CHAPTER 26

Features of the Formation of Milk Composition and Properties Under Different Levels of Protein, Fat, and Concentrate Nutrition

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Abstract The article investigates the impact of dairy cattle feeding conditions on milk yields, chemical composition, and technological properties, as well as the quality of resulting dairy products. Based on generalized data from numerous scientific and practical experiments, the features of milk formation under different levels of protein, fat, and concentrate nutrition are analyzed. It is established that an increase in digestible protein up to 120 g per feed unit enhances milk yields and fat content. However, excessive protein overfeeding (above 70 g per 1 kg of milk) suppresses rumen fermentation, inhibits milk fat synthesis, and can induce metabolic disorders, proving to be economically and physiologically unjustified. Regarding lipid nutrition, the optimal fat allowance is determined to be 65% of the daily milk fat output, which maintains high productivity and ensures a favorable fatty acid profile for high-quality butter production. The study also evaluates the inclusion of various oil cakes in the diets. While moderate amounts (2.5 kg) of sunflower and linseed oil cakes positively affect the organoleptic and storage stability of butter, large doses (230–250 g per 1 kg of milk) lead to texture and flavor defects (tallowy, soft, or pale butter) due to high concentrations of unsaturated fatty acids. Additionally, replacing oil cakes with defatted meals or wheat bran increases the storage stability of whole milk powder and alters butter firmness. The paper highlights the necessity of providing balanced, diverse rations to prevent deviations in milk properties and secure high-quality raw materials for the dairy processing industry.

Keywords *dairy cattle, milk composition, protein nutrition, fat allowance, oil cakes, butter quality, storage stability*

Milk and dairy products occupy a significant place among human food products. Therefore, it is important to know the methods for improving the composition of milk and its nutritional value. An important factor that determines the composition and properties of milk, as well as its suitability for processing into dairy products, is the quantity, quality, and ratio of individual feeds in the animal's diet" [2, 3, 11, 12,].

The overall level of cow feeding during the dry and lactation periods, as well as the content of protein, fat, minerals, and vitamins in feed rations, influence not only milk yields but also change the composition and properties of milk, and consequently, the quality of dairy products [5].

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A scientifically based diet for dairy animals should stimulate milk production, maintain animal health, and ensure high-quality milk yield at the lowest cost of labor and resources. Dairy specialists have paid great attention to this issue and have repeatedly emphasized the importance of proper organization of dairy cattle feeding.

Practice and scientific research show that the level and nutritional adequacy of dairy animal feeding significantly influence lactation, milk synthesis processes, and, consequently, its composition. Under prolonged general undernutrition, the animal's body becomes depleted. This results in decreased milk yields and a reduction in the content of fat, protein, and dry matter in the milk [4, 10].

Protein nutrition of dairy cattle must be organized to obtain high milk yields and milk with the maximum content of fat, protein, and lactose. Practice confirms that introducing protein feeds into the diet of lactating cows significantly increases milk yields and the content of fat, protein, and total dry matter. Feeding cows alfalfa feeds (hay and green mass) resulted in an increase in milk yields and a 0.2% rise in milk fat content[7].

It was established [1] that during the summer period, a decrease in milk fat content was prevented by enhancing the protein nutrition of cows. The feeding of the cows was arranged as follows: the first group received hay, spring straw, chaff, and silage; the second group additionally received compound feed, bran, and oil cake, representing the group of normalized total and protein nutrition; the third group, while maintaining the same total dietary energy/nutritional value as the second group, was given 25-30% more digestible protein. Increasing digestible protein in the dairy cattle diet by 25-30% above the norm elevates milk yields by 9-10%, fat content by 0.1-0.2%, protein content by 0.2-0.3%, and dry matter by 0.3-0.5%. Conversely, underfeeding animals in terms of total nutritional value and protein reduces milk yields by 20%, dry matter content in milk by 0.7-0.9%, and fat and protein content by 0.3-0.4%.

Conducting experiments [8] on cows with a daily milk yield of 14-17 kg, while increasing the amount of digestible protein in the diet to 135 g per 1 feed unit, the

researcher obtained an increase in milk yields by 1-2 liters per cow, with a simultaneous 0.25-0.35% rise in milk fat and a 0.18-0.36% rise in protein content.

In most cases, the experiments were conducted on animals with a productivity of up to 3,000 kg of milk per lactation. The type and level of feeding prior to the experiments were not taken into account, whereas pre-experimental feeding of animals is of major importance when determining the efficiency of protein nutrition in dairy cattle.

