Effects of Different Roughage Combinations on Apparent Nutrient Digestibility and Nitrogen Balance in Goat Diets (Postprint)

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Abstract

This experiment was conducted to investigate the effects of different roughage combinations on nutrient apparent digestibility and nitrogen balance in goat diets. Four Boer × Xuhuai goats (crossbred goats) with a body weight of (26.63±2.60) kg were selected and a 4×4 Latin square design was adopted. The basal diet used rice straw (A) as roughage, while the experimental diets utilized soybean hulls (B), enoki mushroom residue (C), and soybean hulls + enoki mushroom residue (D) to replace a portion of rice straw, respectively. The four dietary groups were iso-nitrogenous, iso-energetic, and iso-fibrous. The experiment consisted of 4 periods, each lasting 15 d, including a 10-d preliminary period and a 5-d formal collection period. The results showed that: 1) No significant differences were observed in the apparent digestibility of dry matter (DM), acid detergent fiber (ADF), phosphorus, and gross energy among the four dietary groups ($P>0.05$). 2) Compared with diet A, diet D significantly increased the apparent digestibility of organic matter (OM) and neutral detergent fiber (NDF) ($P<0.05$), while no significant difference was found between diet B and diet A ($P>0.05$). The apparent calcium digestibility of diets B, C, and D did not differ significantly among them ($P>0.05$), but was significantly higher than that of diet A ($P<0.05$). 3) Compared with diet A, diets B, C, and D significantly increased nitrogen retention rate and nitrogen biological value ($P<0.05$). In conclusion, compared with using rice straw alone as roughage, the combination of soybean hulls, enoki mushroom residue, or both with rice straw improved the apparent digestibility of OM, NDF, and calcium, as well as nitrogen retention rate and nitrogen biological value in goats; under the conditions of this experiment, the combination of soybean hulls and enoki mushroom residue with rice straw as roughage yielded the optimal effect.

Full Text

Effects of Different Roughage Combinations on Dietary Nutrient Apparent Digestibility and Nitrogen Balance in Goats

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Abstract

This experiment was conducted to investigate the effects of different roughage combinations on dietary nutrient apparent digestibility and nitrogen balance in goats. Four healthy crossbred goats (Boer × Xuhuai) with an average body weight of (26.63±2.60) kg were used in a 4×4 Latin square design. The basal diet used rice straw (A) as the roughage source, while experimental diets partially substituted rice straw with soybean hulls (B), Enoki mushroom residues (C), and soybean hulls + Enoki mushroom residues (D), respectively. All four diets were formulated to be iso-nitrogenous, iso-energetic, and iso-fibrous. The experiment consisted of four periods, each lasting 15 days (10 days for adaptation and 5 days for sample collection). The results showed that: (1) There were no significant differences among the four diets in apparent digestibility of dry matter (DM), acid detergent fiber (ADF), phosphorus, or gross energy ($P>0.05$). (2) Compared with diet A, diet D significantly improved apparent digestibility of organic matter (OM) and neutral detergent fiber (NDF) ($P<0.05$), while diet B showed no significant difference from diet A ($P>0.05$). Calcium apparent digestibility did not differ significantly among diets B, C, and D ($P>0.05$), but all were significantly higher than that of diet A ($P<0.05$). (3) Compared with diet A, diets B, C, and D significantly increased nitrogen retention rate and nitrogen biological value ($P<0.05$). It is concluded that, compared with using rice straw alone as roughage, partial replacement with soybean hulls, Enoki mushroom residues, or their combination improved apparent digestibility of OM, NDF, and calcium, as well as nitrogen retention rate and nitrogen biological value in goats. Under the conditions of this experiment, the combination of soybean hulls and Enoki mushroom residues with rice straw yielded the optimal results.

Keywords: goat; rice straw; Enoki mushroom residue; soybean hull; apparent digestibility; metabolism

Introduction

In recent years, as goat production systems in Jiangsu Province have gradually moved toward intensification and standardization, there is an urgent need to

improve flock quality and individual productivity to enhance market competitiveness and risk resistance. However, due to severe shortages of high-quality roughage, most production regions continue to rely on straw-based roughage, employing a "straw + concentrate" binary dietary structure. In pursuit of higher yields, producers often use excessive amounts of concentrate, which is detrimental to rumen physiology and the digestion and utilization of roughage in goats. Using straw alone as the sole roughage source often fails to fully meet the nutritional requirements of ruminants. While treatments such as alkalization, ammoniation, and microbial ensiling can significantly improve straw digestibility, the extent of nutritional improvement achievable through processing alone is limited. Therefore, proper dietary formulation and combination must be emphasized.

