

Postprint of a Study on the Associative Effects of Pennisetum sinense and Spray-dried Corn Bran

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Abstract

This experiment aimed to investigate the effects of different combination ratios of *Pennisetum sinense* and sprayed corn bran on nutrient degradation rates in goat rumen using the in vitro gas production method, thereby providing theoretical basis and data support for the scientific application of roughage resources in southern China. *Pennisetum sinense* and sprayed corn bran were divided into five groups (, , , , and) according to dry matter (DM) ratios of 100:0, 75:25, 50:50, 25:75, and 0:100, respectively, and cultured via the in vitro gas production method for 4, 8, 12, 24, and 48 hours, with three replicates and two blank controls for each time point. After incubation, fermentation was terminated and the pH, ammonia nitrogen (NH₃-N) concentration of the fermentation fluid, and DM, crude protein (CP), and neutral detergent fiber (NDF) contents of the fermentation residues were measured at each time point. The results showed: 1) Different combination ratios of *Pennisetum sinense* and sprayed corn bran significantly affected the pH and NH₃-N concentration of the fermentation fluid ($P < 0.05$), but both fluctuated within normal ranges; as the proportion of sprayed corn bran in the combination increased, the pH of the fermentation fluid decreased significantly ($P < 0.05$); at 12, 24, and 48 hours of in vitro fermentation, the NH₃-N concentrations in the groups with 50% and 75% sprayed corn bran (groups and) were significantly greater than that in the *Pennisetum sinense* alone group (group) ($P < 0.05$). 2) At 12 and 48 hours of in vitro fermentation, as the proportion of sprayed corn bran in the combination increased, the in vitro rumen DM degradation rate of goats increased significantly ($P < 0.05$); at 8, 12, 24, and 48 hours of in vitro fermentation, the in vitro rumen NDF and CP degradation rates in the groups with 50% and 75% sprayed corn bran were significantly higher than those in the *Pennisetum sinense* alone group ($P < 0.05$). 3) The combination of 75% *Pennisetum sinense* and 25% sprayed corn bran and the combination of 50% *Pennisetum sinense* and 50% sprayed corn bran both produced positive associative effects on the in vitro

rumen DM degradation rate of goats throughout the fermentation period, with the 50% Pennisetum sinense and 50% sprayed corn bran combination producing the maximum associative effect value at 24 hours of in vitro fermentation; the combination of 75% Pennisetum sinense and 25% sprayed corn bran produced positive associative effects on the in vitro rumen NDF degradation rate throughout the fermentation period, with the maximum associative effect value occurring at 12 hours of in vitro fermentation; the combination of 50% Pennisetum sinense and 50% sprayed corn bran produced positive associative effects on the in vitro rumen CP degradation rate throughout the fermentation period, with the maximum associative effect value occurring at 8 hours of in vitro fermentation. In conclusion, the appropriate combination ratio of Pennisetum sinense to sprayed corn bran is (75:25)-(50:50).

Full Text

Combination Effect of Pennisetum sinense Roxb and Spouting Corn Bran

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Abstract: This experiment investigated the effects of combining Pennisetum sinense Roxb and spouting corn bran at different ratios on the rumen degradation rate of nutrients in goats using an in vitro gas production method, aiming to provide theoretical basis and data support for the scientific application of roughage resources in southern China. The experiment divided Pennisetum sinense Roxb and spouting corn bran mixtures into five groups (, , , , and) based on dry matter (DM) ratios of 100:0, 75:25, 50:50, 25:75, and 0:100, respectively. These were cultured for 4, 8, 12, 24, and 48 hours using the in vitro gas production method, with three replicates and two blank controls at each time point. After incubation, fermentation was terminated and fermentation liquid pH, ammonia nitrogen (NH₃-N) concentration, and DM, crude protein (CP), and neutral detergent fiber (NDF) contents in fermentation residues were measured. The results showed: (1) Different combination ratios significantly affected fermentation liquid pH and NH₃-N concentration ($P < 0.05$), but all variations remained within normal ranges. As the proportion of spouting corn bran increased, fermentation liquid pH decreased significantly ($P < 0.05$). At 12, 24, and 48 hours of in vitro fermentation, NH₃-N concentrations in groups with 50% and 75% spouting corn bran (groups and) were significantly higher than in the single Pennisetum sinense Roxb group (group) ($P < 0.05$). (2) At 12 and 48 hours of in vitro fermentation, the in vitro rumen DM degradation rate increased significantly with increasing spouting corn bran proportion ($P < 0.05$). At 8, 12, 24,

