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Addition of rice straw or/and wheat bran on composition, ruminal degradability and voluntary intake of bamboo shoot shells silage fed to sheep

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Abstract

This study investigated the quality of bamboo shoot shell silage prepared with or without rice straw (RS) or/and wheat bran (WB), and to evaluate their nutritive value in terms of chemical composition, ruminal degradation characteristics, and voluntary intake by lambs. The bamboo shoot shells silages were prepared in experimental silos to create four treatments: (1) 100% (fresh basis) bamboo shoot shells (control); (2) 90% bamboo shoot shells + 10% RS (RS10); (3) 90% bamboo shoot shells + 5% RS and 5% WB (RS5WB5), and (4) 90% bamboo shoot shells + 10% WB (WB10). Voluntary intakes of the silages were determined in a 4 × 4 Latin square design with four lambs. The bamboo shoot shell silage alone was of poor quality with moulding and seepage to the bottom of the silo. Addition of RS or/and WB improved silage quality, but addition of WB was superior to that with RS. The DM loss was very high in control silage (>17%), but addition with RS increased DM recovery, with little effect on quality of silage. Recovery of DM further increased in both WB-added groups and was higher than that in the RS-added silage. Adding WB improved the quality of silage, judged by a lower pH value, decreased NH_3-N concentration and increased content of lactic and total acids. While adding RS decreased the ruminal degradation of DM and crude protein of bamboo shoot shells silage, WB addition increased both rapidly and slowly degraded fractions of bamboo shoot shells silage, and ruminal degradability of DM and crude protein at 48 h was increased. Voluntary DM intake of bamboo shoot shells silage was 32, 67 and 120% higher for groups RS10, RS5WB5 and WB10 than for the control. The CP intake was 18, 55, and 232% higher with addition of 10% RS, 10% RS plus 5% WB, and 10% WB, compared to the control. Improved performance of lambs may be expected from bamboo shoot shell silage prepared with RS or/and WB, but improvements are substantively higher for WB.

Keywords: Bamboo shoot shells; Rice straw; Wheat bran; Fermentation quality; Intake

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1. Introduction

Bamboo (*Bambusa arundinacea*) shoot is a traditional food in China where 1 million tonnes are produced annually. Output of bamboo shoot shells (BSS) is proportional to the shoots that are consumed fresh or processed products such as dried or canned shoots. The BSS has a high potential nutritional value (Zhou et al., 1991; FAO, 1998). Inclusion of BSS in ammoniated straw diets may increase total dietary intake and improve performance of growing cattle and feed conversion ratio (Liu et al., 2000). As bamboo shoots are mainly produced in spring, BSS is seasonally produced. However, it is disadvantageous to use the BSS as a basal diet (Chen et al., 1979) or at high level (>50% of dietary DM intake) (Liu et al., 2000), probably due to existence of antinutritional factors in BSS (FAO, 1998).

The BSS may be preserved as silage, but since its moisture content is over 90%, it is difficult to prepare BSS silage of good quality without additives. It has been shown that DM losses during ensilage are reduced with decreased moisture content of the raw materials (Savoie et al., 1986; Lu, 1990). Cereal straws provide density and absorb silage effluent when added to grass (Kota, 1989), while addition of brans has improved quality of water hyacinth silage (Lowilai et al., 1994) and alfalfa silage (Shin et al., 1996). Rice straw has been demonstrated to improve quality parameters of silage from high moisture materials such as Chinese milk vetch (Fang et al., 1996) and turnip (Chen et al., 1998).

The objectives of this study were to investigate the quality of BSS silage prepared with or without rice straw (RS) and wheat bran (WB), and to evaluate the nutritional value of these silages in terms of chemical composition, ruminal degradation and voluntary intake by lambs.

2. Materials and methods

2.1. Experimental feeds

Fresh BSS was obtained from the Banqiao Bamboo-processing Plant in Lin'an (China). Before ensilage, contaminating clay on BSS was washed off using fresh water. The RS and WB were supplied by the Banqiao Dairy Farm in Lin'an (China). Rice straw was chopped into 3–5 cm pieces before ensilage using a harvester chopper.

