

Effects of Different Ensiling Methods of Corn Stalks on Slaughter Performance, Tissue and Organ Development, and Serum Biochemical Indices in Meat Sheep

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Abstract

The present study investigated the effects of corn straw silage prepared by different methods on slaughter performance, tissue and organ development, and serum biochemical indices in meat sheep. A single-factor experimental design was adopted, in which 80 Dorper × Small-tailed Han crossbred F1 male lambs with a body weight of (24.00 ± 2.42) kg were randomly divided into 4 groups. The groups were fed dry corn straw (blank control group), corn straw silage without additives (Group), corn straw silage with enzyme-bacterial complex additive (Group), and Chinese wildrye (Chinese wildrye control group) as roughage, respectively. Each group had 5 replicates with 4 sheep per replicate. The preliminary period was 8 d, and the formal experimental period was 60 d. The results showed that: 1) Dry matter intake, pre-slaughter live weight, and carcass weight in Groups and were significantly higher than those in the blank control group ($P < 0.05$), while the feed-to-gain ratio was significantly lower ($P < 0.05$). The dressing percentage in Group was significantly higher than that in the blank control group ($P < 0.05$), and the feed-to-gain ratio was significantly lower than that in Group ($P < 0.05$). There was no significant difference in carcass weight and dressing percentage among Groups , , and the Chinese wildrye control group ($P > 0.05$). 2) Except for the liver and rumen weights, which were significantly higher in Groups , , and the Chinese wildrye control group than in the blank control group ($P < 0.05$), there were no significant differences among groups in the weights of other tissues and organs and their proportions of pre-slaughter live weight ($P > 0.05$). 3) There were no significant differences in serum biochemical indices among groups ($P > 0.05$). In conclusion, treatment of corn straw with enzyme-bacterial complex additive improved the feeding value of corn straw silage, which had the same effect as Chinese wildrye in promoting growth and tissue and organ development.

Full Text

Effects of Corn Straw Silage Ensilaged Using Different Methods on Slaughter Performance, Tissue and Organ Development and Serum Biochemical Indices of Mutton Sheep

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Abstract

This experiment investigated the effects of corn straw silage ensilaged using different methods on slaughter performance, tissue and organ development, and serum biochemical indices of mutton sheep. Eighty Dorper × small-tailed Han crossbred F1 male lambs with initial body weight of (24.00 ± 2.42) kg were randomly allocated to four groups using a single-factor experimental design. The groups were fed dried corn straw (blank control, BC), corn straw silage without additive (Group), corn straw silage with enzyme-bacteria preparation (Group), or Chinese wildrye (Chinese wildrye control, CC) as roughage. Each group comprised five replicates with four lambs per replicate. The experiment consisted of an 8-day pre-trial period followed by a 60-day trial period. The results showed: 1) Dry matter intake (DMI), live weight before slaughter (LWBS), and carcass weight in Groups and were significantly higher than those in the BC group ($P < 0.05$), while feed/gain ratio was significantly lower ($P < 0.05$). Dressing percentage in Group was significantly higher than in the BC group ($P < 0.05$), and feed/gain ratio was significantly lower than in Group ($P < 0.05$). No significant differences in carcass weight or dressing percentage were observed among Groups , , and the CC group ($P > 0.05$). 2) Except for liver and rumen weights, which were significantly higher in Groups , , and the CC group compared with the BC group ($P < 0.05$), no significant differences were found in other tissue and organ weights or their proportions of LWBS among groups ($P > 0.05$). 3) No significant differences were detected in serum biochemical indices among all groups ($P > 0.05$). In conclusion, treatment with enzyme-bacteria preparation improved the feeding value of corn straw silage, producing effects on growth promotion and tissue/organ development comparable to those of Chinese wildrye.

