The role of extruded rapeseed cake in the diet and its impact on milk productivity of cows

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Abstract. The objective of this study was to increase milk productivity in Black-and-White cows and improve the composition and properties of milk by introducing extruded rapeseed cake into their diet. Objectives: to study milk productivity indicators using different doses of extruded rapeseed cake and to analyze the technological properties of milk. A scientific and economic study was conducted under agricultural conditions, within the framework of which four groups of cows were formed, differing in the content of extruded rapeseed cake in the diet (5%, 10% and 15%). The results of the study showed an increase in milk productivity of cows in the experimental groups: an increase in milk yield by 367.6–567.0 kg, an increase in the average daily milk yield by 1.22–1.86 kg, an increase in the mass fraction of fat and protein, as well as the total amount of milk fat and protein. The increase in milk productivity was accompanied by an increase in the coefficients of stability and completeness of lactation, indicating better adaptation of animals to the experimental conditions and the maintenance of consistently high levels of milk yield. The researchers concluded that the optimal level of extruded rapeseed cake inclusion in the diet is 10% of the dry matter, which ensures the best economic and production results. These findings highlight the importance of a rational approach to formulating diets and are of practical interest to farmers seeking to increase livestock farm productivity and improve the quality of dairy products.

1 Introduction

Milk productivity of cows is a key indicator of the effectiveness of dairy farming, directly impacting the economic viability of milk production [1-3]. Dairy cattle productivity fluctuates significantly due to a wide range of ethological, physiological, and zootechnical factors. Key predictors of productivity include genetically inherited traits of the animals, individual phenotypic characteristics of breeds, the overall health of each individual animal,

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the stage of lactation, the body weight of the individual animal, the quality of feeding and the composition of the diet, environmental conditions, the age of each cow, and compliance with accepted mechanical or manual milking technologies. These factors interact with each other, creating a complex system of interrelated factors that influence milk productivity.

Modern agricultural production conditions dictate the need for continuous improvement of livestock diets aimed at increasing the quantity and quality of milk produced and reducing feeding costs.

One effective solution to the problem of optimizing cattle feeding is the use of alternative plant-based protein sources, with rapeseed cake receiving particular attention. Due to its high-quality protein, fats, and essential fatty acids, rapeseed cake has the potential to enhance nutrient digestibility and improve milk composition [4-6].

However, natural forms of rapeseed cake contain compounds that negatively impact animal health and milk production, such as glucosinolates and erucic acid. Therefore, the need arose to develop specialized pre-treatment methods for rapeseed cake, one of which is extrusion technology [7-8].

Extruded rapeseed meal is a highly nutritious feed supplement produced by extruding (pressing, heating, and mechanically mixing) rapeseed. The extrusion process significantly alters the physical structure of the grain particles, facilitates cell wall breakdown, and makes the proteins, fats, and carbohydrates more accessible to the animal's digestive enzymes. Furthermore, heat and pressure treatment eliminates harmful compounds, reduces toxicity, and reduces the concentration of anti-nutritional factors found in raw rapeseed. Extrusion promotes the formation of a number of beneficial metabolites, such as propionic acid, which has a positive effect on the intestinal microflora and immunity of animals. High temperature and pressure help reduce the bacterial load, preventing potential contamination of the feed by pathogenic microorganisms and molds. Furthermore, heat treatment improves the aroma and palatability of the feed, enhancing the appeal of the diet to animals and stimulating increased food intake. Along with increased nutrient availability, energy concentration per unit weight of feed is also increased, which positively impacts productivity and feed cost reduction [9-10].

Thus, the introduction of extrusion technology into rapeseed cake processing opens new prospects for increasing animal productivity, reducing feed costs, and improving the quality of milk produced, turning rapeseed cake into a valuable resource for modern livestock farming.

The primary objective of this study was to comprehensively investigate the impact of extruded rapeseed cake supplementation in lactating cows on milk productivity and milk quality. The study focused on determining optimal supplement dosages that would provide the greatest economic benefit while maintaining animal health and the environmental friendliness of the final product.

To achieve this goal, the following objectives were formulated:

- To evaluate the impact of various extruded rapeseed cake dosages on milk productivity;
- To determine the optimal percentage of extruded rapeseed cake supplementation in the diet to maximize milk yield and improve milk quality;
- To investigate changes in milk quality (fat, protein, lactose, mineral salts, etc.) when including rapeseed cake in the cows' diet.

