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A review on fermentation quality of paddy straw silage

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Abstract
Currently there is great deal of interest worldwide in improving the utilization of low quality roughage and straw. Paddy straw contains only 3% protein and 1900 kcal DE/kg of straw. Because of low nutritive value, it alone cannot support normal growth and development of animals. In spite of large production in India, only a small proportion of rice straw is utilized rest is burnt in the field leading to serious air pollution. Despite the improvements of crop residues through various processing methods such as physical and chemical, the efficient utilization to desirable extent is still awaited. To utilize this crop residue judiciously, there is a need for improvement of its nutritive value to promote its utilization through ensiling. Ensiling is a preservation way, but it could be beneficial, if good and scientific efforts are followed in making silage. Understanding the fundamental principle of ensiling is a prerequisite for successful silage product. Prominent factors influencing quality of silage product include water soluble carbohydrates, natural microbial population, and harvesting conditions of the forage. Various additives are used to control the fermentation processes, to enhance nutrient recovery and improve silage stability. This review emphasizes some practical aspects of silage processing and the use of additives for improvement of fermentation quality of rice straw.

Keywords: Paddy straw, stubble burning, ensiling, molasses, urea, potato vines, distiller's grains

1. Introduction
The area occupied under paddy in India is about 88.07 million hectare. We produces about 350 × 10^7 kg per year of crop residue every year, of which wheat residues constitute about 27% and rice residues about 51% [9]. Rice straw is fed to cattle and buffaloes in India since ages. Dry rice straw is not a suitable feed for ruminant animals because rice straw has limited nutritive value (low crude protein and digestibility & high level of lignification and silicification. Rice straw contains about 3% crude protein (air dry basis), 35% crude fiber and 1900 kcal DE/kg of straw. Because of its low energy and protein content, the straw alone cannot support normal growth, causing a loss of body mass it should be used only as a replacement for part of the forage in a ration. It should not be used as a complete ration. Poorer animal performance has usually occurred when rice straw was the only feed; therefore suitable treatment for rice straw is necessary.

2. The Produce of Crop Stubble and Stubble Burning
In spite of a very high production a very little proportion of paddy straw is utilized as roughage due to its poor feeding value. The remaining is used as firewood, or directly burnt in the field so as to cause serious air pollution. Despite a ban on stubble burning by the National Green Tribunal (NGT) and Pollution Control Board, Indian farmers continue to defy the orders with impunity. In Punjab only a large portion, 12 million tonnes of rice straw is subjected to burning [18] in fields primarily to clear them prior to the sowing of wheat crop. Karnal was among the top violator districts in Haryana and a major contributor to pollution caused by stubble burning. Burning of farm waste causes severe pollution of land and water on local as well as regional scales. It is estimated that the burning of straw results in nutrient losses and adversely affects the nutrient budget in the soil. Burning agriculture residues has multiple negative effects including local air pollution, increase in black carbon and contributions to regional and global climate change [4]. It results in the emission of smoke which if added to the gases present in the air like methane, nitrogen oxide and ammonia, can cause severe atmospheric pollution. One tonne of straw on burning releases 3 kg of particulate matter, 60 kg

of CO, 1460 kg of CO2, 199 kg of ash and 2 kg of SO [5]. These gaseous emissions can result in health risk, aggravating asthma, chronic bronchitis and decreased lung function. Burning of crop residue also contributes indirectly to the increased ozone pollution. On the other hand, non - burning of residue and its incorporation, in the long run, improves the chemical properties of soil and paves way for sustainable agriculture and natural resources [5].