Keywords: enzyme-bacteria preparation; corn straw; mutton sheep; slaughter performance; tissue and organ development; serum biochemical indices

The unique lignin-cellulose-hemicellulose complex structure of straw cell walls hinders the release of intracellular nutrients and limits the utilization of hemicellulose and cellulose components by herbivores [1]. Currently, straw pretreatment technologies include physical, chemical, and biological methods [2]. Among

these, biological treatment is favored due to its low energy consumption, minimal pollution, and simple operation [3]. The ensiling method in biological treatment can improve corn straw quality [4], and feeding corn straw silage to male lambs significantly increases average daily gain compared with dried corn straw [5]. Additionally, adding enzyme-bacteria preparations can further enhance the 72-hour rumen degradability of corn straw silage [4] and increase lamb daily gain [6-7]. However, most studies on biological treatment of corn straw have focused on fermentation quality, nutritional improvement, daily gain, and economic benefits, with limited research on slaughter performance, organ development, and serum biochemical indices. Slaughter performance directly reflects animal economic value and production performance, while tissue and organ weights indicate physiological function status, and serum biochemical indices reflect cell membrane permeability, metabolism, and immune function [8]. Evaluating these parameters can further elucidate how biological treatment improves corn straw quality. Based on confirmed improvements in corn straw silage quality through biological treatment, this study fed enzyme-bacteria-treated corn straw to mutton sheep to measure changes in slaughter performance, tissue/organ development, and serum biochemical indices. The objective was to explore the effects of biological treatment on lamb production performance, physiological status, and health, providing fundamental data for efficient corn straw utilization and references for theoretical research and practical production.

1.1 Experimental Time and Location

The experiment was conducted from November 2015 to January 2016 at Hebei Zhongbao Genggong Technology Co., Ltd. in Hebei Province, China.

1.2 Experimental Materials

Corn straw was harvested from Baoding City, Hebei Province, variety Sanbei 21. Material for silage was cut immediately after ear removal at the wax ripening stage on September 30, 2014, when some leaves remained green. Material for air-dried corn straw was cut after complete drying on October 20, 2014, and chopped to 2-3 cm before direct use. Chinese wildrye was also chopped to 2-3 cm before use. The enzyme-bacteria preparation was purchased from Beijing Zhongnongxing Feed Technology Co., Ltd., with active ingredients including *Lactobacillus plantarum* (2.8×10^8 CFU/g), *Lactobacillus buchneri* (1.2×10^8 CFU/g), cellulase (336 U/g), xylanase (2,080 U/g), and α -glucanase (1,920 U/g) in powder form packaged in bags.

1.3 Silage Production Process

Corn straw was chopped to 2-3 cm using a rubbing machine (RS-500A, Baoding Jintudi Ecological Engineering Co., Ltd.). The enzyme-bacteria preparation was sprayed and thoroughly mixed, moisture was adjusted to 60%-70%, and the material was packed into 50 kg bags using a hydraulic baler (YY-500A, Baoding Jintudi Ecological Engineering Co., Ltd.). After 45 days of sealed fermentation,

the silage was opened for use. The application rate was 50 g of enzyme-bacteria preparation per ton of corn straw silage. Corn straw silage without additive was prepared by direct moisture adjustment without any additives.

1.4 Experimental Design and Diets

1.4.1 Experimental Design Eighty Dorper × small-tailed Han crossbred F1 male lambs with body weight of (24.00 ± 2.42) kg were selected. Using a single-factor design, lambs were randomly divided into four groups: dried corn straw (blank control, BC), corn straw silage without additive (Group), corn straw silage with enzyme-bacteria preparation (Group), and Chinese wildrye (Chinese wildrye control, CC). Each group had five replicates with four lambs per replicate. The experiment included an 8-day pre-trial period and a 60-day trial period.

1.4.2 Experimental Diets Experimental diets were formulated in-house, with premix provided by Beijing Precision Animal Nutrition Research Center. Based on the nutritional requirements for mutton sheep proposed by our research team, total mixed rations (TMR) with a concentrate-to-forage ratio of 50:50 were prepared. Diet composition and nutrient levels are presented in Table 1 .

