Original scientific paper | DOI 10.63356/agrores.2025.024

The role of physical structure in ruminant nutrition

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The advancement of modern technology in livestock farming has introduced new feeding practices for ruminants, optimizing milk production. However, the increased use of concentrated feeds has also led to health challenges in dairy cows. This study examines the impact of silage particle size and the balance between fibrous and concentrated feeds on milk fat content and quality in lactating cows. Research was conducted on eight dairy farms in northern Vojvodina, Subotica district. Silage particle size was analyzed using the Penn State Particle Separator and compared to optimal standards. Information on farm feeding practices was collected from producers. The results showed significant variability in compliance with recommended silage particle sizes. Only one farm (12.5%) fully met Penn State standards, indicating frequent deviations. The study also found that a higher proportion of concentrates in the diet was linked to lower milk fat content, while farms incorporating more fibrous feeds, such as hay, achieved better results. Although silage particle size alone did not directly affect milk fat, the concentrate-to-fiber ratio significantly influenced milk fat levels. Based on these findings, it is recommended that producers increase fibrous feed, particularly hay, and reduce concentrates to improve milk fat content. Additionally, ensuring proper silage processing can contribute to better diet formulation and overall cow health. This study highlights the importance of balanced nutrition in dairy farming to support milk production and quality.

Key words: physical structure, milk fat, dairy cows, penn state separator

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INTRODUCTION

Before the advent of automation and modern machinery, ruminant diets were quite straightforward. Cattle primarily grazed on pastures and were supplemented with grains that were readily available on the farm. As agricultural technology advanced, farmers gained access to a wider variety of feed options, facilitating easier meal preparation and expanding the scope of livestock nutrition. Additionally, industrial growth contributed to an increase in by-products suitable for animal feed, offering more diverse nutritional possibilities. However, with each technological advancement comes a new set of challenges. While modernization allowed for greater feed production, it also introduced certain complications. In the case of dairy cows concentrated feeds and finely processed roughages, such as silage and chopped haylage, replaced the coarser forages they had traditionally consumed. To meet the nutritional demands of high-yielding lactating cows, it is essential to formulate rations that combine quality fibrous feeds with an appropriate level of concentrates (Stojanović et al., 2009). Although the introduction of concentrated feeds increased milk production, it was not without consequences. An excessive reliance on these feeds led to health issues such as acidosis and displaced abomasum, which, if left untreated, often resulted in secondary complications. Problems such as lameness and reproductive disorders emerged, ultimately affecting milk yield and quality. A decline in milk fat content was a notable issue, reducing the overall nutritional value of the milk. Blaxter (1944) emphasized the need for a well-balanced fiber-to-concentrate ratio to prevent negative impacts on cow health and productivity. Furthermore, Krause et al. (2002) demonstrated that while excessive amounts of coarse fibrous feeds can reduce digestibility and milk yield, Couvreur et al. (2007) found that smaller forage particles negatively affect milk fat content. Murphy et al. (2000) highlighted that proper rumen fermentation and a balanced fiber-to-concentrate ratio play a key role in maintaining milk fat levels. Additionally, O'Mara et al. (1998) observed that replacing grass silage with maize silage increased milk yield but did not significantly affect milk composition. Dewhurst (2013) compared different silage types, showing that grass and legume silages supported better milk production, while maize silage contributed to higher energy intake. These findings emphasize the need to balance production efficiency with animal health to ensure both milk quality and quantity.

Rumen acidosis, also known as acid indigestion, is one of the most prevalent digestive disorders in cattle. It arises due to an excessive intake of rapidly fermentable carbohydrates, such as starch and sugars, along with an imbalanced fiber-to-concentrate ratio. The rapid fermentation of these carbohydrates leads to a significant drop in rumen pH, disrupting microbial populations responsible for cellulose digestion. This condition can suppress rumination and reduce saliva production, further exacerbating acidity in the rumen. In severe cases, lactic acid is absorbed into the bloodstream, leading to metabolic acidosis. Another significant issue is displaced abomasum (DA), where the abomasum shifts from its normal position, typically occurring around calving. It is more frequently observed in cows aged three to eight years compared to heifers.

