Forage Res., **40** (3) : pp. 154-158 (2014) **http://forageresearch.in**

UTILIZATION OF PADDY STRAW AS ANIMAL FEED

ANIL KUMAR*, VIJAY K. SINGH[1], NARENDER AND RAJENDER KUMAR[2]

Department of Farm Machinery & Power Engineering
Haryana Agricultural University,
Hisar-125 004 (Haryana), India
**(e-mail : anil_saroha@rediffmail.com)*
(Received : 15 September 2014; Accepted : 21 December 2014)

SUMMARY

This review paper describes the improvement of the degradability and voluntary intake of rice straw. After the review it was found that the pretreatment of paddy straw should either be avoided or made simple and cheap so that the process of treatment is economically viable. There is a need for improvement of already existing strains of lignin degrading micro-organisms. The large scale treatment methods of feed production from paddy straw should be standardized and the end-product should be evaluated, so that no toxic end-products are present.

Key words : Paddy straw, treatment, value addition

In tropical zones in the world, ruminants depend on year-round grazing on natural pastures or the animals are fed with cut grass and crop residues. Most of these areas face seasonal dry periods in which the availability of pasture decreases and also its quality by a reduction in the content of digestible energy and nitrogen. Due to the fact that in these areas paddy straw is abundantly available from cultivating paddy, farmers offer rice straw as the main roughage source to their animals. In most of the developing countries, the fast increasing population size leads to an even increasing demand for food grains for human consumption, which does not leave sufficient land for the cultivation of animal feed crops. According to an estimate of National Commission of Agriculture, there is a deficiency of concentrates and green fodders in India (Kamra, 1998). Paddy straw is the stem part of the rice plant that remains in the paddy after the head has been harvested. It is generated at the tune of about 1.0-1.5 tonnes per tonne of paddy harvested (Singh *et al.,* 1998).

In past years, several studies have been reported on the physical and chemical characterization and utilization of rice straw as ruminant feed (Shen *et al.,* 1998; Abou-El-Enin *et al.,* 1999; Vadiveloo, 2000, 2003). In addition, numerous methods of physical, chemical and biological treatments have been investigated, including supplementation with other feed stuffs or components in order to improve the utilization of paddy straw by ruminants (Reddy, 1996; Karunananda and Varga, 1996a,b; Shen *et al.,* 1999; Vu *et al.,* 1999; Liu and Orskov, 2000; Selim *et al.,* 2004). Paddy straw is usually fed untreated without supplements in spite of the fact that many methods for improved utilization of rice straw have been developed and recommended. There are several reasons for farmers not to apply the already developed methods for improved utilization of straw, such as physical, socio-economic conditions and practical reasons (Devendra, 1997). In general, the use of rice straw as an animal feed as well as its treatment is always an economic decision. Ruminants by the virtue of microbial population present in their rumen can digest cellulose-a high molecular weight polymer of glucose in the native form. But in paddy straw cellulose occurs in association with hemicellulose and lignin, a high molecular weight, three dimensional random polymer of phenyl propane alcohol. Chemically, lignin-carbohydrate bond forms metabolic blocks that generally limit the action of microbial hemicelluloses and cellulases. Unless the lignin is depolymerized, solubilized or removed, the cellulose and hemicellulose cannot be utilized for their conversion into protein by micro-organisms. It has been estimated that one tonne of straw on burning release 3 kg particulate matter, 60 kg CO, 14.06 kg CO_2, 199 kg and 2 kg SO_2, (Gupta *et al.,* 2004). The large amount of rice straw as a by-product of the rice production is mainly used as a source of feed for ruminant livestock. Rice straw is rich in polysaccharides and has a high lignin and silica content,

[1]Department of Processing & Food Engineering.
[2]Basic Engineering Section.

limiting voluntary intake and reducing degradability by ruminal microorganisms. The use of fungi or enzyme treatments is expected to be a more practical and environmental-friendly approach for enhancing the nutritive value of rice straw and can be costeffective in the future. Using fungi and enzymes might be combined with the more classical chemical or physical treatments.

