Effect of Microwave Treatment on Chemical Composition and *In sacco* Digestibility of Wheat Straw in Yak Cow

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ABSTRACT : Wheat straw was treated with microwave for 4 min and 8 min at a power of 750 W and frequency of 2,450 MHz. Chemical compositions of untreated, 4 min treated and 8 min treated straws were analyzed and *in sacco* degradabilities of all these straws in yak rumens were measured. Microwave treatment didn't significantly ($p>0.05$) affect the chemical composition of the straw. *In sacco* dry matter (DM) degradability of the straw after 18 h incubation in rumen was significantly ($p<0.01$) improved by microwave treatment. *In sacco* crude protein (CP) degradability of the straw was not ($p>0.05$) affected by microwave treatment. *In sacco* organic matter (OM) degradability of the straw was increased ($p<0.01$) by around 20% for both the 4 min and 8 min microwave treatment, that of acid detergent fibre (ADF) was increased ($p<0.01$) by 61.6% and 62.8%, and that of ash free ADF was enhanced by 72.1% and 69.6% for the 4 min and 8 min microwave treatment respectively. No significant difference was observed between the 4 min and 8 min microwave treatment on the degradability of DM, OM, CP, ADF and ash-free ADF of the straw. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 1 : 27-31)***

Key Words : Wheat Straw, Microwave, Dry Matter, Crude Protein, Acid Detergent Fibre, *In sacco* Degradability

INTRODUCTION

The yak (*Bos gunnens*) is one of the world's most remarkable domestic animals, the characteristic grazing bovine on the "roof of the world", as the Qinghai-Tibetan Plateau is often refereed to. The yaks play a crucial role in the animal husbandry economy of the plateau. They provide milk, milk products, meat, wool, hides and dung for fuel and are used as pack animals and for draught purposes. They contribute 15% of Chinese milk requirements and more than 90% of milk and 50% of meat requirements for local people (Long, 1994). Due to herbage shortage in the long, harsh cold season (October-May), the grazing yak has to suffer from inadequate feeds under the traditional farming system, resulting in big seasonal body weight variations, low milk production and low fertility (Long, 1994).

The early researches (Zhou, 1984; Wen et al., 1993; Long et al., 1994; Wu et al., 1997; Long et al., 1999) found that the effect of supplementation with hay or straw in cold season on productivities and body condition of yak cows was significant. Although supplements of hay were more effective than straw in reducing body weight loss of the animals (Long et al., 1999), surplus herbage for hay was not widely available at least, in the major yak producing areas (Cai and Wiener, 1995). Improving the feeding values of the straw through physical, chemical or biological treatment may be an effective way to alleviate body weight loss of yak cows in the cold season, as the straw was considered to be a potential source of energy for the ruminants (Rasool and Gilani, 1995).

Commonly used methods for improving the feeding values of straw are urea and alkali treatments. Urea treatment can not only improve the digestibility of the fibrous components of the diets by making more digestible cellulose and hemicellulose available (Silva and Ørskov, 1988) and by increasing degradable fraction of the straw as well as the speed of degradation (Nandra et al., 1983; Ibrahim et al., 1989), but also increase the nitrogen content of straw through ammoniation process and serve undecomposed urea in the straw as ideal nitrogen source if the rumen organisms are used up (Bergener et al., 1997). Alkali treatment with NaOH or alkaline H_2O_2 (AHP) can improve the nutritive value of cereal straws by improving their digestibility through cleavage of lignin-hemicellulose bonds and degradation and solubilisation of lignin (Chaudhry and Miller, 1996). Although these methods are effective in improving the nutritive values of the straws, high cost, hazardous handling and pollution to the environment, and the most important, the low intake of ammoniated alkalized straws by the yaks due to strong smell make it desirable to find effective substitutes.

