Effects of Different Biological Treatments of Rice Straw on Growth Performance, Slaughter Performance, and Organ Development in Meat Sheep (Postprint)

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Abstract

This experiment investigated the effects of different biological treatments of rice straw on growth performance, slaughter performance, and organ development in meat sheep, aiming to explore effective biological agent treatment methods. A single-factor experimental design was adopted, selecting 80 male hybrid F1 lambs of "Dorper × Small-tailed Han sheep"with a body weight of (24.00$±$2.42) kg, randomly divided into 4 groups: blank control group (fed rice straw diet), Group I (fed rice straw diet treated with bacterial and enzymatic compound silage agent), Group II (fed rice straw diet treated with compound enzyme preparation), and Leymus chinensis control group (fed Leymus chinensis diet), with 5 replicates per group and 4 sheep per replicate. The pre-trial period was 8 d, and the formal trial period was 60 d. The results showed that the average daily gain and dry matter intake of experimental sheep in Group I, Group II, and the Leymus chinensis control group were significantly higher than those in the blank control group ($P<0.05$), and the feed-to-gain ratio was significantly lower than that in the blank control group ($P<0.05$), but there were no significant differences among Group I, Group II, and the Leymus chinensis control group ($P>0.05$). There were no significant differences in slaughter rate among groups ($P>0.05$), and no significant differences in the weight of head, hooves, skin+wool, lungs, kidneys, reticulum, omasum, abomasum, small intestine, and large intestine and their proportions to pre-slaughter live weight among groups ($P>0.05$). The liver and rumen weights of experimental sheep in Group I, Group II, and the Leymus chinensis control group were significantly higher than those in the blank control group ($P<0.05$). It can be concluded that treatment of rice straw with bacterial and enzymatic compound silage agent has significant improving effects, and the growth performance, slaughter performance, and organ development of meat sheep approach the feeding effects of Leymus chinensis.

Full Text

Effects of Different Biological Treatments of Rice Straw on Growth Performance, Slaughter Performance and Organ Development of Mutton Sheep

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Abstract

This experiment investigated the effects of different biological treatments of rice straw on growth performance, slaughter performance, and organ development of mutton sheep to explore effective biological agent treatment methods. A single-factor experimental design was adopted, in which eighty "Dorper × Small-tailed Han" hybrid F1 male lambs with initial body weight of (24.00$±$2.42) kg were randomly divided into four groups: a blank control group (fed a rice straw diet), Group I (fed a rice straw diet treated with bacterial and enzyme compound silage preparation), Group II (fed a rice straw diet treated with compound enzyme preparation), and a Leymus chinensis control group (fed a Leymus chinensis diet). Each group consisted of five replicates with four lambs per replicate. The experiment included an 8-day adaptation period followed by a 60-day formal experimental period. The results showed that average daily gain and dry matter intake in Groups I, II, and the Leymus chinensis control group 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). However, no significant differences were observed among Groups I, II, and the Leymus chinensis control group (P>0.05). No significant differences were found in dressing percentage among all groups (P>0.05). Similarly, there were no significant differences in the weights of head, feet, skin+wool, lungs, kidneys, reticulum, omasum, abomasum, small intestine, and large intestine, or their percentages of live weight before slaughter (P>0.05). The liver and rumen weights in Groups I, II, and the Leymus chinensis control group were significantly higher than those in the blank control group (P<0.05). These findings indicate that bacterial and enzyme compound silage preparation treatment significantly improves rice straw, yielding growth performance, slaughter performance, and organ development in mutton sheep that approach the feeding effects of Leymus chinensis.

Keywords: rice straw; compound enzyme preparation; microecological preparation; mutton sheep; growth performance

1 Materials and Methods

1.1 Experimental Time and Location

This experiment was conducted at Hebei Zhongbao Agricultural Technology Co., Ltd. from November 16, 2015, to January 24, 2016, lasting 68 days total, including an 8-day adaptation period and a 60-day formal experimental period.

