Effect of physical form of urea-treated rice straw on nitrogen balance, rumen fermentation and nutrient digestibility in dairy steers

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Abstract: The purpose of this study was to evaluate the effect of chopped urea-treated rice straw on nitrogen balance, fermentation and nutrient digestibility in dairy steers. Four rumen-fistulated dairy steers were randomly assigned according to a 2×2 factorial arrangement in a 4×4 Latin square design to receive four dietary treatments as follows:T1 = untreated long form rice straw (ULRS); T2 = 3% urea-treated long form rice straw (3% ULRS); T3 = untreated chopped (4 cm.) rice straw (UCRS); T4 = 3% urea-treated chopped (4 cm.) rice straw (3% UCRS). The steers were offered the concentrate at 0.5% BW and rice straw was fed *ad libitum*. The experiment lasted for 4 periods, and each lasted for 21 d. During the first 14 d feed intake measurement were made and during the last 7 d, they were moved to metabolism crates for total urine and fecal collection. The findings revealed significant improvements in dry matter intake (DMI) and digestibility of CP, NDF and ADF when steers fed with using 3% ULRS and 3% UCRS. Ruminal pH was significantly decreased (P<0.05) when 3% UCRS was supplemented, while NH_3-N and BUN were found higher (P<0.05) as compared with urea-treated rice straw fed group. In addition, N intake, fecal N, urinary N and N absorption were increased by urea-treated rice straw group. Based on this study, implications could be made that using 3% urea-treated long form rice straw could increase rumen efficiency, N balance and digestibility in dairy steers.

Keywords: rice straw, physical form, urea-treatment, dairy steers, N balance

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Introduction

Ruminants in the tropics are normally fed on low-quality roughages and agricultural crop-residues especially rice straw (Wanapat, 1999). Preston and Leng (1987) have emphasized that matching feed resources to production systems of livestock would lead to efficient productivity. Rice straw is a major structural carbohydrate which contains 70-75% NDF, 50-55% ADF, 5-10% ADL and 2-4 % CP, respectively (Wanapat, 2000). Improvement in the nutrient utilization of low-quality roughages would substantially improve ruminant productivity and milk production (Wanapat, 1999). Improvement of rice straw by treatment with urea (5%) could improve intake, digestibility, rumen fermentation and N balance. However, urea-treated rice straw has been used as a roughage during the dry season but the cost was relatively high due to increasing price of urea (Wanapat, 1994).

Particle size of roughage can impact on numerous aspects of rumen function and rumen health. A certain amount of long forage particles size is important in the diet to ensure proper rumen health by promoting rumination and salivation. Diets with too many small particles may result in feed particles spending less time in the rumen, resulting in less microbial digestion. Zhao et al. (2009) evaluate particle sizes through alteration of the 4 theoretical cut length of rice straw (10, 20, 40, and 80 mm, respectively) in goat resulted that increasing the particle size increased the time spent on rumination and chewing activities, duodenal starch digestibility, ruminal pH, decreased ruminal starch digestibility and increased NH_3-N concentration. Yang et al. (2002) also found that increased forage particle size in dairy cow diets improved fiber digestion and microbial protein synthesis in the rumen, and shifted starch digestion from the rumen to the intestine. Therefore, the objective of this study was to study the effects of various physical form of urea-treated rice straw on nitrogen balance, rumen fermentation and nutrient digestibility in dairy steers.

Materials and Methods

Four rumen-fistulated, two year old crossbred dairy steers with initial BW of 228±16 kg were randomly assigned according to a 2×2 factorial arrangement in a 4×4 Latin square design. The dietary treatments were: T1 = untreated long form rice straw (ULRS); T2 = 3% urea-treated long form rice straw (3% ULRS); T3 = untreated chopped (4 cm.) rice straw (UCRS); T4 = 3% urea-treated chopped (4 cm.) rice straw (3% UCRS). The concentrate was fed at the level of 0.5% body weight (BW) with roughage fed *ad libitum*. Animals were housed individually and fed the experimental diets, twice daily at 08.00 a.m. and 04.00 p.m. Clean fresh water and mineral blocks were available at all times. The experiment was conducted for 4 periods, each period lasted for 21 days, the first 14 days for feed intake measurements and the remaining 7 days for total urine and fecal collection. Chemical composition of concentrate, rice straw and urea-treated rice straw are presented in Table 1. Rice straw was chopped theoretical cut length 4 cm. by machine. Urea-treated rice straw was prepared by using 3 kg+100 kg water, mixing on to 100 kg of straw, and then covered up for 10 days before feeding to animals (Wanapat et al., 2000).