Steam treatment, an environment-friendly method, has been recently developed to improve the nutritive values of straw (Liu et al., 1999), however, it is an energy, time and labor-consuming work conducted at large scale and can not be commonly available in yak production systems at farm house-hold level on the Qinghai-Tibetan Plateau of China. Alternatively, microwave treatment, a quick and economic

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Received February 16, 2004; Accepted July 29, 2004

Table 1. Dry matter (DM), ash, crude protein (CP), acid detergent fibre (ADF) and ash-free ADF contents in untreated, 4 min and 8 min treated straws

Straws	DM	Ash	CP	ADF	Ash-free ADF
	g kg^{-1} ADM	g kg^{-1} DM			
Untreated	948.2	104.4	84.3	531.2	494.4
4 min treated	967.7	103.6	82.6	531.1	497.3
8 min treated	962.4	109.6	85.7	528.5	475.4
SED	7.1	4.4	2.1	4.6	6.8

ADM: air-dried matter.
SED: standard error of the difference.

method, may be attempted at small farm scale by individual households to improve the nutritive values of the straws on the condition that the infrastructures (including transport, power, facilities etc.) in the alpine region of the Qinghai-Tibetan Plateau are being well developed under the current Western Development Policy of China. On the basis of this assumption, the present study was conducted to test the effect of microwave treatment on chemical composition and *in sacco* degradability of wheat straw.

MATERIALS AND METHODS

Straw treatment

The samples of wheat straw were collected from Yongfengtan Yak Farm (located at the northeast of the Qinghai-Tibetan Plateau, the Tianzhu Tibetan Antonomus County of Gansu Province, China) and cut into 5 cm length pieces. 100 g of straw pieces were incubated in an NK-K652 microwave oven (produced by National LTD. of Japan, with power of 750 W and frequency of 2.450 MHz) and treated 4 minutes (4 min) and 8 minutes (8 min) respectively. Around 50 g of untreated straw (CK), 4 min and 8 min treated straws were milled to pass through 1 mm sieve for chemical analysis, and same amount of untreated, 4 min and 8 min treated straws were milled to pass 2.5 mm sieve for *in sacco* degradability analysis.

Chemical analysis

Chemical analysis was conducted on samples of untreated, 4 min treated and 8 min treated straws and those of *in sacco* undegraded residues. Dry matter (DM) and ash contents were determined as described by AOAC (1990). Acid detergent fibre (ADF) analysis was carried out according to Goering and Van Soest et al. (1991). Ash-free ADF was estimated by subtracting ash in ADF. Analysis of total nitrogen was carried out using the Kjeldahl method as modified by Davidson et al. (1970). Crude protein (CP) content was calculated by multiplying N content by a factor of 6.25. Three replicates were required for each measurement.

In sacco degradability analysis

The *in sacco* degradability analysis on the samples of untreated, 4 min treated and 8 min treated straws was carried out according to Mehrez and Ørskov (1977). About 3 g of sample was transferred into nylon bags and incubated in triplicate in the rumens of 3 fistulated yak cows. The cows were fed at twice maintenance level on a high quality of oat hay diet. The nylon bags were withdrawn after 6, 12, 18, 24, 36, 48, 72 and 96 h of incubation, thoroughly washed with cold water until clean and dried at 65°C for 48 h. Three nylon bags with one of 3 samples of untreated, 4 min and 8 min treated straws were soaked in water at 39°C for 1 h, washed and dried. The dried and washed residues for each incubation time were bulked and further ground through a 1 mm sieve for chemical analysis. Data for the *in sacco* DM, OM, CP, ADF, ash-free ADF degradability were fitted by the exponential equation proposed by Ørskov and McDonald (1979): $P=a+b(1-e^{-ct})$, where a, b and c are constant, and P is the degradability at time t.