Alongside studies that demonstrated a positive effect of increased protein nutrition on milk yields and composition, there are numerous research papers where an elevated level of protein in the diet did not yield the expected results.

It was established that when protein nutrition was increased (nearly twice above the norm), the milk fat content in cows did not increase. In experiments, introducing feeds rich in protein (sunflower cake and chickpeas) into the diet of dairy cows did not lead to a rise in milk fat content[6].

Long-term and methodologically sound experiments were conducted on Brown Swiss cows (with a productivity of 4,600-4,800 kg) using diets with various protein levels. The results showed that nutrationally complete diets for dairy cattle containing 70 to 85 g of protein per liter of milk yielded promote high milk yields and milk of normal composition[9].

Increasing the amount of protein in the diet above 120 g per liter of milk (using soybean cake) does not contribute to higher milk yields or improved milk composition. The milk composition in cows receiving different levels of protein nutrition **(**85 and 120 g per one feed unit**)** was, on average, identical throughout lactation: dry matter content was 13.2%**,** fat was 3.86%**,** and protein was 3.76%**.**

Experiments were conducted on Ukrainian Whitehead cows. The diet was nutritionally complete. The milk yields of the cows over several years ranged from 7,800 to 5,000 kg per head**.** The results demonstrated that an elevated level of protein nutrition 25-28% above the established norms (133-136 g of digestible protein per 1 feed unit) does not stimulate an increase in milk yields or fat content. Consequently, protein overfeeding of dairy cattle under conditions of sufficient and nutritionally adequate feeding is economically impractical [6]**.**

The changes in milk fat content were studied depending on the amount of protein and fat in the feed. Experiments proved that with an increase in digestible protein in the feed up to 120 g per one feed unit, the milk fat content increases by 0.16%, and the protein content rises by 0.21%. Concurrently, the content of saturated fatty acids in milk fat increases.

Furthermore, these experiments showed that 10-15% of the total amount of saturated fatty acids are synthesized from feed protein. Conversely, when reducing the amount of protein in the dairy cattle diet to 80 g per one feed unit, the fat and protein content in milk decreases[9].

Based on the data from scientific and practical experiments, we believe that an excessive amount of protein (above 70 g per 1 kg of milk) exerts no positive effect on milk yield and milk fat content.

Relying on the results of numerous studies, the author believes that increasing the provision of protein feeds suppresses the fermentation processes occurring in the rumen of ruminants. This reduces the rumen production of acetic acid, which is a precursor for milk fat synthesis. The author asserts that a type of dairy cattle feeding characterized by an excess of protein inhibits the processes of milk fat synthesis, thereby decreasing milk fat content.

Furthermore, data show that an excess of protein in dairy cattle diets can be not only ineffective but even harmful. In the animal's body, prolonged protein overfeeding can cause poisoning, atony, tympany, retained placenta, abortion, etc[4].

Therefore, protein overfeeding of dairy cattle must be recognized as an economically inefficient practice and physiologically unjustified

The influence of individual feed nutrients, specifically fat, on milk productivity and milk composition has been studied by a number of researchers. Summarizing the materials on this issue, we assert that a decrease in fat within feed rations leads to a decline in milk fat content, whereas an increase in dietary fat raises the fat content in milk[7].

Experiments were conducted on three groups of cows to determine the optimal amount of fat in the feed ration that favorably affects cow milk productivity and milk

composition. The diets of the experimental cows were balanced for total nutritional value, protein, carbohydrates, and minerals, and differed only in the amount of fat**.** The fat sufficiency of the rations was 40%, 65%, and 85% of the amount of fat in the daily milk yield.

When the cows' ration fat sufficiency was at 40%, milk yields decreased, indicating that this level was insufficient to maintain high milk productivity. However, the milk composition remained normal. At 65% and 85% fat in the diet, the decline in milk yields associated with the course of lactation was prevented. An increase from 40% to 65% of fat in the feed resulted in an average 0.12% rise in milk fat content

The results of these studies showed that to achieve a positive effect on milk fat content, the optimal fat allowance in the feed ration can be considered 65% of the fat present **in** the daily milk yield. This norm promotes high milk yields and an optimal ratio of fatty acids in milk fat, which determines the high quality of butter

Experiments showed that increasing fat in the feed raises the content of unsaturated acids in milk fat and decreases the amount of saturated non-volatile high-molecular**-**weight fatty acids. The author believes that the calculation of the fat requirement for the feed ration of dairy cows should be made as a percentage of the amount of fat in the milk obtained per day.