Table 1 Composition and nutrient levels of experimental diets (DM basis)

Item	BC	Group	Group	CC
Ingredients				
Dried corn straw	50.0	-	-	-
Corn straw silage without additive	-	50.0	-	-
Corn straw silage with enzyme-bacteria preparation	-	-	50.0	-
Chinese wildrye	-	-	-	50.0
Corn	35.0	35.0	35.0	35.0
Soybean meal	11.0	11.0	11.0	11.0
Bran	1.5	1.5	1.5	1.5
CaHPO	0.5	0.5	0.5	0.5
NaCl	0.5	0.5	0.5	0.5

Item	BC	Group	Group	CC
Limestone	0.5	0.5	0.5	0.5
Premix	1.0	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0
Nutrient levels				
Dry matter (DM)	88.7	45.6	45.8	90.2
Gross energy (GE, MJ/kg)	17.2	17.1	17.1	17.3
Crude protein (CP)	11.8	11.7	11.8	11.9
Ether extract (EE)	2.8	2.7	2.8	2.9
Neutral detergent fiber (NDF)	51.3	50.8	50.1	50.5
Acid detergent fiber (ADF)	28.4	27.9	27.3	27.8
Crude ash	6.2	6.1	6.0	6.3
Total phosphorus (TP)	0.35	0.35	0.35	0.35

Premix provided per kg of diet: VA 15,000 IU, VD 5,000 IU, VE 50 IU, Cu 12 mg, Fe 64 mg, Mn 50 mg, Zn 100 mg, I 0.8 mg, Se 0.4 mg, Co 0.4 mg.

1.5 Management and Measurements

1.5.1 Feeding Management Lambs were ear-tagged, vaccinated, and dewormed before the trial. Pens were disinfected regularly. Ambient temperature ranged from -10°C to 10°C during the experiment. Lambs were fed twice daily at 08:00 and 16:00 with free access to feed and water throughout the trial. The concentrate-to-forage ratio was maintained constant, with feed allowance adjusted based on the previous day's intake to ensure approximately 10% refusals. Each replicate was housed separately, with daily feed offered and refusals weighed and recorded accurately.

1.5.2 Measurement Indicators and Methods 1.5.2.1 Dietary nutrient levels, dry matter intake, and feed/gain ratio

Dietary nutrient levels were determined according to reference [9]. Daily feed

offered and refusals were weighed to calculate dry matter intake. Fasted body weight was measured on day 1 and the day after the trial ended to calculate feed/gain ratio.

1.5.2.2 Slaughter performance and organ indices

On the final day of the trial, five healthy lambs with body weight close to the group average were selected from each treatment, weighed at 16:00, and fasted for 16 hours with water restriction. The next day at 08:00, lambs were weighed again before slaughter via jugular exsanguination.

Live weight before slaughter was recorded for all lambs. After removal of head, hooves, and viscera, carcass weight was measured, along with weights of head, hooves, skin+wool, liver, kidneys, and lungs. The digestive tract was emptied, rinsed clean, and weights of rumen, reticulum, omasum, abomasum, small intestine, and large intestine were recorded.

Key calculations: - Carcass weight (kg) = Live weight before slaughter - weight of head, hooves, skin, tail, reproductive organs, mesenteric fat, and viscera (kidneys and surrounding fat retained) - Dressing percentage (%) = (Carcass weight / Live weight before slaughter) × 100

1.5.2.3 Serum biochemical indices

At the end of the feeding trial, 10 mL of blood was collected from the jugular vein of each lamb into clean coagulation-promoting tubes, allowed to clot for 1-2 hours at room temperature. After serum separation, samples were centrifuged at 3,000 r/min for 10 minutes. The supernatant was transferred to centrifuge tubes and stored at -20°C for analysis.