3. Rice straw as feed

Rice straw is poorly palatable and its intake by animals is low. However, the intake of straw depends on straw type (coarse, fine, long, dwarf, leafy, steamy, fresh, stored, hard, soft), animal species and breed, body weight of animals, other feed in the ration, physiological state, climatic stress etc. In general, fine (slender), soft, long, leafy and stored rice straw is preferred by animals. The Dry Matter Intake (DMI) is highest in buffaloes followed by cattle, whereas sheep and goats have relatively low DMI's. However, Dry Matter Digestablity (DMD) is similar in cattle, buffaloes and goats but, seems lower in sheep. Rice straw is a poor quality feed in terms of protein and mineral content. It is high in lignocellulose and insoluble ash. The chemical composition on a dry matter basis is presented in Table 1.

Table 1: Chemical composition of rice straw (% on dry matter basis)

Organic Matter	82%
Crude Protein	4%
Crude Fibre	37%
Non Fatty Esters	43%
Total ash	18%
Calcium	0.14%
Phosphorus	0.05%
Neutral Detergent Fibre	75%
Acid Detergent Fibre	54%
Cellulose	37%
Lignin	8%
Silica	8%

4. Ensiling of paddy straw

Although paddy straw is of tremendous value to the farmers, the problem of on-farm burning of paddy straw is intensifying in recent years due to the shortage of human labour, high cost of removing the straw by conventional methods, low feeding value and surplus maize fodder in some parts of the major rice producing states [15]. Various farmers in India are of the view that the burning of straw is an easy way to decompose. Therefore, improving availability of rice straw has become a great concern. Not only, that, such burning can cause many possible accidents, for example, there was a man who died in a rice straw burning in Ambala Haryana [19]. Instead of burning the by-products as waste, the rice straw can be potentially utilized in silage production. In the past, some physical, chemical and microbial treatments were tried to improve the feeding value of rice straw, but they were proven ineffective. Many methods were used to improve the low nutritive value of straws, which was attributed to the low content of crude protein and high content of crude fiber. It was reported that the correct chemical treatment of straws improved crude protein digestibility [13]. Fresh rice straw can be made into silage [20]. In recent years, Japanese and Korean studies showed an improvement in feeding value of rice straw by ensiling. Further studies showed that ensiling rice straw with 4% or 6% Ca $(OH)_2$ gave higher in-vitro dry matter digestibility (IVDMD) [16]. However, successful ensiling of rice straw is difficult due to its hollow stem, low water soluble carbohydrates (WSC) and less epiphytic lactic acid bacteria (LAB) [3].

5. Use of lactic Acid Bacteria (LAB)

In order to improve the fermentation quality of rice straw silage, some commercial LAB have been developed as additives for ensiling. For example, it was found that application of LAB to round baled, whole crop rice could improve the silage quality with lower pH value, butyric acid (BA) and ammonia nitrogen (NH-N) concentrations, and higher lactic acid (LA) and crude protein (CP) concentrations [3]. The inoculation with *Lactobacillus plantarum* could lower the pH value and BA concentration, and increase LA, acetic acid (AA), and CP concentrations in the rice straw silage [7]. Additionally, inoculation with LAB could also decrease neutral detergent fibre (NDF) and acid detergent fibre (ADF) concentrations, and increase digestibility of dry matter (DM) and NDF of rice straw silage. Inoculation with LAB improved the fermentation as reflected in reductions in pH, acetic acid (by 3.7 to 78.3%), butyric acid (by -6.0 to 100.0%) and ammonia nitrogen (by 1.0 to 71.7%) concentrations, and increases in lactic acid (by 43.9 to 282.9%) and crude protein concentrations compared with the control [8].