2.2. Experimental design

The BSS silages were prepared to create four treatments: (1) 100% (fresh basis) BSS (control); (2) 90% BSS plus 10% RS (RS10); (3) 90% BSS plus 5% RS and 5% WB (RS5WB5), and (4) 90% BSS plus 10% WB (WB10). Materials for each treatment were ensiled in triplicate in experimental silos with a capacity of 0.05 m^3. According to their proportions in different treatments, individual materials were weighed and mixed thoroughly. The mixed materials were then trodden down in the silos layer by layer and the top was sealed with plastic sheets. Finally the surface was weighted with stone blocks to prevent re-entry of air. Silos were opened for 40 days after ensiling.

Silages with the same treatments were prepared in four experimental bunker silos with a capacity of 1 t for use in the feeding study.

2.3. Chemical analysis

2.3.1. Experimental feeds

Fresh BSS, RS and WB were measured for dry matter (DM) and crude protein (CP) according to AOAC (1990), and neutral detergent fiber (NDF) by method of Van Soest et al. (1992) without pre-treatment of amylase and with addition of sodium sulfite in detergent. Residual ash was not eliminated from the NDF. Water soluble carbohydrate (WSC) was determined according to the method of Dubois et al. (1956). The buffering capability (BC) of silages was measured by the method of Playne and McDonald (1966), and extracts of silages were measured for pH using a pH meter.

2.3.2. BSS silage

Silages were evaluated by subjective criteria such as color, smell and texture when the experimental silos were opened. Representative samples were taken and determined for pH, chemical composition, NH_3-N and organic acids (lactate, acetate and butyrate).

The determinations of DM, CP and NDF, as well as the pH, were as described above. Silage was extracted with distilled water and the supernatant was used for determination of ammonia-N (NH_3-N) and organic acids. The NH_3-H concentration was determined by steam distillation into boric acid and titration with dilute hydrochloric acid (10 mmol/l).

Organic acids were analyzed on a gas chromatograph (Model SP-502, Hitachi). Samples were injected into a $2\,m \times 4\,mm$ (i.d.) gas column packed with Porapak. Temperatures of the injector and detector were 210 and 260°C, respectively. Nitrogen gas was used a carrier at a flow rate of 55 ml/min. Following injection, concentrations of individual acids were determined by comparing with standard solutions of the corresponding acids.

The materials before and after ensilage were weighed, and the DM recovery was calculated. Recoveries of CP and NDF were also calculated accordingly.

2.4. Ruminal degradation studies

Four rumen-fistulated sheep were used to determine ruminal degradation of silage DM and CP using a nylon bag technique (Ørskov, 1985). Bags were of 300 mesh (pore size, 41 μm) nylon fabric measuring $5\,cm \times 10\,cm$ with mounted corners. Feeds were oven-dried at 60°C and hammer-milled through a 40 mesh sieve. Duplicate 3–4 g samples of each feed were weighed into nylon bags, suspended in the rumen of sheep, removed after 8, 16, 24, 48 and 72 h of incubation, and washed under running tap water (clod) for about 1 h until the water ran clear. Bags and contents were then dried at 60°C oven. Dried residues were used to determine DM (105°C) and CP, and the rates of disappearance of each component were calculated. The parameters of ruminal degradation of DM and CP were calculated according to the model of Ørskov (1985): $p = a + b(1 - e^{-ct})$, where p is disappearance at time t (h), a the rapidly degradable fraction in the rumen, b the fraction degraded slowly, and c the rate of disappearance of b (h^{-1}).

2.5. Dry matter intake

Four castrated lambs weighing 18 ± 0.8 kg were allocated to individual pens. Silages were offered along with 90 g of a concentrate mixture and 30 g of cottonseed meal. The concentrate mixture consisted of ground corn (52%), soybean meal (10%), wheat bran (20%), rapeseed meal (15%), lime (1%), and mineral–vitamin complex (2%).

The experiment was a 4×4 Latin square design in which each period lasted for 21 days with the first 14 days for adaptation. Silage intake was measured over the final 7 day. Diets were offered twice per day in two equal meals at 8.00 and 18.00 h at levels 15% greater than the previous day's consumption. Daily sub-samples of the diets offered and residues were collected, weighed, sampled and bulked each morning for later determination of DM and calculation of DM intake.

