Comparative Analysis of Rumen Degradation Characteristics of Corn Silage from Dairy Farms in the Peri-Urban Areas of Beijing: Postprint

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Abstract

This study aimed to conduct a comparative analysis of the rumen degradation characteristics of dry matter (DM) and neutral detergent fiber (NDF) in corn silage from dairy farms in the peripheral areas of Beijing. Three healthy Holstein dairy cows fitted with permanent rumen fistulas were used as experimental animals, and the nylon bag method was employed to determine the 72-hour rumen degradation rates and rumen degradation parameters of DM and NDF in corn silage from three districts (Changping District, Yanqing District, and Fangshan District), with three dairy farms in each district. The results showed that: 1) The corn silage from dairy farms in Fangshan District had the highest average DM content, but the lowest average NDF and acid detergent fiber (ADF) contents; the average DM contents of dairy farms in Changping and Yanqing districts were similar; Yanqing District had the highest average ADF content, while Changping District had the highest average NDF content. 2) The DM effective degradability of corn silage from Dairy Farm No. 2 in Changping District was the highest, reaching 38.47%; that from Dairy Farm No. 3 in Fangshan District was the lowest, at only 28.91%; the difference between the two was significant ($P<0.05$). 3) The effective rumen degradability of NDF was highest in Dairy Farm No. 1 in Yanqing District, reaching 30.18%, while the lowest was in Dairy Farm No. 2 in Fangshan District at only 19.63%; the difference between the two was significant ($P<0.05$). It can be concluded that the degradation characteristics of corn silage from different dairy farms in the peripheral areas of Beijing vary considerably in the rumen of dairy cows, and diets should be formulated rationally according to the nutritional requirements of dairy cows at different growth, development, and lactation stages, combined with actual nutritional components.

Full Text

Comparative Analysis on Ruminal Degradation Characteristics of Maize Silage Feed in Dairy Farms Around Beijing

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Abstract

This study aimed to compare the ruminal degradation characteristics of dry matter (DM) and neutral detergent fiber (NDF) in maize silage feed from dairy farms in the Beijing metropolitan area. Three healthy Holstein dairy cows fitted with permanent rumen fistulas were used as experimental animals. The 72-hour ruminal degradation rates and parameters of DM and NDF in maize silage feed were determined using the nylon bag method across nine dairy farms located in Changping District, Yanqing District, and Fangshan District (three farms per district). The results showed that: (1) The average DM content of maize silage feed was highest in Fangshan District, while the average NDF and acid detergent fiber (ADF) contents were lowest there. The average DM contents in Changping and Yanqing districts were similar, Yanqing District had the highest average ADF content, and Changping District had the highest average NDF content. (2) Dairy farm No. 2 in Changping exhibited the highest effective degradation rate of DM at 38.47%, while dairy farm No. 3 in Fangshan showed the lowest rate at only 28.91%, with a significant difference between them ($P<0.05$). (3) The effective ruminal degradation rate of NDF was highest in dairy farm No. 1 in Yanqing at 30.18%, whereas dairy farm No. 2 in Fangshan had the lowest value at 19.63%, also showing a significant difference ($P<0.05$). These findings indicate substantial variation in the ruminal degradation characteristics of maize silage feed among different dairy farms in the Beijing area. Therefore, balanced diets should be formulated based on the nutritional requirements of dairy cows at different growth, development, and lactation stages, combined with the actual nutrient composition of the feed.

Keywords: dairy cow; Beijing metropolitan area; maize silage feed; ruminal degradation

Introduction

It is widely recognized that the quality of roughage is closely related to dairy cow health and lactation performance [1], making timely and accurate analysis

of feed ruminal degradation rates essential. Roughage constitutes 40%–70% of dairy cow diets and plays a crucial role in maintaining normal physiological function and milk production levels. Both dry matter (DM) and neutral detergent fiber (NDF) in roughage affect feed utilization efficiency and milk fat percentage in dairy cows, with increased dietary DM, particularly cellulose content, enhancing milk fat percentage [2-3]. Consequently, roughage quality directly impacts dairy production performance. In recent years, numerous large-scale dairy farms have been established in Beijing' s suburban and outlying districts, where farmers formulate their own maize silage feed ratios. Extensive research has demonstrated that maize silage quality is intimately related to harvest timing and geographical origin [4-5]. Therefore, variations in production processes and raw materials may lead to significant differences in the quality of maize silage produced by different farms, raising the question of whether these differences affect ruminal degradation and subsequently influence cow physiological function and lactation levels. This experiment compares and analyzes the ruminal degradation characteristics of DM and NDF in maize silage feed from dairy farms in the Beijing metropolitan area, providing a theoretical basis for evaluating maize silage quality in this region.