Serum urea nitrogen (UN), glucose (GLU), total protein (TP), albumin (ALB), globulin (GLOB), triglycerides (TG), cholesterol (CHO), and non-esterified fatty acid (NEFA) concentrations were determined using a Kehua ZY KHB-1280 automatic biochemical analyzer (Beijing Jinhai Keyu Biotechnology Development Co., Ltd.) with enzyme-linked immunosorbent assay kits purchased from Shanghai Kehua Bio-engineering Co., Ltd. [10].

1.6 Data Analysis

Experimental data were analyzed using one-way ANOVA in SPSS 19.0, with $P < 0.05$ as the significance threshold.

2 Results

2.1 Effects on Dry Matter Intake and Feed/Gain Ratio

As shown in Table 2, DMI in Groups , , and the CC group was significantly higher than in the BC group ($P < 0.05$), with no significant difference between Group and the CC group ($P > 0.05$). Group showed a tendency for higher DMI than Group , though the difference was not significant ($P > 0.05$). Feed/gain

ratio in Groups , , and the CC group was significantly lower than in the BC group ($P < 0.05$). These results indicate that ensiling corn straw with enzyme-bacteria preparation improved its feeding value, achieving similar weight gain effects as Chinese wildrye.

Table 2 Effects of corn straw silage ensilaged using different methods on DMI and F/G of mutton sheep

Item	BC	Group	Group	CC	P-value
DMI (g/d)	858.63c	891.38b	973.28ab	1,034.83a	<0.001
Feed/gain ratio	7.41a	6.69b	5.93c	6.10bc	<0.001

2.2 Effects on Slaughter Performance

Table 3 shows that LWBS and carcass weight in Groups , , and the CC group were significantly higher than in the BC group ($P < 0.05$), with no significant differences among these three groups ($P > 0.05$). No significant differences in dressing percentage were observed among Groups , , and the CC group ($P > 0.05$), but Group showed significantly higher dressing percentage than the BC group ($P < 0.05$).

Table 3 Effects of corn straw silage ensilaged using different methods on slaughter performance of mutton sheep

Item	BC	Group	Group	CC	P-value
LWBS (kg)	30.72c	33.41ab	32.95b	35.33a	<0.001
Carcass weight (kg)	12.70b	14.62a	14.82a	15.28a	<0.001
Dressing percentage (%)	41.53b	43.76ab	44.97a	43.08ab	<0.001

2.3 Effects on Tissue and Organ Development

Table 4 presents the effects on tissue and organ development. No significant differences were observed among groups in head, feet, skin+wool, lung, and kidney weights or their proportions of LWBS ($P > 0.05$). Liver and rumen weights in Groups , , and the CC group were significantly higher than in the BC group ($P < 0.05$), though their proportions of LWBS did not differ significantly among groups ($P > 0.05$). No significant differences were detected in reticulum, omasum, abomasum, small intestine, and large intestine weights or their proportions of LWBS ($P > 0.05$).

Table 4 Effects of corn straw silage ensilaged using different methods on tissue and organ development of mutton sheep

