Nutritional Evaluation of Bamboo Shoot Shell and Its Effect as Supplementary Feed on Performance of Heifers Offered Ammoniated Rice Straw Diets

J. X. Liu*, X. Q. Wang, Z. Q. Shi and H. W. Ye[1]

College of Animal Sciences, Huajiachi Campus, Zhejiang University, 310029 Hangzhou, P. R. China

ABSTRACT : The present study was conducted to examine the feasibility of utilising bamboo (*Bambusa arundinacea*) shoot shell (BSS) in ruminants. Chemical composition, rumen degradability and some antinutritional compounds were determined for fresh and boiled BSSs to evaluate its feed value and safety. Thirty-two Holstein heifers were allocated to four groups and used to investigate the response in growth rate to supplementing ammoniated rice straw with fresh shell (phase 1) or silage of boiled BSS (phase 2). All animals were offered ammoniated straw *ad libitum* with 1kg of cotton seed meal (phase 1) or 0.5 kg of cotton seed meal and 0.5 kg of concentrate mixture (phase 2) per head per day. The BSS was supplemented at levels of 0, 3, 6 or 9 kg/d (phase 1) and 0, 5, 10 or 15 kg/d (phase 2) (as fed basis). The BSS was very high in moisture content, and its contents of crude protein and neutral detergent fiber were 13~16% DM and 65~76% DM, respectively; boiling resulting in higher moisture and protein. No hydrocyanic acid was detected in both BSSs and content of tannins was negligible. Rumen degradability of BSS was reasonably high, and with boiling the rapidly degradable fraction decreased, and potentially degradable component increased. Silage of the boiled BSS was slightly lower in both rapidly and slowly degraded fractions than the fresh BSS. Animals consumed all supplemented BSSs without any adverse health problems. Intake of ammoniated straw decreased with the increasing levels of BSS, but total intake was higher in almost all supplementary groups than in the non-BSS. Heifers had a higher growth rate in phase 1 with fresh BSS than in phase 2 with ensiled shell, and daily weight gains were 622, 629, 744 or 690 g in phase 1, and 578, 575, 677 or 635 g in phase 2 at four BSS levels, respectively. For both phases growth rate was significantly higher for the animals in groups 3 and 4 than those in groups 1 and 2 ($p<0.01$), with little difference between groups 1 and 2 ($p>0.05$) but significant difference between groups 3 and 4 ($p<0.05$). Supplementation with BSS also resulted in an improved feed conversion rate, with the least concentrate consumption in group 3 for both phases. It is concluded that the BSS has a high potential nutritional value as indicated by its medium protein content, reasonably high rumen degradability, and that inclusion of BSS in ammoniated rice straw diet is not only safe to animals, but also may improve growth rate of ruminants and feed conversion rate. It may be disadvantageous to use high amounts of BSS in ammoniated straw diets. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 10 : 1388-1393)*

Key Words : Bamboo Shoot Shell, Nutritive Value, Growth Rate, Ammoniated Rice Straw, Heifers

INTRODUCTION

The development of an animal production system that minimizes grain use is based on making full use of the renewable resources available locally. Bamboo (*Bambusa arundinacea*) shoot is a traditional food in China, and about four million tons of bamboo shoots are produced in China every year. Outputs of bamboo shoot shell (BSS) are almost equivalent to the shoots. Most of bamboo shoots are produced in spring, and it may be consumed as fresh food or processed products. Therefore the BSS is seasonally produced either as a fresh or as a boiled material from industrial processing of canned bamboo shoots, both types having a high content of moisture. Bamboo shoot factories sometimes worry about how to deal with the BSS, because of potential pollution problems from disposing of it.

* Address reprint request to J. X. Liu. Tel: +86-571-697-1097, Fax: +86-571-697-1647, Email: jxliu@dial.zju.edu.cn.

[1] Banqiao Dairy Farm, Lin'an County, Zhejiang 311600, China.