The proportion of various feed ingredients in the diet is one of the main factors affecting crude fiber utilization in ruminants. When the available energy value or digestibility of a mixed feed or diet does not equal the weighted sum of its individual components, associative effects are produced [1]. Zhang et al. [2] investigated associative effects between rice straw and alfalfa using an in vitro gas production method, demonstrating that appropriate proportions could produce positive associative effects. Zhuang et al. [3] reported that different roughage combinations produced varying effects on Suhuai goats. Zhang et al. [4] found that supplementing rice straw-based diets with 40%-60% alfalfa yielded favorable results in ruminants. Rumen digestion is extremely complex, with many factors influencing its processes and metabolism. Diet composition and its interaction with the digestive system affect dietary nutritional value, with these factors either promoting or antagonizing each other. Positive associative effects can increase feed intake and nutrient digestibility, while negative effects may alter dietary energy value and reduce apparent metabolizable energy. Therefore, rational feed combination can maximize positive associative effects to meet maintenance requirements or achieve production goals. This experiment examined the effects of different combinations of rice straw with soybean hulls and Enoki mushroom residues on nutrient apparent digestibility in goats, providing a theoretical basis for rational diet formulation and scientific utilization of soybean hulls and Enoki mushroom residues in goat production.

1.1 Experimental Design

Four crossbred goats (Boer × Xuhuai) weighing (26.63±2.60) kg were used in a 4×4 Latin square design, with goats numbered 1 through 4. Under the premise of iso-nitrogenous, iso-energetic, and iso-fibrous formulation, soybean hulls and Enoki mushroom residues partially replaced rice straw in the diets. Four treatments were established: basal diet with rice straw (A), and experimental diets with partial replacement by soybean hulls (B), Enoki mushroom residues (C), and soybean hulls + Enoki mushroom residues (D). The experiment comprised four periods, each consisting of a 10-day preliminary period followed by a 5-day

collection period.

1.2 Experimental Diets

After determining the dry matter (DM), organic matter (OM), crude protein (CP), calcium (Ca), phosphorus (P), and neutral detergent fiber (NDF) contents of feed ingredients, four iso-nitrogenous, iso-energetic, and iso-fibrous diets were formulated at 1.5 times the maintenance requirement of Chinese Merino growing rams. Diet composition and nutrient levels are presented in Table 1 .

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

Item	Diet A	Diet B	Diet C	Diet D
Ingredients				
Maize	15.00	15.00	15.00	15.00
Soybean meal	8.00	8.00	8.00	8.00
Wheat bran	5.00	5.00	5.00	5.00
Soybean hull	0.00	15.00	0.00	7.50
Enoki mushroom residues	0.00	0.00	15.00	7.50
Straw	65.00	50.00	50.00	50.00
CaHPO	0.50	0.50	0.50	0.50
Limestone	0.50	0.50	0.50	0.50
Premix[1]	0.50	0.50	0.50	0.50
NaCl	0.50	0.50	0.50	0.50
Bentonite	5.00	5.00	5.00	5.00
Total	100.00	100.00	100.00	100.00
Nutrient levels[2]				
CP	11.97	12.01	12.31	12.07
NDF	42.00	42.00	42.00	42.00
DE (MJ/kg)	9.50	9.50	9.50	9.50
Ca	0.72	0.75	0.77	0.74

[1] The premix provided per kg of diet: VA 4,000 IU, VD 400 IU, VE 20,000 IU, FeSO 69.03 mg, CuSO 17.6 mg, K SO 31.70 mg, ZnSO 57.14 mg, MnSO 44.03 mg, CoCl 0.25 mg, Na SeO 8.95 mg, monensin 6.00 mg, NaHCO 740.91 mg.

[2] Nutrient levels were calculated values.

1.3 Animal Management

Experimental goats were housed individually in metabolic cages for feeding. After adaptation, the formal trial began. During the week preceding the experiment, all four goats were fed ad libitum to determine their feed intake. The lowest daily intake among all goats was established as the fixed daily feeding

amount to ensure complete consumption of experimental diets, with daily intake recorded. Each goat was fed at 08:00 and 17:00 daily.