Feeds, refusals and fecal samples were dried at 60 °C and ground (1 mm screen using Cyclotech Mill, Tecator) and analyzed using the standard methods of AOAC (1990) for DM, ash, CP, NDF and ADF were analyzed according to Van Soest et al. (1991). At the end of each period, rumen fluid and jugular blood samples were collected at 0, 2, 4 and 6 h after feeding. Approximately 200 mL of rumen fluid was collected at each time from the middle of the rumen using a 60 mL hand syringe. Rumen fluid was immediately measured for pH were measured at 0, 2, 4 and 6 h after feeding using a portable pH meter (HANNA Instruments HI 8424 microcomputer, Singapore) and NH_3-N by Kjeltech Auto 1030 Analyzer (Bremmer and Keeney, 1995). A blood sample (about 10 ml) was collected from the jugular vein at the same time as rumen fluid sampling into tubes containing 12 mg of EDTA, and plasma was separated by centrifugation at 500×*g* for 10 min at 4°C and stored at −20°C until analysis of blood urea N according to Crocker (1967). Urinary samples were analyzed for total N (AOAC, 1990).

All data were analyzed as a 4×4 Latin square design using the general linear procedure in PROC GLM of Statistical Analysis System (SAS, 1996). Multiple comparisons among treatment means were performed by Duncan's New Multiple Range Test (DMRT) (Steel and Torrie, 1980). Comparison among treatments was tested by orthogonal contrast.

Results and Discussion

The effects of physical form of urea-treated rice straw on voluntary feed intake and nutrient digestibility in dairy steers are show in Table 2. Dairy steers receiving urea-treated rice straw (3% ULRS and 3% UCRS) had higher total DM intake than those fed on untreated rice straw (ULRS and UCRS). Similarly, Wanapat et al. (2009) also reported that also reported that 5.5% urea-treated rice straw increase dry matter intake in dairy cows (from 4.4 to 6.0 kg/day) when compared with untreated rice straw. Moreover, apparent digestibilities of CP were significantly different ($P<0.01$) among treatments with the greatest values for dairy steers fed the 3% urea-treated rice straw group. In addition, NDF and ADF digestibility were higher when steers received UCRS and 3% urea-treated rice straw fed group. Similarly, Wanapat et al. (1985) also reported that urea-treated rice straw could increase overall intake, digestibility of CP, NDF and ADF. Hart and Wanapat (1992) who carried out the experiment to compare the effect of urea-ammonia treatment (5%, w/w) of rice straw, a 18%, 26% and 17% increase in digestibility of NDF and ADF in the urea-ammonia treated diet was found. In contrast to the present study digestibility of DM and OM were not affected by the treatments ($P>0.05$).

The pattern of ruminal fermentation and overall means are presented in Table 3. Ruminal pH of dairy steers was significantly increased in animals receiving the 3% UCRS ($P<0.05$). The ruminal pH ranged from 6.1 to 6.6 and regarded as optimal use for microbial digestion of fiber and within the normal function of the rumen ecosystem (Wanapat and Pimpa, 1999). Ruminal pH was significantly decreased by the decreased particle size of rice straw. Fibre exerts its influence on rumen pH by increasing saliva flow through its effect on chewing. Both ruminal NH_3–N and BUN in the 3% urea-treated rice straw group were higher when compared with untreated rice straw group ($P<0.05$). Ruminal NH_3-N concentration in this study ranged from 12.4 to 22.8 mg/dl. which these results were similar to the values obtained by Khejornsart and Wanapat (2010). Preston et al. (1965) reported that the concentration of BUN is correlated to the level of ammonia production in the rumen. Furthermore, Wanapat et al. (2008) suggested that concentrations of blood urea N are highly correlated to the concentration of NH_3 production in the rumen.

Table 4 shows the effects of physical form and urea-treated rice straw on nitrogen balance in steers. N intake, fecal N, urinary N and N absorption were affected by 3% urea-treated rice straw group (P>0.05) while all treatments were not influenced on N retention (P>0.05). In the present experiment, and based on N balance and N partition data, animals fed the 3% urea-treated rice straw group had a more efficient utilization of dietary N. Owens and Zinn (1988) stated that N excretion and N retention should reflect differences in N metabolism because N retention was the most important index of the protein nutrition status of ruminants.

Conclusions and Recommendations

Based on this experiment, it could be concluded that 3% urea-treated rice straw fed group resulted in increased total DM intake, improve digestibility, rumen fermentation and N balance, when compared with untreated rice straw group. However, no significant effects of chopped rice straw was found. The results suggest that urea-treated (3%) long form rice straw could improve performance, ruminal fermentation and N balance in dairy steers.