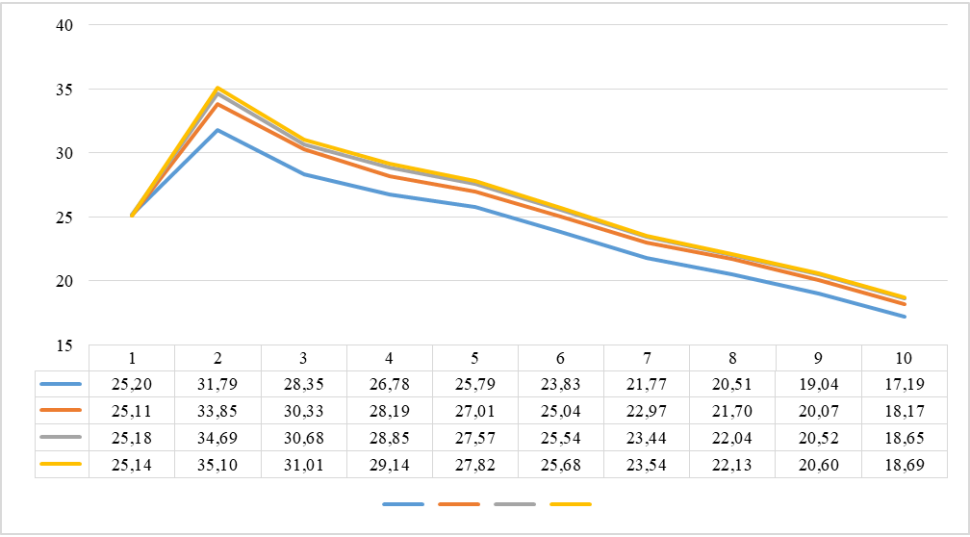
2 Materials and methods

A scientific and economic experiment was conducted at the Tulguz agricultural consumer processing and marketing cooperative in the Askinsky District of the Republic of Bashkortostan in 2025. The experiment involved four groups of 10 dairy cows each,

selected as comparable groups based on age, lactation status, physiological condition, and live weight. All animals were kept in the same conditions – stall and range. The difference in feeding was that animals in Group II (experimental) additionally received extruded rapeseed cake at a dose of 5% of the dry matter in the diet, Group III (experimental) at 10%, and Group IV (experimental) at 15%. Animal productivity was monitored monthly through test milkings. In average milk samples collected from 5 animals from each group in the third month of lactation, the following were determined: acidity – by titration of 0.1 dm^3/mol NaOH solution according to GOST R 54669-2011, density – according to GOST R 54758-2011, dry matter, SNF – was determined by an ultrasonic express method on a Klever-2M milk analyzer, the mass fraction of fat was determined by the Gerber acid method in accordance with GOST 5867-2023, the mass fraction of protein – according to GOST 34454, lactose – on a refractometer, ash and caloric content. Milk samples for research were collected in accordance with GOST 26809.1-2014 in special clean, dry bottles, which were labeled with the date of sample collection and the name of the cow from which the sample was taken. The digital experimental data were subjected to a statistical analysis of variance in Microsoft Office Excel, with the significance of differences determined at three probability levels using the Student t-test. Differences were considered significant at $P \leq 0.05$; $P \leq 0.01$; and $P \leq 0.001$.

3 Research results and their analysis

It is well known that cows' milk production processes undergo significant changes, both quantitatively and qualitatively, throughout the lactation period. The most obvious example of these changes is graphs illustrating the dynamics of average daily milk yield depending on the current month of lactation (Fig. 1).



	1	2	3	4	5	6	7	8	9	10
	25,20	31,79	28,35	26,78	25,79	23,83	21,77	20,51	19,04	17,19
	25,11	33,85	30,33	28,19	27,01	25,04	22,97	21,70	20,07	18,17
	25,18	34,69	30,68	28,85	27,57	25,54	23,44	22,04	20,52	18,65
	25,14	35,10	31,01	29,14	27,82	25,68	23,54	22,13	20,60	18,69

Figure 1. Average daily milk yield of cows by month of lactation, kg.

Figure 1 demonstrates that in the first days after calving, animals undergo a period of intense increase in milk yield, known as the milking period. By the second month of lactation, milk yield reaches its maximum, after which a gradual natural decline in productivity begins. Each subsequent month is accompanied by a gradual decrease in milk production, which is typical of the normal lactation cycle of most cow breeds.