1.4 Sample Collection and Processing

1.4.1 Diet Sampling During diet preparation, 500 g of each diet was sampled from identical positions in each bag, mixed thoroughly, and collected using the quartering method. Samples were ground to pass through a 40-mesh sieve and stored at -20 °C pending analysis.

1.4.2 Fecal Sampling Feces were collected continuously for 5 days, with daily excretion weighed and recorded. Daily samples were collected at 10% of fresh fecal weight, treated with 10% hydrochloric acid for nitrogen fixation (10 mL of 10% HCl per 100 g feces), dried at 75 °C to constant weight, equilibrated at room temperature for 24 hours, weighed, ground to pass through a 40-mesh sieve, and stored in sealed bags at -20 °C pending analysis.

1.4.3 Urine Sampling Urine was collected continuously for 5 days, with daily volume accurately weighed and recorded in sealed containers. A small amount of concentrated hydrochloric acid (1:3) was added for nitrogen fixation. After 5 days, collected urine was mixed thoroughly, filtered through gauze, sampled into 200 mL plastic bottles, and stored at -20 °C pending analysis.

1.5 Analytical Methods

Diet and fecal samples were analyzed for DM, crude ash, NDF, ADF, CP content, and gross energy using conventional methods [AOAC (1995) [5]]. Phosphorus content in diets and feces was determined using the GB/T 6437-2002 vanadium molybdate yellow colorimetric method. Calcium content was measured using the GB/T 13885-2003 acetylene-air flame atomic absorption spectrophotometry method with a Shanghai Spectrum SP-3803AA instrument.

1.6 Calculations

1.6.1 Nutrient Apparent Digestibility Apparent digestibility of a nutrient = [(Intake of the nutrient - Fecal excretion of the nutrient) / Intake of the nutrient] × 100.

1.6.2 Nitrogen Retention, Nitrogen Retention Rate, and Nitrogen Biological Value Nitrogen retention = Nitrogen intake - Fecal nitrogen - Urinary nitrogen;
Nitrogen retention rate (%) = [(Nitrogen intake - Fecal nitrogen - Urinary nitrogen) / Nitrogen intake] × 100;
Nitrogen biological value (BV, %) = [Nitrogen retention / (Nitrogen intake - Fecal nitrogen)] × 100.

1.7 Statistical Analysis

Data were analyzed using one-way ANOVA procedure in SAS 8.0 statistical software, with Duncan's multiple comparison method used for post-hoc analysis. Differences were considered significant at $P<0.05$.

Results

2.1 Effects of Different Roughage Combinations on DM and OM Apparent Digestibility in Goats

As shown in Table 2 , DM intake of diet A was significantly higher than that of diets B, C, and D ($P<0.05$), likely due to an adaptation period required for unconventional feeds. OM intake differed significantly among the four diets ($P<0.05$), with diet B significantly lower than the other three diets ($P<0.05$), possibly attributable to its higher crude ash content. DM excretion of diet A did not differ significantly from diets B and C ($P>0.05$) but was significantly higher than diet D ($P<0.05$). However, DM apparent digestibility did not differ significantly among the four diets ($P>0.05$), indicating that partial replacement of rice straw with soybean hulls or Enoki mushroom residues had no significant effect on DM digestion characteristics. OM excretion of diet A was significantly higher than that of diets B and D ($P<0.05$) but did not differ significantly from diet C ($P>0.05$). OM apparent digestibility of diet D did not differ significantly from diet B ($P>0.05$) but was significantly higher than diets C and D ($P<0.05$).

Table 2 Effects of different roughage combinations on DM and OM apparent digestibility in goats

Item	Diet A	Diet B	Diet C	Diet D
Dry matter				
Intake (g/d)	642.88±0.00	618.71±0.00	612.53±0.00	622.71±0.00
Output (g/d)	264.34±18.16	244.96±22.29	248.82±21.25	231.18±22.37
Apparent digestibility (%)	58.88±2.82	60.41±3.60	59.38±3.47	62.88±3.59
Organic matter				
Intake (g/d)	575.36±0.00	549.79±0.00	553.62±0.00	555.45±0.00
Output (g/d)	172.24±12.47	144.90±18.82	165.22±15.56	138.34±19.71

Item	Diet A	Diet B	Diet C	Diet D
Apparent digestibility (%)	70.06±2.17	73.65±3.42	70.16±2.81	75.09±3.55

In the same row, values with the same or no superscript letters indicate no significant difference (P>0.05), while different letters indicate significant difference (P<0.05). The same applies below.

