

Comparative Study on Rumen Degradation Characteristics of Hewang Grass and Common Roughages for Dairy Cattle: Postprint

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Abstract

This study aimed to investigate the rumen degradation characteristics of seven roughage types: Hewang grass hay and silage at two cutting heights, *Leymus chinensis* hay, alfalfa hay, and whole-plant corn silage. Four Holstein dairy cows fitted with permanent rumen fistulas were used as experimental animals, and the nylon bag method was employed to evaluate the 72-h rumen degradation rates of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF). The results showed: 1) The CP content of Hewang grass hay was significantly higher than that of *Leymus chinensis* hay ($P < 0.05$), while its NDF content was significantly lower ($P < 0.05$); the CP and NDF contents of Hewang grass silage were significantly higher than those of whole-plant corn silage ($P < 0.05$). 2) Alfalfa hay exhibited the highest DM effective degradation rate, which differed significantly from whole-plant corn silage, 2.0 m Hewang grass silage, 2.5 m Hewang grass silage, 2.0 m Hewang grass hay, 2.5 m Hewang grass hay, and *Leymus chinensis* hay in descending order ($P < 0.05$); the DM effective degradation rate of *Leymus chinensis* hay was significantly lower than that of all other roughages ($P < 0.05$). The CP effective degradation rate was highest in alfalfa hay, showing no significant difference with 2.0 m Hewang grass silage ($P > 0.05$), but was significantly higher than 2.5 m Hewang grass silage, 2.0 m Hewang grass hay, whole-plant corn silage, 2.5 m Hewang grass hay, and *Leymus chinensis* hay in descending order ($P < 0.05$). No significant difference was observed in NDF effective degradation rate between whole-plant corn silage and Hewang grass silage ($P > 0.05$), while both were significantly higher than other roughages ($P < 0.05$). The ADF effective degradation rate of Hewang grass silage at 72 h was significantly higher than that of all other roughages ($P < 0.05$). It can be concluded that Hewang grass has potential as a roughage for dairy cows, and ensiling can preserve its nutritional components while improving rumen utilization efficiency of these nutrients.

Full Text

Comparison of Rumen Degradation Characteristics between Pennisetum sp. and Commonly Used Roughages for Dairy Cows

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Abstract: This experiment was conducted to investigate the rumen degradation characteristics of seven roughage types: Pennisetum sp. hay harvested at two cutting heights (2.0 m and 2.5 m), Pennisetum sp. silage prepared from material harvested at two heights (2.0 m and 2.5 m), dried Chinese wildrye hay, dried alfalfa hay, and whole corn silage. Four Holstein dairy cows fitted with permanent rumen cannulas were used as experimental animals. The nylon bag technique was employed to evaluate 72-hour rumen degradability of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF). The results showed: 1) Pennisetum sp. hay had significantly higher CP content and significantly lower NDF content compared to Chinese wildrye hay ($P < 0.05$). Pennisetum sp. silage exhibited significantly higher CP and NDF contents than whole corn silage ($P < 0.05$). 2) Alfalfa hay demonstrated the highest DM effective degradability, which was significantly different from and higher than whole corn silage, 2.0 m Pennisetum sp. silage, 2.5 m Pennisetum sp. silage, 2.0 m Pennisetum sp. hay, 2.5 m Pennisetum sp. hay, and Chinese wildrye hay in descending order ($P < 0.05$). Chinese wildrye hay showed significantly lower DM effective degradability than all other roughages ($P < 0.05$). CP effective degradability was highest in alfalfa hay, which did not differ significantly from 2.0 m Pennisetum sp. silage ($P > 0.05$) but was significantly higher than 2.5 m Pennisetum sp. silage, 2.0 m Pennisetum sp. hay, whole corn silage, 2.5 m Pennisetum sp. hay, and Chinese wildrye hay in descending order ($P < 0.05$). NDF effective degradability did not differ significantly between whole corn silage and Pennisetum sp. silage ($P > 0.05$) but was significantly higher than other roughages ($P < 0.05$). Pennisetum sp. silage exhibited significantly higher ADF effective degradability at 72 hours than other roughages ($P < 0.05$). These findings indicate that Pennisetum sp. has potential as a roughage source for dairy cows, and ensiling can preserve its nutritional components while improving rumen utilization efficiency.