Since previous milk production indicators were taken into account when selecting animals for the experiment, milk yields for all groups in the first month were approximately equal, amounting to approximately 25 kg. However, in the second month, a significant increase in milk yield was observed, reaching its peak for the entire lactation season, varying from 6.59 to 9.69 kg of increase over the initial level.

Then, beginning in the third month, a natural decline in milk yield began, caused by the natural physiology of the lactation process. Thus, the third month showed a decrease in average daily milk yield, regardless of group, by 3.44-4.09 kg, and the fourth by 1.57-2.14 kg. In subsequent months, milk volumes continued to moderately decline. Thus, in the fifth month, the decrease was 0.99-1.32 kg, in the sixth by 1.96-2.14 kg, in the seventh by 2.06-2.14 kg, in the eighth by 1.26-1.41 kg, in the ninth by 1.47-1.63 kg, and in the tenth by 1.85-1.91 kg.

The use of extruded rapeseed cake in diets of dairy cows in different doses showed that the average daily gain in animals of the experimental groups increased relative to their control peers in all observation periods.

Thus, the leadership of animals of the experimental groups over their control analogues in the second month was 2.06-3.31 kg (6.48-10.41%; $P \leq 0.01$-0.001), in the third month 1.98-2.66 kg (6.98-9.38%; $P \leq 0.001$), in the fourth - 1.41-2.36 kg (5.27-8.81%; $P \leq 0.05$-0.001), in the fifth - 1.22-2.03 kg (4.73-7.87%; $P \leq 0.01$-0.001); sixth – 1.21-1.85 kg (5.08-7.76%; $P \leq 0.01$-0.001); seventh – 1.20-1.77 kg (5.51-8.13%; $P \leq 0.01$-0.001); eighth – 1.19-1.62 kg (5.80-7.90%; $P \leq 0.01$-0.001); ninth – 1.03-1.56 kg (5.41-8.19%; $P \leq 0.01$-0.001); tenth – 0.98-1.50 kg (5.70-8.73%; $P \leq 0.05$-0.001). The obtained results support the hypothesis that extruded rapeseed cake promotes improved nutrient absorption and activates physiological processes that contribute to increased milk production.

It should be noted that, among the animals in the experimental groups, cows in experimental groups III and IV consuming extruded rapeseed cake at doses of 10% and 15% of the dry matter in the diet demonstrated the highest average daily gain across all data recording periods. The observed dynamics indicate improved milk production in the animals, while the diet is normalized with energy and protein components.

It is important to note that the regularity and duration of stable productivity are determined not only by milk yield but also by the degree of lactation consistency. Therefore, when assessing productivity, special indices are used, such as the lactation stability coefficient and the lactation duration index, which allow for a more detailed analysis of the lactation curve (Fig. 2).

An analysis of the obtained data confirmed the positive impact of introducing extruded rapeseed cake into the cows' diet on lactation stability and completeness (Figure 2). The lactation stability index, which reflects the stability and level of productivity, varied across the different groups.

The highest lactation stability was recorded in Group I (control), at 75.83%. However, the experimental groups fed extruded rapeseed cake demonstrated minor differences: in Group II (experimental), the stability coefficient decreased by 1.02%, in Group III (experimental), by 1.45%, and in Group IV (experimental), by 0.85%. Despite the slight loss of stability, these groups tend to maintain high productivity and reliable lactation throughout its duration.

Conversely, the lactation completeness coefficient showed better results in the experimental groups. The highest value was observed in Group IV (experimental), which received the highest dose of extruded rapeseed cake, at 90.59%. The lowest value was observed in Group I (control), at 89.56%. This indicates that the inclusion of rapeseed cake contributes to a more complete realization of lactation potential and an increase in average productivity.