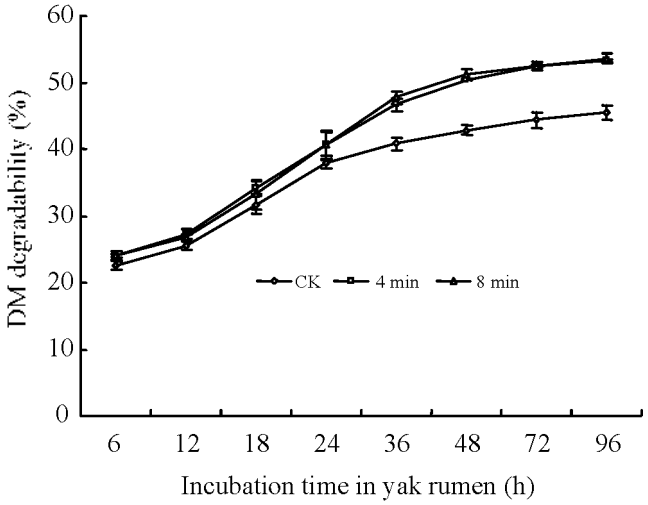

Figure 1. *In sacco* dry matter (DM) degradability (mean±SD) of untreated (CK), 4 min and 8 min treated straws.

Statistical analysis

Analysis of variance was carried out to statistically analyze chemical composition and in sacco degradability data. The least significant difference (LSD) was used to conduct the posteriori comparisons among the means. The analyses were performed by using SPSS10.0 (Huang et al., 2001).

RESULTS

Chemical composition

Microwave treatment didn't significantly ($p>0.05$) affect the chemical composition of the straw (Table 1). Ash, crude protein (CP), acid detergent fibre (ADF) and ash-free ADF concentrations of the straw remained around 110 g kg^{-1} DM, 85 g kg^{-1} DM, 530 g kg^{-1} DM and 490 g kg^{-1} DM respectively whether the straw was treated with microwave

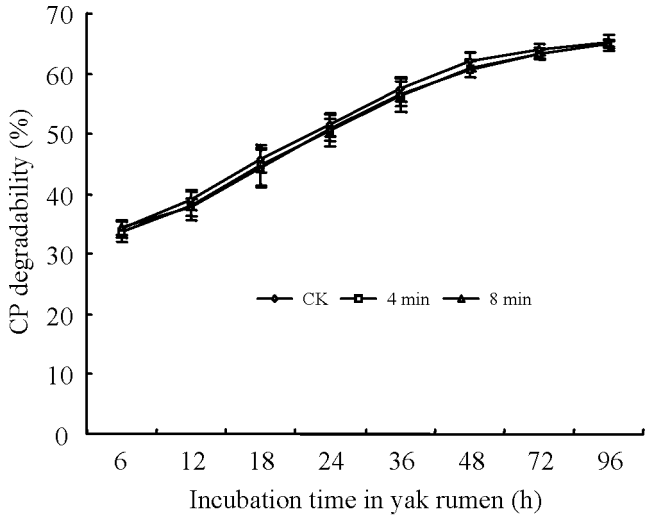

Figure 2. *In sacco* crude protein (CP) degradability (mean±SD) of untreated (CK), 4 min, 8 min treated straws.

or not, and whether the straw treated with 4 minutes or 8 minutes.

In sacco DM degradability

As shown in Figure 1, *in sacco* DM degradability of straw was significantly improved by microwave treatment, the 4 min and 8 min treated straws had higher ($p<0.01$) DM degradability than the untreated straw after 18 h of incubation in yak rumen. No significant difference of *in sacco* DM degradability was observed between the 4 min and 8-min treated straws at any time of incubation. As shown in Table 2, Washing loss (a) and degradation rate (c) were not different among all treatments. As a result, DM disappearance was not different among the untreated, 4 min and 8-min treated straws. Due to the lower ($p<0.01$) water insoluble fraction (b), untreated straw had a lower ($p<0.01$) potential DM degradability (a+b) than the 4 min and 8 min treated straws. No significant difference was observed between the 4 min and 8 min treated straws on the water insoluble fraction (b) and potential DM degradability (a+b).