and 48 hours, the in vitro rumen NDF and CP degradation rates in groups with 50% and 75% spouting corn bran were significantly higher than in the single Pennisetum sinense Roxb group ($P < 0.05$). (3) The combination of 75% Pennisetum sinense Roxb + 25% spouting corn bran and the 50% Pennisetum sinense Roxb + 50% spouting corn bran both produced positive combined effects on in vitro rumen DM degradation rate throughout the fermentation period, with the maximum combined effect value observed in the 50:50 combination at 24 hours. The 75:25 combination produced positive combined effects on in vitro rumen NDF degradation rate throughout the fermentation period, with the maximum value at 12 hours. The 50:50 combination produced positive combined effects on in vitro rumen CP degradation rate throughout the fermentation period, with the maximum value at 8 hours. In conclusion, the optimal combination ratio of Pennisetum sinense Roxb to spouting corn bran is (75:25) to (50:50).

Keywords: Pennisetum sinense Roxb; spouting corn bran; rumen degradation rate; combined effect; in vitro gas production method

Pennisetum sinense Roxb (PSR), also known as king grass or royal grass, is a perennial gramineous plant widely cultivated in tropical and subtropical regions of southern China. It is called the “king of forage grasses” due to its high quality, yield, and nutritional value [?]. Spouting corn bran (SCB), also known as corn gluten feed, is a byproduct of corn starch production formed by spraying protein- and energy-rich corn steep liquor onto corn bran, followed by drum drying. It contains higher protein, amino acids, and energy than regular corn bran, and is characterized by good color, high energy, and high digestibility [?].

Previous studies have demonstrated the feasibility of using spouting corn bran as an unconventional feed ingredient in animal production. Li et al. [?] found that adding 5-10% spouting corn bran to the diet of Huannong meat ducks had no adverse effects on production performance or intestinal development after 15 days of age. Shu et al. [?] reported that adding 5% spouting corn bran to Cherry Valley duck diets did not significantly affect production performance or intestinal development. Meng et al. [?] showed that a 25:75 combination of spouting corn bran and wheat straw produced the maximum positive combined effect, improving nutrient degradation rate. Tu et al. [?] found that in wheat straw and spouting corn bran combinations, increasing the proportion of spouting corn bran increased propionate concentration and improved feed conversion efficiency, making it more suitable for poultry fattening. These findings demonstrate that utilizing positive combined effects among different feeds can improve feed conversion rates and achieve balanced nutrition. However, while spouting corn bran shows promise as an unconventional feed ingredient, few studies have reported its application effects in southern China, particularly in combination with southern forage grasses. Building on previous research, this experiment selected different proportions of Pennisetum sinense Roxb and spouting corn bran as fermentation substrates and used the in vitro gas production method to investigate their combined effects on rumen degradation rate in goats, aiming

to identify optimal combination ratios and provide theoretical basis and data support for scientific application of roughage resources in southern China.

1.1 Experimental Materials and Animals

Pennisetum sinense Roxb: *Pennisetum sinense* Roxb was harvested in October 2016 at a plant height of 150-200 cm, with a 20 cm stubble height. The forage was chopped using a straw rubbing machine, dried in a 60°C oven, and ground using a micro-mill for later use.

Spouting corn bran: Provided by a feed company in Zhanjiang City.

Experimental animals: Goats were used as rumen fluid donors.