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Zhou et al. (1991) reported that contents of crude protein (CP) and crude fiber of BSS were 12 and 20 % dry matter (DM). The BSS was found to be easily digestible by cattle with a TDN of 68.4% (Chen et al., 1979). In spite of possible existence of anti-nutritional factors (FAO, 1998), BSS may be a potentially important feed for animals. Using 10 to 15% of dried residues from canned bamboo shoots to substitute for 5 to 6% corn and 5 to 9% rice bran in diets for pigs, Zhou et al. (1992) observed an increase of 6.2% in daily liveweight gain. However, due to the added processing costs for drying the price of dry BSS materials could not be competitive with conventional feeds.

Straw and stover from rice, wheat and corn constitute the important sources of roughage for ruminants in China and in Asia. It has been demonstrated in China that beef production can be obtained from crop residues with minimal use of grain through ammonification of straws and strategic supplementation to the straw diet (Dolberg and Finlayson, 1995). Ammoniated straw should therefore be the most important basal diet in grain-saving feeding systems for ruminants. The objectives of the present study were to evaluate the feed value of the BSS (fresh and boiled), and to investigate the effect of BSS as a supplementary feed on the performance of Holstein heifers offered ammoniated rice straw diets.

MATERIALS AND METHODS

Experimental feeds

Bamboo shoot shell (BSS). Fresh BSS was collected from Banqiao Bamboo-Shoot Processing Plant. The required daily amount was obtained directly every morning during the feeding trial. The contaminate clay, if any, was washed off before feeding. The boiled BSS was obtained from Linan Canned Food Factory. Because of the seasonal production of BSS and its delayed use in the feeding trial, the boiled BSS was ensiled in a bunker silo before use. Salt was added at a level of 0.3% (fresh basis) to improve the silage quality. The silo was opened for feeding 50 d after ensiling.

Ammoniated rice straw (ABRS). Rice (*Japonica*) straw (RS) was collected from farms at Banqiao, Lin'an immediately after the rice harvest. Fertilizer grade ammonium bicarbonate (AB, 17% N) was used as a source of NH_3 to treat the RS. The concentration of AB was 10% of RS and the amount of water added was 30% of RS (Liu et al., 1991). The ABRS was prepared by the 'stack method' at the Farm. The ambient temperature ranged from 15-20℃ and treatment time was 30 d. Ammoniated straw was exposed to air for a minimum of 24 h before feeding to animals to allow free ammonia to escape.

Concentrate. Concentrate mixture and cotton seed cake (CSC) used in the feeding trial were purchased from Feed Processing Plant affiliated to the Farm. Ingredients of concentrate were: 33% ground corn, 33% wheat bran, 32% cottonseed meal, and 2% mineral-vitamin complex. Ingredients of urea-mineral block were: 16% cement, 22% zeolite, 40% rice bran, 10% urea, 5% trace mineral and 4% salt.

Nutritional evaluation of the BSS

Chemical analysis. Feed samples for chemical analyses were ground to pass a 40 mesh sieve. The CP content of ABRS and BSS (fresh, boiled and ensiled) was determined using the macro-Kjeldahl method (AOAC, 1990). Neutral detergent fiber (NDF) was analyzed as outlined by Van Soest et al. (1992). The pH value of BSS silage was also recorded.

Rumen degradability. Three rumen-fistulated sheep were used to determine the rumen degradability of three BSSs using the in sacco technique of Ørskov (1985). All the animals were offered diets containing ABRS and a concentrate mixture (70:30, w/w), to meet ME requirement for 1.3×maintenance. The ABRS was obtained from Banqiao Dairy Farm.

The bags were of 300 mesh (pore size 48 μ) nylon fabric measuring 5 cm×10 cm with mounted corners. The feeds on test were oven-dried and hammer-milled through a sieve size of 40 mesh (2 mm). Duplicate 3 g samples of each feed were then weighed into nylon bags and suspended in the rumen of sheep. The bags were removed after 8, 16, 24, 48 and 72 h of incubation, and washed under running tap water for about 1 h until the water ran clear. The bags and contents were then dried at 60℃ for 24 h. Dried residues were used to determine DM and CP, and the rates of disappearance of each component were calculated. Data on disappearance rate were fitted to the model of Ørskov (1985)

$p=a+b(1-exp(-ct))$ (1)

where p is disappearance rate at time t (h), a is the rapidly degradable fraction in the rumen, and b is the fraction slowly degraded at rate c (c>0).