1.2 Experimental Materials

1.2.1 Rice Straw The rice straw used in this experiment was of the "Daohuaxiang" variety, harvested after grain collection in 2014 from Jilin City, Jilin Province, with a moisture content of 69.85%.

1.2.2 Additives **Compound enzyme preparation:** Composed of cellulase, xylanase, β-glucanase, pectinase, and laccase, in powder form and bagged packaging.

Bacterial and enzyme compound silage preparation: Composed of *Lactobacillus plantarum*, *Lactobacillus buchneri*, cellulase, xylanase, β-glucanase, pectinase, and laccase, in powder form and bagged packaging.

1.2.3 Roughage Production Process **Rice straw:** Naturally air-dried rice straw was chopped to 2–3 cm and used directly.

Leymus chinensis: Leymus chinensis was chopped to 2–3 cm and used directly.

Rice straw treated with bacterial and enzyme compound silage preparation: Rice straw was chopped to 2–3 cm, sprayed with bacterial and enzyme compound silage preparation, and thoroughly mixed. After adjusting moisture content to 60%–70%, the material was packed into a compactor, the straw weight was recorded, and it was sealed for 45 days of fermentation before opening for use.

Rice straw treated with compound enzyme preparation: The compound enzyme preparation powder was diluted with clean water to a 4% solution (4 g of compound enzyme preparation added to 100 mL water), sprayed onto the surface of rice straw (chopped to 2–3 cm), and then mixed evenly with concentrate supplement for direct feeding.

1.3 Experimental Animals and Diets

1.3.1 Experimental Animals Eighty "Dorper × Small-tailed Han" hybrid F1 male lambs with body weight of (24.00$±$2.42) kg were selected as experimental animals.

1.3.2 Experimental Diets The experimental diets were self-formulated, 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-roughage ratio of 5:5 were formulated. Diet composition and nutrient levels are shown in Table 1 .

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

Items	Rice straw diet	Leymus chinensis diet
Ingredients		
Rice straw	50.00	–
Leymus chinensis	–	50.00
Corn	28.00	28.00
Soybean meal	10.00	10.00
Bran	9.00	9.00
$CaHPO_4$	1.00	1.00
NaCl	0.50	0.50
Limestone	0.50	0.50
Premix[1]	1.00	1.00
Total	100.00	100.00
Nutrient levels[2]		
DM	90.21	90.21
ME/(MJ/kg)	9.12	9.12
CP	12.01	12.01
EE	2.10	2.10
NDF	53.21	53.21
ADF	28.12	28.12
Ash	6.50	6.50
Ca	0.60	0.60
TP	0.35	0.35

[1]The premix provided the following per kg of diets: 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.
[2]ME was a calculated value[11], while the others were measured values.

1.4 Experimental Design and Management

This experiment adopted a single-factor design. The 80 lambs were randomly divided into four groups: a blank control group (fed rice straw diet), Group I (fed rice straw diet treated with bacterial and enzyme compound silage preparation), Group II (fed rice straw diet treated with compound enzyme preparation), and a Leymus chinensis control group (fed Leymus chinensis diet). Each group had five replicates with four lambs per replicate. All experimental lambs were ear-tagged, vaccinated, and dewormed. The pens were regularly disinfected. During the feeding period, the barn temperature ranged from -10 °C to 10 °C. Lambs were fed twice daily at 08:00 and 16:00, with free access to feed and water throughout the experiment. The concentrate-to-roughage ratio was kept constant, and feed amounts were adjusted daily based on the previous day' s intake to ensure approximately 10% residual feed in the trough. Each replicate was housed in a separate pen, and daily feed offered and residual amounts were accurately weighed and recorded. Diet and residual feed samples were collected every 7 days for routine nutrient analysis. Body weight was measured before morning feeding at the start of the adaptation period, at the start of the formal experimental period, and at the end of the experiment.

1.5 Measurement Indicators and Methods

1.5.1 Growth Performance **Weight gain performance:** Body weight was measured and recorded before morning feeding during the adaptation period, formal experimental period, and at the end of the experiment.
Feed consumption: Each replicate was housed separately, and daily feed intake was measured and recorded by pen.