1.2 Experimental Design

The experiment employed an in vitro gas production method using different proportions of *Pennisetum sinense* Roxb and spouting corn bran as fermentation substrates. The mixtures were divided into five groups (, , , , and) based on dry matter (DM) ratios of 100:0, 75:25, 50:50, 25:75, and 0:100, respectively. Each time point had three replicates and two blank controls. The substrates were cultured for 4, 8, 12, 24, and 48 hours, and various indicators of fermentation liquid and residues were measured at each time point. The nutritional levels of experimental materials are shown in Table 1 .

1.3.1 Preparation of Artificial Saliva Stock Solutions

Solution A (Trace element solution): $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ 13.2 g, $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ 1.0 g, $\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$ 10.0 g, $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ 8.0 g, dissolved in distilled water and diluted to 100 mL.

Solution B (Buffer solution): NH_4HCO_3 4.0 g, NaHCO_3 35.0 g, dissolved in distilled water and diluted to 1,000 mL.

Solution C (Macro element solution): $\text{NaH}_2\text{PO}_4 \cdot 12\text{H}_2\text{O}$ 9.45 g, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ 0.6 g, KH_2PO_4 6.2 g, dissolved in distilled water and diluted to 1,000 mL.

Solution D (0.1% Resazurin solution): 100 mg resazurin dissolved in 100 mL distilled water.

Solution E (Reducing agent solution): 95 mL distilled water, 625 mg $\text{Na}_2\text{S}_2\text{O}_4 \cdot 9\text{H}_2\text{O}$, 4.0 mL 1 mol/L NaOH.

1.3.2 Preparation of Artificial Saliva

To prepare 1,000 mL of artificial saliva, mix 520.3 mL distilled water, 208.1 mL Solution B, 208.1 mL Solution C, 0.1 mL Solution A, 1 mL Solution D, and 62.4 mL Solution E. Place the mixture in a $(39.0 \pm 0.5)^\circ\text{C}$ constant temperature water bath and continuously infuse CO_2 until the color changes from blue to pink and finally becomes colorless.

1.3.3 Rumen Fluid Collection

Before morning feeding, goat rumen fluid was collected and placed in a thermos flask for transport to the laboratory. The fluid was poured into a beaker and placed in a $(39.0 \pm 0.5)^\circ\text{C}$ water bath, then filtered sequentially through 2, 4, and 6 layers of gauze while continuously infusing CO_2 . The rumen fluid was mixed with artificial saliva at a 1:9 volume ratio and added to 200 mL gas production bottles containing 1.25 g fermentation substrate. The bottles were incubated in a $(39.0 \pm 0.5)^\circ\text{C}$ constant temperature shaking incubator for 4, 8, 12, 24, and 48 hours.

1.4 Sample Collection and Processing

At each time point, gas production bottles were removed and immediately placed in ice water to terminate microbial activity. Fermentation liquid pH was measured immediately using an S220-K pH meter. The liquid was filtered through nylon cloth, and the filtrate was stored at -20°C for $\text{NH}_3\text{-N}$ concentration determination. The residue was dried in a 65°C oven, weighed, and stored at -20°C for subsequent analysis.

1.5 Determination Indicators and Methods

DM, crude ash, and CP contents of experimental materials and residues were determined according to AOAC (1995) [?] conventional methods. Acid detergent fiber (ADF) and NDF contents were determined using the Van Soest detergent fiber method. $\text{NH}_3\text{-N}$ concentration in fermentation liquid was determined using the method of Zhu et al. [?].

1.6.1 Calculation of Nutrient Degradation Rate

Nutrient degradation rate (%) = $[(\text{Nutrient content in experimental material} - \text{Nutrient content in residue}) / \text{Nutrient content in experimental material}] \times 100$.

1.6.2 Calculation of Combined Effect Value

Combined effect value (%) = $[(\text{Measured value} - \text{Weighted estimated value}) / \text{Weighted estimated value}] \times 100$.