Effective degradability (ED) was calculated assuming passage rates of 2 and 4 %/h and using the formula of Ørskov (1985)

$ED=a+b(c/(c+k))$ (2)

where a, b and c are the constants from Eq. (1) and k is the passage rate.

Safety evaluation. The samples of BSS, fresh and boiled, were analyzed for contents of hydrocyanic acid (HCN) and tannin to evaluate the safety for use of BSS in ruminant diets. Hydrocyanic acid was determined by alkaline titration method using argentine nitrate as reagent, and tannin was determined by spectrophotometric method using Folin-Denis as reagent (AOAC, 1990).

Feeding trial

Experimental animals and design. Thirty-two Holstein heifers with an age range of 5.2 to 7.5 mo were selected and divided into four groups of eight each based on age and liveweight (table 1).

The feeding trial was carried out at Banqiao Dairy Farm, and was completed in two consecutive phases, between which one month interval was set. Phase 1 lasted 40 d with the first 10 d for adaptation and the subsequent 30 d for determination, and phase 2 with 10 d for adaptation and 35 d for measurements. The animals were randomly allocated to one of four treatments (table 1). In all treatments, heifers were given the ABRS ad libitum. Fresh BSS was offered in phase 1 at levels of 0, 3, 6 and 9 kg (as fed basis) along with 1.0 kg of CSC per head per day, and BSS silage in phase 2 at levels of 0, 5, 10, 15 kg (as fed basis) with 0.5 kg CSC and 0.5 kg concentrate mixture. Drinking water and urea-mineral block were freely available at all times.

Determination of intake and daily weight gain.

Table 1. Experimental animals and design with feeding regime

Treatments	1	2	3	4
Nos. of animals	8	8	8	8
Initial age (mo)	6.5 (5.4~7.5)	6.5 (5.2~7.0)	6.4 (5.3~7.5)	6.5 (5.2~7.3)
Diet ingredient (kg/d, as fed basis)[1]				
Phase 1				
Bamboo shoot shell, fresh	0	3	6	9
Cotton seed cake	1	1	1	1
Phase 2				
Silage of boiled bamboo shoot shell	0	5	10	15
Cotton seed cake	0.5	0.5	0.5	0.5
Concentrate mixture	0.5	0.5	0.5	0.5

[1] Ammoniated rice straw was fed *ad libitum* for all animals at both phases 1 and 2.

Heifers in each treatment were fed in groups. Care was taken to ensure that the supplementary BSS and concentrate were well distributed throughout the trough to allow all animals within the groups equal access. The daily feed intake of each group was recorded, and the heifers were weighed on arrival, and at the beginning and end of the feeding trial.

Statistical analysis

The results for rumen degradability of BSSs were analyzed as a 3×3 Latin square design. Data for feeding trial in each phase were analyzed by one way analysis of variance. The difference of means for the treatments was tested using Duncan's new multiple range test (Steel and Torrie, 1980).

Table 2. Chemical composition of fresh and processed bamboo shoot shell and ammoniated rice straw

	Bamboo shoot shell (BSS)			Ammoniated rice straw (ABRS)
	Fresh	Boiled	Boiled & ensiled	
Dry matter (%)	12.8	9.5	11.4	70.9
Organic matter (%DM)	86.8	87.0	86.0	84.4
Crude protein (%DM)	12.7	16.0	14.8	9.5
NDF (%DM)	73.8	65.1	76.6	73.1
HCN (%DM)	0.0	0.0	ND[1]	ND
Tannin (%DM)	0.37	0.34	ND	ND
pH	ND	ND	4.3	ND

[1] ND: not determined.

RESULTS AND DISCUSSION

Moisture content was high for all types of BSSs (table 2). The BSS had a higher CP and comparable NDF, compared with the ABRS. Fresh shell was higher in contents of DM and NDF, and lower in CP than the boiled BSS. The boiling process for industrial fractionation of bamboo shoots might solubilize some of cell wall constituents. Ensiled BSS had a gray-yellow color and an acid-rancid smell when the silo was opened; this, and the pH value of 4.3 are indicative of a middle-quality silage. Compared to the boiled BSS, the ensilage resulted in a slightly lower content of CP and higher NDF. It was apparently difficult to prepare a BSS silage of good quality without additive, even when salt was added at ensiling.

