TREATMENT OF FRESH RICE STRAW FOR IMPROVEMENT OF ITS UTILIZATION AS RUMINANT FEED

Nguyen Xuan Trach, Bui Quang Tuan, Mai Thi Thom, Le Van Ban
Hanoi University of Agriculture

SUMMARY

Treatment of fresh straw right after harvesting was tried as an effort for improvement of its utilization as feed for cattle and buffaloes. Fresh straw was ensiled with either molasses (0, 1, 2, and 3% w/w) or urea (1, 1.5, and 2% w/w) in small silos for 30, 60 or 90 days. Evaluation was made based on color, mold, smell, pH, chemical composition (DM, CP, ADF, NDF, ADL, ash), in-sacco degradability and cattle responses (voluntary intake and growth rate). Results showed that straw silage making with molasses reduced pH low enough for effective preservation of straw with good color and smell. However, an upper part of straw silage was molded. Especially, silage making of fresh straw without addition of molasses resulted in extensive mold development and could not reduce pH low enough for good preservation. Whereas, urea treatment allowed to preserve fresh straw without mold and with dramatically increased crude protein, highly increased pH (>8), significantly reduced NDF, and improved in-sacco degradability. Straw dry matter intake was significantly higher (P<0,05) in cattle fed on fresh straw treated with 1.5% urea as compared with those fed on dry straw. The average daily gain (ADG) was higher in 1.5% urea treated FRS and 4% urea treated dry straw fed cattle (357.3 and 337.9 g/head/day, respectively) in comparison with in cattle fed untreated dry straw (209.3g/head/day). It is therefore concluded that fresh rice straw can be treated with 1.5-2% urea for long term preservation with improved feeding value.

Key words: Fresh rice straw, chemical composition, pH, in-sacco, intake, cattle, ADG

Introduction

Cattle in Vietnam are underfed during the winter time while rice straw is abundant (Nguyen Xuan Trach, 1998). Because rice straw is voluminous it is costly for farmers to transport and store and difficult for cattle to consume enough nutrients. Although numerous methods of treatment have been developed to improve the feeding value of rice straw **(**Schiere and Ibrahim, 1989), the level of practical application by farmers has been limited (Devendra, 1997). One of the reasons is that the techniques which have been developed are for dry straw treatment. That is, the farmer has to dry straw and store it for a long time before treatment. This is inconvenient for farmers because: (1) It is time and labor consuming while the farmer is too busy with rice harvesting, (2) It is subjected to weather conditions, (3) It requires large space for straw drying and storing in addition to the space needed for treatment (silo), and (4) It causes much loss of nutrients during the drying process. Consequently, while cattle are in shortage of forage, vast amounts of rice straw are left or burnt in the field. If there is a method to preserve and/or treat fresh straw right after rice harvesting, it would be more convenient for farmers. Actually, both small and large scale cattle producers are now requesting researchers to investigate into appropriate methods for them to preserve fresh rice straw (FRS) without drying so that they can use this abundant roughage to feed cattle during the winter period.

The present study was aimed to look at:

- Possibility for preservation of FRS by ensiling with easily fermentable carbohydrates (molasses).

- Possibility for preservation and improvement of available nutrients of FRS by ensiling with graded levels of urea.

- Response of cattle fed on treated FRS in terms of growth rate.

Materials and Methods

Fresh rice straw treatments in small silos

Fresh rice straw was ensiled in small plastic silos (2 litter/silo) either with molasses (silage making) at 0, 1, 2, and 3% or with urea (alkali treatment) at 1, 1.5, and 2% on a fresh matter basis (w/w). After paddy threshing straw was collected and chopped into 3-5cm long pieces and well mixed with the additives before pressing into the silo until it was full. The silo was then sealed air-tight. Each treatment was made in triplicates and kept for 30, 60 or 90 days before opening for quality evaluation.

Assessment of color, smell and mold

After opening the silo the straw was first assessed in terms of color and smell. Mold growth was graded based on the molded proportion of the straw sample.

Determination of pH

The method proposed by Hartley and Jones (1978) was applied for determining of pH of straw. Samples of 5g each were milled into 1-2mm pieces and well stired in 100ml distilled water. The mix was left for 15 minutes and then pH was measured with a pH meter.