2.2 Effects of Different Roughage Combinations on NDF and ADF Apparent Digestibility in Goats

As shown in Table 3 , NDF and ADF intake did not differ significantly among the four diets (P>0.05). NDF and ADF excretion of diet A did not differ significantly from diets B and C (P>0.05) but were significantly higher than diet D (P<0.05). NDF apparent digestibility of diet D did not differ significantly from diets B and C (P>0.05) but was significantly higher than diet A (P<0.05). ADF apparent digestibility did not differ significantly among the four diets (P>0.05), though diet D showed a trend toward higher values than the other three diets. These results indicate that diet D had higher digestibility of NDF and ADF, while diet A had the poorest digestibility of these fiber fractions.

Table 3 Effects of different roughage combinations on NDF and ADF apparent digestibility in goats

Item	Diet A	Diet B	Diet C	Diet D
Neutral detergent fiber				
Intake (g/d)	263.91±0.00	264.30±0.00	263.19±0.00	263.91±0.00
Output (g/d)	122.97±8.15	109.36±6.15	115.19±10.06	105.85±8.63
Apparent digestibility (%)	53.40±3.09	58.62±2.33	56.23±3.82	59.89±3.27
Acid detergent fiber				
Intake (g/d)	143.05±1.81	149.01±7.17	143.18±3.11	146.98±7.63
Output (g/d)	53.99±2.99	52.08±4.28	50.85±3.76	48.40±3.13

Item	Diet A	Diet B	Diet C	Diet D
Apparent digestibility (%)	62.24±2.59	65.01±3.18	64.45±3.04	66.97±3.20

2.3 Effects of Different Roughage Combinations on Calcium and Phosphorus Apparent Digestibility in Goats

As shown in Table 4 , although calcium intake of diet C was significantly higher than diets A, B, and D ($P<0.05$), the numerical differences among the four diets were small. Calcium excretion did not differ significantly among the four diets ($P>0.05$). Calcium apparent digestibility of diets B, C, and D did not differ significantly from each other ($P>0.05$) but was significantly higher than diet A ($P<0.05$), indicating that dietary inclusion of soybean hulls or Enoki mushroom residues enhanced calcium digestion and absorption. Phosphorus intake differed significantly among diets ($P<0.05$), with diet C showing the highest and diet B the lowest, significantly differing from the other three diets ($P<0.05$). Phosphorus excretion did not differ significantly among diets ($P>0.05$), and phosphorus apparent digestibility did not differ significantly either ($P>0.05$), though diet B showed a trend toward higher values than diets A, C, and D. This suggests that dietary inclusion of soybean hulls and Enoki mushroom residues, particularly soybean hulls, may improve phosphorus apparent digestibility.

Table 4 Effects of different roughage combinations on calcium and phosphorus apparent digestibility in goats

Item	Diet A	Diet B	Diet C	Diet D
Calcium				
Intake (g/d)	4.62±0.00	4.62±0.00	4.69±0.00	4.62±0.00
Output (g/d)	2.59±0.03	2.40±0.04	2.44±0.05	2.38±0.04
Apparent digestibility (%)	43.83±0.64	48.08±0.78	48.05±1.13	48.54±1.79
Phosphorus				
Intake (g/d)	4.39±0.00	4.37±0.00	4.49±0.00	4.40±0.00
Output (g/d)	2.45±0.18	2.38±0.25	2.45±0.41	2.45±0.24
Apparent digestibility (%)	44.19±2.64	45.53±3.72	45.43±3.03	44.31±3.24

2.4 Effects of Different Roughage Combinations on Gross Energy Apparent Digestibility in Goats

As shown in Table 5 , gross energy intake differed significantly among diets ($P<0.05$), with diet A significantly higher than the other three diets ($P<0.05$), though numerical differences were small. Fecal energy did not differ significantly among the four diets ($P>0.05$). Gross energy apparent digestibility did not differ significantly among diets ($P>0.05$), though diets B, C, and D showed trends toward higher values than diet A, possibly due to higher fiber apparent digestibility in these diets.