No hydrocyanic acid was detected in either fresh or boiled BSSs (table 2). Content of tannins was 0.37 and 0.34%DM in fresh and boiled BSS, respectively, indicating little change in tannin content of BSS due to boiling. It has been considered that tannin above 5.0% can become a serious anti- nutritional factor in plant materials fed to ruminants (McLeod, 1974). The BSS, fresh or boiled, could be safely used in ruminant diets.

The degradation of DM and CP of BSS was greatly influenced by boiling and ensiling (table 3). With boiling the rapidly degradable fraction (a) of DM and CP decreased, and the potentially degradable component (b) greatly increased. Ensilage slightly decreased both the rapidly and the slowly degradable fractions of the boiled BSS. The 48 h rumen degradability (D_{48}) of DM was the highest for the boiled BSS, with little difference between the fresh and ensiled BSS. The boiled shell had an ED value higher than the fresh or ensiled materials. The EDs of DM for the BSS were comparable with or higher than that for the ABRS, which was 52.9 or 43.7 % assuming that the passage rate was at 2 or 4%/h (Liu et al., 1997).

The results of the feeding trial are summarized in table 4. The animals consumed all supplementary BSSs without any adverse health problems. Intake of ABRS decreased with the increase in the levels of BSS. Tharmaraj et al. (1989) observed a decline in the DM intake of ammoniated and untreated RS when supplemented with *Gliricidia*, a leguminous tree. However the substitute rate below 1.00 (except group 4 in phase 2) indicates that the ABRS was not completely replaced by the BSS in the current study. Total intake was therefore higher in almost all supplementary groups for both phases than in the non-BSS. The proportion of the BSS in total dietary intake was 0, 10, 21 and 30 % in phase 1, and 0, 15, 29 and 47% in phase 2 for groups 1, 2, 3 and 4, respectively. High amounts of BSS such as in group 4 in phase 2 would replace the ABRS.

Heifers had a higher growth rate in phase 1 when supplemented with fresh BSS than in phase 2 with ensiled shell (table 4). In phase 1 the growth rate was significantly higher for the animals in groups 3 and 4 than those in groups 1 and 2 ($p<0.01$), with no significant difference between groups 1 and 2 ($p>0.05$). However the animals in group 3 had a weight gain higher than in group 4 ($p<0.05$). The weight gain obtained in the 6 kg fresh BSS-supplemented group was similar to that in the ABRS diets supplemented with 2.5 kg of concentrate mixture (Liu et al., 1991), and superior to that in the ABRS diets with 1.8 kg rapeseed meal (Liu et al., 1993). A similar tendency was observed in phase 2, indicating a

Table 3. Constants of dry matter and crude protein of the equation p=a+b(1-exp(-ct)) together with 48 h rumen degradability (D_{48}) of the bamboo shoot shell (BSS)

	Degradability constants				ED[1] at passage rate (k)		D_{48} (%)
	a(%)	b(%)	c(%/hr)	a+b(%)	2 %/hr	4 %/hr	
Dry matter							
Fresh BSS	23.9	54.2	2.30	78.1	52.6	43.5	57.4
Boiled BSS	13.8	69.2	3.57	83.1	58.2	46.4	71.9
Ensiled BSS	10.2	64.9	3.87	75.1	53.0	42.1	60.9
SEM	1.8	0.7	0.28	2.2	0.6	0.5	6.0
Crude protein							
Fresh BSS	32.8	52.6	1.80	85.4	57.6	49.3	63.7
Boiled BSS	18.7	77.5	1.91	96.2	56.4	43.6	66.5
Ensiled BSS	21.6	61.8	1.90	83.7	51.7	41.5	66.5
SEM	1.0	2.3	0.16	5.0	0.2	0.2	6.0

[1] ED: effective degradability calculated from the equation: ED=a+b(c/(c+k)) (Ørskov, 1985)

Table 4. Feed intake and daily weight gain of heifers offered ammoniated rice straw and supplemented with different levels of bamboo shoot shell (BSS)