Fibrous feeds play a fundamental role in the ruminant diet by promoting rumination, but on their own, they may not maximize production efficiency. Thus, they are often combined with concentrates to optimize milk yield. Apart from nutritional composition, the physical structure of fibrous feeds, particularly particle size, is a crucial factor when formulating rations (Stojanović et al., 2009). Various fibrous feeds are used in milk production, with corn silage being the most common in this region. Alfalfa haylage is also utilized, though predominantly on larger farms, while alfalfa hay has largely replaced meadow hay due to declining natural grassland areas.

The objective of this study is to assess the quality of silage particle size and examine its relationship with milk fat content, as well as determine the ratio of roughages to concentrates in the diets, in order to gain insight into how it affects milk quality, specifically the amount of milk fat, with the ultimate goal of optimizing feeding strategies for improved dairy production.

MATERIAL AND METHODS

The research was conducted on 8 dairy farms located in the northern part of Vojvodina, within the Subotica district with data collection including detailed observations of feeding routines, milk production records, and farm-specific conditions affecting dairy cow performance. Information about the farms can be found in Table 1.

Table 1. Information about of the farms

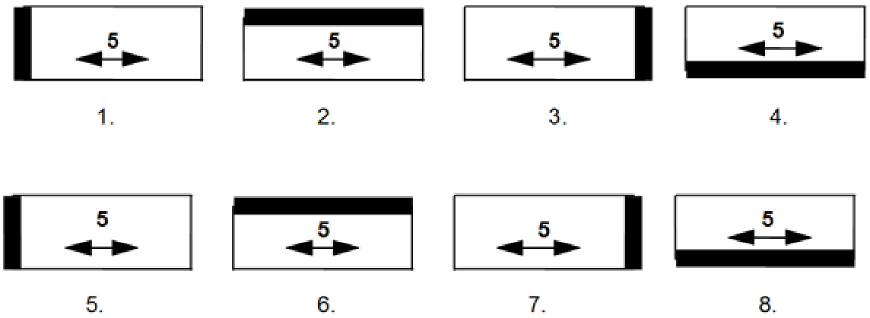
Nº	Year	Nº IIH	DMY (kg)	MF (%)	MP (%)
1.	35	11	23	4.128	3.313
2.	30	6	15	4.266	3.364
3.	10	21	10	3.991	3.241
4.	40	11	25	3.550	3.388
5.	35	58	24	4.056	3.305
6.	5	21	26	4.203	3.258
7.	45	180	26	3.486	3.356
8.	20	145	31	3.252	3.431
Average	27.5	56.6	22.5	3.866	3.332

Table legend: Year - number of years engaged in milk production, Nº IIH – number of individuals in the herd, system – housing system (fs. – free stall), DMY – daily milk yield, MF – milk fat, MP – milk protein

The farms where the research was conducted are family-owned and have been engaged in dairy production for many years, often spanning multiple generations. Additionally, all the farms in this study utilize a free-stall housing system, which allows cows to move freely and provides better comfort and management efficiency compared to tie-stall systems.

The sieving of fibrous feeds was conducted using an older model of the Penn State Particle Separator, a widely recognized tool for evaluating the physical characteristics of feed particles. For this study, samples were collected from whole-plant corn silage and finely chopped alfalfa haylage, ensuring a representative assessment of the feed structure. The samples were directly taken from the silage bunkers. To enhance the accuracy and reliability of the measurements, five separate samples were taken from different locations within each bunker. Each sample volume was approximately 1.4 liters, and the final result was calculated as the average of all five samples.

The sieving procedure followed the official guidelines established by Penn State. The sieving methodology is illustrated in the image below.