Eight male cattle of Local Yellow breed with an average live weight of 121 kg and an average age of 18 months were used to evaluate the effects of different levels of sun-dried cassava foliage supplementation (*Manihot esculenta*) on intake, digestibility and N retention (Sath *et al.*, 2012). Using the long form combined with urea treatment of rice straw improved feed intake, digestibility, rumen fermentation and efficiency of microbial N synthesis in crossbred dairy steers (Gunun, *et al.*, 2013). Using a proper amount of coarse-texture rice straw with high value nutritive alfalfa pellets may stimulate chewing activity in dairy cows without decreasing milk yield and composition even though the quantity of rice straw was 40 per cent of TH (Na *et al.*, 2014). Rural communities need a source of energy for electrical energy and small industry. Determination of the potential surplus of rice straw performed by compared the total potential of rice straw produced and portion used for other usage such as animal feed and raw materials for industry (Anshar *et al.*, 2015).

The aim of this contribution is to provide an overview of existing knowledge on how to treat rice straw to increase its feed value for ruminants. Emphasis is placed on new approaches using various physical, chemical and biological methods which have been tried for increasing the digestibility of paddy straw.

Value Addition in Paddy Straw Using Physical Treatments

Crop residues can be ground, soaked, pelleted or chopped to reduce particle size or can be treated with steam or X-rays or pressure cooked. Steam under high pressure makes the lignocellulosic complex in paddy straw, easily accessible to hydrolytic enzymes, thus increasing ruminant digestibility (Walker, 1984). Solar digesters to wet pasteurize straws, reducing microbial levels precluding competition with ligninolytic organisms. The pasteurization treatment increased the available cellulose by 20-40 per cent, thus increasing the digestibility of straw as feed (Milstein *et al.*, 1987). Uden (1988) observed that grinding and pelleting of grass hay decreased dry matter degradability in cows from 73 to 67 per cent, which was mainly due to a decreased fermentation rate (9.4-5.1%/h) and decreased total retention time of the solids from 73 to 54 h, resulting in an increased intake (Stensig *et al.*, 1994). Rivers (1988) milled paddy straw until passing a 1-mm screen in a cyclotec laboratory mill to simulate comminution in a fine grind from a hammer mill and observed that milling did not change much, the cellulose crystallinity index.

Liu *et al.* (1999) reported that the use of steam treatment in a high pressure vessel at different pressures and for a range of different treatment times increased the degradation *in vitro* in rumen fluid after 24 h and the rate of degradation, but could not enhance the potential degradability of the fibrous fractions. Ooshima *et al.* (1984) irradiated paddy straw with 84 per cent water content with microwave (2450 MHz) in sealed glass vessels and observed marked enhancement in the accessibility of the cellulosic materials, which resulted in increased digestibility of the straw. Physical treatments of crop residues have received an appreciable amount of research. Many of these treatments are not practical for use on small-scale farms, as they require machines or industrial processing. This makes these treatments in many cases economically unprofitable for farmers as the benefits may be too low or even negative (Schiere and Ibrahim, 1989).

Value Addition in Paddy Straw Using Chemical Treatments

Chemicals to improve the utilization of rice straw may be alkaline, acidic or oxidative agents. Among these, alkali agents have been most widely investigated and practically accepted for application on farms. Basically, these alkali agents can be absorbed into the cell wall and chemically break down the ester bonds between lignin and hemicellulose and cellulose, and physically make the structural fibers swollen (Chenost and Kayouli, 1997; Lam *et al.*, 2001).

Urea and molasses treatment of paddy straw increases the palatability and so voluntary intake by cattle, in addition to the increased nutritional value. But its application is not economically feasible as supplementation with starch substance like cereal grain is required (Ranjan and Khera, 1976). Urea either as uromol or after its microbial bioconversion can make straws as complete and safe basal ration for ruminants when supplemented with a little cereal or cereal by-products source (Langar *et al.*, 1985).

As urine contains urea, urine can be used as a source of urea and ammonia to improve the quality of rice straw. Urine can be sprayed on the straw in a similar way as is done with urea solutions (Dias da Silva, 1993) and can provide a nearly equal improvement of the degradability and nitrogen content as other methods of ammonia treatment (Dias da Silva, 1993; Schubert and Flachowsky, 1994). However, research on this subject has been quite limited and there is currently inadequate information available to define clearly the conditions to optimize urine treatment (Dias da Silva, 1993). Moreover, the use of urine is hampered by the difficulty of separation of urine from feces in ruminant husbandry. This also makes the use of urine rather unhygienic and therefore not advisable to use, although its use is without costs for farmers and urine is normally available in excess.