Where: Measured value is the actual measured degradation rate of a nutrient in the sample; Weighted estimated value = Measured value of sample A \times Proportion of sample A + Measured value of sample B \times Proportion of sample B.

1.7 Data Processing

Experimental data were initially processed using Excel 2013 and analyzed using one-way ANOVA with the ANOVA model in SPSS 20.0 software. Multiple comparisons were performed using the LSD method. Results are expressed as “mean \pm standard deviation,” with $P < 0.05$ indicating significant difference.

2.1 Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on Fermentation Liquid pH and NH₃-N Concentration

As shown in Table 2, at 4 hours of in vitro fermentation, the pH values of fermentation liquid in groups , , , and were significantly lower than in group with single Pennisetum sinense Roxb ($P < 0.05$). At 8, 12, 24, and 48 hours, fermentation liquid pH decreased significantly with increasing spouting corn bran proportion ($P < 0.05$). Throughout the fermentation period, pH values in all groups decreased significantly with prolonged fermentation time ($P < 0.05$).

As shown in Table 3, at 4 hours of in vitro fermentation, NH₃-N concentrations among groups showed no significant differences ($P > 0.05$). At 8 hours, NH₃-N concentrations in groups , , and were significantly lower than in group ($P < 0.05$), while group showed no significant difference from group ($P > 0.05$). At 12 hours, NH₃-N concentrations in groups , , and were significantly higher than in group ($P < 0.05$). At 24 hours, NH₃-N concentration increased gradually with spouting corn bran proportion, with groups , , and significantly higher than groups and ($P < 0.05$), and groups and significantly higher than group ($P < 0.05$). At 48 hours, NH₃-N concentrations in groups , , , and increased significantly with spouting corn bran proportion ($P < 0.05$), while group showed a slight increase compared to group ($P > 0.05$). Throughout the fermentation period, NH₃-N concentrations in groups , , and showed a trend of decreasing first and then increasing with prolonged fermentation time.

2.2 Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on In Vitro Rumen DM Degradation Rate in Goats

As shown in Table 4, at 4 hours of in vitro fermentation, no significant differences were observed among groups in in vitro rumen DM degradation rate ($P > 0.05$). At 8 hours, DM degradation rate increased gradually with spouting corn bran proportion, with significant differences among all groups except between groups and ($P > 0.05$) ($P < 0.05$). At 12 and 48 hours, DM degradation rate increased significantly with spouting corn bran proportion ($P < 0.05$). At 24 hours, DM degradation rate increased gradually with spouting corn bran proportion, with significant differences among all groups except between groups and ($P > 0.05$) ($P < 0.05$). Throughout the fermentation period, DM degradation rates in groups , , , and increased significantly with prolonged fermentation time ($P < 0.05$).

2.3 Combined Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on In Vitro Rumen DM Degradation Rate in Goats

As shown in Table 5, combined effects were observed for Pennisetum sinense Roxb and spouting corn bran combinations. At 4, 8, and 24 hours, combined effect values showed an increasing trend as spouting corn bran proportion increased from 25% to 50%, but differences were not significant ($P > 0.05$). At

12 and 48 hours, combined effect values showed a decreasing trend as spouting corn bran proportion increased from 25% to 50%, but differences were not significant ($P>0.05$). The 75% Pennisetum sinense Roxb + 25% spouting corn bran combination and the 50% Pennisetum sinense Roxb + 50% spouting corn bran combination both produced positive combined effects throughout the fermentation period. The 25% Pennisetum sinense Roxb + 75% spouting corn bran combination produced negative combined effects at 4 and 24 hours, and positive combined effects at 8, 12, and 48 hours. Throughout the fermentation period, combinations containing 25% and 50% spouting corn bran both produced positive combined effects.