2.6. Statistical analysis

Feed composition was analyzed by a one way analysis of variance. Silage intake and ruminal degradation of DM and CP were analyzed according to 4×4 Latin square design, and differences of means were tested using Duncan's new multiple range test (Steel and Torrie, 1980).

3. Results

3.1. Subjective evaluation and chemical composition of silage

Fresh BSS was low in DM with a very high BC (Table 1). The RS was low in WSC and BC. The BSS silage had a light-yellow color and an acetic acid smell when the silos were opened, compared with straw-yellow in RS10 or bright-yellow in WB10. Mould was observed on the top of BSS silage and seepage in the bottom of the silage. When the BSS was ensiled with wheat bran, silage smelled sweet and acidic, the WB10 being superior to the RS5WB5.

The DM content increased about 50% when RS or/and WB was added (Table 2). Addition of WB significantly increased CP content, with highest value in 10% WB-added

Table 1
Chemical composition, buffering capacity and pH value of fresh bamboo shoot shells, rice straw and wheat bran[a]

	Bamboo shoot shells	Rice straw	Wheat bran
Dry matter (g kg^{-1})	128	889	846
Crude protein (g kg^{-1} DM)	127	58	210
Neutral detergent fiber (g kg^{-1} DM)	738	764	486
Water soluble carbohydrate (g kg^{-1} DM)	39	36	90
Buffering capacity (mEinstein kg^{-1} DM)	588	149	320
pH	5.78	6.10	5.10

[a] Assays represented triplicate assays of two samples of each material.

Table 2
Chemical composition before and after ensilage, and dry matter recovery of silage made from bamboo shoot shell added with rice straw (RS) or/and wheat bran (WB)[a]

	Treatments				S.E.M.
	Control	RS10	RS5WB5	WB10	
Proportion (% as mixed)					
Bamboo shoot shell	100	90	90	90	
Rice straw	0	10	5	0	
Wheat bran	0	0	5	10	
Chemical composition					
Before ensiling[b]					
Dry matter (g kg^{-1})	128	204	202	200	–
Crude protein (g kg^{-1} DM)	127	96	120	162	–
Neutral detergent fiber (g kg^{-1} DM)	738	750	791	631	–
Water soluble carbohydrate (g kg^{-1} DM)	39	39	49	60	–
After ensiling					
Dry matter (g kg^{-1})	126 b	185 a	176 a	186 a	4.1
Crude protein (g kg^{-1} DM)	86 c	91 c	116 b	158 a	1.4
Neutral detergent fiber (g kg^{-1} DM)	794 a	737 b	697 c	585 d	14.0
Recovery (%)					
Dry matter	82.9 c	89.8 b	92.5 a	94.1 a	0.60
Crude protein	56.1 c	85.1 b	89.4 a	91.8 a	1.05
Neutral detergent fiber	89.2 a	88.2 a	81.5 b	87.2 a	2.02

[a] Means in a row with different letters differ significantly ($P < 0.05$).
[b] S.E.M. are not available, as values represent the compositions of a single sample.

silage, while there was little difference between control and RS10. The NDF content was highest in control, followed by RS10, RS5WB5, and the lowest in WB10.

Recovery of DM was very low in control (82.9%, Table 2), but significantly increased in RS or/and WB-added groups ($P < 0.05$), with significantly higher value ($P < 0.05$) in WB10 than in RS10. The CP recovery showed similar tends to that of DM, with a very low value for control silage. Recovery of NDF was lowest in RS5WB5, with little differences between other three groups.

According to Table 3, pH was highest in RS10 ($P < 0.05$). The pH decreased from 5.08 in control down to 4.15 in WB10. The NH_3-N concentration was highest in control, followed by RS10, RS5WB5, and the lowest in WB10. Content of lactic acid was relatively low for BSS silage, but addition with 10% RS decreased the contents of individual and total acids. With inclusion of WB in BSS silage, both lactate and acetate increased significantly, resulting in higher contents of total acids. No butyric acids were detected in all BSS silages.