Several NaOH treatment methods to improve the use of crop residues for ruminant feeding have been developed as reviewed by Jackson (1977), Berger *et al.* (1994) and Arieli (1997). The principal advantages of the different NaOH treatment methods increase degradability and palatability of treated straw, compared to untreated straw (Chaudhry and Miller, 1996; Vadiveloo, 2000). However, NaOH is not widely available as a resource for small-scale farmers and may be too expensive to use. In addition, the application of NaOH can be a cause of environmental pollution, resulting in a high content of sodium in the environment (Sundstol and Coxworth, 1984).

Value Addition in Paddy Straw Using Biological Treatments

The metabolize lignocelluloses of fungi is a potential biological treatment to improve the nutritional value of straw by selective delignification, as mentioned in the review by Jalc (2002). Nevertheless, it is currently too early to apply this method in developing countries due to the difficulties and lack of technology to produce large quantities of fungi or their enzymes to meet the requirements. There are also a number of serious problems to consider and overcome (Schiere and Ibrahim, 1989). For example, the fungi may produce toxic substances. It is also difficult to control the optimal conditions for fungal growth, such as pH, temperature, pressure, O_2 and CO_2 concentration when treating the fodder. With recent developments in fermentation technology and alternative enzyme production system, the costs of these materials are expected to decline in the future. Hence, new commercial products could play important roles in future ruminant production systems (Beauchemin *et al.*, 2004).

Shetty and Krishnamurthy (1980) noted 50 per cent increase in nitrogen and protein of rice straw cultivated with *Pleurotus sajor caju* which indicated possibility of dual purpose of improving feed quality of paddy straw and mushroom production. Langer *et al.* (1980) cultivated *Agaricus bisporus* and *Volvariella displasia*, respectively, on wheat and paddy straw. The crude protein, cell soluble and lignin contents increased in post fungal harvested straw unlike that in the untreated straw. Zafar *et al.* (1981) reported a 43 per cent *in vivo* digestibility of paddy straw biodegraded by *Pleurotus sajor caju* as compared with 28.3 per cent for the non-biodegraded rice straw. Paddy straw was nutritionally upgraded as feed by fermentation with Cellulomonas species by Thanikachalam and Rangarajan (1986).

White-rot fungi treatment : White-rot fungi, belonging to the wood-decaying *basidiomycetes*, as lignocellulolytic microorganisms are able to decompose and metabolize all plant cell constituents (cellulose, hemicellulose and lignin) by their enzymes (Eriksson *et al.*, 1990). Many species of white-rot fungi which are effective lignin degraders have been used to assess their ability to improve the nutritive value of fodder for ruminant nutrition (Yamakava and Okamnto, 1992; Howard *et al.*, 2003). Using white-rot fungi to increase the degradability of straw is often at the expense of easy assessable carbohydrates, such as cellulose and hemicellulose, resulting in less degradable feed for ruminants (Karunanandaa *et al.*, 1995; Karunanandaa and Varga, 1996a, b; Jalc, 2002). Rodrigues *et al.* (2008) were able to extract the enzymes from white-rot fungi that are responsible for breaking down the bonds in lignin and within the matrix of cell wall carbohydrates, but without also extracting enzymes affecting hemicelluloses and cellulose.

Exogenous fiber-degrading enzyme treatment : Most commercially available exogenous fiber-degrading enzyme products consist of cellulases and xylanases, as produced for non-feed applications. Twenty-two commercial enzyme products were examined for biochemical characteristics and for *in vitro* ruminal degradation of alfalfa hay and corn silages (Comlombatto *et al.*, 2003b).

