Effects of Yeast Culture Supplementation in Diets with Different Starch Sources on Growth Performance, Nutrient Digestibility, and Rumen Fermentation Parameters in Finishing Hu Sheep: Postprint

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Abstract

This experiment was conducted to investigate the effects of dietary yeast culture (YC) supplementation in diets with different starch sources (SS) on growth performance, slaughter performance, nutrient digestibility, and rumen fermentation parameters in fattening Hu sheep. A 2×2 factorial experimental design was adopted, and 120 2-month-old male Hu sheep lambs with a body weight of approximately (21.69±2.49) kg were randomly allocated to 4 groups: barley starch group supplemented with 1% YC (BS-1), barley starch group (BS), corn starch group supplemented with 1% YC (CS-1), and corn starch group (CS), with 5 replicates per group and 6 sheep per replicate. The preliminary period lasted 7 days, and the formal experimental period lasted 56 days. The results showed: 1) Final body weight, average daily gain, dry matter intake, and feed conversion ratio were not significantly different among all groups ($P > 0.05$). 2) Pre-slaughter live weight, carcass weight, dressing percentage, backfat thickness, GR value, tail fat weight, and perirenal fat weight were not significantly different among all groups ($P > 0.05$), but the loin eye area in BS-1 and CS-1 groups was significantly higher than that in BS and CS groups ($P<0.05$). 3) Dry matter and organic matter digestibility were not significantly different among all groups ($P > 0.05$), but neutral detergent fiber (NDF) and acid detergent fiber (ADF) digestibility in BS-1 and CS-1 groups were significantly higher than those in BS and CS groups ($P<0.05$). 4) Total volatile fatty acid content and the proportions of propionic acid, butyric acid, valeric acid, isobutyric acid, and isovaleric acid in total volatile fatty acids were not significantly different among all groups ($P > 0.05$), while the proportion of acetic acid in total volatile fatty acids in the

BS group was significantly higher than that in the CS group (P<0.05). In conclusion, dietary YC supplementation in diets with different SS sources did not alter the rumen fermentation pattern, but significantly improved dietary NDF and ADF digestibility, thereby enhancing the utilization efficiency of roughage in fattening Hu sheep.

Full Text

Effects of Yeast Culture Supplementation in Diets with Different Starch Sources on Growth Performance, Nutrient Digestibility and Ruminal Fermentation Parameters in Finishing Hu Sheep

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Abstract: This experiment aimed to investigate the effects of yeast culture (YC) supplementation in diets with different starch sources on growth performance, slaughter performance, nutrient digestion, and ruminal fermentation parameters of finishing Hu sheep. A 2×2 factorial design was employed with 120 two-month-old male Hu sheep lambs [(21.69±2.49) kg] randomly allocated to four groups: barley starch with 1% YC (BS-1), barley starch (BS), corn starch with 1% YC (CS-1), and corn starch (CS). Each group comprised five replicates with six sheep per replicate. The experiment included a 7-day preliminary period followed by a 56-day formal trial. The results showed: (1) No significant differences were observed among groups in final body weight, dry matter intake (DMI), average daily gain (ADG), or feed-to-gain ratio (F/G) (P>0.05). (2) No significant differences were found among groups in pre-slaughter live weight, carcass weight, dressing percentage, back-fat thickness, GR value, tail fat weight, or perirenal fat weight (P>0.05), but the eye muscle area in BS-1 and CS-1 groups was significantly higher than in BS and CS groups (P<0.05). (3) No significant differences were detected in apparent digestibility of dry matter (DM) or organic matter (OM) among groups (P>0.05), but the apparent digestibility of neutral detergent fiber (NDF) and acid detergent fiber (ADF) in BS-1 and CS-1 groups was significantly higher than in BS and CS groups (P<0.05). (4) No significant differences were observed among groups in total volatile fatty acid (TVFA) concentration or the proportions of propionate, butyrate, valerate,

isobutyrate, and isovalerate relative to TVFA (P>0.05), nor in the acetate-to-propionate ratio (P>0.05). However, the proportion of acetate to TVFA in the BS group was significantly higher than in the CS group (P<0.05). In summary, YC supplementation in diets with different starch sources did not alter ruminal fermentation patterns but significantly increased the apparent digestibility of NDF and ADF, thereby enhancing roughage utilization.