Acknowledgements

The authors would like to express their most sincere gratitude and appreciation to the Tropical Feed Resources Research and Development Center (TROFREC) and Graduate School of Khon Kaen University for their financial support of research and the use of research facilities.

References

AOAC. 1990. Official Methods of Analyses, 15th ed. Association of Official Analytical Chemists, Arlington, VA.

Bremmer, J.M., and D.R. Keeney. 1965. Steam distillation methods to determination of ammonium, nitrate and nitrite. Anal.Chem. Acta. 32:485–495.

Crocker, C.L. 1967. Rapid determination of urea nitrogen in serum or plasma without deproteinization. Am. J. Med. Technol. 33:361–365.

Hart, F.J., and M. Wanapat. 1992. Physiology of digestion of urea-treated rice straw in swamp buffaloes. Asian-Aust. J. Anim. Sci. 5:617–626.

Kategile, J.A., A.N. Said, and F. Sundstøl. 1981. Utilization of low quality roughages in Africa. Proceedings of a Workshop, Arusha, Tanzania. January 18–22, 1981. Agricultural Development Report no. 1. Agricultural University of Norway, Aas, Norway.

Khejornsart, P., and M. Wanapat. 2010. Effect of chemical treatment of rice straw on rumen fermentation characteristic, anaerobic fungal diversity in vitro. J. Anim. Vet. Adv. 24:3070-3076.

Krause, K.M., D.K. Combs, and K.A. Beauchemin. 2002. Effects of forage particle size and grain fermentability in midlactation cows. I. Milk production and diet digestibility. J. Dairy Sci. 85:1936–1946.

Leng, R.A. 1999. Feeding strategies for improving milk production. In: L. Falvey and C. Chantalakhana (Eds.), Smallholder Dairying in the Tropics International Livestock Research Institute (ILRI), Nairobi, Kenya. pp. 462.

Preston, R.L., D.D. Schnakanberg, and W.H. Pander. 1965. Protein utilization in ruminants. I. Blood urea nitrogen as affected by protein intake. J. Nutr. 86:281–288.

Preston, T.R., and R.A. Leng. 1987. Matching Ruminant Production Systems with Available Resources in the Tropics and Sub-Tropics. Penambul Books, Armidale, Australia. pp 245.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and Procedures of Statistics. McGraw Hill Book Co., New York, USA.

Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant, 2nd ed. Cornell University Press, Ithaca, NY.

Wanapat, M. 2000. Rumen manipulation to increase the efficient use of local feed resources and productivity of ruminants in the tropics. Asian-Aust. J. Anim. Sci. 13 (suppl.): 59-67.

Wanapat, M. 1999. Feeding of Ruminants in the Tropics Based on Local Feed Resources. Khon Kaen Publishing Company Ltd., KhonKaen, Thailand. pp. 236.

Wanapat, M., 1994. Supplementation of straw-based diets for ruminants in Thailand. Improving Animal Production Systems based on Local Feed Resources. Proceedings “Sustainable Animal Production and the Environment”. The 7th AAAP Animal Science Congress, Bali, Indonesia.

Wanapat, M., S. Polyorach, K. Boonnop, C.Mapato, and A. Cherdthong. 2009. Effect of treating rice straw with urea or urea and calcium hydroxide upon intake, digestibility, rumen fermentation and milk yield of dairy cows.Livest. Sci. 125:238–243.

Wanapat, M., A. Cherdthong, P. Pakdee, and S. Wanapat. 2008. Manipulation of rumen ecology by dietary lemongrass (*Cymbopogon citrates*Stapf.) powder supplementation. J. Anim. Sci. 86:3497–3503.

Wanapat, M., and O. Pimpa.1999. Effect of ruminal NH_3-N levels on ruminal fermentation purine derivatives, digestibility and rice straw intake in swamp buffaloes. Asian-Aust. J. Anim. Sci. 12:904–907.

Wanapat, M. 1999. Feeding of ruminants in the tropics based on local fed resources. Department of animal science, Khon Kaen University, Thailand.

Yang, W.Z., K.A. Beauchemin, and L.M. Rode. 2002. Effects of particle size of alfalfa-based dairy cow diets on site and extent of digestion. J. Dairy Sci. 85:1958-1968.

Zhao, X.G., M. Wang, Z.L. Tan, S.X. Tang, Z.H. Sun, C.S. Zhou, and X.F. Han. 2009. Effect of rice straw particle size on chewing activity, feed intake, rumen fermentation and digestion goats. Asian-Aust. J. Anim. Sci. 22:1256-1266.