Table 5 Effects of different roughage combinations on gross energy apparent digestibility in goats

Item	Diet A	Diet B	Diet C	Diet D
Gross energy intake (kJ/d)	117.87±0.00	113.84±0.00	111.97±0.00	112.55±0.00
Fecal energy (kJ/d)	43.25±4.24	37.95±3.56	39.08±3.20	37.12±3.59
Gross energy apparent digestibility (%)	63.31±3.60	66.67±3.12	65.10±2.87	67.02±3.19

2.5 Effects of Different Roughage Combinations on Nitrogen Balance in Goats

As shown in Table 6 , nitrogen intake, fecal nitrogen, and urinary nitrogen did not differ significantly among the four diets ($P>0.05$). Nitrogen retention of diet A was significantly lower than that of diets B, C, and D ($P<0.05$), which did not differ significantly from each other ($P>0.05$). Nitrogen retention rate and nitrogen biological value of diets B, C, and D were significantly higher than those of diet A ($P<0.05$), with no significant differences among them ($P>0.05$), though diet D showed numerically higher nitrogen biological value than diets B and C. These results demonstrate that dietary inclusion of soybean hulls and Enoki mushroom residues enhanced nitrogen digestion and utilization.

Table 6 Effects of different roughage combinations on nitrogen balance in goats

Item	Diet A	Diet B	Diet C	Diet D
Nitrogen intake (g/d)	11.97±0.00	12.01±0.00	12.31±0.00	12.07±0.00
Fecal nitrogen (g/d)	4.80±0.38	3.63±0.63	4.30±0.46	3.20±0.61
Urinary nitrogen (g/d)	4.85±0.17	3.12±1.13	4.72±0.70	2.77±0.46
Nitrogen retention (g/d)	3.54±0.38	4.51±0.46	4.33±1.03	4.58±0.68
Nitrogen retention rate (%)	29.58±3.16	37.55±3.81	35.20±2.39	37.94±2.65
Nitrogen biological value (%)	49.55±6.74	58.60±6.24	58.26±4.46	62.22±5.61

Discussion

3.1 Effects of Different Roughage Combinations on DM and OM Apparent Digestibility in Goats

Apparent digestibility of DM and OM reflects the digestive characteristics of a diet in animals [6], and different roughage sources exhibit varying degradation degrees in the rumen [7-9]. The present results showed that diets B, C, and D had higher DM and OM apparent digestibility than diet A, indicating associative effects among rice straw, soybean hulls, and Enoki mushroom residues. This may be attributed to differences in palatability and rumen degradation characteristics of fiber components from different roughage sources, which promoted optimal fermentation of highly degradable dietary components in the rumen, increased fiber-degrading bacterial populations, and improved overall dietary fiber utilization, thereby affecting nutrient digestibility.

3.2 Effects of Different Roughage Combinations on NDF and ADF Apparent Digestibility in Goats

Dietary fiber plays a crucial role in ruminants, serving not only as an important energy source for rumen microorganisms but also maintaining rumen wall health and saliva secretion [10-12]. NDF and ADF digestibility reflects the ability of ruminants to utilize dietary fiber [13]. Fiber digestion is influenced by multiple factors, including diet composition, rumen fermentation environment, rumen

microbial composition, and rumen retention time [14]. The present findings align with Gao et al. [15], who reported that diets with soybean hulls as the main fiber source improved NDF apparent digestibility. According to Quicke et al. [16], in vitro DM digestibility of soybean hulls can reach 90%, with crude fiber digestibility up to 96%. Soybean hulls promote a "positive interaction effect" on rumen cell wall digestion, as demonstrated through in vivo trials [17] and nylon bag studies [18] showing that soybean hull addition enhances the "positive interaction effect" on dietary fiber digestibility. Compared with other roughages, soybean hulls contain more potentially degradable NDF with higher degradation rates [19]. Therefore, dietary inclusion of soybean hulls can improve fiber apparent digestibility. In diet D, which contained soybean hulls, NDF and ADF apparent digestibility was slightly higher than in diet B, indicating that the effect of soybean hulls on fiber utilization depends on dietary combination and inclusion level. The low NDF and ADF apparent digestibility in diet A was consistent with its significantly lower DM and OM apparent digestibility. High lignification in diets reduces not only fiber digestibility but also overall dietary digestibility, consistent with Li et al. [20]. Through biological nitrogen fixation and enzymatic hydrolysis during mushroom cultivation, cellulose, hemicellulose, and lignin in substrates are partially degraded [21], facilitating fiber digestion and decomposition. Additionally, bioactive substances in mushroom residues may improve the rumen fermentation environment, promoting fiber digestion in the rumen and increasing fiber digestibility. Consequently, although NDF and ADF apparent digestibility of diet C did not differ significantly from diet A, it showed a numerical trend toward higher values.