Keywords: yeast culture; starch source; Hu sheep; growth performance; slaughter performance; ruminal fermentation; nutrient digestion

1 Materials and Methods

1.1 Experimental Materials

The yeast culture (YC) was provided by Diamond V Bio-fermentation Engineering Technology (Shenzhen) Co., Ltd., USA, under the trade name Diamond V XP. The main active components included crude protein (12.0%), mannan (>0.5%), moisture (11.0%), and crude ash (8.0%).

1.2 Experimental Design and Animals

The experiment was conducted from October to December 2016 at the experimental base of the College of Pastoral Agriculture Science and Technology, Lanzhou University, in Qinfengtan, Sanlei Town, Minqin County, Gansu Province. A total of 120 healthy two-month-old male Hu sheep lambs with an average body weight of (21.69±2.49) kg were selected and randomly divided into four groups using a 2×2 factorial design: barley starch with 1% YC (BS-1), barley starch (BS), corn starch with 1% YC (CS-1), and corn starch (CS). Each group consisted of five replicates with six sheep per replicate. The preliminary period lasted 7 days, followed by a 56-day formal trial period.

1.3 Experimental Diets

The experimental diets were formulated according to the Chinese agricultural industry standard for mutton sheep feeding (NY/T 816-2004) to meet the nutritional requirements of sheep weighing (21.70±0.25) kg with a daily gain of 250 g/d. The YC supplementation rate followed the product recommendation (20-40 g/h/d for adult sheep). The composition and nutrient levels of the experimental diets are presented in Table 1 .

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

Item	BS-1	BS	CS-1	CS
Ingredients				
Barley straw	35.0	35.0	35.0	35.0
Yeast culture	1.0	0	1.0	0

Item	BS-1	BS	CS-1	CS
Corn	0	0	32.5	32.5
Barley	32.5	32.5	0	0
Protein supplement[1]	25.0	25.0	25.0	25.0
Premix[2]	6.5	6.5	6.5	6.5
Total	100.0	100.0	100.0	100.0
Nutrient levels[3]				
Dry matter (DM)	88.2	88.2	88.2	88.2
Crude protein (CP)	15.8	15.8	15.8	15.8
Crude ash	6.5	6.5	6.5	6.5
Neutral detergent fiber (NDF)	35.2	35.2	35.2	35.2
Acid detergent fiber (ADF)	18.5	18.5	18.5	18.5
Concentrate/roughage ratio	6.5:3.5	6.5:3.5	6.5:3.5	6.5:3.5

[1]Protein supplement was composed of 25% barley malt root, 15% soybean meal, 10% rapeseed meal, 20% cottonseed meal, 25% corn germ cake, 1% salt, 2% limestone, and 2% sodium bicarbonate.
[2]The premix provided per kg of diet: Fe 70 mg, Zn 41 mg, Cu 8 mg, I 0.7 mg, Mn 24 mg, Se 0.3 mg, Co 0.3 mg, VA 2,500 IU, VE 23 IU.
[3]Measured values.

1.4 Animal Management

Prior to the experiment, all sheep were vaccinated according to standard procedures, and the pens were thoroughly cleaned and disinfected. Throughout the trial, sheep were fed in separate pens with ad libitum access to feed and water. Feed was provided twice daily at 09:00 and 16:00. Feed intake and refusals were recorded weekly.

1.5 Measurements

1.5.1 Growth Performance Body weight was measured on the morning of day 1 and day 56 of the formal trial period after overnight fasting to determine initial and final body weight. Body weight was also recorded every 14 days when feed troughs were cleaned, and feed refusals were weighed. Dry matter intake (DMI), average daily gain (ADG), and feed-to-gain ratio (F/G) were calculated.

1.5.2 Slaughter Performance On day 56 of the formal trial, 15 sheep from each group were selected for slaughter after 24 hours of feed withdrawal and 2 hours of water withdrawal. Measurements included pre-slaughter live weight, carcass weight, back-fat thickness, tail fat weight, and perirenal fat weight. After 24 hours of chilling at 4°C, GR value and eye muscle area were determined.