Keywords: Pennisetum sp.; nutritional composition; nylon bag technique; rumen degradation rate

Roughages, primarily consisting of hay and silage, typically comprise 40%–70% of dairy cow diets and provide most of the nutrients [1]. With the rapid development of animal husbandry in China, feed resource shortages have become a direct constraint on industry growth, making the search for new roughage re-

sources critically important. *Pennisetum* sp., a genus of grasses in the Poaceae family, offers high yield, strong stress resistance, and high nutritional value with elevated crude protein and sugar contents. This high-quality cut-type forage is suitable for cultivation in tropical, subtropical, and temperate regions and can be processed into both hay and silage. *Pennisetum* sp. hay contains up to 13% CP, and when fresh *Pennisetum* sp. is ensiled, it maintains a green color, strong acidity, and minimal nutrient loss.

Rumen degradation characteristics of feed nutrients represent a crucial indicator for evaluating ruminant feed nutritional value [2-3]. The rumen degradation patterns of DM, NDF, and ADF reflect feed digestibility, and the nylon bag technique is the standard method for assessing ruminant feed degradability. Numerous studies have employed this technique to evaluate rumen degradation patterns of commonly used roughages [4-6]. This study utilized the nylon bag technique to investigate the rumen degradation patterns of nutritional components in *Pennisetum* sp. hay and silage, providing a theoretical basis for application in ruminant production.

1.1 Experimental Materials

Pennisetum sp. was cultivated in Zheng Village, Licun Town, Luquan City, Shijiazhuang, Hebei Province. Harvesting occurred when plants reached approximately 2.0 m and 2.5 m heights. Fresh whole plants at both heights were chopped to 3 cm lengths, then either sun-dried to produce hay or baled in silage bags for ensiling. Chinese wildrye hay, alfalfa hay, and whole corn silage were obtained from Jinzhou Zhoujiazhuang Animal Husbandry Co., Ltd. All experimental samples were dried at 65°C for 48 hours to produce air-dried samples, which were then ground using a micro-mill and sieved through a 1 mm screen.

1.2 Experimental Design

Four healthy Chinese Holstein dairy cows in late lactation, fitted with permanent rumen cannulas and with similar body weight (550 ± 30 kg), milk yield (15 ± 0.4 kg), and parity, were selected. Exactly 3 g of air-dried sample was weighed into each nylon bag, with four replicates per sample and four parallel bags per cow per time point. Four bags were attached to a 50 cm flexible plastic tube, which was tied to a coarse nylon rope fixed at the external end of the rumen cannula. All nylon bags were inserted into the rumen 1 hour before morning feeding following the principle of “simultaneous insertion, sequential removal.” Bags were retrieved at 4, 8, 16, 24, 36, 48, and 72 hours post-incubation. Retrieved bags were rinsed with tap water until the filtrate ran clear, then dried to constant weight at 65°C for analysis.

1.3 Experimental Diet and Management

The experiment was conducted at Beijing Zhongdi Dairy Science and Technology Park. Experimental cows were fed according to *Nutrient Requirements and*

Feeding Standards for Dairy Cows. The basal diet was formulated and fed twice daily with free access to water. Composition and nutrient levels of the basal diet are presented in Table 1 .

1.4 Detection Indicators and Methods

Residual contents in nylon bags were ground to pass through a 1 mm sieve after drying. Samples were analyzed for DM, CP, NDF, and ADF contents following the methods described by Zhang Liying [7], and relative feed value (RFV) was calculated.

1.5.1 Calculation of Real-Time Degradation Rate

Real-time degradation rates of specific nutrients at various time points were calculated using the formula method referenced from Chen Yan et al. [5].

1.5.2 Calculation of Degradation Parameters and Effective Degradability

Rumen degradation parameters were estimated using the model proposed by Ørskov et al. [8]:

$$P = a + b(1 - e^{-ct})$$
$$ED = a + b \times \frac{c}{k + c}$$

Where:

t = feed retention time in rumen (h)

P = real-time degradation rate of a nutrient at time t (%)

a = rapidly degradable fraction of the nutrient (%)

b = slowly degradable fraction (%)

c = degradation rate of fraction b (%/h)

ED = effective degradability of the nutrient (%)

k = rumen outflow rate of the nutrient (%/h). Following Gong Fuchen et al. [9], k was set at 0.031%/h.

1.6 Statistical Analysis

Data were organized using Excel. The NLIN procedure in SAS 9.2 software was used to calculate a , b , and c values. Data were analyzed by one-way ANOVA using the GLM procedure, and Duncan's multiple comparison test was applied. Results are expressed as means \pm standard deviation, with $P < 0.05$ considered statistically significant.