In sacco CP degradability

In sacco CP degradability of straw was not ($p>0.05$) affected by microwave treatment, the curves of *in sacco* CP degradability of the untreated, 4 min and 8 min treated straws almost completely overlapped (Figure 2). The degradation rate of CP in the straw didn't change with different microwave treatment throughout the incubation period of 96 h (Figure 2). Washing loss (a), the water insoluble fraction (b), potential DM degradability (a+b) and the degradation rate (c) were not ($p>0.05$) different among all treatments (Table 2), reflecting the stable disappearance and potential degradation of CP of the straw in spite of microwave treatment.

48 h *in sacco* degradability of OM, ADF and ash-free ADF

As presented in Table 2, microwave treatment can improve ($p<0.01$) 48 h *in sacco* degradability of organic matter (OM) by around 20%, almost the same extent of improvement on the 48 h *in sacco* degradability of DM by microwave treatment. No significant ($p>0.05$) difference of the 48 h *in sacco* degradability of OM was obtained between the 4 min and 8 min treated straws. The 48 h *in sacco* degradability of acid detergent fibre (ADF) was increased ($p<0.01$) by 61.6% and 62.8%, and that of ash free ADF was enhanced by 72.1% and 69.6% for the 4 min and 8 min microwave treatment respectively. The 4 min and 8 min microwave treatment showed no significant difference on improving the 48h *in sacco* degradabilities of ADF and ash-free ADF.

DISCUSSION

It was reported that alkali treatment can dramatically

Table 2. *In sacco* degradability of Dry matter (DM), crude protein (CP), organic matter (OM), acid detergent fibre (ADF) and ash-free ADF of untreated, 4 min and 8 min treated straws after 48 h incubation in yak rumen

Degradability of nutrients		Straws			
		Untreated	4 min treated	8 min treated	SED
DM	a (g kg^{-1} DM)	125.2	126.4	116.9	9.3
	b (g kg^{-1} DM)	331.5^{A}	420.1^{B}	435.0^{B}	9.0
	a+b (g kg^{-1} DM)	456.7^{A}	546.4^{B}	551.9^{B}	27.8
	c (% h^{-1})	5.11	4.35	4.32	0.43
CP	a (g kg^{-1} DM)	231.0	229.7	240.2	12.5
	b (g kg^{-1} DM)	432.8	432.5	423.6	8.7
	a+b (g kg^{-1} DM)	663.7	662.2	663.9	6.5
	c (% h^{-1})	4.31	4.14	3.96	0.64
OM	a+b (g kg^{-1} DM)	472.4^{A}	569.6^{B}	571.4^{B}	13.6
ADF	a+b (g kg^{-1} DM)	189.1^{A}	305.5^{B}	307.8^{B}	14.4
Ash-free ADF	a+b (g kg^{-1} DM)	149.8^{A}	257.8^{B}	254.1^{B}	12.2

a: washing loss of the soluble fraction; b: degradability of the water insoluble but fermentable fraction; a+b=potential degradability; c=rate of degradation of b. Means with different superscripts within a row are significantly different ($p<0.01$).
SED: standard error of the difference.

lower the fibre contents of the straw (Rasool and Gilani, 1995; Chaudhry and Miller, 1996), and that urea (either urine or ammonia) treatment can significantly increase nitrogen content of the straw (Hasan et al., 1993; Orden et al., 2000; Fadel Elseed et al., 2003). However, no significant effect of microwave treatment on the chemical composition of the straw was observed in the current study. It is, therefore, speculated that the microwave treatments is not as efficient as alkali and urea treatments in improving nutrient contents of the straw. Extra energy and protein supplements, such as urea multinutritional molasses block (Dong et al., 2003) may be needed when the yaks are fed with microwave-treated straw.