Chemical analyses

Straw samples were analyzed for dry matter (DM), nitrogen (N), and total ash following Official Methods of AOAC (Cunniff, 1997). In addition, neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest and Robertson (1985).

In-sacco studies

The nylon bag technique was used to determine degradation characteristics of the dry matter (DM) of the untreated and treated straws incubated together in the rumen of 3 fistulated Yellow oxen fed on a fixed diet consisting of 50% medium hay and 50% green grass given at a maintenance level. The nylon bag technique as described by Ørskov *et al.* (1980) was applied for determination of DM loss. Air-dried substrate samples were ground to pass a 2.5 mm sieve. *In-sacco* samples of 3 g each were then taken into nylon bags in duplicates. The pore size of the nylon bags was 37 micron and the inner size of the bag was 6 cm x 12 cm. The bags were incubated starting 1h after the cattle were offered the morning meal. The incubation times were 4, 8, 16, 24, 48, 72, and 96 hours. After incubation, the bags with residues were taken out of the rumen, dipped immediately into cold water to stop microbial activity, then rinsed by cold tap water to remove the rumen matter from the outside of the bags. Thereafter, the bags with contents were rinsed with cold water for 30 minutes in a washing machine. Finally, they were dried at 60^{o}C for 48 hours. To determine the contents of water-soluble fraction, two sample bags of each straw type were soaked in a water bath for 24 hours and then underwent the same washing and drying procedures as the incubated bags. Duplicate bags of each sample were similarly dried for determination of the DM content of the samples for calculation of DM disappearance. The Neway Excel program (Chen, 1997) was used for the computation of degradation parameters as described by Orskov and Ryle (1990): water soluble fraction (A), fermentable insoluble fraction (B), potential degradability (A+B), degradation rate constant (c), and lag phase (L).

Feeding trial

A feeding trial was organized to determine growth performance of young cattle fed on FRS treated with urea as compared to DRS untreated or treated with urea. A total of 18 young Lai Sin bulls at 12-15 months of age with an average liveweight of 138.3 ± 1.2 kg were

randomly divided into 3 groups of 6 cattle each to be fed in confinement according to the experimental design summarized in Table 1.

Table 1: Design of the straw feeding trial on growing cattle

Group	**I (negative control)**	**II (possitive control)**	**III (experimental)**
Number of cattle (heads)	6	6	6
Age (months)	12-15	12-15	12-15
Liveweight (kg/head)	139.1 ± 2.0	137.4 ± 2.4	138.5 ± 2.2
Diet:			
- Untreated DRS	***ad libitum***	**0**	**0**
- 4% urea treated DRS*	**0**	***ad libitum***	**0**
- 1.5% urea treated FRS*	**0**	**0**	***ad libitum***
- Green grass (kg/head/day)	5	5	5
- Concentrate (kg/head/day)	0.5	0.5	0.5
- Drinking water	free access	free access	free access
- Mineral blocks	free access	free access	free access
Adaptation period (days)	14	14	14
Experimental period (days)	75	75	75

*N.B: * The level of urea applied was equal for the two types of straw treated on a DM basis (4.5%)*

Dry straw (89% DM) was treated with 4% urea and fresh straw (33%DM) with 1.5% urea in plastics sacks (1.5m x 2.5m) sealed airtight for 3 weeks before feeding. The animals were worm-drenched and went through an adaptation period of 2 weeks prior to the main experimental period of 75 days. During the trial the animals were kept in confinement to make sure the diets were consumed as designed. Straw was fed ad libitum. In addition, green grass (5 kg/head/day) and concentrate (0.5 kg/head/day) were given to each animal. All the animals had free access to drinking water and commercial mineral blocks. Every day the animals were let go out for exercises for 2 hour in the morning and in the afternoon in an open yard where drinking water was available but not feed. Each animal was weighed at the beginning and the end of trial, each time on two consecutive days at ca. 7 a.m.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using the GLM Procedure of MINITAB12 (1998). Pairwise comparisons of means were made using the Tukey method.