Materials and Methods

1.1 Experimental Design

The trial was conducted at a dairy farm in Beijing from November 1 to November 15, 2016, lasting 15 days. Maize silage feed samples were collected from dairy farms in Changping District, Yanqing District, and Fangshan District in the Beijing metropolitan area. Three large-scale dairy farms (with more than 200 cows) were randomly selected from each district for on-site sampling. Samples were sealed in plastic bags, transported to the laboratory on the same day, and processed for subsequent analysis. Crude protein content was determined using a KDN-BI nitrogen analyzer, neutral detergent fiber and acid detergent fiber contents were measured using an ANKOM200I automatic fiber analyzer, crude fat content was determined by ether extraction, and crude ash and dry matter contents were measured according to reference methods [6]. Samples were dried at 65°C to constant weight to produce oven-dried samples, which were then passed through a 1 mm sieve and stored in self-sealing bags.

For the nylon bag method, 300-mesh nylon cloth was cut into 13 cm × 8 cm bags and sewn with double seams using nylon thread. Prepared bags were numbered, dried at 65°C to constant weight, cooled, weighed to record initial mass, and stored in sealed plastic bags. Exactly 3.5 g of sample was weighed into each pre-weighed nylon bag and secured with a rubber band. Two replicate bags were prepared per cow at each time point. Bags containing two different silage feeds from different samples at the same time point were tied to the lower end of a semi-rigid plastic tube and fastened with nylon thread. The experiment began before morning feeding, following the principle of "sequential insertion and simultaneous removal." Nylon bags were placed in the rumen at 4, 8, 12, 24,

48, and 72 hours before the end of the trial and removed simultaneously after 72 hours. Retrieved samples and 0-hour samples (not placed in the rumen) were rinsed in water until the water ran clear to stop fermentation. Cleaned nylon bags were then oven-dried at 65°C to constant weight and weighed.

Residual samples from the dried nylon bags were ground and passed through a 1 mm sieve for DM and NDF content determination. DM content was measured using the constant temperature drying method: clean, pre-weighed aluminum boxes were dried in an oven at 105°C for 4 hours, cooled in a desiccator for 30 minutes, and weighed (m_1). Approximately 1 g of test sample was weighed (m_2), placed in the box with the lid ajar, dried at 105°C for 4 hours, cooled in a desiccator for 30 minutes, and weighed (m_3). DM content was calculated as:

$DM = [(m_3 - m_1) / (m_2 - m_1)] \times 100$

NDF content was determined using an ANKOM-2000I automatic fiber analyzer.

1.2 Feeding Management

Three healthy Holstein dairy cows fitted with permanent rumen fistulas were selected for the trial. The cows were similar in body size and in good health. They were fed total mixed rations at 08:00 and 18:00 daily, with free access to feed and water, and were tethered during the trial. The composition and nutrient levels of the basal diet are shown in Table 1.

1.3 Measurement Indicators

Ruminal degradation characteristics were calculated using the exponential model proposed by Ørskov et al. [7]:

$Y = a + b(1 - e^{(-ct)})$

Effective degradation rate $= a + b \times c / (c + k)$

where Y is the degradation rate (%) of a nutrient after t hours of incubation in the rumen; a is the rapidly degradable fraction (%); b is the slowly degradable fraction (%); c is the degradation rate constant of the slowly degradable fraction (%/h); and k is the rumen outflow rate, with a value of k = 0.046%/h [8].

1.4 Data Processing and Statistical Analysis

Experimental data were analyzed using the PROC GLM procedure of SAS 9.2 software, with differences among group means tested using Tukey' s multiple comparison method. Significance was defined as $P < 0.05$.

