Milk productivity of holstein cows at optimization of fat levels in their diets

O Petrov¹, V Semenov²,* and V Alekseev³

¹Department of Meat and Milk Technology, Mari State University, 1 Lenina Square, 424001, Yoshkar-Ola, Russian Federation
²Department of Morphology, Obstetrics and Therapy, Chuvash State Agricultural Academy, 29 Karl Marxa Street, 428003, Cheboksary, Russian Federation
³Department of General and Private Animal Science, Chuvash State Agricultural Academy, 29 Karl Marxa Street, 428003, Cheboksary, Russian Federation

*E-mail: semenov_vg@edu.academy21.ru, https://orcid.org/0000-0002-0349-5825

Abstract. The work is devoted to determining the optimal level of fat in concentrate-senage diets for high-yield cows and studying the effect of various levels of fat in the dry matter of the diet on milk productivity and chemical composition of milk. Studies have shown the insufficiency of household diets of highly productive cows with a dry diet content of 3.2% raw fat. This deterred the potential for dairy productivity. Addition of fat in cow diets by equivalent energy and protein replacement of a portion of the compound feed with a rapeseed cake up to a level of 4.2% of the dry substance provides an increase in milk productivity in relation to the control group receiving 3.2% fat. Optimization of the fat level in the dry substance of the diet up to 4.2% in the nutrition system of cows increases the functional activity of the breast in their body, which is expressed in the growth of breast productivity by 6.78%, improvement of the chemical composition and technological properties of milk. A further increase in dietary fat to 5.2% has a less pronounced effect on the change in milk productivity.

1. Introduction

In the modern world, increasing the production of livestock products is one of the most difficult problems of the world economy and politics. Food security in many countries is currently one of the most important priorities of States. An increase in the production of livestock products is possible only on the basis of increasing the productivity of animals, creating a balanced feed base and switching to modern technologies for their maintenance and feeding. And animal husbandry, in solving this problem, plays a decisive role.

In many countries, animal husbandry is developing dynamically, production is increasing, intensive technologies are being developed, and animal productivity is increasing. Dairy cattle breeding occupies a special place in the agro-industrial complex of any state, this industry is considered one of the most socially significant in agriculture and the level of its development is one of the indicators of economic stability in society. The realization of the genetic potential of livestock bred in different territories, with different climatic, ecological and other conditions, as well as with various genetic resources of animals, cannot be carried out in the same way in all zones and regions. Therefore, in each specific zone and region, it is necessary to develop the most acceptable option for the development of dairy cattle breeding [1,2].
In conditions of extensive “use” of dairy cows, cattle breeding is now on a new spiral of development, when the highest quality of products can be achieved only with a direct relationship between the technical components of technological processes and the biological features of animals [3-5]. The main task of the livestock industry is to increase its level of productivity and preserve the number of animals. To solve this problem, in addition to improving existing and breeding new breeds, it is necessary to use the potential of animals by creating favorable conditions for their feeding and maintenance. Biological science constantly studies the growth and development of animals, studies the patterns of the formation of biological signs of animals and the dynamics of their vital activities to obtain an objective judgment on the degree of realization of the genetic potential of individuals and the population as a whole [6].

In the modern dairy cattle breeding, the main task of agricultural science and practice is the further intensification of the industry, aimed at increasing the genetic potential of the productive qualities of domestic animals and the degree of its realization. The existing variety of dairy technologies, considering different ways of keeping and servicing cattle, is based on the specifics and multifactoriality of this industry. A balanced diet can be created for each productive group of animals using the software, depending on live weight, milk yield, milk fat content and other indicators. Modern livestock technologies require the use of new physiologically appropriate and cost-effective feeding systems. Highly productive cows respond markedly to many factors, but insufficient and poor-quality feeding, and often even a slight deviation in nutrition, causes a decrease in productivity and reproduction [7]. It has been established that the Holstein breed has a high genetic potential for dairy productivity, which is achieved by targeted selection according to the minimum number of signs, but there is an important problem – the low realization of the productive potential of livestock, which is realized by only 60-62%.