1.5.2 Slaughter Performance and Organ Indices At the end of the experiment, five healthy lambs with body weight close to the group average were selected from each group (20 lambs total). They were weighed at 16:00, then fasted for 16 hours with water withheld, and weighed again at 08:00 the next day before slaughter. Slaughter was performed by jugular exsanguination.

Live weight before slaughter (LWBS) was recorded for all lambs. After removing the head, feet, internal organs, and skin, carcass weight and the weights of head, feet, skin, and internal organs (liver, kidneys, and lungs) were measured. After clearing digesta and rinsing, the weights of rumen, reticulum, omasum, abomasum, small intestine, and large intestine were recorded.

Key indicators were calculated as follows:
Carcass weight (kg) = LWBS -weight of head, feet, skin, tail, reproductive organs, omental fat, and internal organs (kidneys and surrounding fat retained);
Dressing percentage (%) = 100 × carcass weight / LWBS.

1.6 Data Processing and Analysis

Experimental data were organized using Excel 2007 and analyzed using the ANOVA procedure in SAS 9.1 statistical software for one-way analysis of variance. Duncan' s multiple comparison test was used when significant differences were detected. $P<0.05$ was set as the criterion for significant difference.

2 Results

2.1 Effects of Different Biological Treatments of Rice Straw on Growth Performance of Experimental Sheep

As shown in Table 2 , no significant differences were found in initial body weight among groups ($P>0.05$), confirming the randomization principle. Different biological treatments of rice straw significantly affected final body weight (P<0.05), with Groups I, II, and the Leymus chinensis control group showing increases of 9.64%, 7.93%, and 10.79% compared to the blank control group (P<0.05), though no significant differences were observed among these three groups (P>0.05). Average daily gain in Groups I, II, and the Leymus chinensis control group was significantly higher than in the blank control group (P<0.05), with no significant differences among the three treatment groups (P>0.05). Correspondingly, the feed-to-gain ratio in Groups I, II, and the Leymus chinensis control group was significantly lower than in the blank control group (P<0.05), but did not differ significantly among themselves (P>0.05). Dry matter intake in Groups I, II, and the Leymus chinensis control group was significantly higher than in the blank control group (P<0.05), with no significant differences among the three groups (P>0.05). These results indicate that biological treatment of rice straw improved its feeding value to some extent, achieving weight gain effects comparable to Leymus chinensis.

Table 2 Effects of different biological treatments of rice straw on growth performance of experimental sheep

Items	Blank control	Group I	Group II	Leymus chinensis control	P-value
Initial body weight (IBW)/kg	24.00	24.00	24.00	24.00	>0.05
Final body weight (FBW)/kg	31.13	34.13	33.60	34.49	<0.05
Average daily gain (ADG)/(g/d)	112.51	151.89	142.06	169.64	<0.05
Dry matter intake (DMI)/(g/d)	813.58	992.65	940.75	1,034.83	<0.05
Feed-to-gain ratio (F/G)	7.25	6.59	6.64	6.17	<0.05

In the same row, values with no letter or the same small letter superscripts mean no significant difference (P>0.05), while with different small letter superscripts mean significant difference (P<0.05). The same as below.

2.2 Effects of Different Biological Treatments of Rice Straw on Slaughter Performance of Experimental Sheep

As shown in Table 3 , no significant differences were found in carcass weight or live weight before slaughter among Groups I, II, and the Leymus chinensis control group (P>0.05), but all were significantly higher than in the blank control group (P<0.05). No significant differences were observed in dressing percentage among all groups (P>0.05).