3.3 Effects of Different Roughage Combinations on Mineral Apparent Digestibility in Goats

The primary route of calcium and phosphorus excretion in ruminants is through feces (enterohepatic circulation), with minimal urinary excretion; therefore, only apparent digestibility was measured in this experiment. Calcium and phosphorus play important roles in ruminants by maintaining rumen microbial activity and influencing rumen digestive capacity [22]. Research indicates that subnormal rumen phosphorus levels impede microbial growth and reduce fiber digestibility [23]. Durand et al. [24] demonstrated in vitro with dairy cows that phosphorus not only promotes rumen microbial activity but also alters the rumen environment to enhance crude fiber digestion. In the present study, inclusion of unconventional feeds (soybean hulls and Enoki mushroom residues) improved calcium and phosphorus absorption, consistent with Gao et al. [15], who reported a trend toward improved calcium and phosphorus apparent digestibility with soybean hull supplementation. This may be related to the solubility product of calcium and phosphorus in the small intestine. The lower calcium apparent digestibility in diet A may be attributed to high oxalic acid content in rice straw, which forms insoluble calcium oxalate excreted in feces, thereby reducing calcium digestibility [25]. Diet D showed slightly higher calcium apparent digestibility than diets B and C, while phosphorus apparent digestibility

was slightly lower, possibly due to associative effects between soybean hulls and Enoki mushroom residues that promoted calcium absorption while inhibiting phosphorus absorption. The specific mechanisms require further investigation.

3.4 Effects of Different Roughage Combinations on Gross Energy Apparent Digestibility in Goats

Energy is the foundation of all metabolic and productive activities in animals, with dietary fiber being an important energy source for ruminants [26]. Ruminants obtain 70%-80% of their required energy from volatile fatty acids (VFA) produced through rumen fermentation of carbohydrates. Studies show that fecal energy accounts for 40%-50% of gross energy intake when ruminants consume roughage, 20%-30% when consuming concentrate, and up to 60% when consuming low-quality roughage [27]. In this experiment, fecal energy accounted for 32.98%-34.90% of gross energy intake, consistent with these findings. Diet A had relatively higher fecal energy than the other three diets, likely related to the low quality of rice straw and low effective fiber degradation rate. Xia et al. [28] and Narenhua et al. [29] reported relatively high fecal energy in straw-based diets.

3.5 Effects of Different Roughage Combinations on Nitrogen Balance in Goats

Ingested nitrogen is either deposited in the body as protein for utilization or excreted as metabolic waste products in feces and urine. Nitrogen retention rate reflects the degree of dietary protein utilization in animals. Due to variable efficiency of rumen-degradable nitrogen utilization, nitrogen retention rate is more meaningful than digestibility alone. Nitrogen retention rate not only reflects dietary CP quality but also accurately indicates the degree of protein digestion and absorption in animals [30]. Studies show that alterations in carbohydrate structure can improve nitrogen utilization efficiency [31]. In this experiment, compared with rice straw alone, inclusion of unconventional feeds (soybean hulls and Enoki mushroom residues) altered dietary carbohydrate structure to favor nitrogen digestion and utilization, thereby improving nitrogen digestibility. Gao et al. [15] reported that dietary soybean hulls improved protein apparent digestibility. Lin et al. [32] investigated the effects of different proportions of Enoki mushroom residues on nutrient apparent digestibility in fattening cattle, finding that 23% inclusion significantly improved protein digestibility, consistent with the present results.

Conclusions

1. Compared with using rice straw alone as roughage, partial replacement with soybean hulls, Enoki mushroom residues, or their combination improved apparent digestibility of organic matter, neutral detergent fiber,

and calcium, as well as nitrogen retention rate and nitrogen biological value in goats.

2. Under the conditions of this experiment, the combination of soybean hulls and Enoki mushroom residues with rice straw produced the optimal results.

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