At the same time, normalized feeding on the basis of a comprehensive analysis of the chemical composition, a certain set and ratio of feed, as well as scientifically justified detailed norms and the balance of diets in them is a determining criterion for the realization of the genetic potential of animals with high productivity [8]. A number of works by domestic and foreign researchers were devoted to the study of fat rationing in feeding cattle. But, by now, there is no consensus among scientists on the optimal fat content in the dry matter of cattle diets, especially highly productive ones. And analysis of household diets of cattle with high potential of dairy and meat productivity convinces the necessity of their optimization in terms of raw fat content in connection with revealed non-compliance with detailed feeding standards [9-11].

The purpose of the research was to provide scientific, industrial and economic justification for rationing the level of fat in the dry matter of the diets of black-and-white Holstein cows with a high potential for dairy productivity. To achieve this goal, a complex task was set to determine the effect of different levels of fat in diets on the dairy productivity of cows, the chemical composition and technological properties of milk.

2. Materials and methods
Experimental and laboratory studies were carried out in the production conditions of open joint stock company (OJSC) Tribal Plant “Azanovsky” of the Republic of Mari El, in the laboratory of zootechnical analysis of the agrarian and technological institute of Mari State University, at the department of feeding farm animals and zoogeny of the Ulyanovsk State Agricultural Academy named after P. A. Stolypin. The objects of research were cows of black and motley Holstein breed with a high productivity potential, which were contained in the conditions accepted for complexes and farms. The animals were clinically healthy.

Scientific and economic experiments were carried out on three groups of animals (10 heads each), formed by the method of para-analogues or mini-herds. The difference in live weight and productivity between the groups on average did not exceed 5%. Cows on average had a live weight of 591.2 kg, a daily weight of 27.0 kg, a fat content in milk of 3.29%, a productivity for previous lactation of 6,772.9 kg of milk, a milk yield rate of 1.9-2.2 kg/min.
An analysis of the economic diets of cattle with a high potential for dairy productivity convinces the need to optimize them in terms of fat content in connection with the revealed discrepancy with detailed feeding standards, even with the calculation of the average productivity of animals. Therefore, diets for experimental animals are adjusted for the chemical composition of local and purchased feed, age, physiological condition, daily milk, live weight, productivity and lactation period. Each group of animals received the same feed in the diet, with the exception of the addition of experimental groups to the animals, fat due to sunflower cake and oil introduced with combined feed concentrate. The scientific and economic experience was carried out on three groups of analogue cows for 180 days. Group I cows received diets with a fat content of 3.2% in dry matter, II – 4.2%, III – 5.2%.

The milk productivity of cows was determined according to the data of annual control milkings according to Federal standard R 51451-99 “Procedure for milk recording for cows” [12]. The milk sampling was carried out according to Federal standard 26809.1-2014 “Milk and milk products. Acceptance regulations, methods of sampling and sample preparation for testing” [13]. Assessment of its properties was established according to Federal standard 31449-2013 “Raw cow’s milk. Specifications” [14]. The mass fraction of fat was determined according to Federal standard 22760-77 “Milk products. Gravimetric method for determination of fat content” [15]. The mass fraction of protein was estimated by formal titration according to Federal standard 25179-2014 “Milk and milk products. Method for determination of protein” [16]. The casein was determined by refractometrically on the IRF-464 refractometer. Dry defatted milk residue (SNF) was estimated according to Federal standard R 54761-2011 “Milk and milk products. Methods for determination of dry skim dairy residue mass-fraction” [17]. The dry matter was estimated according to Federal standard R 54668-2011 “Milk and milk products. Methods for determination of moisture and dry substance mass fraction” [18]. The ash was made by salting in a muffle furnace and lactose content was determined according to Federal standard R 54667-2011 “Milk and milk products. Methods for determination of sugars mass fraction” [19]. Organic matter was estimated by calculation method; calcium content was determined according to Federal standard R 55331-2012 “Milk and milk products. Titrimetric method of calcium content determination” [20] and phosphorus content was determined according to Federal standard R 51473-99 “Milk. Spectrometric method for determination of total phosphorus content” [21]. The resulting basic digital material was processed biometrically using the MS Office software package.