Similar to urea (Sirohi and Rai, 1999), alkali (Chaudhry and Miller, 1996) and steam (Liu et al., 1999) treatments, microwave treatment can improve the feeding value of the straw through increasing its degradability. However, there are differences in the kinetics of degradation improvement between microwave treatments and other methods. First, urea or urine treatment can improve the degradation of both the fibrous fraction and CP fraction (Hasan et al., 1993; Sirohi and Rai, 1999; Fadel Elseed et al., 2003), but no effect of microwave treatment on CP degradability was observed in the present study. Second, the urea and alkali treatments can enhance the DM degradability of straw by increasing the solubilisation of lignin (Chaudhry and Miller, 1996) or the rate of degradation (Nandra et al., 1983; Ibrahim et al., 1989) in addition to increasing the degradable fraction of the straw. Microwave treatment can increase the DM degradability of straw solely by increasing the degradable fraction of the straw in the present study.

The significant increment in DM degradability of 4 min and 8-min treated straw compared with untreated straw after 18 h incubation may be contributed by an increase in the slowly degradable fraction of DM. An increased slowly degradable fraction of DM, therefore, may be attributed to an increased degradability of fibrous fraction, reflecting in the increased ADF degradability in the present study. The same result has been obtained with ammonia and urine treated straws by Fadel Elseed et al. (2003).

Improved degradability of straw fibre by microwave treatment in the present study may be explained by the fibre possessing the characteristics of degradation under heat treatment, because heat radiation as well as oxygen can decrease the stability of fibre or fibrous materials by completely changing their structures (Chen et al., 1999). Microwave treatment may make more digestible cellulose and hemicellulose available through cleaving the lignin-hemicellulose bonds. To test this assumption, further studies are needed to analyze the changes in the structures of fibre of microwave treated straw.

Effect of microwave treatment on nutritive values of the straw may vary with treatment time and frequency as well as the amount of straw, although no significant difference between 4 min and 8 min treatment was observed on chemical composition and *in sacco* degradability of the straw. It was found that the materials were burnt after 8 min treatment when 100 g of wheat straw pieces were treated with an NK-K652 microwave oven of 750 W power and 2.450 MHz frequency. It is imperative to optimize the treatment time, microwave power and frequency for given amount of the straw during microwave treatment.

CONCLUSION

Microwave treatment is promising for improving the feeding values of the straw through increasing the *in sacco* degradability in yak rumen, especially the *in sacco* degradability of fibre. Although microwave treatment has a minor weakness in upgrading nutrients contents of the straw, it is a simple but quick and efficient method to improve the quality of the straw feeds. Therefore, this method can be extended in yak production systems at farm house-hold level on the Qinghai-Tibetan Plateau of China and in some other similar livestock production systems in the world.

ACKNOWLEDGEMENT

The authors wish to thank Prof. Wang X., two reviewers for their suggestions and comments and to thank Mr. Zhang, Y.L., Miss Yang, Z.J., Miss Fei, S.Y. and Mr. Yang, H.H. for their skill assistance. This work was supported by grants from National Key Subject (NKBRSF project G2000018607), National Natural Science Foundation of China (NSFC 40071002) and IAEA (RAS/5/030). Authors wish to give their best thanks to their supports.

REFERENCE

Association of Official Analytical Chemists (AOAC) 1990. Official methods of analysis of the Association of Official Analytical Chemists, 15th edition. Washington, DC, USA.

Bergener, H., D. Woidke and J. Lenk. 1997. The *in sacco* digestibility of dry matter of wheat after treatment with urea-sucrose mixtures. Anim. Res. Dev. 45:37-45.

Cai, L. and G. Wiener. 1995. The Yak. Published by the Regional Office for Asia and the Pacific of the Food and Agriculture Organisation of the United Nations, Bangkok, Thailand.

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.

Chen, Y. F., Y. Q. Guo and L. S. Xie. 1999. Effects of heat radiation and oxygen on the stability of fibre. J. Cellulose Sci. Technol. 7(3):13-19.

Davidson, J., J. Mathieson and A. W. Boyne. 1970. The Use of automation in determining nitrogen by the Kjeldahl method

with final calculation by computer. Analyst 96:181-193.