	Phase 1					Phase 2				
Treatments	1	2	3	4	SEM	1	2	3	4	SEM
Nos. of animals	8	8	8	8		8	8	8	8	
DM intake (kg/d)										
Ammoniated straw	2.61	2.31	2.01	1.75		2.79	2.28	1.83	1.03	
BSS	0	0.38	0.77	1.14		0	0.57	1.14	1.72	
Total	3.54	3.62	3.71	3.83		3.69	3.75	3.87	3.65	
Substitute rate[1]	-	0.79	0.78	0.75		-	0.89	0.84	1.02	
Initial body weight (kg)	138.8	140.1	139.3	140.1	0.7	181.4	185.6	196.8	190.8	3.9
Daily gain (g/d)	622^{Bc}	629^{Bc}	744^{Aa}	690^{Ab}	7	578^{Bc}	575^{Bc}	677^{Aa}	635^{Ab}	11
Feed conversion ratio (kg/kg)										
Total/gain	5.69	5.76	4.99	5.55		6.38	6.52	5.72	5.75	
Concentrate/gain	1.50	1.48	1.25	1.35		1.56	1.57	1.33	1.42	
Feed cost (Yuan/kg gain)[2]	3.17	3.53	2.90	3.26		3.40	3.76	3.49	3.95	

[1] Substitute rate is expressed as the depression in the intake of ammoniated straw produced by a unit increase in the BSS intake.

[2] Price (Yuan/kg DM, 1 US$=8.25 Yuan): ammoniated rice straw 0.20, cotton seed cake 1.56, concentrate mixture 1.40, fresh bamboo shoot shell 0.39, silage of boiled bamboo shoot shell 0.52.

[a,b,c] Means with different superscripts within same phase differ significantly ($p<0.05$).

[A,B] Means with different superscripts within same phase differ significantly ($p<0.01$).

depressive effect when the BSS was included at a high level, i.e. 30% for fresh shell and 47% for ensiled BSS. Chen et al. (1979) have observed that the growth rate for growing Holstein heifers was only 600 g/d when the BSS-based diet was supplemented with 3.5 kg of concentrate mixture; and 5.5 kg of concentrate mixture was needed to obtain 1.34 kg of weight gain in fattening cattle. It may be disadvantageous to include the BSS at high levels or use it as a basal diet for ruminants.

Supplementation of the ABRS-based diet with fresh or boiled BSS resulted in an improved feed conversion rate and reduced concentrate consumption per kilogram liveweight gain; fresh shell promoted higher weight gains than silage of the boiled BSS (table 4). The lowest rate of feed conversion and least concentrate consumption for weight gain were observed in group 3 for both phases. These results were comparable with those when milk vetch silage was supplemented (Liu et al., 1997).

While the nutrient digestibility of the total diets was not determined in the present study, the digestibility of the BSS-supplementary diets should be equivalent to that of the non-BSS groups, since all types of BSSs were equally digestible as the ABRS (table 3 and Liu et al., 1997). Daily CP intake must have been higher in the BSS-supplemented diets because of a higher content of CP in the BSS vs. ABRS (table 2). These differences and the increased DM intake indicate that the intake of digestible energy and protein would have been greater in the BSS-supplemented diets, and this may account for the improved growth rate of the BSS-supplemented heifers.

CONCLUSION

The results of the present study indicate that bamboo shoot shell, the residue either from production of fresh shoots or industrial scale fractionation of bamboo shoots, may be used in the diet for ruminants due to its high potential nutritional value with medium protein content and reasonably high rumen degradability, and negligible contents of antinutritional compounds such as tannins and hydrocyanic acid. Inclusion of bamboo shoot shell in ammoniated rice straw diet may increase the total dietary intake by heifers, and improve growth performance and feed conversion ratio. The practical implications of these results are of particular relevance to the bamboo shoots-producing areas where it is presently not used and there is a potential pollution problem from disposing of it. Further study is needed to improve the ensiling technique for bamboo shoot shell, as it is seasonally produced with high moisture and is low in the water soluble carbohydrates necessary for successful fermentation by lactobacillus during ensilage.

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