Results and Discussion

Effect of treatment on color, smell, and molding of rice straw

Effects of silage making and urea treatment of straw on color, smell, and mold growth are presented in Table 2.

Table 2: Effects of treatment on color, smell and molding of straw

Straw treatment		Color	Smell	Mold
Silage making	No additive	Black-brown	Unpleasant	+++
	1% molasses	Yellowish	Slightly acidulous	+
	2% molasses	Yellow	Fragrant acidulous	+
	3% molasses	Yellow	Fragrant acidulous	+
Alkali treatment	1% urea	Brown	Slightly pungent	-
	1.5% urea	Brown	Pungent	-
	2% urea	Brown	Strongly pungent	-

N.B. - : no mold, + : slight mold, +++ : Heavy mold.

The straw samples ensiled without additives showed blackish brown color, while those samples ensiled with molasses became yellow. All urea treated samples had a brown color. The straw samples ensiled without molasses had an unpleasant smell of heavy molds. The samples ensiled with molasses were also molded at different levels, but the moldless parts had a fragrant smell of a fermented product. All the samples treated with urea showed no sign of mold and had a pungent smell. The higher the level of urea was applied the stronger the pungent smell was found.

Effect of treatment on straw pH

Table 3 shows that silage making of FRS with 1-3% molasses reduced pH low enough (<4.5) for its preservation. The higher the level of molasses was applied the lower the pH value was found. The pH value of FRS ensiled without molasses was much higher indicating that in FRS the sugar content was not enough for lactic fermentation to lower pH to a needed level. On the other direction, urea treatment increased pH of straw to a level higher than 8, which is needed for straw delignification. The higher the level of urea was applied the higher the pH value became.

Table 3: Effect of different treatments on straw pH

Straw treatment		pH		
		30 days	*60 days*	*90 days*
Untreated FRS		6,02^{c}	6,02^{d}	6,02^{c}
Silage making	No additive	4,91^{d}	4,99^{e}	5,06^{d}
	1% molasses	4,47^{e}	4,42^{g}	4,43^{g}
	2% molasses	4,28^{g}	4,20^{h}	4,23^{h}
	3% molasses	4,05^{h}	4,18^{h}	4,13^{i}
Alkali treatment	1% urea	8,01^{b}	8,13^{c}	8,24^{b}
	1.5% urea	8,51^{a}	8,46^{b}	8,74^{a}
	2% urea	8,60^{a}	8,77^{a}	8,86^{a}
SEM		0.24	0.21	0.20

N.B. Means in the same column bear different superscripts are statistically different at P< 0.05.

Effect of treatment on chemical composition of rice straw

Table 4 shows the chemical composition of FRS as affected by silage making and urea treatment. Silage making did not significantly affect crude protein (CP), ash and cell wall components (NDF, ADF, ADL) of straw. Whereas, urea treatment highly increased CP ($P<0.001$) and reduced NDF ($P<0.05$), but did not significantly affect the other cell wall components and ash as compared with untreated straw.

Table 4: Chemical composition of straw subjected to different treatments

Straw treatment		DM (%)	Chemical composition (%DM)			
			CP	NDF	ADF	ADL
Untreated straw		26.33	7.37^{a}	69.03^{a}	35.74	4.29
Silage making	No additive	26.29	7.61^{a}	67.90^{a}	36.03	4.72
	1% molasses	25.51	7.79^{a}	67.89^{ab}	36.56	4.63
	2% molasses	26.13	7.76^{a}	68.09^{a}	34.40	4.33
	3% molasses	27.56	7.90^{a}	67.36^{a}	35.50	4.16
Alkali treatment	1% urea	25.67	9.04^{b}	66.28^{ab}	35.14	4.07
	1.5% urea	28.07	9.25^{b}	64.17^{b}	34.16	4.83
	2% urea	28.06	9.34^{b}	63.20^{b}	35.04	4.58
SEM		1.23	0.37	1.48	0.87	0.33

N.B. Means in the same column bear different superscripts are statistically different at $P< 0.05$.