CONCLUSIONS

Although several treatments have been used to improve the degradability and voluntary intake of rice straw, such as physical, chemical and biological treatments, the practical use of these treatments is still restricted in terms of safety concerns, costs and potentially negative environmental consequences. The pre-treatment of paddy straw should either be avoided or made simple and cheap, so that the process of treatment is economically viable. There is a need for improvement of already existing strains of lignin degrading micro-organisms. The large scale treatment methods of feed production from paddy straw should be standardized and the end- product should be evaluated, so that no toxic end-products are present.

REFERENCES

Abou-EL-Enin, O. H., J. G. Fadel, and D. J. Mackill. 1999 : Differences in chemical composition and fibre digestion of rice straw with and without anhydrous ammonia from 53 rice varieties. *Anim. Feed Sci. Technol.* **79** : 129-136.

Anshar, M., F. A. Nasir, and A. S. Kader. 2015 : Potential surplus of rice straw as a source of energy for rural communities in Indonesia. *Appl. Mech. and Mate.* **695** : 806-810.

Arieli, A. 1997 : Whole cottonseed in dairy cattle feeding : a review. *Anim. Feed Sci. Technol.*, **72** : 97-110.

Beauchemin, K. A., D. Colombatto, and D. P. Morgavi. 2004. A rationale for the development of feed enzyme products for ruminants. *Can. J. Anim. Sci.*, **84** : 23-36.

Berger, L. L., G. C. Fahey, L. D. Bourquin, and E. C. Tilgeyer. 1994 : Modification of forage quality after harvest. In : *Forage Quality, Evaluation and Utilisation*, G. C. Fahey (ed.). American Society of Agronomy, Inc, Madison, USA. pp. 922- 966.

Chaudhry, A. S., and E. L. Miller. 1996 : The effect of sodium hydroxide and alkaline hydrogen peroxide on chemical composition of wheat straw and voluntary intake, growth and digesta kinetics in store lambs. *Anim. Feed Sci. Technol.* **60** : 69-86.

Chenost, M., and C. Kayouli. 1997 : *Roughage Utilisation in Warm Climates*. FAO Animal Production and Health Paper 135, Rome.

Colombatto, D., D. P. Morgavi, A. F. Furtado, and K. A. Beauchemin. 2003b : Screening of exogenous enzymes for ruminant diets : relationship between biochemical characteristics and *in vitro* ruminal degradation. *J. Anim. Sci.* **81** : 2628-2638.

Devendra, C. 1997 : Crop residues for feeding animals in Asia : Technology development and adoption in crop/livestock systems. In : *Crop Residuals in Sustainable Mixed Crop/Livestock Farming System*, C. Renard (ed.). CAB International, Wallingford, UK. pp. 241-267.

Dias da Silva, A. A. 1993 : Upgrading of low quality feeds by means of urinary urea. In : *Urine–a Wasted Renewable Natural Resource*, F. Sundstøl and E. Owen (eds.). NORAGRIC Occasional Papers Series C. *Development and Environment*, **12** : 42-49.

Eriksson, K-EL, R. A. Blanchette, and P. Ander. 1990 : Microbial and enzymatic degradation of wood and wood components. Springer, Berlin, Heidelberg, New York.

Gunun, P., M. Wanapat, and N. Anantasook. 2013 : Effects of physical form and urea treatment of rice straw on rumen fermentation, microbial protein synthesis and nutrient digestibility in dairy steers. *Asian-Aust. J. Anim. Sci.*, **26** : 1689-1697.

Gupta , P. K., Sahai, S., Singh, N., Dixit, C. K., Singh, D. P., Sharma, C., Tiwari, M. K., Gupta, R. K., and Garg, S. C. 2004 : Residue burning in rice-wheat cropping system : Causes and implication. *Curr. Sci.*, **87** : 1713-1717.

Howard, R. L., E. Abotsi, E. L. Jansen, and S. Howard. 2003 : Lignocellulose biotechnology : Issues of bioconversion and enzyme production. *Afr. J. Biotechnol.*, **2** : 602-619.

Jackson, M. G. 1977 : Review article : The alkali treatment of straw. *Anim. Feed Sci. Technol.*, **2** : 105-130.

Jalc, D. 2002 : Straw enrichment for fodder production by fungi. In : *The Mycota XI Agricultural Applications*, F. Kempken (ed.). Springer-Verlag, Berlin, Heidelberg. pp. 19-38.