Picture 1. Way of sifting along Penn State Particle Separator

The sieved particles were weighed separately from each sieve using a scale. The results were then recorded, and the obtained masses were summed to determine the total sample mass. After the sampling was completed, the results were processed using Excel. Since 5 samples were taken on each farm, their masses were summed and divided by 5 to obtain the average. The obtained results were then compared with the standards set by Penn State. The standards are shown in Table 2.

Table 2. Standards prescribed by Penn State Particle Separator

Sieve diameter size	Silage from the whole corn plant	Alfalfa hay
19 mm	3-8 %	10-20 %
8 mm	45-65 %	45-75 %
1.18 mm	30-40 %	20-30 %
<1.18 mm	<5 %	<5 %

RESULTS AND DISCUSSION

Table 3 shows the results of the milk fat content on each farm. Considering that the optimal milk fat content ranges from 3.5% to 4.5%, the table allows us to see which farms have an appropriate amount of milk fat and which do not.

Table 3. Milk fat content (%) on farms

Farm	1.	2.	3.	4.	5.	6.	7.	8.	Average milk fat
Milk fat	4.128	4.266	3.991	3.550	4.056	4.203	3.486	3.252	3.866

All eight of the surveyed farms prepare and use whole-plant corn silage, so eight samples were analyzed. Table 4 shows the proportions of specific particle sizes, with the standards listed in the last column.

Table 4. Proportion (%) of fractions of silage with specific particle sizes

Farm	1.	2.	3.	4.	5.	6.	7.	8.	Norm
>19 mm	14.73	18.50	10.01	6.83	7.41	10.46	7.80	6.90	3 - 8%
8-19 mm	54.38	56.52	56.23	53.21	62.87	63.39	64.63	77.22	45 - 65%
1.18-8 mm	30.47	23.36	32.29	37.80	27.89	24.03	25.16	14.45	30 - 40%
<1.18 mm	0.42	1.62	1.47	2.16	1.82	2.12	2.40	1.43	< 5%

As shown in Table 4, the results indicate significant deviations from the Penn State standards regarding the particle size of silage on the farms. Only one farm (farm 4.) fully meets all the Penn State requirements related to particle size, suggesting that most farms do not meet all the ideal standards for proper silage preparation. These standards are important to us, as they can help improve our feeding strategies by ensuring the correct particle size in silage, which would affect digestion efficiency, cows' feeding behavior, and overall milk quality, including the composition of milk fat. Interestingly, four samples (farms 1., 3., 5. and 7.) show deviations on just one sieve, indicating that most farms face minor issues in achieving the optimal particle size but still do not meet the ideal standards. These problems could stem from various factors, including differences in silage preparation techniques, types of plant materials used, or the equipment utilized on the farms. However, three samples (farms 2., 6. and 8.) come from farms that do not meet the standards for two particle fractions, indicating more significant problems in the silage preparation process. These deviations suggest that these farms may be facing issues with grinding equipment. An interesting pattern emerges with deviations primarily occurring on the first and last sieves. The first sieve, which retains the largest particles, may indicate insufficient chopping during the grinding process, preventing efficient digestion in cows. The last sieve, which retains the smallest particles, may suggest over-chopping, which can hinder rumen fermentation and reduce the quality of nutrients. These deviations can have long-term consequences for cows' health and productivity. Moreover, these deviations emphasize the importance of careful monitoring and adherence to silage preparation standards to optimize animal health and farm productivity.

In addition to whole-plant corn silage, two out of the eight farms also produce chopped alfalfa haylage. Table 5 shows the proportions of specific particle sizes, with the standards listed in the last column.

Table 5. Proportion of fractions of haylage with specific particle sizes (%)

Farm	7.	8.	Norm
>19 mm	40.15	46.15	10-20 %
8-19 mm	39.26	35.46	45-75 %
1.18-8 mm	18.67	16.27	20-30 %
<1.18 mm	1.92	2.12	<5 %

As can be seen from Table 5, neither of the two farms meets the standards prescribed by Penn State. On both farms, the only fractions that comply with the prescribed standards are those that passed through the last sieve (<1.18 mm). This indicates that while some fine particles are within the required size range, the larger fractions on both farms do not meet the recommended specifications. The failure to meet the standards for the larger fractions may suggest issues with the equipment used for chopping or with the processing technique. Such deviations could have significant implications for the quality of silage, as the size distribution of the particles directly affects the digestibility and fermentation processes in the rumen.