2.1 Conventional Nutritional Components

As shown in Table 2 , substantial differences existed among roughages in nutritional composition. Among hays, alfalfa hay had significantly higher CP content

than other hays ($P < 0.05$). CP contents of 2.0 m and 2.5 m Pennisetum sp. hay did not differ significantly ($P > 0.05$) but were both significantly higher than Chinese wildrye hay ($P < 0.05$). Except for alfalfa hay, NDF contents of all hays exceeded 60%, with Chinese wildrye hay being significantly higher than others ($P < 0.05$). ADF content did not differ significantly between 2.5 m Pennisetum sp. hay and Chinese wildrye hay ($P > 0.05$), but both were significantly higher than 2.0 m Pennisetum sp. hay and alfalfa hay ($P < 0.05$). Alfalfa hay exhibited significantly higher RFV than other hays ($P < 0.05$), with 2.0 m Pennisetum sp. hay showing 13.47% higher RFV than Chinese wildrye hay.

Among silages, whole corn silage had significantly higher DM content than Pennisetum sp. silage ($P < 0.05$). CP and NDF contents did not differ significantly between 2.0 m and 2.5 m Pennisetum sp. silage ($P > 0.05$) but were significantly higher than whole corn silage ($P < 0.05$). ADF content of 2.5 m Pennisetum sp. silage was significantly higher than other silages ($P < 0.05$).

2.2 DM Degradation Rate

As shown in Table 3, alfalfa hay exhibited significantly higher DM degradation rates than other hays at all time points ($P < 0.05$), exceeding 60% at 24 hours. The 2.0 m Pennisetum sp. hay showed the second-highest DM degradation rate within 72 hours ($P < 0.05$). The 72-hour degradation rates of the two Pennisetum sp. hay heights did not differ significantly ($P > 0.05$). Pennisetum sp. hay demonstrated rapid DM degradation within the first 24 hours, followed by a plateau. Chinese wildrye hay achieved over 50% DM degradation at 72 hours, but degradation was relatively slow during the first 16 hours, with significantly lower rates than other hays at all time points ($P < 0.05$).

Among silages, whole corn silage showed significantly higher 72-hour DM degradation rate than Pennisetum sp. silage ($P < 0.05$). Pennisetum sp. silage exhibited rapid degradation between 8-16 hours, with no significant differences between the two cutting heights at any time point ($P > 0.05$).

Table 4 reveals significant differences in DM degradation parameters among roughages. Among hays, alfalfa hay had the highest rapidly degradable fraction, while Chinese wildrye hay had the lowest. The two Pennisetum sp. hay heights did not differ significantly in DM rapidly degradable fraction ($P < 0.05$). Slowly degradable fractions of DM ranged from 47% to 55% across the four hays. Alfalfa hay exhibited the highest DM effective degradability, with significant differences among all four hays ($P < 0.05$).

Among silages, whole corn silage had significantly higher DM rapidly degradable fraction and effective degradability than Pennisetum sp. silage ($P < 0.05$), but significantly lower slowly degradable fraction ($P < 0.05$). The 2.0 m Pennisetum sp. silage showed significantly higher DM rapidly degradable fraction than 2.5 m Pennisetum sp. silage ($P < 0.05$), though effective degradability did not differ significantly between heights ($P > 0.05$).

2.3 CP Degradation Rate

Table 5 shows that Chinese wildrye hay had significantly lower CP degradation rates than other hays at all time points ($P < 0.05$). Both Pennisetum sp. and alfalfa hays exceeded 50% CP degradation by 8 hours, with 2.0 m Pennisetum sp. hay and alfalfa hay surpassing 70% at 24 hours. The 72-hour CP degradation rates of the two Pennisetum sp. hay heights did not differ significantly ($P > 0.05$).

Among silages, CP degradation rates did not differ significantly among the three silages at 4 hours ($P > 0.05$). Pennisetum sp. silage approached 70% CP degradation at 24 hours, with steady subsequent growth, achieving significantly higher 72-hour CP degradation rate than whole corn silage ($P > 0.05$).

As shown in Table 6, alfalfa hay had the highest CP rapidly degradable fraction at 29.05%, significantly higher than other hays ($P < 0.05$). The 2.5 m Pennisetum sp. hay exhibited significantly higher CP slowly degradable fraction than other hays ($P < 0.05$). Chinese wildrye hay had significantly lower CP effective degradability than other hays ($P < 0.05$), while the two Pennisetum sp. hay heights did not differ significantly ($P > 0.05$).

Among silages, 2.0 m Pennisetum sp. silage had significantly higher CP rapidly degradable fraction than other silages ($P < 0.05$). The two Pennisetum sp. silage heights did not differ significantly in CP effective degradability ($P > 0.05$), but both were significantly higher than whole corn silage ($P < 0.05$).