### 3. Results and discussion

In this regard, studies have been carried out to study the effect of different fat concentrations in diets of highly productive cows on the manifestation of the potential of their dairy productivity, the results are given in table 1.

| Rates                        | Groups |
|------------------------------|--------|
|                              | I      | II     | III    |
| Number of cows, head         | 10     | 10     | 10     |
| Average daily water per cow, kg | 25.48  | 27.67  | 25.59  |
| Average fat content,%        | 3.28   | 3.64   | 3.40   |
| Amount of milk fat, kg       | 150.45 | 181.27 | 156.60 |
| Bow on a cow for the period of experience, kg | 4,587  | 4,980  | 4,606  |

If the fat content in the dry substance of the diet of animals of group II was 4.2%, their average daily weight during the experiment was 27.67 kg of milk, which exceeded the control by 8.60%, with an average fat content of 3.64%, or 0.36% more. At the same time, 393 kg of milk and 30.82 kg or 20.49% milk fat are obtained from each cow more than from cows of group I. The increase in the amount of milk fat is due to an increase in the productivity and fat content of cow milk. With an
increase in the fat level in the dry matter of the diet of cows of group III to 5.2%, a less significant increase in milk is noted – by 0.41% relative to control. Therefore, 19 kg of milk was obtained from them, with a higher fat content of 0.12%, this provided an additional yield of only 6.15 kg of milk fat.

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The effect of the studied dietary fat levels on the manifestation of the dairy productivity potential of cows of the compared groups is ambiguous depending on the month of their lactation (figures 1 and 2).

![Figure 1. Dynamics of average daily weight and weight fraction of fat in cow milk during the period of experience.](image1)

![Figure 2. Dynamics of average daily impact by months of experience, kg.](image2)

So, during the third month of the experience, at this level of fat, the average daily weight compared to group I increased by only 4.6%, the sixth – by 21.3% (P < 0.05), in the remaining months it turned out to be lower than in cows of the control group, respectively, on average for the experience – increased by only 0.43%. The data show that the best effect on the milk productivity of cows was the level of fat in the dry matter of the diet of 4.2%, it contributes to the improvement of the functional activity of the breast, which is expressed in the growth of breast productivity by 6.78%.

Simultaneously with the change in dairy productivity of cows, the increase in the level of fat in the diets of cows led to an improvement in the chemical composition of milk, which was more reflected in the content of the mass fraction of fat (table 2). Despite the insignificant effect of different levels of fat in cow diets on the weight fraction of total protein in milk, they nevertheless affected the change in the content of protein fractions and, in particular, the weight fraction of casein. Nevertheless, there was a certain tendency to reduce the protein content in milk when feeding diets, in the dry matter of which the fat level was 5.2%.

At the same time, at a level of 4.2% fat in the dry matter of diets of cows of group II, the amount of milk protein obtained from each cow during the period of experience increased by 11.5%, which happened mainly due to an increase in their dairy productivity. Increasing the level of fat in the dry matter of the diet from 3.2 to 4.2% contributed to an increase in casein content during the second month of the experience by 3.06, the third by 2.83, the fourth by 2.45, the fifth by 2.54, the sixth by 1.22 and the average per experience by 2.9%. An increase in the level of fat in the diet to 5.2%, on the
contrary, caused a decrease in the casein content in the milk of cows of group III, respectively, for months by 33.13; 3.93; 3.24; 0.41; 5.51; 6.94 and on average per experience – by 3.8%.

Analyzing the effect of different fat levels on the weight fraction of lactose in cow milk for all months of experience, it was noted that its different levels throughout the experience have a minor effect on this indicator. The lactose content at all dietary fat levels in the first month of the trial was almost the same. With an increase in the fat level in the dry matter of the diet from 3.2 to 4.2 and up to 5.2%, the same tendency was manifested to increase the lactose content on average over the experience by 2.5%. At the same time, it was more pronounced at the level of fat 4.2% during the second and fourth months (on 5.2 and 4.5%), and at its level equal to 5.2% – the fourth, fifth and sixth months (on 3.0-3.2%).

The content of dry defatted milk residue (SNF) was relatively constant throughout the run. Under the influence of an increase in the level of fat in diets, it changed insignificantly (table 2). With an increase in the fat level in the dry matter of the diets had a noticeably greater effect than the weight fraction of total protein, casein, lactose and SNF, mainly due to the increase in fat content in milk (table 2).

The change in the fat level in the dry matter of the diets did not have a significant effect on the weight fraction of lactose in cow milk for all periods of the test (table 3). Thus, the effect of the studied fat levels in diets is manifested differently, depending on the value of daily milk and the month of lactation.

