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Advancement in Silage Additives to Improve forage Quality: A new Approach

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ABSTRACT

Silage is an important source of conserved livestock fodder, where agricultural land and year-round availability of quality forages are low. However, the primary goal of silage making is to maximum preservation of original nutrients in the forage crop for feeding of livestock at a scarcity period of fodder. The Ensiling is an anaerobic fermentation process that preserves green fodder and maintaining their nutritional value, with the help of additive. The function of additives in silage is to ensure the growth of lactic bacteria predominates during the fermentation process and producing lactic acid in high enough quantities to ensure good silage; depress the activities of unwanted microorganisms such as *clostridia* and *enterobacteria*. Moreover, by adding additive is to improve nutrient composition of silage, to reduce storage losses by promoting rapid fermentation, to reduce fermentation losses by limiting extent of fermentation, and to improve bunk life of silage (increase aerobic stability). Thus, use of advance Additives in silage like, microbial inoculants (homoferntative and heterofermentative), exogenous enzymes, aerobic spoilage inhibitors (organic acids) nutrients and adsorbents can enhance fermentation and improve silage quality. Similarly, these additives help reduce pH, undesirable microbial activity, proteolysis, nutrient losses, and ammonia production while improving aerobic stability and nutrient retention. High-quality silage contributes to better feed utilization, rumen health, animal performance, and milk production. Thus, proper ensiling practices and suitable additives are essential for producing nutritious, stable, and long-lasting livestock feed throughout the year.

Keywords: Additive, fermentation, aerobic quality, organic acid, enzymes, quality silage

INTRODUCTION

Fodder plays a crucial role in maintaining livestock health, productivity, and the safety of animal-derived food products. A balanced feed containing adequate protein, fat, carbohydrates, minerals, and vitamins is essential for optimal growth and production efficiency. India faces substantial fodder shortages, estimated at 36% for green fodder, 40% for dry fodder, and 57% for feed concentrates Saha Sk, (2020). Agricultural residues offer a potential alternative feed resource. Ensiling is an effective method for preserving crop residues and green fodder through anaerobic fermentation,

producing nutritious silage for livestock feeding. It improves year-round feed availability, reduces seasonal fodder scarcity, feed wastage, and reliance on costly concentrates. By utilizing crop residues, ensiling also helps minimize residue burning and environmental pollution, supporting a circular agricultural economy. Furthermore, mixed ensiling with suitable by-products can improve the nutritional quality of drought-affected crops and enhance livestock performance while reducing feed costs Kumar *et al.* (2019). Silage is often preferred over hay because it permits multiple harvests and is less dependent on favorable weather conditions. However, silage production presents several challenges, including variability in quality due to air exposure, which can promote undesirable microbial growth and impair fermentation. Poor-quality silage is often characterized by excessive moisture, nutrient losses, contamination, and the presence of harmful microorganisms Duniere *et al.* (2013). The use of additives during silage production can enhance fermentation, improve nutrient preservation, increase aerobic stability, and reduce spoilage. Aerobic stability refers to the ability of silage to resist deterioration when exposed to air during storage or feeding. Additives can also promote the growth and activity of beneficial microorganisms, resulting in improved silage quality, greater nutrient digestibility, and enhanced livestock performance, thereby optimizing feed efficiency and farm productivity. Depending on their type and mode of action, additives may increase dry matter, crude protein, and lactic acid contents while reducing fiber fractions, pH, and ammoniacal nitrogen, ultimately contributing to improved silage quality Muck *et al.* (2018). This review provides an overview of the different types of additives used in silage preservation, their roles and mechanisms of action during fermentation and storage, and their effects on silage quality

Phases of ensiling:

Phase	Duration	Main Events	Outcome
1. Aerobic phase	Few hours–2 days	Plant respiration and proteolysis occur; sugars are consumed and heat is produced.	Oxygen is rapidly depleted.
2. Anaerobic/ Fermentation phase	2–8 days	LAB ferment water-soluble carbohydrates and produce mainly lactic acid. pH rapidly decreases.	Undesirable microbes and proteolysis are inhibited.
3. Stable phase	Until air enters	Very little microbial activity if silo is well sealed and pH is low.	Silage remains preserved and stable.
4. Feedout/ Aerobic spoilage phase	Starts when exposed to air	Yeasts, moulds and acetic acid bacteria consume acids and nutrients, producing heat.	pH rises, causing heating, nutrient and dry-matter losses.