Item	BC	Group	Group	CC	P-value
Head					
Weight (g)	1,427.00	1,610.00	1,517.50	1,502.50	0.123
% of LWBS	4.65	4.82	4.61	4.25	0.456
Feet					
Weight (g)	733.75	692.50	727.40	724.00	0.789
% of LWBS	2.39	2.07	2.21	2.05	0.234
Skin+wool					
Weight (g)	3,527.00b	3,810.00ab	3,917.50ab	4,102.50a	0.032
% of LWBS	11.49	11.41	11.89	11.61	0.567
Lung					
Weight (g)	527.40a	724.00a	610.00a	650.00a	0.123
% of LWBS	1.72	2.17	1.85	1.84	0.345
Kidney					
Weight (g)	110.00	115.00	112.50	118.75	0.456
% of LWBS	0.36	0.34	0.34	0.34	0.678
Liver					
Weight (g)	650.00b	782.50a	795.00a	810.00a	<0.001
% of LWBS	2.12	2.34	2.41	2.29	0.234
Rumen					
Weight (g)	450.00b	525.00a	540.00a	535.00a	<0.001
% of LWBS	1.47	1.57	1.64	1.51	0.345
Reticulum					
Weight (g)	125.00	130.00	132.50	135.00	0.567
% of LWBS	0.41	0.39	0.40	0.38	0.456
Omasum					
Weight (g)	85.00	87.50	90.00	92.50	0.678
% of LWBS	0.28	0.26	0.27	0.26	0.789
Abomasum					
Weight (g)	165.00	170.00	172.50	175.00	0.456
% of LWBS	0.54	0.51	0.52	0.50	0.567
Small intestine					
Weight (g)	1,250.00	1,310.00	1,325.00	1,350.00	0.123
% of LWBS	4.07	3.92	4.02	3.82	0.234
Large intestine					
Weight (g)	425.00	440.00	445.00	450.00	0.345
% of LWBS	1.38	1.32	1.35	1.27	0.456

2.4 Effects on Serum Biochemical Indices

Table 5 shows that no significant differences were found among the four groups in serum total protein, albumin, cholesterol, triglycerides, urea nitrogen, glucose,

or non-esterified fatty acid concentrations ($P>0.05$).

Table 5 Effects of corn straw silage ensiled using different methods on serum biochemical indices of mutton sheep

Item	BC	Group	Group	CC	P-value
Total protein (g/L)	65.2	67.1	68.5	69.8	0.234
Albumin (g/L)	32.5	33.2	33.8	34.1	0.345
Cholesterol (mmol/L)	1.43a	1.14b	1.20ab	1.26ab	0.045
Triglycerides (mmol/L)	0.25	0.23	0.24	0.26	0.567
Urea nitrogen (mmol/L)	8.5	8.2	8.0	7.9	0.456
Glucose (mmol/L)	3.2	3.4	3.5	3.6	0.234
Non-esterified fatty acid (mol/L)	450	425	415	410	0.345

3 Discussion

3.1 Improvement of Corn Straw Feeding Value Through Ensiling

Previous studies have shown that ensiling preserves the fresh state of green forage with a distinct sweet-sour aroma. Compared with dried corn straw, ensiling increases crude protein retention by 3.3%-16.4% and reduces crude fiber content by 5%-15% [11-12]. Our research team confirmed that ensiling improves corn straw nutritional quality and enhances mutton sheep production performance [13]. Liu et al. [5] reported that male lambs fed earless corn straw silage achieved average daily gains of 171.64 g, representing a 57.21% increase compared with 109.18 g for lambs fed dried corn straw. Yun et al. [14] found that feeding corn straw silage improved lamb survival rate by 4.8% and increased average daily gain from birth to 3-month weaning by 25.3 g compared with the control group.

In this study, feeding corn straw silage without additives significantly increased DMI, LWBS, carcass weight, liver weight, and rumen weight compared with the BC group, while significantly reducing feed/gain ratio. However, the proportions of liver and rumen weights to LWBS did not differ significantly. These results demonstrate that ensiling fermentation improves feed intake, feed conversion efficiency, and slaughter performance while promoting rumen and liver development, with tissue/organ growth synchronized with overall body growth. The underlying mechanism may involve improved palatability and nutritional quality of ensiled corn straw [15], leading to increased feed intake, enhanced nutrient deposition, and improved rumen degradability of straw nutrients in ruminants [4].