Table 3 Effects of different biological treatments of rice straw on slaughter performance of experimental sheep

Items	Blank control	Group I	Group II	Leymus chinensis control	P-value
Live weight before slaughter (LWBS)/kg	31.17	35.34	34.74	35.65	<0.05
Carcass weight/kg	13.48	15.18	15.06	15.28	<0.05
Dressing percentage/%	43.25	42.96	43.35	42.86	>0.05

2.3 Effects of Different Biological Treatments of Rice Straw on Tissue and Internal Organ Development of Experimental Sheep

As shown in Table 4 , no significant differences were found in the weights of head, feet, and skin+wool, or their percentages of LWBS among groups (P>0.05). Similarly, no significant differences were observed in the weights of kidneys and lungs, or their percentages of LWBS (P>0.05). The liver and rumen weights in Groups I, II, and the Leymus chinensis control group were significantly higher than those in the blank control group (P<0.05), with increases of 2.10%, 1.91%, 2.77% for liver weight and 8.90%, 10.62%, 11.15% for rumen weight, respectively. However, no significant differences were found in the percentages of liver and rumen weights relative to LWBS among groups (P>0.05). No significant differences were observed in the weights of reticulum, omasum, abomasum, small intestine, and large intestine, or their percentages of LWBS (P>0.05).

Table 4 Effects of different biological treatments of rice straw on tissue and internal organ development of experimental sheep

Items	Blank control	Group I	Group II	Leymus chinensis control	P-value
Head					
Weight/g	513.20	524.00	523.00	527.40	>0.05
Percentage of LWBS/%	1.65	1.48	1.51	1.48	>0.05
Feet					
Weight/g	651.40	709.40	720.60	724.00	<0.05
Percentage of LWBS/%	2.09	2.01	2.07	2.03	>0.05
Skin+wool					
Weight/g	2,150.20	2,340.60	2,360.80	2,380.40	>0.05
Percentage of LWBS/%	6.90	6.63	6.80	6.68	>0.05
Liver					
Weight/g	513.20	524.00	523.00	527.40	<0.05
Percentage of LWBS/%	1.65	1.48	1.51	1.48	>0.05
Kidney					
Weight/g	65.40	69.20	68.80	70.20	>0.05
Percentage of LWBS/%	0.21	0.20	0.20	0.20	>0.05
Lung					
Weight/g	185.60	198.40	196.20	201.60	>0.05
Percentage of LWBS/%	0.60	0.56	0.56	0.57	>0.05
Rumen					
Weight/g	385.20	419.40	426.20	428.20	<0.05
Percentage of LWBS/%	1.24	1.19	1.23	1.20	>0.05
Reticulum					
Weight/g	65.40	69.20	68.80	70.20	>0.05
Percentage of LWBS/%	0.21	0.20	0.20	0.20	>0.05

Items	Blank control	Group I	Group II	Leymus chinensis control	P-value
Omasum					
Weight/g	45.20	48.60	47.80	49.40	>0.05
Percentage of LWBS/%	0.15	0.14	0.14	0.14	>0.05
Abomasum					
Weight/g	85.60	91.20	90.40	92.80	>0.05
Percentage of LWBS/%	0.27	0.26	0.26	0.26	>0.05
Small intestine					
Weight/g	420.80	450.60	445.20	458.40	>0.05
Percentage of LWBS/%	1.35	1.28	1.28	1.29	>0.05
Large intestine					
Weight/g	185.60	198.40	196.20	201.60	>0.05
Percentage of LWBS/%	0.60	0.56	0.56	0.57	>0.05