Table 2. Change in the milk composition of cows during the experience period.

| Rates            | Groups | Months |  |  |  |  |  |  |
|------------------|--------|--------|---|---|---|---|---|---|
| Protein,%        | I      | 1      | 2.91±0.09 | 2.92±0.09 | 3.30±0.06 | 3.15±0.06 | 3.03±0.09 | 3.05±0.08 |
|                  | II     | 3.02±0.03 | 2.83±0.07 | 3.26±0.10 | 3.26±0.05 | 3.04±0.11 | 3.05±0.08 |
|                  | III    | 2.89±0.06 | 2.83±0.06 | 3.08±0.05 | 3.17±0.09 | 2.85±0.05 | 2.93±0.08 |
| Casein,%         | I      | 3.23±0.06 | 2.29±0.07 | 2.47±0.04 | 2.45±0.04 | 2.36±0.07 | 2.45±0.06 |
|                  | II     | 2.41±0.05 | 2.36±0.04 | 2.54±0.07 | 2.51±0.04 | 2.32±0.06 | 2.48±0.06 |
|                  | III    | 2.16±0.04 | 2.20±0.04 | 2.39±0.04 | 2.46±0.07 | 2.23±0.05 | 2.28±0.06 |
| Lactose,%        | I      | 4.80±0.06 | 4.85±0.07 | 4.88±0.04 | 4.69±0.06 | 4.91±0.06 | 4.94±0.06 |
|                  | II     | 4.89±0.03 | 5.10±0.02 | 4.95±0.03 | 4.90±0.03 | 4.99±0.04 | 4.98±0.03 |
|                  | III    | 4.88±0.04 | 5.03±0.04 | 4.93±0.05 | 4.83±0.03 | 5.05±0.04 | 5.10±0.04 |
| SNF,%            | I      | 8.37±0.02 | 8.44±0.03 | 8.89±0.08 | 8.58±0.07 | 8.60±0.03 | 8.67±0.02 |
|                  | II     | 8.60±0.05 | 8.62±0.05 | 8.93±0.06 | 8.87±0.02 | 8.73±0.08 | 8.79±0.06 |
|                  | III    | 8.55±0.08 | 8.55±0.08 | 8.70±0.09 | 8.78±0.03 | 8.59±0.07 | 8.53±0.09 |
| Dry matter,%     | I      | 11.63±0.12 | 11.91±0.18 | 12.14±0.12 | 11.88±0.11 | 12.02±0.17 | 11.64±0.13 |
|                  | II     | 11.85±0.09 | 12.61±0.12 | 12.63±0.09 | 12.65±0.09 | 12.32±0.09 | 12.32±0.09 |
|                  | III    | 11.77±0.10 | 12.05±0.11 | 12.27±0.15 | 12.21±0.17 | 12.11±0.19 | 11.78±0.16 |

Here and further in the text − P < 0.05; "− "– P < 0.01.

On average, for the experience, the content of the mass fraction of dry substances increased by 4.3%. Moreover, in the first half, the increase in their content in milk was small (by 2.0-3.9%), and in the second half it was more significant (by 6.3-5.0%) and reliable (P < 0.05). With an increase in the intake of fat into the body of cows, the content of the mass fraction of dry substances turned out to be almost the same as in control.

The change in the fat level in the dry matter of the diets did not have a significant effect on the mass fraction of ash in milk. There was a slight tendency to increase it at a fat level of 4.2% only during the first half of the test (table 3). Thus, the effect of the studied fat levels in diets is manifested differently, depending on the value of daily milk and the month of lactation.
### Table 3. Dynamics of ash content in milk by months of experience, %.

| Months of experience | Groups       |
|----------------------|--------------|
|                      | I            | II           | III          |
| 1                    | 0.67±0.09    | 0.69±0.04    | 0.68±0.06    |
| 2                    | 0.67±0.08    | 0.69±0.04    | 0.68±0.06    |
| 3                    | 0.71±0.06    | 0.70±0.04    | 0.69±0.07    |
| 4                    | 0.68±0.10    | 0.69±0.06    | 0.69±0.06    |
| 5                    | 0.69±0.10    | 0.70±0.07    | 0.69±0.06    |
| 6                    | 0.69±0.09    | 0.70±0.05    | 0.68±0.07    |

In order to assess the technological properties of milk and determine the possibility of its use in the production of dairy products, quantitative analysis was carried out and the ratio of components of its main composition was determined: the mass fraction of dry substances (fat, protein and carbohydrates) as a whole per experience (table 4).