Science and practice have proven that adding various oil cakes to the dairy cattle diet causes changes in milk composition and, consequently, in the quality of dairy products made from this milk.

Feeding sunflower, cottonseed, and linseed oil cakes noticeably increases milk fat content (by 0.2-0.4%). Conversely, including poppyseed, rapeseed, and hempseed oil cakes in animal rations reduces its fat content. This is explained by the fact that the positive or negative impact of such feed on milk fat content depends on the composition and properties of the vegetable oils contained in the oil cake.

The influence of a specific dairy cattle feeding regimen significantly alters the iodine value of milk fat intended for butter production and, accordingly, the consistency of the resulting butter.

It was established that when feeding linseed oil cake, the iodine value of milk fat increases**,** the amount of volatile water-soluble fatty acids decreases, and the butter consistency becomes soft and greasy. Replacing oil cake in the diet with wheat bran gives the butter a firm consistency. Feeding cows linseed and sunflower oil cakes causes the butter to acquire a soft consistency, with the iodine value becoming high and reaching 34-39. Conversely, feeding sunflower meal and corn grain lowers the iodine value to 29 and promotes the production of butter with a normal consistency**.**

Experiments established that including linseed oil cake in the feed ration of Kholmogory cows instead of wheat bran promotes higher animal productivity and an increase in the total amount of fat in the daily milk yield. The basal diet of the experimental animals consisted of hay, straw, turnip, beet, and bran. The rations for the individual experimental groups differed only in the amount of linseed oil cake. The cows of the first group received no bran [Note: or oil cake, depending on the context of the control group], the second group was fed 2.5 kg per day (or 140 g per 1 kg of milk)**,** and the animals of the third group received 5 kg (or 250 g per kilogram of milk**)**. In the second group, the fat and protein content in milk increased. However, introducing a large amount of linseed oil cake **(**250 g per 1 kg of milk**)** into the dairy cattle diet causes a deterioration in milk quality and butter storage stability, which is explained by the presence of a high amount of unsaturated fatty acids in linseed oil cake.

The inclusion of linseed oil cake in the cows' diet increases the total protein content in milk by 0.2–0.3% compared to a ration equal in nutritional value but without linseed oil cake. The ratio between different protein fractions changes as the amount of linseed oil cake in the diet increases. The rise in milk protein occurs due to albumin and globulin, which is apparently associated with metabolic disorders in the animal's body when large amounts of linseed oil cake are fed.

The comparative effect of sunflower, linseed, and cottonseed oil cakes, meals, and wheat bran in various amounts on milk composition and butter quality was also studied. The butter from the milk of cows whose diets included moderate amounts (2.5 kg) of linseed and sunflower oil cakes, as well as cottonseed meal and wheat bran, received the highest organoleptic score. Moderate doses of oil cake in the

rations have a positive effect on preserving the flavor qualities of butter during long-term storage[2].

It confirms that feeding cows large amounts of sunflower oil cake (230–240 g per 1 liter of milk yielded) deteriorates the quality of butter obtained from the milk of these animals. With such feeding, the butter acquired a soft consistency and a vegetable oil off-flavor, which intensified during the storage process.

Experiments showed that introducing un-defatted hempseed oil cake into the cows' diet negatively affects butter quality. However, when the hempseed oil cake was defatted, its negative impact on butter quality was eliminated. Four experimental groups of cows received 1, 2, 3, and 4 kg of cottonseed oil cake in their rations, while maintaining equal total dietary nutritional value. The milk yields of all cow groups remained identical throughout the experiment; therefore, introducing cottonseed oil cake in various amounts did not alter milk yields, density, or acidity.

The milk fat content increased compared to the group that received 1 kg of cottonseed oil cake. However, the butter produced from the milk of the experimental groups was inferior in quality to the butter from the control group's milk. It exhibited defects in flavor, consistency, and color, being tallowy, hard, and pale. The severity of these defects corresponded to the amount of oil cake introduced into the dairy cattle diet. When the high doses of cottonseed oil cake were discontinued, the butter regained a normal flavor and consistency.

Experiments were conducted to identify the influence of specific concentrated feeds on milk yields and milk fat content. Sunflower and cottonseed oil cakes, oatmeal, and compound feed were provided as supplements during summer cattle grazing/housing

. The best results were obtained when the cows were fed sunflower oil cake; milk yields increased by 10% and fat content rose by 0.47% compared to the period when the cows did not receive any supplementation[11].