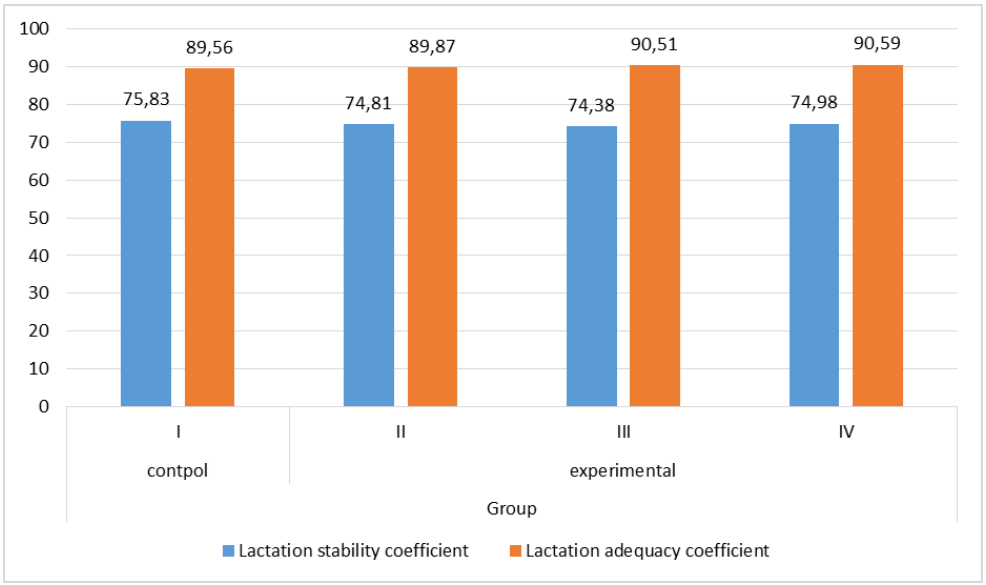


Figure 2. Coefficient of stability and completeness of lactation.

The overall milk yield of cows increased significantly throughout the lactation period (Table 1). Analyzing the data, we see that in the experimental groups consuming extruded rapeseed cake, average daily milk yield exceeded control values. This effect is explained by the enrichment of the diet with nutrients and energy contained in the cake, which increased the body's ability to produce milk and maintain its production at a high level for a long time.

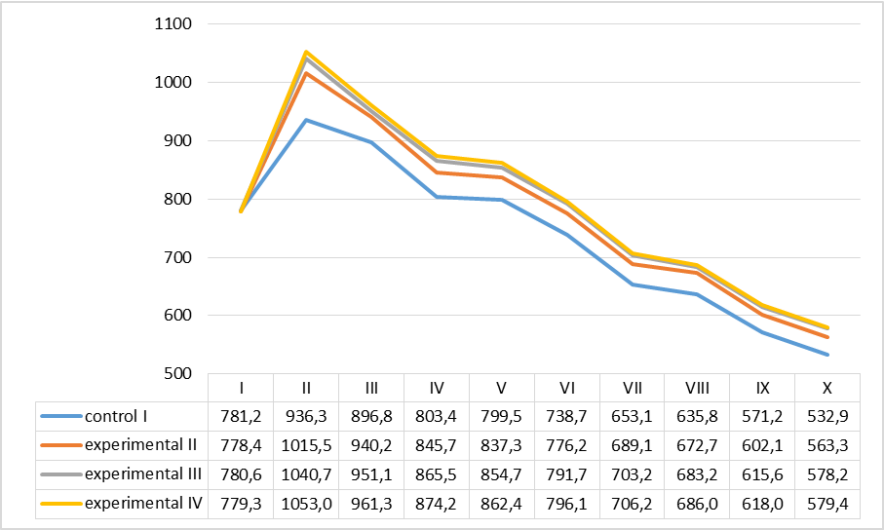
Table 1. Milk productivity indicators of experimental cows for 305 days of lactation (X±Sx).

Indicator	Group			
	control	experienced		
	I	II	III	IV
Milk yield, kg	7349.0±63.31	7720.6±52.70***	7864.5±45.12**	7916.0±36.72***
Average daily milk yield, kg	24.09±0.21	25.31±0.17***	25.79±0.15***	25.95±0.12***
Fat content, %	3.81±0.003	3.86±0.006***	3.89±0.009***	3.88±0.008***
Milk fat content, kg	280.29±3.285	296.22±1.863***	305.35±3.504***	305.18±1.167***
Protein content, %	3.13±0.004	3.21±0.004***	3.24±0.004***	3.23±0.005***
Milk protein content, kg	230.69±2.923	245.80±1.796***	253.92±2.946***	253.85±0.802***
Milk yield coefficient, %	1306.45±12.38	1359.76±9.00**	1376.37±10.11***	1384.23±7.21***