3.2. Ruminal degradation and dry matter intake

Determined ruminal degradation of DM at 48 h (D_{48}) was 40.9% in control silage, slightly decreased in RS10 silage, and increased in WB10 silage (Table 4). Compared to

Table 3
The pH, NH_3-N and organic acid contents in silages made from bamboo shoot shells with added rice straw (RS) or/and wheat bran (WB)[a]

	Treatments				S.E.M.
	Control	RS10	RS5WB5	WB10	
pH	5.08 b	5.20 a	4.79 c	4.15 d	0.02
NH_3-N (g kg^{-1} TN)	141 a	109 b	76 c	45 d	3.0
Organic acids (g kg^{-1} DM)					
Lactate	38 c	25 d	60 b	71 a	2.0
Acetate	13 b	7 c	19 a	24 a	1.5
Butyrate	ND[b]	ND	ND	ND	

[a] Means in a row with different letters differ significantly ($P < 0.05$).
[b] ND: not detected.

the control, the rapidly degradable fraction (*a*) of DM increased modestly when only RS was added, but increased significantly with either WB addition, being the highest in WB10. The slowly degraded fraction (*b*) decreased in RS10 (versus control), increased in WB10 and was the same in RS5WB5. The CP degradation parameters showed similar trends to those for DM.

Compared to control silage, intake of DM from silage increased when BSS was ensiled with addition of RS or/and WB (Table 5). DM intake of silage was 32, 67 and 120% higher in groups RS10, RS5WB5 and WB10 versus control. Total DM intake, CP intake and NDF intake showed similar tends to that of silage DM intake.

Table 4
Ruminal degradation parameters (a, b, c) of DM and CP together with 48 h ruminal degradability (D_{48}) of silage made from bamboo shoot shells with added rice straw (RS) or/and wheat bran (WB)[a]

	Treatments				S.E.M.
	Control	RS10	RS5WB5	WB10	
Dry matter[b]					
a (%)	5.2 d	8.3 c	15.7 b	27.5 a	0.53
b (%)	54.1 b	42.1 c	55.2 b	60.8 a	1.77
c (% h^{-1})	3.87 ab	4.27 a	4.30 a	3.12 b	0.140
D_{48} (%)	40.9 c	36.9 d	45.1 b	58.8 a	0.29
Crude protein					
a (%)	31.6 c	31.0 c	46.5 b	50.1 a	0.75
b (%)	41.8 a	26.5 b	27.6 b	44.7 a	1.64
c (% h^{-1})	1.90 c	3.30 b	4.40 a	2.13 c	0.250
D_{48} (%)	56.6 c	52.3 d	70.1 b	80.9 a	0.91

[a] Means in a row with different letters differ significantly ($P < 0.05$).
[b] *a*: rapidly degradable fraction; *b*: slowly degradable fraction; *c*: fractional degradation rate of fraction *b*; D_{48}: determined ruminal degradation at 48 h incubation.

Table 5
Dry matter intake of silage and total diets by lambs in the feeding study[a]

	Treatments				S.E.M.
	Control	RS10	RS5WB5	WB10	
Silage intake					
g per day	200 d	264 c	334 b	440 a	16.0
g (kg $W^{0.75}$)$^{-1}$ per day	22.9 d	30.2 c	38.2 b	50.3 a	1.83
Total intake (g per day)					
Dry matter	308 d	372 c	442 b	548 a	12.5
Crude protein	40 d	47 c	62 b	93 a	2.1
NDF	184 d	219 c	258 b	282 a	4.6

[a] Means in a row with different letters differ significantly ($P < 0.05$).

4. Discussion

Characteristics of an ideal material for preservation as silage are that it should contain an adequate level (>100 g kg^{-1}) of fermentable substrate in the form of WSC, a relatively low BC (200–300 mEinstein kg^{-1} DM) and a DM content of above 200 g kg^{-1} (McDonald et al., 1991). The BSS had contents of DM (127 g kg^{-1}) and WSC (39 g kg^{-1} DM) lower than those of temperate grasses but similar to those of tropical grasses (McDonald et al., 1991). The BC of BSS (587.8 mEinstein kg^{-1} DM) is much higher than values of most herbage species that can not successfully ensiled. These features of BSS indicate that it is difficult to ensile without an additive. In the previous study (Liu et al., 2000), we could not obtain a good quality BSS silage when ensiling it with no additive or salt. Addition with RS or/and WB increased the DM to about 180 g kg^{-1}, and WB addition also increased the WSC content.