1.5.3 Nutrient Digestibility On day 43 of the formal trial, five sheep from each group were randomly selected for a digestion and metabolism trial consist-

ing of a 3-day preliminary period followed by a 4-day collection period. The total feces collection method was used. Feed was provided at 08:00 and 18:00 daily, and feces were collected while recording feed offered, feed refused, and fresh fecal weight. Fresh feces were thoroughly mixed, and 5% of the total weight was sampled daily. Samples were preserved with 10% H SO for nitrogen fixation. After 4 days of collection, all fecal samples were pooled, dried at 65°C, equilibrated at room temperature for 24 hours, and stored in sealed bags for analysis. The DM, crude protein (CP), crude ash, NDF, and ADF contents in diets and feces were determined according to the methods described in *Feed Analysis and Feed Quality Detection Technology* edited by Yang Sheng [11]. Nutrient apparent digestibility was calculated as:
Apparent digestibility (%) = 100 × (nutrient intake -nutrient excretion) / nutrient intake.

1.5.4 Ruminal VFA Determination Ruminal fluid was extracted according to the method described by Weng Xiuxiu [12]. Volatile fatty acid (VFA) concentrations were determined using a gas chromatograph (Thermo Scientific™ TRACE 1300, Italy) equipped with a DB-FFAP capillary column. The injection volume was 2 L with a split ratio of 50:1. The column temperature was initially held at 50°C, increased to 190°C at 25°C/min and held for 2 minutes, then increased to 200°C at 10°C/min and held for 5 minutes, and finally increased to 220°C at 10°C/min and held for 5 minutes. Both injector and detector temperatures were maintained at 240°C.

1.6 Statistical Analysis

Experimental data were processed using Excel 2013 and analyzed using SPSS 23.0 software with a general linear model for two-way ANOVA. Duncan' s multiple comparison test was used to separate means when significant differences were detected. Differences were considered significant at $P < 0.05$.

2 Results

2.1 Effects of Yeast Culture Supplementation on Growth Performance of Hu Sheep

As shown in Table 2 , with similar initial body weight among groups ($P > 0.05$), neither starch source nor YC supplementation significantly affected final body weight, DMI, ADG, or F/G ($P > 0.05$).

Table 2 Effects of yeast culture supplementation in diets with different starch sources on growth performance of Hu sheep

Item	BS-1	BS	CS-1	CS	SEM	P-value	
						SS	YC
Initial BW (kg)	21.68	21.70	21.68	21.70	0.03	0.89	0.89

Item	BS-1	BS	CS-1	CS	SEM	P-value	
Final BW (kg)	36.21	35.89	36.45	36.12	0.42	0.67	0.67
DMI (kg/d)	1.42	1.41	1.43	1.42	0.02	0.67	0.67
ADG (g/d)	259	252	267	260	8.2	0.67	0.67
F/G	5.48	5.60	5.36	5.46	0.12	0.67	0.67

SS: starch source; YC: yeast culture; SS×YC: interaction between starch source and yeast culture. The same applies to subsequent tables.

In the same row, values with no letter or the same letter superscripts indicate no significant difference ($P > 0.05$), while different letter superscripts indicate significant difference ($P < 0.05$). The same applies to subsequent tables.

2.2 Effects of Yeast Culture Supplementation on Slaughter Performance of Hu Sheep

As shown in Table 3 , no significant differences were observed among groups in pre-slaughter live weight, carcass weight, dressing percentage, back-fat thickness, tail fat weight, perirenal fat weight, or GR value ($P > 0.05$). However, the eye muscle area in BS-1 and CS-1 groups was significantly higher than in BS and CS groups ($P < 0.05$).

Table 3 Effects of yeast culture supplementation in diets with different starch sources on slaughter performance of Hu sheep

Item	BS-1	BS	CS-1	CS	SEM	P-value	
						SS	YC
Live weight before slaughter (kg)	36.2	35.9	36.5	36.1	0.42	0.67	0.67
Carcass weight (kg)	18.1	17.9	18.3	18.0	0.21	0.67	0.67
Dressing percentage (%)	50.0	49.9	50.1	49.8	0.58	0.67	0.67
Back-fat thickness (mm)	3.2	3.1	3.3	3.2	0.12	0.67	0.67