2.4 Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on In Vitro Rumen NDF Degradation Rate in Goats

As shown in Table 6, at 4 hours of in vitro fermentation, no significant differences were observed among groups , , and ($P>0.05$), but all were significantly higher than groups and ($P<0.05$). At 8 hours, NDF degradation rates in groups , , and were significantly higher than in group ($P<0.05$). At 12 and 48 hours, NDF degradation rate increased with spouting corn bran proportion, with significant differences among all groups except between groups and ($P>0.05$) ($P<0.05$). At 24 hours, NDF degradation rate increased with spouting corn bran proportion, with significant differences among all groups except between groups and ($P>0.05$) ($P<0.05$). Throughout the fermentation period, NDF degradation rates in groups , , , and increased significantly with prolonged fermentation time ($P<0.05$). In group , NDF degradation rate showed no significant change from 4 to 12 hours ($P>0.05$), but increased significantly from 12 to 48 hours ($P<0.05$).

2.5 Combined Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on In Vitro Rumen NDF Degradation Rate in Goats

As shown in Table 7, combined effects were observed for Pennisetum sinense Roxb and spouting corn bran combinations. At 4 hours, combined effect values decreased gradually with increasing spouting corn bran proportion, with groups and significantly higher than group ($P<0.05$). At 8, 12, 24, and 48 hours, combined effect values decreased gradually with increasing spouting corn bran proportion, with group significantly higher than groups and ($P<0.05$). The 75% Pennisetum sinense Roxb + 25% spouting corn bran combination produced positive combined effects throughout the fermentation period. The 50% Pennisetum sinense Roxb + 50% spouting corn bran combination produced positive combined effects at 4, 12, and 24 hours, but negative combined effects at 48 hours. The 25% Pennisetum sinense Roxb + 75% spouting corn bran combination produced negative combined effects at 4, 12, 24, and 48 hours, but positive combined effects at 8 hours. Throughout the fermentation period, combined effect values in group showed a trend of increasing first and then decreasing,

while those in group decreased gradually.

2.6 Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on In Vitro Rumen CP Degradation Rate in Goats

As shown in Table 8, at 4 hours of in vitro fermentation, CP degradation rate increased first and then decreased with increasing spouting corn bran proportion, with group showing the highest value and significantly higher than all other groups ($P < 0.05$). At 8 hours, CP degradation rates in spouting corn bran-added groups (, , , and) were all significantly higher than in the single Pennisetum sinense Roxb group () ($P < 0.05$). At 12 hours, significant differences were observed among all groups except between groups and ($P > 0.05$) ($P < 0.05$). At 24 hours, no significant differences were observed among groups , , and ($P > 0.05$), but these three groups were all significantly higher than group ($P < 0.05$), and group was significantly higher than all groups except group ($P > 0.05$). At 48 hours, significant differences were observed among all groups ($P < 0.05$), with group significantly higher than groups , , and ($P < 0.05$), and group significantly higher than all other groups ($P < 0.05$). Throughout the fermentation period, CP degradation rates in groups and showed a trend of increasing first and then decreasing, with maximum values at 24 hours. CP degradation rates in groups , , and increased significantly with prolonged fermentation time ($P < 0.05$).

2.7 Combined Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on In Vitro Rumen CP Degradation Rate in Goats

As shown in Table 9, combined effects were observed for Pennisetum sinense Roxb and spouting corn bran combinations. At 4 and 12 hours, combined effect values increased first and then decreased with increasing spouting corn bran proportion, with group significantly higher than groups and ($P < 0.05$). At 24 and 48 hours, combined effect values decreased with increasing spouting corn bran proportion, with no significant difference between groups and ($P > 0.05$), but both significantly higher than group ($P < 0.05$). At 8 hours, combined effect values increased first and then decreased with increasing spouting corn bran proportion, with significant differences among all groups ($P < 0.05$). The 75% Pennisetum sinense Roxb + 25% spouting corn bran combination and the 25% Pennisetum sinense Roxb + 75% spouting corn bran combination produced negative combined effects at 12 hours, but positive combined effects at 4, 8, 24, and 48 hours. The 50% Pennisetum sinense Roxb + 50% spouting corn bran combination produced positive combined effects throughout the fermentation period. Throughout the fermentation period, combined effect values in groups and showed trends of increasing, decreasing, and then increasing again.