Effect of treatment on in-sacco degradability of straw dry matter

Table 5 and Figure 1 show *in-sacco* degradability of straw DM subjected to different treatments after different incubation times. In addition, table 6 shows degradation characteristics of the straw DM. As can be seen, like *in-vitro* digestibility, silage making did not significantly increase straw DM *in-sacco* degradability, whereas urea treatment significantly improved its degradation characteristics.

Table 5: In-sacco degradability of straw DM after different incubation times

Straw treatment		Incubation time (h)						
		4	8	16	24	48	72	96
Untreated straw		26.0^{b}	29.4^{b}	35.4^{a}	42.6^{a}	52.3^{a}	57.9^{ab}	60.1^{ab}
Silage making	No additive	22.9^{a}	24.9^{a}	34.1^{a}	43.2^{ab}	51.7^{a}	55.7^{a}	57.9^{a}
	1% molasses	28.8^{bc}	32.9^{bc}	36.7^{ab}	45.3^{ab}	56.6^{b}	58.7^{ab}	62.5^{bc}
	2% molasses	30.2^{c}	31.2^{bc}	36.8^{ab}	46.4^{b}	55.4^{b}	61.1^{b}	63.9^{bc}
	3% molasses	31.6^{c}	33.9^{c}	39.1^{b}	45.9^{b}	56.7^{b}	60.2^{b}	64.0^{c}
Alkali treatment	1% urea	29.7^{c}	34.1^{c}	44.7^{c}	51.1^{c}	62.2^{c}	69.4^{c}	70.6^{d}
	1.5% urea	32.3^{cd}	39.5^{d}	46.8^{c}	56.6^{d}	67.9^{d}	72.1^{cd}	74.2^{e}
	2% urea	33.8^{d}	43.3^{e}	50.2^{d}	58.5^{d}	68.6^{d}	74.2^{d}	75.8^{e}
SEM		1.4	1.6	1.5	1.7	1.6	1.9	1.7

N.B. Means in the same column bear different superscripts are statistically different at $P< 0.05$.

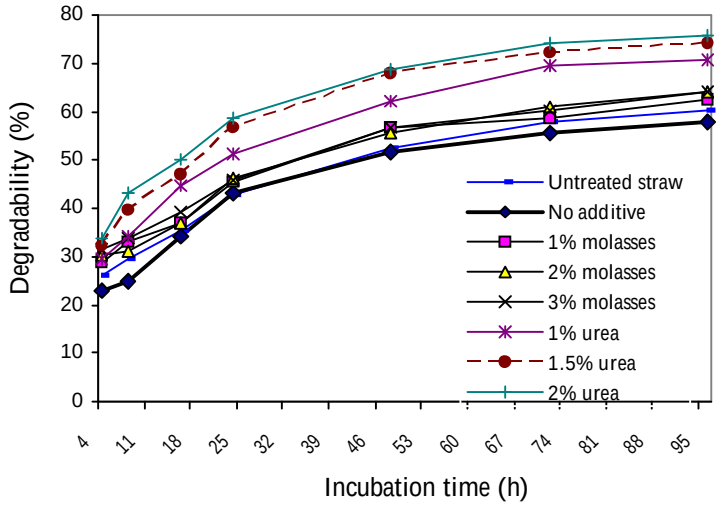

Figure 1: In-sacco degradability of straw DM subjected to different treatments

Straw ensiled without molasses had a very low soluble faction (A), lower than that of untreated straw. It is possible that some soluble substances in fresh straw had been fermented during silage making. Addition of molasses tended to increase the soluble fraction (A) of the product and thus straw degradability at early incubation times. However, the potential degradability (A+B) was not significantly increased by adding molasses. That is mainly because the fermentable insoluble fraction (B) was not increased by silage making.