Results

2.1 Nutritional Composition of Maize Silage Feed from Dairy Farms in the Beijing Metropolitan Area

As shown in Table 2 , the nutrient composition of maize silage feed varied considerably among dairy farms in the Beijing metropolitan area. Dairy farm No. 2 in Fangshan had the highest DM content at 31.3%, while dairy farm No. 3 in Changping had the lowest at only 25.1%. Dairy farm No. 1 in Changping had the highest crude fat content at 5.9%, whereas dairy farm No. 1 in Yanqing had the lowest at 3.3%. Dairy farm No. 3 in Yanqing had the highest crude protein content at 10.2%, while dairy farm No. 2 in Fangshan had the lowest at only 6.8%. Dairy farm No. 1 in Yanqing had the highest ADF content at 39.9%, and dairy farm No. 3 in Fangshan had the lowest at only 28.5%. Dairy farm No. 3 in Changping had the highest NDF content at 52.6%, while dairy farm No. 2 in Fangshan had the lowest at 42.1%.

Across the different districts, Fangshan District had the highest average DM content but the lowest average NDF and ADF contents. The average DM contents in Changping and Yanqing districts were similar. Yanqing District had the highest average ADF content, while Changping District had the highest average NDF content.

2.2 Ruminal Degradation Characteristics of DM in Maize Silage Feed

As shown in Table 3 , dairy farm No. 1 in Yanqing exhibited higher DM ruminal degradation rates at 4, 8, 24, 48, and 72 hours than the other eight farms, while dairy farm No. 2 in Fangshan had lower DM ruminal degradation rates at all time points. Dairy farm No. 1 in Yanqing achieved the highest 72-hour DM ruminal degradation rate, followed by dairy farm No. 3 in Changping, with no significant difference between them ($P > 0.05$).

Overall, among the Beijing metropolitan area dairy farms, Changping District had the highest DM ruminal degradation rate in maize silage feed, followed by Yanqing District, while Fangshan District had the lowest.

As shown in Table 4 , the highest rapidly degradable fraction of DM was observed in dairy farm No. 2 in Changping at 18.99%, followed by dairy farm No. 1 in Changping and dairy farm No. 1 in Yanqing at 18.03% and 17.86%, respectively. In contrast, dairy farm No. 1 in Fangshan had the lowest rapidly degradable fraction at only 6.83%. The effective ruminal degradation rate of DM was highest in dairy farm No. 2 in Changping at 38.47%, followed by dairy farm No. 3 in Yanqing at 34.36%, while the lowest value was found in dairy farm No. 3 in Fangshan at only 28.91%, which was significantly lower than that of dairy farm No. 2 in Changping ($P < 0.05$).

The average effective degradation rate of DM in maize silage feed was highest in Changping District, followed by Yanqing District, and lowest in Fangshan District.

2.3 Ruminal Degradation Characteristics of NDF in Maize Silage Feed

As shown in Table 5 , the ruminal degradation rate of NDF increased slowly from 4 to 24 hours, accelerated markedly from 24 to 48 hours, and slowed again from 48 to 72 hours, indicating that rapid NDF degradation in maize silage feed occurred primarily between 24 and 48 hours. At 4, 8, 12, 24, and 72 hours, dairy farm No. 1 in Yanqing had the highest NDF ruminal degradation rate, while dairy farm No. 1 in Fangshan had the lowest, with a significant difference between them ($P < 0.05$).

Overall, among the Beijing metropolitan area dairy farms, Yanqing District had the highest NDF ruminal degradation rate in maize silage feed, followed by Changping District, while Fangshan District had the lowest.

As shown in Table 6 , the highest rapidly degradable fraction of NDF was observed in dairy farm No. 3 in Changping at 10.92%, followed by dairy farm No. 2 in Changping and dairy farm No. 1 in Yanqing at 10.76% and 7.82%, respectively. Dairy farm No. 2 in Fangshan had the lowest rapidly degradable fraction at only 3.16%. The effective ruminal degradation rate of NDF was highest in dairy farm No. 1 in Yanqing at 30.18%, while dairy farm No. 2 in Fangshan had the lowest value at only 19.63%, with a significant difference between them ($P < 0.05$).

Overall, the average effective degradation rate of NDF in maize silage feed was highest in Yanqing District, followed by Changping District, and lowest in Fangshan District.