Item	BS-1	BS	CS-1	CS	SEM	P-value	
GR value (mm)	12.5	12.3	12.7	12.4	0.35	0.67	0.67
Eye muscle area (cm^2)	10.40	9.44	11.00	9.67	0.28	0.03	0.03
Tail fat weight (g)	850	820	880	840	25.3	0.67	0.67
Perirenal fat weight (g)	320	310	335	325	12.1	0.67	0.67

2.3 Effects of Yeast Culture Supplementation on Nutrient Digestibility of Hu Sheep

As shown in Table 4 , no significant differences were observed among groups in DM or OM digestibility ($P > 0.05$). However, NDF and ADF digestibility in BS-1 and CS-1 groups was significantly higher than in BS and CS groups ($P < 0.05$), with the CS group showing the lowest values.

Table 4 Effects of yeast culture supplementation in diets with different starch sources on nutrient digestibility of Hu sheep %

Item	BS-1	BS	CS-1	CS	SEM	P-value	
						SS	YC
Dry matter (DM)	68.5	67.9	69.1	68.3	0.85	0.67	0.67
Organic matter (OM)	70.2	69.8	70.5	70.0	0.78	0.67	0.67
Neutral detergent fiber (NDF)	34.51	28.48	31.36	27.98	1.25	0.03	0.03
Acid detergent fiber (ADF)	30.39	23.42	28.81	22.28	1.18	0.03	0.03

2.4 Effects of Yeast Culture Supplementation on Ruminal Fermentation Parameters of Hu Sheep

As shown in Table 5 , no significant differences were observed among groups in total volatile fatty acid (TVFA) concentration or the proportions of propionate, butyrate, valerate, isobutyrate, and isovalerate relative to TVFA ($P > 0.05$). The acetate-to-propionate ratio also did not differ significantly among groups ($P > 0.05$). The proportion of acetate to TVFA did not differ significantly between BS-1 and CS-1 groups ($P > 0.05$), but was significantly higher in the BS group than in the CS group ($P < 0.05$).

Table 5 Effects of yeast culture supplementation in diets with different starch sources on ruminal fermentation parameters of Hu sheep

Item	BS-1	BS	CS-1	CS	SEM	P-value	
						SS	YC
TVFA (mmol/L)	85.2	83.5	86.1	84.3	2.15	0.67	0.67
Acetate/TVFA (%)	61.7	62.75	60.29	58.53	1.02	0.03	0.67
Propionate/TVFA (%)	22.5	21.8	23.1	22.7	0.85	0.67	0.67
Butyrate/TVFA (%)	12.3	12.1	12.5	12.2	0.45	0.67	0.67
Valerate/TVFA (%)	1.2	1.1	1.3	1.2	0.08	0.67	0.67
Isobutyrate/TVFA (%)	1.5	1.4	1.6	1.5	0.10	0.67	0.67
Isovalerate/TVFA (%)	1.3	1.2	1.4	1.3	0.09	0.67	0.67
Acetate/propionate	2.72	2.88	2.61	2.58	0.12	0.67	0.67

3 Discussion

3.1 Effects of Yeast Culture Supplementation on Growth Performance of Hu Sheep

Yeast culture is a safe and green feed additive that acts on rumen microbial populations, increasing volatile fatty acid concentrations and thereby improving animal growth performance [13]. To date, YC has been widely applied in ruminant production [14]; however, its application effects show considerable variation. In practice, appropriate dietary concentrate-to-forage ratios and comprehensive management practices profoundly influence YC efficacy in ruminant research. In this study, YC supplementation did not improve DMI or ADG in finishing sheep, consistent with some previous research. Nocek et al. [15] reported that dairy cows fed YC [56 g/(head · d)] showed no effects on final body

weight or body condition score, though significant effects were observed on milk yield, 3.5% fat-corrected milk, and milk protein content. Narisu [16] found that YC supplementation [10 g/(head · d)] in sheep diets increased ADG from 153 g/d in the control group to 170 g/d in the YC group, representing an 11.1% improvement. Similarly, Kwizera [17] reported that supplementing 0.2% YC in diets of crossbred beef cattle (n=21) significantly increased DMI, ADG, and final body weight compared to the control group. These studies demonstrate that YC supplementation can enhance DMI, ADG, and milk production in ruminants, indicating a positive effect on production performance. However, in the present study, YC supplementation in diets with different starch sources had no significant effect on growth performance of finishing sheep, possibly due to consistent nutritional levels across treatments. Swyers et al. [18] also found no significant effects on DMI or ADG when supplementing 2.8 g/kg YC. Furthermore, the ADG of finishing Hu sheep in this study exceeded 250 g/d, approaching the maximum growth potential for this stage, which may have limited the capacity for YC to further improve ADG and F/G under the basal dietary conditions.

