed every year for knowledge of farmers.

Field day on silage making

BOOKLETS/BULLETINS DEVELOPED ON SILAGE

Booklet/Bulletin developed in local language by GADVASU Ludhiana



Pamphlets on silage making developed by KVK Tarn Taran

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