2.4 NDF Degradation Rate

Table 7 indicates that among hays, 2.0 m Pennisetum sp. hay had significantly higher 72-hour NDF degradation rate than 2.5 m Pennisetum sp. hay ($P < 0.05$), but did not differ significantly from alfalfa hay ($P > 0.05$). Chinese wildrye hay had lower NDF degradation rates than other hays before 48 hours but higher at 72 hours. Alfalfa hay showed rapid NDF degradation before 24 hours, while Pennisetum sp. hay degraded most rapidly between 16–24 hours.

Among silages, all three silages exhibited low NDF degradation rates at 4 hours. At 24 hours, whole corn silage reached 38.16% NDF degradation, significantly higher than Pennisetum sp. silage ($P < 0.05$). Pennisetum sp. silage maintained steady growth before 24 hours, with the fastest increase occurring between 24–36 hours, achieving 72-hour NDF degradation rates not significantly different from whole corn silage ($P > 0.05$).

Table 8 shows that all roughages had very low NDF rapidly degradable fractions, with whole corn silage highest at only 1.38%. Alfalfa hay had significantly lower NDF slowly degradable fraction than other roughages ($P < 0.05$). NDF effective degradability did not differ significantly between Pennisetum sp. silage and whole corn silage ($P > 0.05$). The lowest NDF effective degradability was observed in 2.5 m Pennisetum sp. hay at 30.60%.

2.5 ADF Degradation Rate

Table 9 reveals that at 4 hours, 2.5 m Pennisetum sp. silage had the highest ADF degradation rate at 11.50%, while whole corn silage had the lowest at 6.43%. Between 4-16 hours, Pennisetum sp. silage and alfalfa hay showed rapid ADF degradation, with alfalfa hay slowing after 36 hours. At 72 hours, Pennisetum sp. silage exhibited significantly higher ADF degradation rate than other roughages ($P < 0.05$), while alfalfa hay and Pennisetum sp. hay remained at relatively low levels between 47%-50%.

As shown in Table 10, Pennisetum sp. silage had significantly higher ADF rapidly degradable fraction than other roughages ($P < 0.05$), while Chinese wildrye hay had the lowest at 0.98%. The 2.5 m Pennisetum sp. silage had the highest ADF slowly degradable fraction at 77.49%, with alfalfa hay significantly lower than other roughages ($P < 0.05$). Potential degradable fractions of ADF ranged from 46% to 84% across all roughages. The 2.5 m Pennisetum sp. silage demonstrated significantly higher ADF effective degradability than other roughages ($P < 0.05$).

3.1 Nutritional Components of Roughages

Feed variety, harvest time, growing environment, and processing method all influence nutritional value. In this experiment, DM contents of the four hays were similar at approximately 93%, while CP and NDF contents varied substantially, consistent with previous findings [10]. Alfalfa hay contained 19.07% CP with only 46.48% NDF, resulting in high RFV. The 2.0 m Pennisetum sp. hay had higher CP and lower NDF content than the 2.5 m hay. Yu Ruhua et al. [11] reported that corn stalk NDF content increases with growth stage, consistent with our results. This occurs because as plants mature, cell wall content increases while cell contents decrease. Pennisetum sp. silage had significantly lower DM content than whole corn silage, likely due to higher moisture content in Pennisetum sp. The 2.5 m Pennisetum sp. silage showed 44.71% higher CP content than whole corn silage, attributed to earlier harvest with more leaves preserving higher protein levels. Compared to Pennisetum sp. hay, Pennisetum sp. silage had lower NDF and ADF contents with similar CP content and higher RFV, indicating that ensiling improved fiber characteristics and nutritional value.

3.2 DM Degradation Characteristics of Different Roughages

Appropriate dry matter intake (DMI) is essential for maintaining ruminant health and meeting nutritional requirements. Rumen DM degradability significantly affects DMI, with higher degradation rates promoting greater intake. All roughages showed increasing DM degradation rates over incubation time, though the magnitude varied. Among hays, alfalfa hay achieved the highest 72-hour DM degradation rate, consistent with Xia Ke et al. [4]. Both 2.0 m and 2.5 m Pennisetum sp. hays exceeded 67% DM degradation at 72 hours, significantly higher than Chinese wildrye hay, demonstrating superior digestibility. The 2.0

m Pennisetum sp. hay reached 58.48% DM degradation by 24 hours, with stable subsequent increases, indicating degradation occurred primarily within 24 hours, similar to alfalfa hay. The slightly higher 72-hour DM degradation rate in 2.0 m versus 2.5 m hay may reflect that later harvest at 2.5 m increased plant maturity, reducing cell contents and DM degradability.