Advance silage additive and their major role

Silage additives are substances added during ensiling to improve fermentation, reduce nutrient losses, enhance nutritive value, palatability, and aerobic stability of silage. They may be natural or synthetic and are available in liquid or solid forms. Proper selection of additives helps improve silage quality, preservation, and storage stability Neto JM, (2018).

Type of silage additive

Sr. No.	Type of Additive	Selection of Active Ingredients	Remarks
1	Fermentation stimulants	Molasses (sugars), enzymes, and lactic acid bacteria (LAB)	May impair aerobic stability
2	Fermentation inhibitors	Formic acid, acetic acid, lactic acid, propionic acid, mineral acids, formaldehyde, sodium nitrite, and sodium metabisulphite	Inhibit clostridia and undesirable fermentation
3	Aerobic spoilage inhibitors	Propionic acid, benzoic acid, sorbic acid, and some inoculants	Help prevent aerobic spoilage
4	Nutrients	Urea, ammonia, grain, minerals, and sugar beet pulp	Can improve the nutritional value and, in some cases, aerobic stability of silage
5	Absorbents	Grain, straw, bentonite, sugar beet pulp, and polyacrylamide	Improve crop preservation and feeding value

Role of microbial inoculants on silage fermentation

There are two main types of microbial inoculants are: a) Homofermentive b) Heterofermentive

a) Homofermentative inoculants contain bacteria such as *Lactobacillus plantarum, Pediococcus* and *Lactococcus* species. They promote a rapid fermentation producing mainly lactic acid and bring the pH down to 4 rapidly, preventing further breakdown of the sugar and protein in the crop.

b) Heterofermentative inoculants-contain bacteria such as *Luconostoc Mesenteroids Lactobacillus buchneri* and *Lactobacillus brevis.* They produce a mix of lactic and acetic acid which results in a slower fermentation than the homofermentative inoculants. They are designed to inhibit yeast and moulds that initiate the process of aerobic deterioration during feed out.

Role of yeast in silage fermentation

Yeasts play an important role in improving silage fermentation, nutritional quality, and aerobic stability. *Pichia anomala* and *Saccharomyces* spp. reduce spoilage microrbs, reduces Enterobacteriaceae, and promotes lactic acid bacteria (LAB) growth with improving fermentation. Similarly, yeast inoculation with *Saccharomyces cerevisiae*, *Humicola grisea* var. *thermoidea*, and

Candida glabrata improves crude protein content, lowers pH, and suppresses spoilage organisms in rice straw silage.

Enzymes in silage fermentation

Enzymes are proteins in nature that help in metabolic processes, to digest plant fiber and starch have used as silages additives. So, Plant fiber-digesting enzymes (cellulase and hemicellulase) are the most widely used enzyme additives. These enzymes could relatively digest the plant cell walls yielding soluble sugars which could be fermented by LAB to let down the silage pH. This would get silage fermentation and improve fermentation quality by increasing the rate and extent of decline in pH, increasing the concentration of lactic acid, improving the lactic acid**:** acetic acid ratio (which is indicative of greater efficiency of fermentation), and hence reduce DM losses**.**

Role of chemical additives in silage fermentation

Chemical additives such as formic acid, formalin, propionic acid, sorbic acid, and sodium diacetate improve silage fermentation by inhibiting undesirable microorganisms and reducing pH. Combination of acid with LAB, molasses, enhance the fermentation quality, preservation, and aerobic stability of sugarcane–Napier and Napier grass silages. Urea, molasses, and probiotics improve crude protein, reduce fibre content and pH, and enhance the nutritive value, physical quality, and storage stability of silage.

Enduring some Challenges during utilization of additives

- **Variable fermentation:** LAB may not produce sufficient lactic acid, resulting in inadequate pH reduction and nutrient preservation.
- **Unpredictable microbial shifts:** Additives can alter microbial communities and sometimes favour undesirable microorganisms over beneficial bacteria.
- **Heterofermentative activity:** *L. brevis* may increase acetic acid and reduce lactic acid production, affecting fermentation efficiency.
- **Climate effects:** High temperatures accelerate undesirable fermentation and aerobic spoilage, while cold conditions can limit microbial fermentation.
- **Reduced aerobic stability:** Some additives may promote yeast growth and increase spoilage after silo opening.
- **Improper additive application:** Incorrect selection or dosage can disrupt microbial balance and reduce silage quality and stability.

CONCLUSION

In conclusion, silage additives enhance fermentation, preservation, nutritional value, and digestibility of silage. Proper selection of additives based on crop characteristics, moisture content, and pH helps reduce spoilage and improve silage quality. Thus, the effective use of additives can support better feed utilization and sustained milk production in cattle.

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