3 Discussion

3.1 Effects of Biological Treatment of Rice Straw on Growth Performance of Experimental Sheep

3.1.1 Effects of Compound Enzyme Preparation Treatment on Growth Performance Yin et al.[12] reported that cellulase compound enzyme preparation significantly increased average daily gain in sheep. Yang et al.[13] found that adding cellulase compound enzyme preparation significantly improved feed conversion rate and average daily gain in lambs. The present study showed similar results, with compound enzyme preparation treatment significantly increasing dry matter intake and average daily gain while improving feed-to-gain ratio compared to the blank control group. These effects result from the interaction between compound enzymes and substrates. For instance, cellulase attacks the glucosidic bonds of cellulose, loosening the rice straw cell wall structure. Xylanase and β-glucanase specifically degrade xylan, a structural unit of hemicellulose, ultimately producing D-xylose that can be directly absorbed and utilized by animals[14]. Due to its water solubility, pectin easily forms cross-linked gels with strong water-holding capacity in the digestive tract, increasing intestinal chyme viscosity and hindering intestinal peristalsis. This slows the diffusion rate of digestive enzymes and nutrient substrates, creating physical barriers to nutrient digestion and absorption. Pectinase degrades pectin substances, causing significant structural changes in colloidal components. The stability of colloidal complexes (pectin substances, hemicellulose components, and lignin) is greatly compromised. When some pectin substances are degraded, their original adhesive effect is substantially reduced, creating larger gaps between other non-cellulose substances and increasing the biological or chemical reactivity of these macromolecules. This enhances their sensitivity to other enzymes, facilitating further degumming[15]. Laccase directly attacks lignin through side-chain oxidation and methylation, followed by cleavage of benzene rings in lignin and further degradation that softens the structure and increases surface area. This enlarges the contact area with microorganisms and promotes degradation of fiber components[16], thereby improving the nutritional composition of straw and its palatability. The apparent digestibility of cellulose substances by sheep increases, enhancing carbon and nitrogen deposition and daily weight gain, thus improving total weight gain. However, Zobell et al.[17] reported that adding exogenous compound enzyme preparation to the diet of British hybrid bulls did not significantly affect average daily gain, dry matter intake, or feed conversion rate. Kung et al.[18] also reported that cellulase compound enzyme preparation did not significantly affect dry matter intake in lactating dairy cows. These discrepancies may be related to enzyme type, application level, animal species, physiological stage, or diet structure and nutrient level[19].

3.1.2 Effects of Bacterial and Enzyme Compound Silage Preparation Treatment on Growth Performance The present results demonstrate that applying bacterial and enzyme compound silage preparation to rice straw significantly improved weight gain and feed efficiency, likely due to synergistic effects between bacteria and enzymes. Adding lactic acid bacteria or compound enzyme preparation alone can improve silage quality to some extent, but the effects are unstable, and silage quality remains suboptimal with some additives[4]. Therefore, some researchers have mixed cellulase and lactic acid bacteria preparations, believing that combined additives improve silage quality. Xing[20] investigated the effects of lactic acid bacteria and cellulase compound preparation on different silage feeds and found that combined addition significantly reduced pH, ammonia nitrogen content, and acetic acid content while increasing lactic acid content in rice straw silage, and significantly degraded fiber content. Fu[21] added *Lactobacillus plantarum* and cellulase compound preparation to whole-plant corn silage, reducing neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents by 15.8% and 15.0%, respectively, while significantly increasing 24-hour rumen disappearance rate compared to the control group. Other reports have shown that applying lactic acid bacteria and cellulase compound preparation to Italian ryegrass[22], *Chloris gayana*[23], and barley straw[24] silage improved fermentation quality and dry matter and organic matter digestibility while reducing NDF and ADF contents[25-26]. Zhang[27] found that the degree and rate of NDF digestion affect rumen digesta volume, thereby influencing dry matter intake in ruminants.

In this experiment, adding bacterial and enzyme compound silage preparation to rice straw significantly increased dry matter intake and average daily gain while significantly reducing feed-to-gain ratio compared to the blank control group. The possible reasons are twofold: First, since the number of lactic acid bacteria naturally attached to rice straw surfaces is limited and cannot ensure successful silage alone, adding lactic acid bacteria increases their population on rice straw surfaces, allowing them to rapidly become the dominant microbial community during silage. This promotes lactic acid production, rapidly reduces pH, inhibits harmful microorganisms, and ensures or improves the nutritional value of rice straw[9]. Second, since rice straw contains limited fermentable water-soluble carbohydrates (WSCs), cellulase compound preparation can partially degrade carbohydrates (cellulose, hemicellulose, lignin, pectin, starch, etc.) into fermentable sugars[26], thereby increasing fermentation substrate availability for lactic acid bacteria fermentation. Therefore, adding lactic acid bacteria and cellulase compound preparation achieves dual benefits: improving the nutritional value of rice straw silage while destroying cell wall structure, reducing the degree of lignin complexation with cellulose and hemicellulose, and increasing straw digestibility rate or extent[29]. This enhances hydrolytic activity in the rumen[30], improves rumen microbial degradation of cellulose[31], particularly NDF degradation rate[32], thereby achieving weight gain. However, some reports differ from our results. Keles et al.[32] showed that adding lactic acid bacteria and cellulase compound preparation to triticale and Hungarian vetch did not significantly affect dry matter intake in lambs. These differences may also be related to bacterial strain and source, dosage, substrate, or animal species[19].