Milk productivity during the lactation period of cows in the experimental groups increased by 367.6-567.0 kg (P≤0.001) compared to the control group, the average daily milk yield - by 1.22-1.86 kg (P≤0.001). In addition to the increase in quantitative characteristics, the quality of milk also improved. The mass fraction of fat increased by 0.05-0.08 percentage points (P≤0.001), the amount of milk fat - by 15.93-24.89 kg

(P≤0.001), the mass fraction of protein - by 0.08-0.11% (P≤0.001) and the amount of milk protein - by 15.11-23.16 kg (P≤0.001). The milk yield coefficient, which reflects a cow's potential milk production capacity, also increased from 1359.76% to 1384.23%. These data suggest that including extruded rapeseed cake in the diet has a beneficial effect on the productivity and quality of milk in lactating cows.

Cow milk yield varies by month of lactation and has its own characteristic patterns (Figure 3).



	I	II	III	IV	V	VI	VII	VIII	IX	X
control I	781,2	936,3	896,8	803,4	799,5	738,7	653,1	635,8	571,2	532,9
experimental II	778,4	1015,5	940,2	845,7	837,3	776,2	689,1	672,7	602,1	563,3
experimental III	780,6	1040,7	951,1	865,5	854,7	791,7	703,2	683,2	615,6	578,2
experimental IV	779,3	1053,0	961,3	874,2	862,4	796,1	706,2	686,0	618,0	579,4

Figure 3. Milk yield of cows by months of lactation, kg.

Thus, in the first month of lactation, no intergroup differences were revealed, indicating the homogeneity of the studied groups. Maximum indicators were achieved by the second month. During this period, animals of group I (control) were inferior to their counterparts in group II (experimental) by 79.20 kg (8.46%; P≤0.01), group III (experimental) by 104.4 kg (11.15%; P≤0.001), and group IV (experimental) by 116.7 kg (12.46%; P≤0.001). A similar pattern was established in subsequent periods. Thus, in the third month of lactation, the animals of the experimental groups exceeded their control analogues by 43.40-64.48 kg (4.84-7.19%; P≤0.01-0.001), in the fourth - by 43.20-70.80 kg (5.27-8.81%; P≤0.01-0.001), the fifth - by 37.82-62.93 kg (4.73-7.87%; P≤0.01-0.001), the sixth - by 37.51-5.35 kg (5.08-7.76%; P≤0.01-0.001), the seventh - by 36.00-53.10 kg (5.51-8.13%; P≤0.010.001), the eighth - by 36.89-50.22 kg (5.80-7.90%; P≤0.001), the ninth - by 30.90-46.80 kg (5.41-8.19%; P≤0.01-0.001), the tenth - by 30.38-46.50 kg (5.70-8.73%; P≤0.001). Of practical importance is the study of animal productivity for 100 days of lactation. Animals of the II (experimental) group were superior to their peers of the I (control) group by - 131.1 kg (4.64%; P≤0.001); In group III (experimental) by 174.6 kg (6.17%; P≤0.001) and in group IV (experimental) by 198.2 kg (7.01%; P≤0.001), and over the entire lactation cycle of 305 days – by 371.61 kg (5.06%; P≤0.001), 515.51 kg (7.01%; P≤0.001) and 567.02 kg (7.72%; P≤0.001), respectively.

A study of the physicochemical parameters of milk from experimental animals showed that extruded feed increased the dry matter content in milk by 0.24-0.35% (P≤0.001) (Table 2).

Table. 2. Physicochemical parameters of cow's milk (X±Sx, n=5).

Indicator	Group			
	control	experienced		
	I	II	III	IV
Acidity, ΔT	17.16±0.024	17.23±0.028	17.25±0.025**	17.26±0.004***
Density, ΔA	28.38±0.465	29.12±0.244	29.47±0.260**	29.50±0.137*
Moisture, %	87.91±0.012	87.67±0.015***	87.57±0.029***	87.56±0.010***
Dry matter, %	12.09±0.012	12.33±0.015***	12.43±0.029***	12.44±0.010***
SNF, %	8.40±0.019	8.55±0.016***	8.61±0.027***	8.62±0.005***
Fat, %	3.69±0.010	3.78±0.011***	3.83±0.013***	3.82±0.013***
Protein, %	3.07±0.018	3.16±0.014**	3.18±0.012***	3.19±0.013***
Lactose, %	4.63±0.013	4.66±0.010*	4.68±0.011***	4.69±0.011**
Ash, %	0.71±0.009	0.73±0.007*	0.75±0.011**	0.75±0.013**
Calories, kcal	70.85±0.104	72.34±0.084***	72.98±0.160***	72.97±0.142***