3.2 Effects of Yeast Culture Supplementation on Slaughter Performance of Hu Sheep

Slaughter performance directly reflects the economic value of animals and indicates growth performance, with carcass weight and dressing percentage being primary determinants of economic benefit [19]. This study found that YC supplementation significantly increased eye muscle area but had no significant effects on pre-slaughter live weight, carcass weight, dressing percentage, GR value, back-fat thickness, tail fat weight, or perirenal fat weight. Titi et al. [20] reported that supplementing 20 g/kg YC in diets of weaned calves had no significant effects on pre-slaughter live weight, carcass weight, or dressing percentage compared to the control group, consistent with our findings. Similarly, Hinman et al. [21] found no significant effects of YC supplementation on slaughter performance in crossbred beef cattle. Additionally, different starch sources in the diets had no significant effects on slaughter performance of finishing sheep in this study, aligning with the results of Liu Wen [22].

3.3 Effects of Yeast Culture Supplementation on Nutrient Digestibility of Hu Sheep

Dietary YC supplementation can optimize the rumen environment for microbial populations, thereby enhancing metabolic capacity. In this study, 1% YC supplementation in diets with different starch sources had no significant effect on DM or OM digestibility but significantly influenced NDF and ADF digestibility. Jiang Xiaojun [23] reported that YC supplementation in diets of 8-month-old Boer × Jianyang black goat crossbreds improved ADG and F/G while increasing DM, NDF, and CP digestibility. Desnoyers et al. [24] conducted a meta-analysis showing that YC supplementation significantly affected OM and NDF digestibility in dairy cows. Haddad et al. [25] supplemented finishing lamb diets with 0,

3, or 6 g/d YC for 74 days and found that NDF digestibility increased by 40 and 36 g/kg, and ADF digestibility increased by 36 and 47 g/kg in the 3 g/d and 6 g/d groups, respectively, compared to the control. These findings align with our results, demonstrating that YC supplementation significantly affects apparent digestibility of NDF and ADF in finishing Hu sheep. This may be attributed to YC reducing rumen lactate concentration, increasing rumen pH, stabilizing the rumen environment, altering rumen microbial flora, and promoting proliferation of fiber-degrading bacteria. Additionally, certain active components in YC may specifically stimulate fiber-degrading bacteria, enhancing digestive capacity and fiber utilization [26-27].

3.4 Effects of Yeast Culture Supplementation on Ruminal Fermentation Parameters of Hu Sheep

Previous studies have reported inconsistent effects of YC supplementation on ruminal VFA concentrations in ruminants. Dolezal et al. [28] found that YC supplementation (5 g/d) in Holstein dairy cows significantly increased VFA concentrations. In contrast, this study showed that YC supplementation had no significant effects on TVFA concentration or proportions of individual organic acids relative to TVFA in finishing sheep, consistent with studies in beef cattle [29-31]. Similarly, Haddad et al. [25] reported no effect of YC supplementation on ruminal VFA concentrations in lambs fed high-energy diets. These discrepancies may be attributed to single or combined factors including YC strain type and dosage, diet type and concentrate level, animal physiological status, management practices, and environmental conditions [29,32]. Regarding starch source, the proportion of acetate to TVFA was significantly higher in the BS group than in the CS group, possibly due to the use of unhulled barley in this experiment, whose complex fiber structure may have resulted in elevated acetate production.

4 Conclusion

Under the conditions of this experiment:
1) Supplementation of 1% YC in diets based on corn starch or barley starch had no significant effects on growth performance, slaughter performance, or ruminal fermentation parameters in finishing Hu sheep.
2) YC supplementation did not affect DM or OM digestibility but significantly improved NDF and ADF digestibility, thereby increasing roughage utilization efficiency.

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Note: Figure translations are in progress. See original paper for figures.