Kamra, D. N. 1998 : Biodelignification of lignocellulosic feeds with white rot fungi for the feeding of ruminants. In : *Fungi in Biotechnology'* Edited by AnN Prakash. pp. 81.

Karunanadaa, K., and G. A. Varga. 1996a : Colonization of rice straw by white-rot fungi (*Cyathus stercoreus*): Effect on ruminal fermentation pattern, nitrogen metabolism and fiber utilization during continuous culture. *Anim. Feed Sci. Technol.*, **61** : 1-16.

Karunanadaa, K., and G. A. Varga. 1996b. Colonization of rice straw by white-rot fungi : cell wall monosaccharides, phenolic acids, ruminal fermentation characteristics and digestibility of cell wall fiber components *in vitro*. *Anim. Feed Sci. Technol.*, **63** : 273-288.

Karunanandaa, K., G. A. Varga, D. E. Akin, L. L. Rigsby, and D. J. Royse. 1995 : Botanical fractions of rice straw colonized by white-rot fungi : Changes in chemical composition and structure. *Anim. Feed Sci. Technol.*, **55** : 179-199.

Lam, T. B. T., K. Kadoya, and K. Iiyama. 2001 : Bonding of hydroxycinnamic acids to lignin : ferulic and p-coumaric acids are predominantly linked at the benzyl position of lignin, not the b-position, in grass cell walls. *Phytochem.*, **57** : 987-992.

Langar, R. N., J. R. Sehgal, and H. S. Garcha. 1980 : Chemical changes in wheat and paddy straws after fungal cultivation. *J. Anim. Sci.*, **50** : 942.

Langar, R. N., M. R. S. Bakshi, and V. K. Gupta, 1985 :

Utilization of Agricultural Wastes. Proc. Symposium held on 25th Feb., 1984, PAU, Ludhiana.

Liu, J. X., and E. R. Orskov. 2000. Cellulase treatment of untreated and steam pre-treated rice straw-effect on *in vitro* fermentation characteristics. *Anim. Feed Sci. Technol.,* **88** : 189-200.

Liu, J. X., E. R. Orskov, and X. B. Chen. 1999 : Optimization of steam treatment as a method for upgrading rice straw as feeds. *Anim. Feed Sci. Technol.,* **76** : 345-357.

Milstein, O., A. Bechar, L. Shragina, and J. Gressal1. 1987. Solar pasteurization of straw for nutritional upgrading and as substrate for ligninolytic organisms. *Biotechnol. Letters,* **9** : 269-274.

Na, Y. J., I. H. Lee, S. S. Park, and S. R. Lee. 2014. Effects of combination of rice straw with alfalfa pellet on milk productivity and chewing activity in lactating dairy cows. *Asian-Aust. J. Anim. Sci.,* **27** : 960-964.

Ooshima, H., K. Aso,Y. Harana, and T. Yamamota, 1984 : Microwave treatment of cellulosic materials for their enzymatic hydrolysis. *Biotechnol. Let.,* **6** : 289-294

Ranjan, S. K., and R. C. Khera. 1976 : Feeding for animals during scarcity. ICAR Publication 15.

Reddy, D. V. 1996 : Evaluation of rice straw-poultry droppings based rations supplemented with graded levels of rice bran in fistulated buffaloes. *Anim. Feed Sci. Technol.,* **58** : 227-237.

Rivers, D. B. 1988 : Factors affecting the enzymatic hydrolysis of bagasse and ricestraw. *Biological Wastes.,* **26** : 85-95.

Rodrigues, M. A. M., P. Pinto, R. M. F. Bezerra, A. A. Dias, C. V. M. Guedes, V. M. G. Gardoso, J. W. Cone, L. M. M. Ferreira, J. Colaco, and C. A. Sequeira. 2008. Effect of enzyme extracts isolated from white-rot fungi on chemical composition and *in vitro* digestibility of wheat straw. *Anim. Feed Sci. Technol.,* **141** : 326-338.

Sath, K., K. Sokun, T. Pauly, and K. Holtenius. 2012 : Feed intake, digestibility, and N retention in cattle feed rice straw and para grass combined with different levels of protein derived from cassava foliage. *Asian-Aust. J. Anim Sci.,* **25** : 956-961.