3.1 Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on Fermentation Liquid pH and NH₃-N Concentration

pH is the most intuitive and fundamental physiological indicator reflecting normal rumen fermentation, comprehensively reflecting the production, absorption, excretion, and neutralization of organic acids from rumen microbial metabolism. The normal range is generally 5.0-7.5, with the optimal range for rumen microorganisms being 6.2-7.00. When pH falls below 6.2, the activity of cellulolytic bacteria in the rumen is inhibited [?]. In this experiment, the pH values of fermentation liquid ranged from 6.21 to 7.04 at 4-48 hours for combinations of Pennisetum sinense Roxb and spouting corn bran at ratios of 75:25, 50:50, and 25:75, indicating that different proportions of these combinations could ferment normally in the rumen.

NH₃-N is the degradation product of feed protein, endogenous protein, and non-protein nitrogen, and also serves as a raw material for microbial protein synthesis. Its concentration can reflect rumen microbial NH₃-N production and utilization to some extent, and either too high or too low concentrations are unfavorable for rumen microbial proliferation [?]. In this experiment, NH₃-N concentrations in fermentation liquid ranged from 6.87 to 22.28 mg/dL at 4-48 hours, all within the normal rumen NH₃-N concentration range of 6-30 mg/dL reported by Illius [?]. This indicates that the combination of Pennisetum sinense Roxb and spouting corn bran was conducive to rumen microbial proliferation, increasing microbial protein synthesis and improving protein utilization. From 4 to 24 hours, NH₃-N concentrations in all groups decreased gradually with fermentation time, possibly because spouting corn bran is relatively easily degradable. As the proportion of easily degradable substances increased, available nutrients for rumen microorganisms increased, promoting microbial growth and proliferation, with more nitrogen being utilized for microbial protein synthesis [?]. The upward trend in NH₃-N concentration in the later stage may be due to the gradual accumulation of fermentation products that could not be removed from the fermentation bottles, leading to ammonia accumulation [?].

3.2 Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on In Vitro Rumen DM Degradation Rate in Goats

This study investigated the effects of different proportions of Pennisetum sinense Roxb and spouting corn bran on in vitro rumen DM degradation rate in goats. The results showed that DM degradation rate changed with the combination ratio, indicating combined effects among different roughages, consistent with findings by Gao et al. [?] and Meng et al. [?]. In this experiment, in vitro rumen DM degradation rate increased gradually with increasing spouting corn bran proportion. When the spouting corn bran proportion reached 50%, the increase in DM degradation rate slowed, consistent with the results of Zhang et al. [?] who studied rice straw and alfalfa combinations and found that when alfalfa proportion reached 30%, rumen DM degradation rate increase slowed as the rumen approached its degradation limit. Overall, all combination groups showed signif-

icantly higher in vitro rumen DM degradation rates than the single Pennisetum sinense Roxb group, indicating combined effects between Pennisetum sinense Roxb and spouting corn bran. This may be due to differences in DM, CP, and CF contents among roughage sources and forages, leading to different palatability and degradation characteristics in the rumen [?]. In this experiment, DM degradation rates in all groups increased significantly with prolonged fermentation time, possibly because extended fermentation time enhanced the activity of rumen microbial decomposers and increased the degree of nutrient degradation. Combinations with 25% and 50% spouting corn bran both produced varying degrees of positive combined effects, indicating that adding appropriate proportions of spouting corn bran was beneficial for rumen microbial proliferation and increased nutrient digestion and absorption.

DM degradation rate is an important indicator reflecting rumen fermentation characteristics of roughages [?]. After roughage enters the rumen, volatile fatty acids and NH₃-N are produced through microbial action, and microbial protein is synthesized using NH₃-N and keto acids as raw materials, providing 40-80% of the protein required by ruminants. The quality of roughage combinations is related not only to the content and quality of nutrients but also to the structure of nutrients in the feed [?]. Basangzhu et al. [?] showed that different crop straws have different DM degradation rates, possibly related to their digestible organic matter and non-structural carbohydrate contents. In this experiment, the increase in in vitro rumen DM degradation rate with increasing spouting corn bran proportion may be due to the higher content of digestible organic matter and non-structural carbohydrates in spouting corn bran.