On all the farms, a survey was conducted with the producers, from whom we gathered information about the amount of feed in the rations. Information about the proportion of feed in the rations is provided in Table 6.

Table 6. Feeds and their quantities used in the cows rations

Nutritious	1.	2.	3.	4.	5.	6.	7.	8.	Average
Concentrate	6.16 (24.56%)	4.4 (26.67%)	5.28 (32.88%)	7.48 (32.21%)	7.04 (36.33%)	7.04 (30.48%)	6.16 (33.88%)	7.92 (40.16%)	6.44 (32.15%)
Silage	6.6 (26.32%)	3.3 (20%)	1.98 (12.33%)	6.6 (28.42%)	5.94 (30.65%)	4.62 (20%)	7.26 (39.94%)	6.6 (33.47%)	5.36 (26.39%)
Alfalfa haylage	/	/	/	0.8 (3.45%)	/	/	0.8 (4.4%)	0.8 (4.06%)	0.80 (3.97%)
Rye haylage	/	/	/	0.8 (3.45%)	2 (10.32%)	/	1.2 (6.6%)	/	1.33 (6.79%)
Sugar beet pulp	/	/	/	2.64 (11.37%)	/	/	/	/	2.64 (11.37%)
Alfalfa hay	5.28 (21.05%)	8.8 (53.33%)	5.28 (32.88%)	4.4 (18.95%)	4.4 (22.7%)	11.44 (49.52%)	1.76 (9.68%)	4.4 (22.31%)	5.71 (28.80%)
Meadow hay	7.04 (28.07%)	/	3.52 (21.91%)	/	/	/	/	/	5.28 (24.99%)
Brewers' grain	/	/	/	0.5 (2.15%)	/	/	1 (5.5%)	/	0.75 (3.82%)
Total amount of the diet	25.08	16.5	16.06	23.22	19.38	23.1	18.18	19.72	20.155
Concentrate portion	6.16 (24.56%)	4.4 (26.67%)	5.28 (32.88%)	10.62 (45.74%)	7.04 (36.33%)	7.04 (30.48%)	7.16 (39.38%)	7.92 (40.16%)	6.953 (34.5%)
Fibrous portion	18.92 (75.44%)	12.1 (73.33%)	10.78 (67.12%)	12.6 (54.26%)	12.34 (63.67%)	16.06 (69.52%)	11.02 (60.62%)	11.8 (59.84%)	13.203 (65.5%)
Do they all get the same?	YES	YES	NO	NO	NO	YES	NO	NO	YES (37.5%) NO (62.5%)

From Table 6, we can conclude that the three main feeds used on all the farms are concentrate, whole-plant corn silage, and alfalfa hay. These feeds form the foundation of the cows' diet, providing essential nutrients for milk production and overall animal health. Interestingly, only one farm includes sugar beet pulp in the cows' rations, which is often added for energy. Other feeds used on the farms include alfalfa and rye haylage (on three farms), which is a good source of fermentable fiber, and meadow hay (used on two farms), which provides roughage and essential minerals. Additionally, brewers' grains are used on two farms, contributing protein and energy, especially for lactating cows. The diversity in feed types across farms suggests a tailored approach to meet the specific nutritional needs of the cows, although the most common ingredients are still focused on ensuring a balanced diet rich in fiber and energy for optimal milk production.

Wing and Wilcox (1963) assessed the impact of feeding strategies, including individual concentrate allocation and total mixed rations, on milk production. Their results showed no significant differences in milk yield between groups, despite variations in feeding methods. Similarly, our study indicates that farms with varying levels of dry matter intake tend to show differences in milk yield, with lower intake leading to reduced production. However, for farms with similar dry matter intake, milk yield remained consistent, reinforcing the idea that beyond a certain threshold, feed composition and distribution methods may not drastically affect production levels.