Table 1. Ingredients and chemical compositions of concentrate, rice straw and urea-treated rice straw (UTRS)

Item	Concentrate	Rice straw	3% UTRS
		-------- % DM basis -------	
Ingredient			
Cassava chip	65.3	-	-
Coconut meal	8.8	-	-
Palm meal	6.8	-	-
Rice bran	9.5	-	-
Urea	3.1	-	-
Molasses	2.0	-	-
Tallow	1.5	-	-
Salt	1.0	-	-
Sulfur	1.0	-	-
Mineral mix	1.0	-	-
Chemical composition, % of DM			
DM	87.5	93.7	51.0
		-------------------- % of DM ------------------	
OM	92.4	86.7	85.0
CP	14.1	2.5	5.4
NDF	29.3	75.5	77.4
ADF	19.4	55.2	54.6
Ash	7.6	13.3	14.5
TDN[1]	75.2	51.5	51.0

[1]Calculated values

Table 2. Effect of chopped urea-treated rice straw on feed intakes and apparent nutrient digestibility of dairy steers

	Treatment					Contrast[1]		
Item	ULRS	3%ULRS	UCRS	3%UCRS	SEM	U	C	U*C
Total DM intake								
kg/d	4.7[a]	5.7[b]	4.9[a]	5.7[b]	0.11	*	NS	NS
%BW	2.1[a]	2.4[b]	2.1[a]	2.5[b]	0.06	*	NS	NS
g/kgBW$^{0.75}$	79.1[a]	92.0[b]	80.0[a]	94.6[b]	2.47	*	NS	NS
Apparent digestibility, %								
DM	56.7	62.4	56.5	63.1	1.52	NS	NS	NS
OM	61.7	67.3	61.5	67.6	1.27	NS	NS	NS
CP	50.9[a]	67.9[b]	50.6[a]	68.4[b]	1.42	**	NS	NS
NDF	55.8[a]	65.7[b]	60.0[ab]	64.7[b]	1.02	*	NS	NS
ADF	51.3[a]	60.2[b]	55.6[ab]	60.0[b]	1.26	*	NS	NS

[a-c]Values within the same row not bearing a common superscript differ ($P < 0.05$).[1]U = untreated rice straw vs 3% urea-treated rice straw, C = unchopped vs chopped rice straw, U*C = urea-treated rice straw and particle size of rice straw interaction, * p<0.05, ** p<0.01, NS: p>0.05.

Table 3. Effect of chopped urea-treated rice straw on rumen fermentation in dairy steers

	Treatment					Contrast[1]		
Item	ULRS	3%ULRS	UCRS	3%UCRS	SEM	U	C	U*C
Ruminal pH	6.3[a]	6.4[a]	6.6[a]	6.1[b]	0.02	*	NS	*
Ruminal temperature, °C	38.9	39.2	39.1	39.2	0.04	NS	NS	NS
NH_3-N, mg/dL	14.1[a]	19.6[b]	12.4[a]	22.8[b]	0.50	**	NS	NS
BUN, mg/dL	3.2[a]	12.5[b]	4.6[a]	12.4[b]	0.57	**	NS	NS

[a-b]Values within the same row not bearing a common superscript differ ($P < 0.05$). [1]U = untreated rice straw vs 3% urea-treated rice straw, C = unchopped vs chopped rice straw, U*C = urea-treated rice straw and particle size of rice straw interaction, * p<0.05, ** p<0.01, NS: p>0.05.

Table 4. Effect of chopped urea-treated rice straw on nitrogen balance in dairy steers

	Treatment					Contrast[1]		
Item	ULRS	3%ULRS	UCRS	3%UCRS	SEM	U	C	U*C
N balance, g/d								
N intake	43.9[a]	71.5[b]	43.8[a]	73.1[b]	1.31	**	NS	NS
Fecal N	27.4[a]	36.4[b]	30.1[a]	40.0[b]	1.24	*	NS	NS
Urinary N	7.6[a]	21.1[b]	5.5[a]	19.0[b]	1.02	**	NS	NS
N Absorption	16.5[a]	35.2[b]	13.7[a]	33.2[b]	0.69	**	NS	NS
N Retention	8.9	14.1	11.0	14.2	1.17	NS	NS	NS

[a-b]Values within the same row not bearing a common superscript differ ($P < 0.05$). [1]U = untreated rice straw vs 3% urea-treated rice straw, C = unchopped vs chopped rice straw, U*C = urea-treated rice straw and particle size of rice straw interaction, * p<0.05, ** p<0.01, NS: p>0.05.