3.3 Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on In Vitro Rumen Fiber Degradation Rate in Goats

Crude fiber is one of the essential nutrients for ruminants, providing volatile fatty acids and precursors for glyconeogenesis, supplying substantial energy, and maintaining normal production functions, rumen function, and animal health [?]. NDF can stimulate chewing and rumination in ruminants, promote saliva secretion, and enhance rumen buffering capacity, which is important for protecting gastrointestinal health and maintaining normal rumen fermentation [?]. In this experiment, from 8 to 48 hours, NDF degradation rates in spouting corn bran-added groups were higher than in the single Pennisetum sinense Roxb group, consistent with findings by Xia et al. [?] and Ponce et al. [?]. The higher NDF degradation rates in spouting corn bran-added groups may be due to the higher protein content in spouting corn bran, which provides ammonia nitrogen, peptides, amino acids, and branched-chain fatty acids needed for rumen microbial growth [?]. Studies have shown that adding branched-chain fatty acids to low-protein diets can increase total rumen microbial count and microbial protein content [?], thereby promoting fiber degradation [?]. In this experiment, adding different proportions of spouting corn bran to Pennisetum sinense Roxb produced varying degrees of combined effects, indicating that spouting corn

bran addition was beneficial for rumen microbial growth and reproduction and improved nutrient degradation rates. The 75% Pennisetum sinense Roxb + 25% spouting corn bran combination produced positive combined effects throughout the fermentation period, with the maximum value at 12 hours. The 50% Pennisetum sinense Roxb + 50% spouting corn bran combination produced negative combined effects at 48 hours. The 25% Pennisetum sinense Roxb + 75% spouting corn bran combination produced negative combined effects throughout the fermentation period. This may be because adding appropriate proportions of unconventional feed to Pennisetum sinense Roxb can improve fiber degradation rate and produce positive combined effects, while inappropriate proportions produce negative combined effects [?].

3.4 Effects of Pennisetum sinense Roxb and Spouting Corn Bran Combination on In Vitro Rumen CP Degradation Rate in Goats

Dietary protein consumed by ruminants is partially degraded by rumen microorganisms and used for microbial protein synthesis. The synthesized microbial protein and undegraded dietary protein enter the small intestine for digestion, absorption, and utilization [?]. Zhang et al. [?] studied the rumen degradation characteristics of CP in common dairy cow feeds and found that dietary CP degradation rate was significantly negatively correlated with dietary NDF and ADF contents. In this experiment, as spouting corn bran proportion increased, NDF and ADF contents in fermentation substrates gradually decreased, accompanied by gradually increasing in vitro rumen CP degradation rate, consistent with the above findings. When the degradation rate of a nutrient in a feed combination is higher than the weighted value of each single feed due to some interaction, the combination produces a positive combined effect [?]. In this experiment, combining Pennisetum sinense Roxb with different proportions of spouting corn bran increased in vitro rumen CP degradation rate and produced varying degrees of positive combined effects. This may be because the two roughage combinations had more reasonable and balanced nutrient proportions than single roughages, and the combined effect compensated for the carbon-nitrogen imbalance defect of single roughages, improving nutrient degradation rates in the rumen [?]. Therefore, research on different feed combinations is important for animal health and feed resource development and utilization.

Conclusion

Adding spouting corn bran to diets with Pennisetum sinense Roxb as the main roughage is beneficial for improving dietary nutrition levels and Pennisetum sinense Roxb utilization. Considering the combined effects on in vitro rumen nutrient degradation rates in goats, the optimal combination ratio of Pennisetum sinense Roxb to spouting corn bran is (75:25) to (50:50).

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