Table 6: Degradation characteristics of straw subjected to different treatments

Straw treatment		Water-soluble fraction	Fermentable Insoluble fraction	Potential degradability	Degradation rate	Lag phase
		A (%)	B (%)	A+B (%)	c (%/h)	L (h)
Untreated straw		23.5^{b}	39.6^{a}	62.1^{a}	0.033^{a}	2.6^{a}
Silage making	No additive	17.9^{a}	41.6^{a}	59.5^{a}	0.034^{a}	2.3^{a}
	1% molasses	23.0^{b}	41.2^{a}	64.2^{a}	0.035^{a}	2.4^{a}
	2% molasses	$25,0^{bc}$	40.7^{a}	65.7^{a}	0.036^{ab}	2.2^{a}
	3% molasses	27.7^{c}	40.2^{a}	67.9^{ab}	0.036^{ab}	2.3^{a}
Alkali treatment	1% urea	25.5^{bc}	46.9^{b}	72.4^{b}	0.039^{bc}	2.1^{a}
	1.5% urea	28.5^{cd}	47.7^{b}	76.2^{bc}	0.041^{c}	1.5^{b}
	2% urea	31.3^{d}	47.4^{b}	78.7^{c}	0.040^{c}	1.2^{b}
SEM		1.9	2.3	2.6	0.002	0.25

N.B. Means in the same column bear different superscripts are statistically different at P< 0.05.

All urea treatments (1%, 1.5%, and 2%) brought about significant increases in all the values of water solubility (A), insoluble but degradable fraction (B), the potentially degradable proportion (A+B), and the rate constant (c), compared to untreated straw and straw silage. The lag phase (L) was effectively reduced by urea ($P<0.05$). The dose responses were almost linear with higher responses to increasing levels of urea.

Effect of urea treatment of straw on cattle growth performance

Results of the feeding trial (Table 8) show that the two groups given urea treated straw (either DRS or FRS) had higher growth rates compared to the control group fed on untreated DRS ($P<0.01$). These results are in agreement with those reported earlier concerning urea treatment of DRS (Shiere *et al.*, 1985; Doyle *et al.*, 1986, Nguyen Xuan Trach, 2000; Nguyen Xuan Trach *et al.*, 2002). According to previous studies, urea treatment increased the crude protein content and improved rumen degradability of DRS; as a result, cattle fed on treated straw were able to consume more and grew faster than those fed on untreated straw.

As of FRS, it has been also shown that urea treatment improved its crude protein content, *in-vitro* digestibility, *in-sacco* degradability (Nguyen Xuan Trach *et al*., 2006) as well as voluntary intake as mentioned above. Therefore, better growth performance of young cattle fed on urea treated FRS compared to those fed on untreated DRS in the present study can also be explained in the same manner as for urea treated DRS.

Table 8: Growth performance of young cattle fed on different types of rice straw

Group	**I** **(fed DRS)**	**II** **(fed urea treated DRS)**	**III** **(fed urea treated FRS)**
Number of cattle (heads)	6	6	6
Initial weight (kg/head)	139.1	137.4	138.5
Final weight (kg/head)	154.8^{a}	162.7^{b}	165.3^{b}
Increase in weight (kg/head)	15.7^{a}	25.3^{b}	26.8^{b}
Average daily gain (g/head/day)	**209.3^{a}**	**337.7^{b}**	**357.3^{b}**

N.B.: Means in the same row with different superscripts are significantly different at $P<0.05$

In the present study, urea treated FRS seemed to be better than urea treated DRS; however, the difference in cattle growth rate between the two groups fed on the two types of treated straw was not statistically significant ($P>0.05$). Even so, this study at least proved that treatment of FRS for long term preservation was a good alternative to drying it after harvesting. The alternative would allow to save time, storage space and labour for straw handling in comparison with drying straw before preservation and then treatment of it for feeding. If in fact urea treated FRS has a better feeding value than urea treated DRS, it may be due to that straw nutrients are better preserved when straw is not subjected to drying. Nevertheless, to prove this more detailed studies are warranted.

Results from the whole present study indicate that FRS cannot be made silage without addition of a source of sugar like molasses. In this case, straw becomes molded and pH is not lowered to a level safe enough (<4.5) for long term preservation of it as a silage. Use of molasses as an additive to FRS before ensiling could help reduce pH to a lower level, but there still existed the problem of getting straw molded. This should result in loss of organic matter and reduced palatability of straw. Even molasses was added, degradation characteristics of the silage made

was not clearly improved. Therefore, FRS should not be recommended for silage making.