Dong, S. K., R. J. Long, M. Y. Kang, X. P. Pu and Y. J. Guo. 2003. Effect of urea multinutritional molasses block supplementation on liveweight change of yak calves and productive and reproductive performances of yak cows. Can. J. Anim. Sci. 83:141-145.

Fadel Elseed, A. M. A., J. Sekine, M. Hishinuma and K. Hamana. 2003. Effects of ammonia, urea plus calcium hydroxide and animal urine treatments on chemical composition and in sacoo degradability of rice straw. Asian-Aust. J. Anim. Sci. 16:368-373.

Hasan, S., M. Shimoji and I. Goto. 1993. Improvement in the nutritive value of straw by treatment with the urine of goats. Asian-Aust. J. Anim. Sci. 6:36-40.

Huang, H., Y. F. Luo and Z. Y. Chen. 2001. SPSS 10.0 for windows: Statistic analysis. Beijing: People's Posts and Telecommunications Publishing House.

Ibrahim, M. N. M., S. Tamminga and G. Zemmelink. 1989. Effect of urea treatment on rumen degradation characteristics of rice straw. Agric. Wastes. 18:225-232.

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.

Long, R. J. 1994. Milk performance of yak cows under traditional feeding and management on small Tibetan farms. Acta Prata. Sinica 4 (1):71-76.

Long, R. J., D. G. Zhang, X. Wang, Z. Z. Hu and S. K. Dong. 1999. Effect of strategic feed supplementation on productive and reproductive performance in yak cows. Prevent. Vet. Medi. 38:195-206.

Mehrez, A. Z. and E. R. Orskov. 1977. A study of the artificial fibre bag technique for determining the digestibility of feeds in the rumen. J. Agric. Sci. (Cam.). 88:645-650.

Nandra, K. S., A. Hendry and R. C. Cobos. 1983. A study of voluntary intake and digestibility of roughages in relation to their degradation characteristics and retention time in the rumen. Anim. Feed Sci. and Technol. 43:227-237.

Orden, E. A., K. Yamaki, T. Ichinohe and T. Fujihara. 2000. Feeding value of ammoniated rice straw supplemented with rice bran in sheep: II. *In situ* rumen degradation of untreated and treated rice straw. Asian-Aust. J. Anim. Sci. 13:563-566.

Orskov, E. R. and I. McDonald. 1979. The estimation of the protein degradability in the rumen from incubation measurements weighed according to rate of passage. J. Agric. Sci. (Cam.). 92:499-503.

Rasool, E. and A. H. Gilani. 1995. Chemical composition of wheat straw as influenced by urea and alkali treatments at different moisture levels. Asian-Aust. J. Anim. Sci. 8:563-566.

Silva, A. T. and E. R. Orskov. 1988. Fibre degradation in the rumens of animal receiving hay, untreated or ammonia-treated straw. Anim. Feed Sci. Technol. 19:277-287.

Sirohi, R. G. D. and J. H. Rai. 1999. Synergistic effect of urea and lime treatment of wheat on chemical composition, *in sacco* and *in vitro* digestibility. Asian-Aust. J. Anim. Sci. 12:563-566.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Wen, Y. L., Z. H. Chen, Y. Chen, C. L. Zhao, Y. K. Chen and J. F. Wang. 1993. Influence of two simple methods of supplement during the winter on the performance of female yaks. Journal of Southwest Nationalities College (Natural Science Edition) 20(2):166-170.

Wu, K. X., J. T. Xu and R. Z. Yang. 1997. Effect of supplementary feeding in warm shed on the performance of yak containing different wild blood in winter season. In: (Ed. R. Z. Yang, X. T. Han and X. L. Luo). Yak Production in Central Asian Highlands-Proceeding of the Second International Congress on Yak. Sept., 1-6, 1997, Xining, China.

Zhou, S. R. 1984. Study on the forage and feeding habits of yak. A Research on the Utilization and Exploitation of Grassland in the Northwestern Part of Sichuan Province. Sichuan National Publishing House.