Discussion

In this experiment, the ruminal degradation rate of DM in maize silage feed increased gradually with incubation time, consistent with previous studies showing similar dynamic degradation patterns for DM in maize silage from different dairy farms [9-11]. However, the effective degradation rates of DM detected in this study were lower than those reported by Zhao Tianzhang et al. [11], possibly due to differences in experimental timing and individual animal variation. In this trial, Changping District had the highest effective DM degradation rate among Beijing metropolitan area dairy farms, yet its maize silage DM content was not the highest. Conversely, Fangshan District, which had the highest DM content, exhibited the lowest effective DM degradation rate. This demonstrates that DM content in maize silage does not have a linear relationship with DM ruminal degradation rate, and simply increasing DM content does not necessarily enhance ruminal degradation.

NDF intake not only stimulates saliva secretion and accelerates rumination in dairy cows, but also significantly increases DM intake and milk production when its ruminal degradation rate is improved [9,12-13]. NDF is primarily composed of cellulose, hemicellulose, and lignin, with lignin being indigestible by microorganisms [14-15]. Therefore, NDF composition also affects its ruminal degrada-

tion rate. In this study, dairy farm No. 1 in Yanqing had the highest effective NDF degradation rate at 30.18%, while dairy farm No. 2 in Fangshan had the lowest at only 19.63%. The NDF ruminal degradation rate increased slowly during the first 24 hours, accelerated noticeably between 24 and 48 hours, indicating that NDF degradation in the rumen mainly occurs after 24 hours. Yanqing District had the highest effective NDF degradation rate among Beijing metropolitan area dairy farms, yet the NDF content in Changping District' s maize silage was higher than that in Yanqing District. This suggests that merely increasing NDF content in maize silage cannot improve its ruminal degradation rate.

It is well known that feed intake is related to milk production in dairy cows, and intake is a prerequisite for maintaining normal physiological function and ensuring milk yield [3]. Previous reports indicate that adjusting dietary concentrate-to-forage ratios and increasing DM intake, particularly of crude fiber, can improve lactation performance [12]. Based on these results, we recommend that dairy farms in Fangshan District appropriately reduce DM content when formulating maize silage feed, while farms in Yanqing District should increase DM content. Dietary cellulose content affects ruminal feed passage rate and effective digestibility [16-17] and can induce satiety, thereby suppressing feed intake [18-20]. Cellulose in dairy cow diets originates from forages, primarily provided by alfalfa, grasses, and maize silage [21]. Dairy cows utilize cellulose, hemicellulose, and pectin from plant cell walls, which are converted to volatile fatty acids in the rumen for energy supply. According to our findings, Changping District farms could appropriately reduce NDF content in maize silage feed, whereas Yanqing District farms should increase NDF content.

Comparing the composition and ruminal degradation rates of DM and NDF in maize silage feed from Beijing metropolitan area dairy farms reveals that issues remain in silage production. Farms can adjust the DM-to-NDF ratio in maize silage feed based on these results and their specific conditions to improve ruminal degradation rates and consequently enhance production performance. In addition to adjusting DM and NDF contents, attention should be paid to raw materials for maize silage production. Currently, most silage in China uses corn stalks rather than whole-plant corn. Research by Cui Taoqi [22] comparing corn stalk silage with whole-plant corn silage for dairy cows demonstrated that, beyond providing nutritionally balanced concentrate feed, supplying high-quality roughage is essential. Whole-plant corn silage resulted in superior ruminal digestibility of DM and NDF compared to de-eared corn stalk silage, while also improving feed palatability and nutritional value [22]. We recommend that dairy farms in the Beijing metropolitan area consider using whole-plant corn silage instead of de-eared corn stalk silage as raw material, optimizing dietary formulation while improving silage quality to enhance ruminal degradation rates of DM and NDF, thereby further improving lactation performance.

Conclusions

1. Significant differences existed in DM degradation rates of maize silage feed among different dairy farms in the Beijing metropolitan area. The highest DM ruminal degradation rate was observed in Changping District at 38.47%, while the lowest was in Fangshan District at only 28.91%.

2. Significant differences were also found in NDF degradation rates of maize silage feed among different dairy farms. The highest NDF ruminal degradation rate was achieved by the three farms in Yanqing District, reaching 30.18%, while the lowest rate occurred in the three farms in Fangshan District at only 19.63%.

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