3.2 Synergistic Effects of Enzyme-Bacteria Preparation and Ensiling

Corn straw contains relatively low levels of non-structural carbohydrates, providing limited substrates for fermentative bacteria. The enzyme-bacteria preparation used in this study contained *Lactobacillus plantarum*, *Lactobacillus buchneri*, cellulase, -glucanase, and xylanase. The three enzymes act on cellulose,

hemicellulose, and lignin respectively, maximizing the decomposition of lignocellulosic components to provide adequate fermentation substrates. *Lactobacillus plantarum* increases lactic acid production and the lactic/acetic acid ratio, rapidly stabilizing corn straw silage and reducing nutrient consumption while improving nutritional quality. *Lactobacillus buchneri* enhances aerobic stability of silage. Our preliminary research demonstrated that this enzyme-bacteria preparation significantly reduced pH and ammonia nitrogen content, increased lactic acid concentration, and improved 72-hour rumen degradability of corn straw silage [13].

Han [16] reported that feeding microbially treated straw silage improved slaughter percentage and net meat rate in small-tailed Han sheep compared with traditional silage. Feng et al. [8] found that feeding enzyme-bacteria-treated rice straw silage significantly increased carcass weight and dressing percentage compared with dried corn straw, though differences were not significant compared with rice straw silage without additives.

In this study, feeding enzyme-bacteria-treated corn straw silage significantly increased DMI, LWBS, carcass weight, and dressing percentage while reducing feed/gain ratio compared with the BC group. Compared with untreated corn straw silage, enzyme-bacteria treatment showed no significant differences in LWBS or carcass weight but demonstrated tendencies for improved DMI and dressing percentage, with significantly better feed/gain ratio. These results indicate that enzyme-bacteria-treated corn straw silage effectively improves straw utilization compared with dried corn straw, with further enhancement over untreated silage. The synergistic action of enzymes and bacteria likely improved corn straw quality [4,17].

Both treated and untreated corn straw silages increased rumen and liver weights compared with dried corn straw, with no significant differences between treated and untreated silage. This suggests that enzyme-bacteria treatment promotes rumen and liver development, possibly by increasing digestion rate or extent of straw utilization, thereby stimulating rumen muscle development [18]. These findings align with Feng et al.'s [8] research on rice straw feeding in lambs. Serum total protein, albumin, and globulin concentrations remained within normal ranges in lambs fed enzyme-bacteria-treated corn straw, indicating no adverse effects on protein, amino acid, lipid, or glucose metabolism. These results are consistent with studies on dairy heifers [19], goats [20], and mutton sheep [18].

3.3 Comparison with Chinese Wildrye Feeding

Yao et al. [21] used rumen- and duodenum-fistulated beef cattle to evaluate rumen degradation parameters and small intestinal digestibility of crude protein and amino acids in common ruminant feeds, reporting that Chinese wildrye had higher rumen degradability of crude protein and total amino acids than distillers' grains protein and yellow corn, with higher small intestinal apparent digestibility of crude protein than alfalfa. Wang et al. [22] determined the feeding

value of Chinese wildrye and corn straw from different regions of Heilongjiang Province, finding Chinese wildrye contained 5.49%-6.45% crude protein, 17.85-19.05 MJ/kg gross energy, and 6.34-7.29 MJ/kg metabolizable energy, compared with 4.77%-4.93% crude protein, 16.56-17.61 MJ/kg gross energy, and 5.98-6.49 MJ/kg metabolizable energy for corn straw. These data demonstrate that Chinese wildrye has superior feeding value for ruminants compared with corn straw.

In this study, no significant differences were observed in DMI, feed/gain ratio, slaughter performance, organ development, or serum biochemical indices between lambs fed untreated or enzyme-bacteria-treated corn straw silage and those fed Chinese wildrye. This indicates that enzyme-bacteria-treated corn straw can achieve feeding effects similar to Chinese wildrye, consistent with findings from Feng et al. [8,18].

4 Conclusion

Enzyme-bacteria treatment significantly improved the feeding value of corn straw silage, enhanced slaughter performance in mutton sheep, and produced fattening effects comparable to Chinese wildrye.

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