Note: * – P < 0,05; ** – P < 0,01; *** – P < 0,001

A similar pattern was established for the fat content, where the difference was 0.09-0.13% (P≤0.001), protein - 0.09-0.12% (P≤0.01), lactose - 0.03-0.06% (P≤0.05-0.01). An increase in the content of the main components of milk in the experimental samples contributed to an increase in the energy value by 1.79-2.43 kcal (2.54-3.44%; P≤0.001) relative to the control. One of the key indicators is the study of the dynamics of milk fat content in milk by months of lactation, which reflects the physiological processes occurring in the body of productive animals (Figure 4).

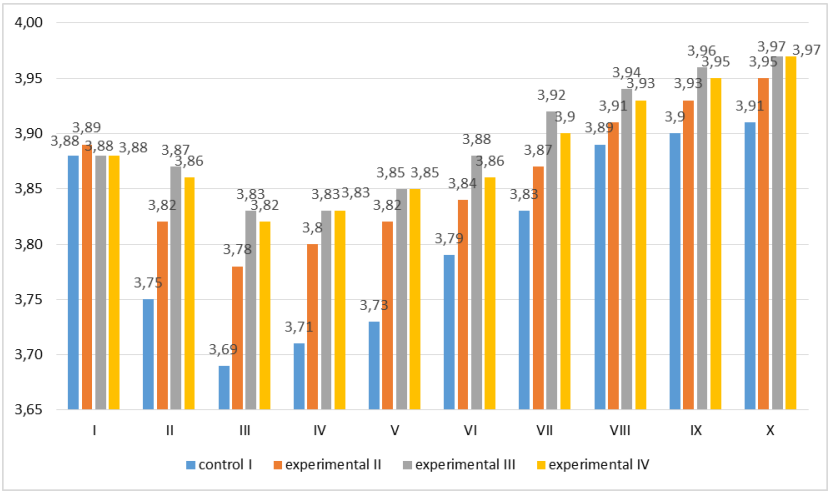


Figure 4. Milk fat content in monthly dynamics, %.

Analysis of the obtained data shows that at the beginning of lactation, milk fat content was similar in all groups. Significant changes were recorded by the third month of lactation. For example, in animals of Group I (control), the decrease by the third month relative to the first month was 0.19%, in Group II (experimental) it was 0.11%, in Group III (experimental) it was 0.05%, and in Group IV (experimental) it was 0.06%. From the fourth month until the end of lactation, an increase in milk fat content was observed. This increase was 0.22% in cows of Group I (control), 0.17% in Group II (experimental), 0.14% in Group III (experimental), and 0.15% in Group IV (experimental).

Analysis of intergroup differences across all observation periods revealed a superiority of animals in the experimental groups over their control counterparts in terms of milk fat content. Thus, in the second month of lactation, this indicator was higher by 0.07-0.12% in cows of groups II-IV (experimental), by 0.09-0.14% (P≤0.001) in the third, by 0.09-0.12% (P≤0.05-0.01) in the fourth and fifth, by 0.05-0.09% (P≤0.01) in the sixth, by 0.04-0.09% (P≤0.005) in the seventh, by 0.02-0.05% in the eighth, by 0.03-0.06% in the ninth, and by 0.04-0.06% in the tenth, compared to their control peers.

Towards the end of lactation, an increase in milk fat content is observed, which is associated with changes in metabolism. It should be noted that the study of the fat content in milk over 100 days of lactation showed that the value of the studied parameter was higher in cows of group IV (experimental) than in cows of the control group by 0.12% (P≤0.001), in group II (experimental) – by 0.05% (P≤0.001); in group III (experimental) – by 0.08% (P≤0.001). Over 305 days of lactation, the highest indicator was observed in animals of group III (experimental), amounting to 3.89%, which is higher than in analogs of group I (control) by 0.08%; group II (experimental) – by 0.03%; and group IV (experimental) – by 0.01%, respectively.

Changes in the milk protein content in milk throughout the lactation period clearly demonstrate the impact of internal physiological processes in the animal's body (Figure 5).