3.2 Effects of Different Biological Treatments of Rice Straw on Slaughter Performance of Experimental Sheep

Slaughter performance is a direct reflection of animal economic value and growth performance[33], with carcass weight and dressing percentage being key factors affecting economic returns. The present results showed no significant differences in live weight before slaughter or carcass weight among Groups I, II, and the Leymus chinensis control group, indicating that biologically treated rice straw achieved feeding effects comparable to Leymus chinensis. However, both Groups I and II were significantly higher than the blank control group, possibly because biological treatment improved straw palatability and increased feed intake in fattening sheep[13]. Additionally, biological treatment facilitated the release of nutrients from cell contents, enabling better digestion by endogenous enzymes and improving utilization of other nutrients in straw, thereby increasing protein and fat deposition and improving carcass weight[12]. Similar to our results, Kim et al.[34] reported that adding lactic acid bacteria preparation to ryegrass silage and rice straw silage did not significantly affect slaughter weight, dressing percentage, or eye muscle area in Korean beef cattle. Zobell et al.[17] also found that adding exogenous cellulase compound enzyme preparation to diets did not significantly affect carcass weight, eye muscle area, backfat thickness, or lean meat percentage in growing and finishing beef cattle. In this experiment, the lambs were in a critical growth and development stage, with more nutrients allocated to organ growth and bone development. Additionally, the feeding environment was cold winter, requiring some nutrients for animal maintenance. Moreover, the experimental lambs were large-breed hybrid mutton sheep that had just reached physical maturity at slaughter; as body development becomes fully established, consumed nutrients will primarily be used for fat deposition, potentially yielding higher dressing percentages.

3.3 Effects of Different Biological Treatments of Rice Straw on Tissue and Internal Organ Development of Experimental Sheep

Tissue and organ weights reflect animal physiological condition to some extent and are important for both theoretical research and production practice[35]. In this experiment, no significant differences were found in head, feet, and skin+wool weights or their percentages of LWBS, indicating that organ growth rate was synchronized with overall body growth. No significant differences were observed in kidney and lung weights or their percentages of LWBS among groups. However, liver weight in Groups I, II, and the Leymus chinensis control group was significantly higher than in the blank control group, suggesting that biological treatment of rice straw promoted liver growth and development. No significant differences in liver weight percentage of LWBS among groups indicate coordinated organ development with overall body growth. For ruminants, well-developed rumen is fundamental for achieving optimal growth performance and feed conversion efficiency[12]. The present results showed no significant differences in reticulum, omasum, abomasum, small intestine, and large intestine weights or their percentages of LWBS, indicating that biological treatment of rice straw did not significantly affect development of some gastrointestinal organs. The significantly higher rumen weight in Groups I, II, and the Leymus chinensis control group may be due to increased digestion rate or extent of straw by animals after biological treatment, which stimulated rumen muscle development[28]. However, no significant differences in rumen weight percentage of LWBS among groups indicate that rumen development was coordinated with overall body development. Biological treatment of rice straw benefited development of some tissues and internal organs, with effects comparable to the Leymus chinensis group.

4 Conclusion

Adding bacterial and enzyme compound silage preparation to rice straw for silage fermentation can improve growth performance, slaughter performance, and organ development in mutton sheep, approaching the feeding effects of Leymus chinensis.

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