An experiment was conducted to comparatively study linseed oil cake, cottonseed oil cake, and cottonseed meal. The trial was carried out on three groups of Kholmogory cows. During the pre-experimental (preliminary) period of 38 days, the cows of all groups were kept on identical daily rations containing: 8 kg of clover-

timothy hay; 23–25 kg of fodder beet; 20 kg of sunflower silage; and 4.4–5.2 kg of a concentrate mixture. In addition, the animals received 150 g of linseed oil cake per 1 liter of milk.

During the experimental period of 64 days, the cows of the second group were fed 2.8 kg of cottonseed oil cake instead of linseed oil cake, while the cows of the third group received 2.6 kg of cottonseed meal. The cows of the first group continued to receive the preliminary period ration throughout the entire trial. The study demonstrated that replacing linseed oil cake with cottonseed oil cake and meal in the cows' diets did not affect milk fat content, density, viscosity, titratable acidity, or active acidity (pH) [6].

Significant differences were observed in the protein composition of the milk. In the cows of the second group, the total amount of protein and casein in the milk decreased. The reduction in casein content can be explained by the animal's organism poorly utilizing the protein from cottonseed oil cake. This might be a result of a significant increase in dietary fat and a change in the ratio between digestible fat and protein.

The influence of feeding linseed and cottonseed oil cakes and meal on milk composition, as well as the quality and stability of whole milk powder produced from it (the whole milk powder was manufactured using the spray-drying method), was investigated. The experiment was conducted on three groups of Kholmogory cows.

During the preliminary period (38 days), all animals received the same ration, which consisted of: linseed oil cake, hay, fodder beet, sunflower silage, wheat bran, and barley flour. During the experimental period (64 days), the linseed oil cake in the diets of the second and third groups was replaced with cottonseed oil cake and meal (2.6–2.8 kg per head per day). The cows of the first group continued to receive the previous ration. Protein and mineral nutrition for the cows of all groups remained identical throughout the trial.

The rations differed across groups and feeding periods only in the quality and quantity of digestible fat. In the preliminary period, the amount of fat in the rations was equal in all groups (23.3–24.5 g [Note: assuming grams per liter/head based on

context]). During the experimental period, the animals of the first group received fat at a rate of 24.3 g per liter of milk yielded, the second group received 31.1 g, and the third group received 16.1 g. Moreover, the cows of the third group received cottonseed fat (iodine value 106–110)

instead of linseed fat (iodine value 174). Consequently, the amount of fat in the diet of the second group increased by 31%, while in the third group, conversely, it decreased by 31% compared to the preliminary period.

The properties of milk fat directly depend on the properties of the feed fat included in the dairy cows' diet. It may contain either an increased or a negligible amount of unsaturated fatty acids**.** The experiment demonstrated that replacing linseed oil cake with cottonseed oil cake and meal did not alter the density, viscosity, and acidity of the milk.

The milk fat content of the cows in the first and second groups increased by 0.12–0.13% during the experimental period, while the milk of the third group cows remained unchanged. All whole milk powder samples produced from the milk of the experimental cows were rated as extra grade based on their composition.

To test their stability, the samples were stored at a temperature of 14–16 °C. The organoleptic properties of the milk powder changed in accordance with the intensity of oxidative processes. Based on this, the author concludes that replacing linseed and cottonseed oil cakes in cow rations with cottonseed meal, which contains a lower amount of vegetable oil, increases the storage stability of whole milk powder.

Based on the results obtained by many researchers, it can be concluded that concentrated feeds, and specifically certain oil cakes, have a positive effect on milk fat content provided that the concentrate is introduced in moderate amounts (140–150 g per 1 kg of milk). In this case, providing concentrated feeds raised the milk productivity of the animals to the level inherent to the given cattle breed.

However, when animals are provided with diets that are already complete in terms of total nutritional value and protein, introducing additional concentrated feeds negatively affects the quality of dairy products, especially butter, as well as the animals' condition. The flavor qualities of milk, its composition, and its suitability for manufacturing various dairy products were not taken into account in most studies,

whereas these issues are of major importance for dairy farming and various branches of the dairy industry.

It is known that certain dairy product defects, such as the blowing (puffing) and self-splitting of cheeses, as well as the crumbly and tallowy texture of butter, are directly linked to dairy cattle feeding conditions.