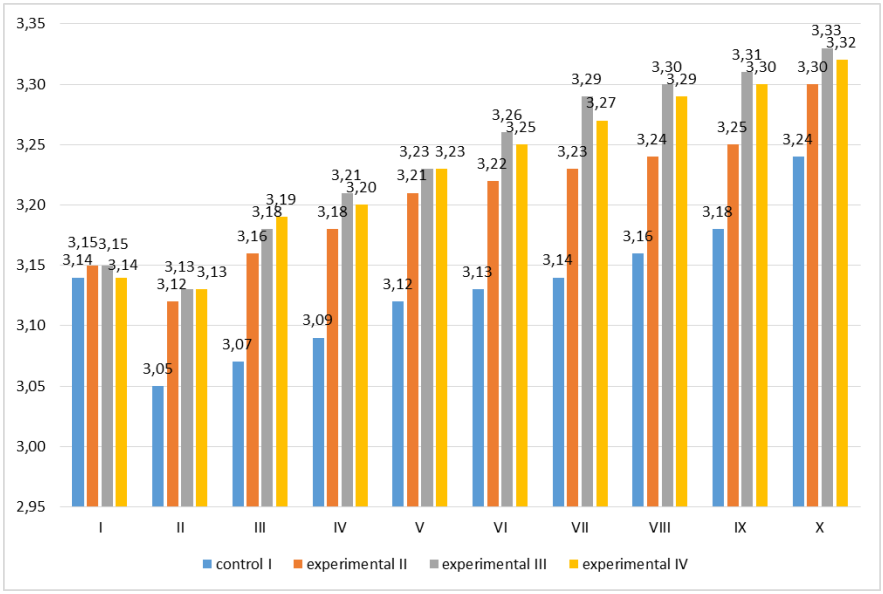


Figure 5. Changes in milk protein content by months of lactation, %.

These changes are important for understanding the animals' nutrient status, thereby contributing to increased productivity.

Analysis of the obtained data shows that, beginning in the second month of lactation, a decrease in milk protein concentration is observed in animals of all study groups. Specifically, this decrease in milk protein by the second month was 0.09% in cows of Group I (control), 0.03% in Group II (experimental), 0.02% in Group III (experimental), and 0.01% in Group IV (experimental). By the third month, the protein content of milk increased for cows of all experimental groups by 0.02%, 0.04%, 0.05%, and 0.06%. In subsequent periods and until the end of lactation, the trend of increasing milk protein content in cows of all experimental groups continued.

An intergroup comparison of milk protein content values revealed a superiority among animals from the experimental groups. Thus, in the second month of lactation in cows of groups II-IV (experimental), this indicator was higher by 0.07-0.08% (P≤0.001), the third - by 0.09-0.12% (P≤0.01-0.001), the fourth - by 0.09-0.12% (P≤0.01), the fifth - by 0.09-0.11% (P≤0.01), the sixth - by 0.09-0.13% (P≤0.01-0.001), the seventh - by 0.09-0.15% (P≤0.05-0.001), the eighth - by 0.08-0.145% (P≤0.05-0.001), the ninth - by 0.07-0.13% (P≤0.01-0.001), the tenth – by 0.06-0.09% (P≤0.01-0.001).

When analyzing the milk protein content over 100 days of lactation, it was found that the highest value was observed in milk samples from groups III and IV (experimental) and amounted to 3.15%, which is higher than that of analogs from group I (control) – by 0.06% and group II (experimental) – by 0.05%. Over 305 days of lactation, the highest value was in the milk sample from group III (experimental) and amounted to 3.24%, which is higher than that of analogs from group I (control) – by 0.11%, group II (experimental) – by 0.03%, and group IV (experimental) – by 0.01%.

4 Conclusion

Thus, the obtained data confirm the potential of using extruded rapeseed cake in cow diets to increase milk production and improve the physicochemical composition of milk. This is explained by its use leading to the complex activation of mechanisms aimed at increasing milk production. By improving nutrient availability, optimizing metabolism, and supporting the immune system, this feed promotes high production rates and improved milk quality.

It should be noted that the highest milk production rates were observed in cows in Groups III and IV (experimental groups). However, given the minor differences between them, a recommended extruded rapeseed cake supplementation rate of 10% of the dry matter in the diet is recommended as an effective means of intensifying dairy farming and increasing farm profitability. This method will increase the volume of high-quality dairy products, reduce the cost of concentrated feed, and ensure a stable economic effect.

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