6. Ensiling straw with Sugar Rich Products

Ensiling is a preservation way, but it could be beneficial, if a good and scientific effort were followed in making silage. Sugar or sugar-rich materials (like molasses, glucose etc.) are used as effective additives for ensiling crops that have low WSC. However, adding sugar alone might induce the proliferation of undesirable microorganisms and thus result in fermentation losses [3].Therefore, it is better to use the combination of sugar and LAB for ensiling rice straw [10] [3]. Molasses has been proven to be an effective silage additive by promoting lactic acid bacteria fermentation, reducing silage pH, discouraging clostridia fermentation and proteolysis, and generally decreasing organic matter losses when applied to crops with low water soluble carbohydrates (WSC) [2]. Compared to rice straw silage, molasses addition alone significantly decreased NDF and ADF, probably due to acid hydrolysis of cell walls carbohydrates resultant from reduction in silage pH by lactic acid fermentation [1]. However regardless of condition of rice straw it was hard to achieve good silage where few of the silage bales developed visible white mold and light musty odor. Molasses or inoculant alone could not improve fermentation quality and nutritional value of rice straw silage; except that inoculant decreased NH_3-N/TN and molasses decreased structural carbohydrate content [22]. Application of LAB plus glucose was more effective in improving fermentation quality than LAB alone. The variety of rice straw which contained relatively high levels of water soluble carbohydrates (WSC) tended to obtain better fermentation quality [8]. LAB inoculation, especially the addition together with cellulase, improves the fermentation quality of wheat straw silage [11]. Rice-straw was ensiled with a 5-6% urea solution for 3 weeks before being fed. Cattle fed with urea-ensiled rice straw alone can maintain weight. However, to obtain a daily weight gain of 300-450 g in Holstein Friesian heifers (8-12 months old) fed with urea-ensiled rice straw it is necessary to supplement with some form of concentrate [14]. The cattle fed with urea-ensiled rice straw alone, can maintain normal growth and sometimes increase body mass (ADG of 35-400 g) [14].

7. Ensiling straw with Agricultural Products

Sugar rich materials like sugar beet, potatoes, apple pomace, rice bran, Distiller's grains and other agricultural by products are also commonly used as effective additives for ensiling crops that have low WSC. Adding sweet potato vine was effective in improving the fermentation quality of rice straw silages with lower pH value, NH3-N ratio of total N and propionic acid content, and higher concentrations of lactic acid and acetic acid [8]. The ensiling of straw with fruit pomace or poultry excreta does not need sophisticated infrastructure with such facilities available at farmer's level. The application of a large amount of effective microbial culture to rice straw and bran ensiled at different ratios produced well-preserved silage but too high amount can affect the ash content [17]. Distiller's grains addition alone improved the fermentation quality even at the lowest level of inclusion, revealing lower pH and BA concentration, and higher LA/AA, WSC and LA concentration. Plant respiration and aerobic bacteria dominated the initial stage of ensiling due to poor compaction for rice straw silage resulted in the fermentable substrates and nutrient loss, while residual ethanol contained in distiller's grain possessed the ability to depress the growth of clostridia and other undesirable aerobic bacteria 2)[12]. Combined addition of distiller's grains and molasses further improved the fermentation quality compared to silage with molasses alone; however, there were no great differences in pH, LA and BA concentrations among combination addition silages. Based on the perspective of maximum utilization of rice straw, the mixture of rice straw and distiller's grains at 9:1 associated to 5% molasses at ensilage was recommended for efficiently utilizing rice straw [21].

8. Conclusion

Utilization of paddy straw can be improved by various physical, chemical and biological methods including ensiling. The ensiling of paddy straw is very difficult due to its low Water Soluble Carbohydrate concentration and less epiphytic Lactic Acid Bacterial count. However to improve its fermentation quality sugar rich material can be added along with LAB cultures. Ensiling paddy straw alone with molasses may or may not improve its quality; in turn it may deteriorate due to development of undesirable microbes, yeasts and moulds. Ensiling straw and molasses with Effective Microbial culture (like LAB) can give better results than ensiling alone with molasses. Paddy or wheat straw can be ensiled with sugar rich agricultural byproducts like apple pomace, potato vines, sweet potatoes and sugar rich fodders like maize, sorghum etc. Inclusion of paddy straw in silage may turn out to be beneficial by reducing cost of silage production, improving its own utilization and reducing air pollution, which is otherwise caused by stubble burning.

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