The main purpose of ensiling is to preserve feedstuffs for later use, and recovery of DM after ensiling is an important indicator of silage quality. When BSS was alone ensiled, the DM loss was higher than 17%, but recovery of DM increased to 90% with addition of RS and reached the highest with either WB addition. In the present study, the silage was prepared in experimental silos from which effluent could not be lost. However, effluent losses would be greater in field conditions, where DM loss indicates effluent loss (Miller and Clifton, 1965). Reduced DM loss with addition of RS and WB is consistent with others (Hough et al., 1994; Fang et al., 1996; Jones and Jones, 1996). The CP recovery was very low (56.1%) when BSS was alone ensiled. Addition with RS or/and WB increased CP recovery greatly, with higher value in RS5WB5 and WB10 than in RS10. A part of protein might be broken down and volatilized in control silage, which may be explained by higher concentrations of NH_3-N (Table 3). Contrary to DM recovery, NDF recovery was highest in control silage but lower with either WB addition, indicative of the loss of soluble cell contents in control.

All silages had a high proportions of organic acids as lactic (66–70% of the total acids) with no detectable butyric acid. Total acid concentrations were low in control and RS10 silage, and the pH was high for these silages. Addition with WB lowered the pH, compared to RS, due to the increase in concentrations of total acids. However, NH_3-N concentrations decreased in RS10 silage, and further decreased with either WB addition. Similar results have been observed when RS was added to turnip silage (Chen et al., 1998).

The BSS silage had a low degradation of DM and CP in the rumen at 48 h, but addition of 10% RS further decreased the D_{48} value. This demonstrates that while the silage effluent may be absorbed by high fiber materials such as rice straw, the nutritive value of the straw-added silage may be inferior to that of the control, if the nutritive value of the rice straw is lower than the silage per se (Jones and Jones, 1996). Kota (1989) observed that fermentation may be improved by straw application, but the net energy content of the silage is reduced. Addition of RS and WB together increased fraction *a*, and hence the D_{48} increased.

Voluntary DM intake of forages is a major factor determining their nutritive value for animals. Intake is influenced by level and rate of fiber digestion in the rumen as well as passage of indigestible and digestible residues from the rumen (Van Soest, 1994). Voluntary intake of silage is also regulated by the digestion of their fibrous materials in the rumen (Liu et al., 1988). However, intake of silage DM is generally lower than that of fresh or dried forage of the same materials. Wilkins et al. (1971) found that intake of DM was positively correlated with the increasing content of silage DM, total N, and lactic acid as a percentage of total acids, and negatively with the contents of acetic acid and NH_3-N (TN (%)). Using 19 grass silages, Ostrowski (1995) obtained a positive correlation of DM intake with contents of DM, lactate and CP. Addition of RS, though with little improvement in silage quality and ruminal degradation, did increase intake of silage DM, probably due to lower NH_3-N and increased DM content. When WB was added, both quality of BSS silage and DM digestion in the rumen were greatly improved. The intake of DM from silage in 10% WB-added group (WB10) doubled that of control. Reflective of DM intake from silage, total DM intake was 21, 44 and 78% higher in groups RS10, RS5WB5 and WB10, compared to control. While CP content was lower in RS than in BSS, addition of RS increased CP intake significantly, mainly attributed to the increase in silage intake. The CP intake was 55 and 232% higher in RS5WB5 and WB10 versus control.

5. Conclusions

Bamboo shoot shells, a residue of seasonal production of bamboo shoot, must be ensiled to assure continuous supply throughout the year. However, its low contents of DM and WSC, and high buffering capacity, make it difficult to prepare good quality BSS silage. Addition of 10% rice straw at ensiling increased DM recovery of BSS, and DM intake by lambs, although rumen degradation of DM and CP was reduced. Adding 10% WB at ensiling improved the fermentation quality of the BSS silage, enhanced ruminal degradation and increased DM intake of BSS silage. Addition of 5% RS and 5% WB resulted in silage intermediate to the 10% WB and 10% RS silages. Improved performance of animals may be expected if BSS is ensiled with RS or WB, but performance with WB was much better than that of RS, with alone or with WB.

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