Grant et al. (1990 a, b) explored how the particle size of corn silage and alfalfa haylage influences milk composition and rumination. Their study found that while particle size had little impact on milk yield, it significantly affected milk fat content, with finely chopped feeds reducing milk fat content from 3.8% to 3%. Our results similarly suggest that the proportion of concentrates in the diet influences milk fat levels. Farms where the concentrate portion was close to 40% (farms 4, 7, and 8) exhibited lower milk fat content, supporting the established understanding that high concentrate levels can lead to reduced milk fat due to changes in rumen fermentation patterns.

Kononoff et al. (2003) investigated the impact of corn silage particle size on rumination and ruminal fermentation, noting that cows consuming coarser particles ruminated for longer periods. Although our study did not specifically assess particle size, it reinforces the importance of fiber intake in balancing rumen function. Farms with higher fiber content maintained milk fat levels, while those with higher concentrate intake saw a reduction, suggesting a potential link between feed structure and rumen efficiency.

Overall, our study supports previous research, emphasizing the role of dry matter intake, concentrate proportion, and feed structure in influencing milk yield and composition. These findings highlight the need for a balanced approach to dairy nutrition, ensuring both optimal production and milk quality.

CONCLUSION

Our study highlights significant variations in feeding strategies across farms and their impact on milk yield and composition. Differences in dry matter intake, concentrate proportion, and silage particle size demonstrate how feeding practices influence production efficiency and milk quality. Farms with lower dry matter intake generally exhibited reduced milk yield, while those with a higher proportion of concentrates (around 40%) tended to have lower milk fat content. Although silage particle size might seem like a potential factor affecting milk fat content, the data suggests that it is not directly responsible for lower fat levels. Instead, the primary influence on milk fat content is the ratio of concentrates to bulky feeds, such as hay. Farms with a higher proportion of concentrates and a lower amount of hay tend to have lower milk fat content, likely due to the higher starch content in concentrates, which can alter rumen fermentation and reduce milk fat synthesis. Conversely, farms that incorporate a greater proportion of fibrous feeds, particularly hay, tend to achieve higher milk fat levels, as fiber positively influences digestion and metabolic processes.

To optimize milk production and improve milk fat content, it is essential to ensure cows receive sufficient dry matter intake while maintaining a balanced ratio of concentrates and fiber-rich feeds. Reducing the proportion of concentrates and increasing bulky feeds, such as hay, could enhance milk fat quality and improve overall production efficiency. Additionally, incorporating energy and fiber sources like sugar beet pulp and brewers' grains may help balance rumen function and support milk fat synthesis. Continuous monitoring of the diet, along with seasonal adjustments, is crucial for maintaining consistent milk quality. The use of targeted supplements, such as fatty acids or fibrous additives, could further support higher milk fat percentages. Moreover, improving silage preparation by ensuring the correct particle size through better equipment calibration and monitoring can optimize digestion and rumen function, leading to improved milk composition.

Another potential solution for maintaining milk fat levels in herds with a high proportion of concentrates is the use of rumen buffers, such as sodium bicarbonate or magnesium oxide. These additives help stabilize rumen pH, preventing excessive acidity caused by high-starch diets, which can disrupt rumen microbial activity and negatively affect milk fat synthesis. By including buffers in the diet, farms can mitigate the negative effects of high-concentrate feeding while still supporting adequate milk production.

Equally important is the role of farmer education and training in feed management, silage processing, and ration balancing, which can contribute to more efficient and sustainable dairy production. By adopting a well-balanced nutritional approach and regularly adjusting feeding strategies based on milk composition data, dairy farms can achieve stable milk yields while enhancing milk fat content. This holistic strategy will not only improve production efficiency but also promote better long-term cow health and overall farm profitability.

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