Among silages, whole corn silage showed 74.02% DM degradation at 72 hours, lower than results from Xia Ke et al. [4], possibly due to differences in feed sources and animal physiological status. Pennisetum sp. silage demonstrated higher effective degradability than Pennisetum sp. hay, indicating that ensiling preserved nutritional value while improving palatability and digestibility. All three silages showed high initial and 72-hour DM degradation rates, with steady increases throughout incubation. These data suggest that DMI of Pennisetum sp. hay may exceed that of Chinese wildrye hay, while DMI of Pennisetum sp. silage may be comparable to whole corn silage.

3.3 CP Degradation Characteristics of Different Roughages

CP degradation in the rumen depends primarily on retention time, fermentation difficulty, CP composition, and true protein content [12]. In this experiment, effective degradability of alfalfa hay and Chinese wildrye hay was 71.03% and 45.57%, respectively, similar to previous reports [4]. Among the four hays, alfalfa hay had the highest CP content and correspondingly the highest degradation rates and effective degradability at all time points, indicating good rumen utilization. Pennisetum sp. hay showed CP content and effective degradability intermediate between alfalfa and Chinese wildrye hays, suggesting that CP degradability of hays correlates with CP content.

Among silages, Pennisetum sp. silage exhibited higher 72-hour CP degradation rate and effective degradability than whole corn silage, likely due to its higher CP content. Pennisetum sp. silage reached 70% CP degradation by 24 hours, indicating that CP degradation occurred mainly within 24 hours. The higher CP effective degradability of Pennisetum sp. silage compared to hay suggests that fermentation improved protein characteristics. Yao Qing et al. [13] reported significantly increased rumen CP degradability of corn stalks after fermentation, consistent with our findings. These results demonstrate that CP degradability is strongly influenced by feed properties. Feed protein comprises rapidly degradable, slowly degradable, and undegradable fractions with varying proportions among feeds [14]. The slowly degradable fraction and effective degradability significantly affect nutritional value. In this experiment, silages had higher rapidly degradable fractions than alfalfa hay but lower slowly degradable fractions, resulting in lower CP effective degradability than alfalfa hay.

3.4 NDF and ADF Degradation Characteristics of Different Roughages

Fiber in roughages plays a vital role in rumen fermentation, and NDF and ADF rumen degradability are important indicators of roughage nutritional value. Improved NDF degradability can enhance DMI and milk production. NDF comprises cellulose, hemicellulose, and lignin, with lignin being indigestible to microorganisms. Consequently, fiber digestion is primarily limited by lignin content. ADF consists mainly of cellulose and lignin, with effective degradability varying among feed sources [15]. Xia Ke et al. [4] reported higher NDF degradability in corn stalk silage than in corn stalks, indicating that ensiling improves nutrient degradability. This aligns with our finding that Pennisetum sp. silage had higher NDF effective degradability than Pennisetum sp. hay, supported by Jia Haijun [16] and Song Weihong et al. [17] who confirmed that ensiling improves nutrient degradability of straws. Dynamic trends showed that NDF and ADF degradation rates of silages were generally low before 24 hours but high at 72 hours, indicating that degradation occurred mainly after 24 hours.

The 2.0 m Pennisetum sp. hay showed higher NDF effective degradability than the 2.5 m hay because NDF is a cell wall component that increases with plant maturity while digestible components decrease. Qiu Yan [15] reported higher ADF effective degradability in alfalfa hay than in Chinese wildrye hay, contrary to our results, possibly due to differences in experimental animals and feed sources. In this experiment, Pennisetum sp. hay and Chinese wildrye hay had higher NDF and ADF slowly degradable fractions than alfalfa hay but lower degradation rates, consistent with Hoffman et al. [18]. Jung et al. [19] also noted that grasses have higher potentially degradable fiber fractions than legumes but lower degradation rates, aligning with our findings. Legume NDF degrades faster in the slowly degradable fraction but contains more indigestible components, resulting in similar overall NDF degradability to grasses. ADF is the most recalcitrant component in roughages, with lignin being nearly completely resistant to rumen microbial degradation, thus ADF degradability is generally low.

Conclusion

The results demonstrate that Pennisetum sp. hay, Chinese wildrye hay, and alfalfa hay all exhibited increasing DM, CP, NDF, and ADF degradation rates with prolonged incubation time, with degradation rates stabilizing between 48–72 hours. Pennisetum sp. hay showed relatively high DM and CP degradation rates, with effective degradability significantly higher than Chinese wildrye hay. Furthermore, Pennisetum sp. silage exhibited significantly higher CP and ADF effective degradability than whole corn silage, indicating that ensiling Pennisetum sp. can improve rumen utilization efficiency of its nutritional components.

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