In contrast, urea treatment brought about three improvements for FRS. *First*, the treated straw was free of mold as results of anti-molding effect of ammonia released during treatment (Fradhan *et al.*, 1997). This would allow for using urea for long-term preservation of FRS. *Second*, urea treatment of FRS resulted in an increase in its CP content, which would be needed for effective growth of rumen microbes as the level of CP in the original straw was too low (7.37% DM). *Third*, although the changes in the cell wall components may not give much information on the feeding quality of straw, the improved *in-sacco* degradation characteristics of straw DM clearly indicated a positive effect of urea treatment of rice straw when it was fresh on cell wall delignification, which would allow for better attack of rumen microbes to straw cell walls. As a result, the voluntary intake of urea treated FRS by cattle was higher than that of untreated DRS ($P<0.05$) and cattle fed on a urea treated straw (either DRS or FRS) based diet grew faster than those fed on an untreated DRS based diet ($P<0.01$).

Based on the present studies, treatment of FRS with 1.5-2% urea (4-5% straw DM) should be recommended long term preservation of rice straw and improvement of its nutritional value for cattle feeding.

Acknowledgments

The authors would hereby like to express sincere thanks to the Norwegian Council of Universities' Committee for Development Research and Education (NUFU) for the financial support to the present studies.

References

Chen X. B. (1997) Neway Excel: A utility for processing data of feed degradability and *in-vitro* gas production (version 5.0). Rowett Research Institute. UK.

Chenost M. and Kayouli C. (1997) *Roughage utilization in warm climates*. FAO animal production and health paper 135. Rome.

Cunniff P. (ed.) (1997) Official Methods of Analysis of AOAC International. Maryland, USA.

Devendra C. (1997) Crop residues for feeding animals in Asia: Technology development and adoption in crop/livestock systems. In **Renard C. (ed.)** Crop Residues in Sustainable Mixed Crop/Livestock Farming Systems. CAB International. pp 241-268.

Doyle P. T., Devendra C., and Pearce G. R. (1986) *Rice straw as a feed for ruminants*. International Development Program of Australian Universities and Colleges Limited (IDP), Canberra.

Hartley R. D. and Jones E. C. (1978) Effect of aqueous ammonia and other alkalis on the in-vitro digestibility of barley straw. *J. Sci. Food Agric*. **29**: 92-98.

Minitab Release 12 (1998) *MINITAB User's Guide.* USA.

Nguyen Xuan Trach (1998) The need for improved utilization of rice straw as feed for ruminants in Vietnam: An overview. *Livestock Research for Rural Development* **10**.

Nguyen Xuan Trach (2000) Improved utilization of rice straw for ruminant feeding in Vietnam. *PhD thesis*. Agricultural University of Norway.

Nguyen Xuan Trach, Magne Mo, and Cu Xuan Dan (2002) Treatment and supplementation of rice straw for ruminant feeding. *Proceedings of the Workshop on Improved Utilization of Byproducts for Animal Feeding in Vietnam, held on 28-30 March 2001 in Hanoi.* Pp: 178-204.

Ørskov E. R. and Ryle M. (1990) *Energy Nutrition in Ruminants.* Elsevier. Amsterdam.

Ørskov E. R., De b Hovell F. D. and Mould F. (1980) The use of the nylon bag technique for the evaluation of feedstuffs. *Tropical Animal Production* **5**: 195-213.

Pradhan R., Tobioka H. and Tasaki I. (1997) Effect of moisture content and different levels of additives on chemical composition and *in-vitro* dry matter digestibility of rice straw. *Animal Science and Technology (Japan)* **68**: 273-284.

Schiere J. B. and Ibrahim M. N. M. (1989) Feeding of urea-ammonia treated rice straw. *Pudoc Wageningen. Netherlands*.

Schiere J. B., Ibrahim M. N. M., and de Rond A. (1985) Supplementation of urea-treated rice straw. **In Wanapat M. and Devendra C. (Editors.)** *Relevance of Crop residues as Animal Feeds in Developing Countries*. Funny Press. Bangkok. Thailand.

Van Soest P. J. and Robertson J. B. (1985) Analysis of Forages and Fibrous Foods. A Laboratory Manual for Animal Science 613. Cornell University. USA.