When animals are fed large amounts of a single type of succulent feed (fodder beet, turnip), a feed off-flavor appears in the milk, and the quality of cheese and butter deteriorates.

Researchers believe that when feeding high-quality silage, which is an excellent feed for cows, it is possible to obtain milk of normal composition that is entirely suitable for butter making and the production of Dutch-type cheeses, provided that the necessary sanitary rules for milking and milk processing on farms are strictly followed.

Among the studies evaluating the impact of various succulent feeds in dairy cattle diets on milk yield and composition, a prominent place is occupied by experiments on feeding sugar beet to cows, conducted across different regions and on many cattle breeds.

Experiments were conducted on feeding sugar beet to high-producing Black-and-White cows. When cows were given 15 kg of sugar beet per day, the milk fat content increased by 0.2%. However, a further increase of sugar beet in the cows' diet to 30 kg per day led to a decrease in milk fat content. When feeding sugar beet to cows, the protein content in the milk increased. A similar phenomenon has been noted in other published studies.

The rise in milk protein can be explained by the fact that a high sugar level in the diet reduces the animal organism's need for amino acid deamination. Consequently, proteins are utilized more efficiently, which leads to the increase in milk protein content.

The impact of turnip, sugar beet, potato, and sunflower silage in various dietary combinations on milk yield, composition, and butter quality was studied. The experiments were conducted on Red Steppe cows. When giving up to 10 kg of sugar beet per day per cow, the amount of proteins and sugar in the milk increased.

Conversely, when feeding up to 60 kg of turnip**,** a feed off-flavor and bitterness appeared in the milk. The authors believe that cows whose milk is processed into butter should be fed a moderate norm of sugar beet combined with silage, avoiding excessive allowances of a single type of succulent feed.

It has been proven expedient to simultaneously use several types of succulent feeds in dairy cattle diets, because feeding large doses of a single feed type leads to deviations in milk properties and a decline in the quality of products obtained from such milk. This primarily concerns cheese, the quality of which significantly depends on cattle feeding.

In experiments with Red Steppe cattle, feeding high amounts of sugar beet increased milk fat content by 0.5–0.7%, though milk yields declined due to digestive depression from excess easily digestible carbohydrates. Optimal productivity and performance are achieved when sugar beets are fed at a rate providing 150–180 grams of sugar from root crops per liter of milk produced. For further translation and terminology refinement, you can continue working with the assistant.

With such feeding, the milk fat content increases by 0.3%, protein by 0.2%, and milk yields rise by 8–13%. Higher doses of sugar (from root crops) in the diet do not contribute to increased milk yields or improved milk composition.

In the second experiment, the comparative effect of several succulent feeds on productivity and milk composition was studied. When sugar beet (10 kg) and corn silage (7 kg) were replaced [Note: or adjusted, depending on the exact control ration setup], an increase in milk dry matter by 0.75% was observed, including a 0.33% rise in casein and a 0.31% rise in milk fat. These changes were clearly pronounced during the colder season.

It was established that feeding sugar beet to cows during the warm season leads to a decrease in milk yields and a reduction in milk fat content. However, when sugar beet was fed to Black-and-White cows**,** an increase in milk fat content was noted compared to the period when the animals received turnip and green grass as their succulent feeds.

In Latvian Brown cows, an increase in milk fat content by 0.3–0.4% was obtained when feeding sugar beet. The experiment indicates that introducing a large amount

of fodder kale (up to 40 kg and more per head per day) into the cows' diet instead of pasture green forage led to a 0.2–0.3% decrease in fat and protein content in the milk. The gradual replacement of kale with silage, root crops, and hay was accompanied by an increase in milk fat and protein content, which is associated with the rising amount of dry matter in the feed ration.

When dairy cattle are fed large amounts of industrial by-products (beet pulp, distillers grains/stillage, maize gluten feed), the flavor qualities of milk and dairy products deteriorate.

Conclusion

Against the background of nutritionally complete diets with sufficient protein provision, replacing one type of succulent feed with another does not significantly alter milk composition or product quality. However, high, unbalanced allowances of a single feed type—combined with a disruption in dietary completeness and insufficient protein supply—cause undesirable changes in the chemical composition and technological properties of milk, consequently leading to a deterioration in the quality of products made from it.

Most authors believe that the more diverse the variety of feeds, the more beneficial the impact of the ration on the quality of milk obtained from the animal, and, therefore, on dairy products.

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