Schiere, J. B., and M. N. M. Ibrahim. 1989. Feeding of urea-ammonia treated rice straw : A compilation of miscellaneous reports produced by the Straw Utilization Project (Sri Lanka). Pudoc, Wageningen.

Schubert, R., and G. Flachowsky. 1994 : Investigations on nitrogen flow into and out of nylon bag after ruminal incubation and feeding of untreated or 15N horse urine treated wheat straw in small ruminants. *Anim. Feed Sci. Technol.,* **48** : 199-209.

Selim, A. S. M., J. Pan, T. Takano, T. Suzuki, S. Koike, Y. Kobayashi, and K. Tanaka. 2004 : Effect of ammonia treatment on physical strength of rice straw, distribution of straw particles and particle-associated bacteria in sheep rumen. *Anim. Feed Sci. Technol.,* **115** : 117-128.

Shen, H. S., D. B. Ni, and F. Sundstol. 1998 : Studies on untreated and urea-treated rice straw from three cultivation seasons: 1. Physical and chemical measurements in straw and straw fractions. *Anim. Feed Sci. Technol.,* **73** : 243-261.

Shen, H. S., F. Sundstol, E. R. Eng, and L. O. Eik. 1999. Studies on untreated and urea-treated rice straw from three cultivation seasons. 3. Histological investigations by light and scanning electron microscopy. *Anim. Feed Sci. Technol.,* **80** : 151-159.

Shetty, K. Shivappa, and V. Krishnamurthy. 1980. Feasibility of protein enrichment of paddy straw by mushroom *Pleurotus sajor caju.* In : *Recycling Residues of Agricultural and Industry,* edited by M. S. Kaira.

Singh, K., G. R. Singh, and B. N. Gupta. 1998 : Fungal biotechnology for animal feed. In : *Fungal Biotechnology,* edited by Anil Prakash. pp. 237-245.

Stensig, T., M. R. Weisbjerg, J. Madsen, and T. Hvelplund. 1994. Estimation of voluntary feed intake from *in sacco* degradation and rate of passage of DM or NDF. *Livest. Prod. Sci.,* **39** : 49-52.

Sundstol, F., and E. M. Coxworth. 1984. Ammonia treatment. In : *Straw and Other Fibrous By-products as Feed.* Veterinary Sciences, 14. Elsevier, Amsterdam. pp. 196-247.

Thanikachalam, A., and M. Rangarajan. 1986 : Protein enrichment of rice straw by fermentation with collulomonas sp. *Agril. Wastes,* **15** : 215-224.

Uden, P. 1988 : The effect of grinding and pelleting hay on digestibility, fermentation rate, digesta passage and rumen and faecal particle size in cows. *Anim. Feed Sci. Technol.,* **19** : 145- 157.

Vadiveloo, J. 2000. Nutritional properties of the leaf and stem of rice straw. *Anim. Feed Sci. Technol.,* **83** : 57-65.

Vadiveloo, J. 2003. The effect of agronomic improvement and urea treatment on the nutritional value of Malaysian rice straw varieties. *Anim. Feed Sci. Technol.,* **108** : 33-146.

Vu, D. D., L. X. Cuong, C. A. Dung, and P. H. Hai. 1999 : Use of urea-molasses-multinutrient block and urea-treated rice straw for improving dairy cattle productivity in Vietnam. *Prev. Vet. Med.,* **38** : 187-193.

Walker, H. A. 1984 : Physical treatment. In : *Straw and Other Fibrous By-products as Feed.* F. Sundstol and E. Owen (eds.). Elsevier, Amsterdam. pp. 79.

Yamakava, M., and H. A. Okamnto. 1992. Effect of incubation with edible mushroom, *Pleurotus ostreatus* on voluntary intake and digestibility or rice bran by sheep. *Anim. Feed Sci. Technol.,* **63** : 133-138.

Zafar, S. l., T. Kansar, and F. H. Shah. 1981. Biodegradation of the cellulose component of rice straw by *Pleurotus sajorcaju* Folia. *Microbiol.,* **26** : 394-397.