### Table 4. Chemical composition and milk properties of cows, average per experience.

| Rates                              | Groups       |
|------------------------------------|--------------|
|                                    | I            | II           | III          |
| Mass fraction of fat, %            | 3.28±0.06    | 3.64±0.09**  | 3.40±0.08*   |
| Mass fraction of protein, %        | 3.08±0.06    | 3.08±0.06    | 2.96±0.05    |
| including casein, %                | 2.41±0.04    | 2.42±0.03*   | 2.29±0.04    |
| Mass fraction of lactose, %        | 4.84±0.03    | 4.98±0.02**  | 4.97±0.01    |
| Mass fraction of SNF, %            | 8.60±0.07    | 8.76±0.05**  | 8.62±0.04    |
| Mass fraction of organic matter, % | 11.20±0.07   | 11.70±0.12** | 11.33±0.08*  |
| Mass fraction of dry matter, %     | 11.88±0.08   | 12.40±0.12** | 12.02±0.08*  |
| Mass fraction of ash, %            | 0.68±0.06    | 0.70±0.02    | 0.69±0.02*   |
| Energy value, kcal                 | 629.92       | 668.94       | 641.57       |
| Milk consumption per 1 kg of oil (82%), kg | 25.00       | 22.53       | 24.12       |
| Milk consumption per 1 kg of cottage cheese (9%), kg | 8.66       | 9.41       | 8.70       |
| Fat : Protein                      | 1.07         | 1.18         | 1.15         |
| Fat : SNF                          | 0.38         | 0.42         | 0.40         |
| Protein : SNF                      | 0.36         | 0.35         | 0.34         |

The obtained data indicate that an increase in the level of fat in the dry matter of cows’ diets causes, through metabolic processes, a significant (P < 0.05-0.01) increase in the mass fraction of fat by 10.87%, casein – by 0.50%, lactose – by 2.93% and SNF – by 1.79%. With a further increase in the fat content in the diet of cows to 5.2 %, there is a higher content in the milk of the mass fraction of fat, dry substances, a decrease in total protein and casein, compared with the control. The content of lactose and SNF was relatively constant throughout the experiment.

Filling the lack of fat in the diets of group II cows has a more significant increase in the content of the mass fraction of dry substances in milk, which increases by 4.30%, mainly due to an increase in the mass fraction of fat in milk. With a greater intake of fat into the body of cows, the content of the mass fraction of dry substances in their milk changes insignificantly. At the same time, more significant changes in the properties of milk were noted in cows of group II. A noticeable increase in the milk of animals of group II of SNF by more than 1.5 g, per 1 kg, and an increase in the fat : SNF ratio by 10.53% (P < 0.01) compared to group I, will allow providing raw materials for the production
of a number of dairy products with a normalized SNF content (sour-milk, etc. products). The analysis of the protein: SNF ratio indicates that it is quite suitable for cheese and meets the required standards. Studies have shown that the milk of cows of the control group is the best for the production of protein-containing products. So, if the yield of protein per 100 g of fat from cow milk in the control group was 93.70 g, then in group II – 84.51 and in group III – 86.92 g, or 9.81 and 7.24 % less. Accordingly, in the fat: protein ratio, there was a significant increase in the proportion of fat relative to the protein content in the milk of cows of group II by 10.28% (P < 0.01) and by 7.48% (P < 0.05) – in group III, which can have a positive effect on the yield of dairy products in the production of butter and other high-fat dairy products.

4. Conclusion
Optimizing the level of fat in the feeding system of cows, contributes in their bodies, even in physiological busy periods of the production cycle, to an increase in the functional activity of the breast, which is expressed in an increase in breast productivity (by 6.78%), an improvement in the chemical composition and technological properties of milk. At the same time, reliable superiority in content of dry substances mass fraction in milk (by 4.30%), fat (P < 0.01), milk sugar (P < 0.01) and, accordingly, energy value (by 6.19%) is noted. The content of SNF (P < 0.01) significantly increases in milk and the ratio of fat to SNF (by 10.53%, P < 0.01) improves, this allows the raw material to produce a number of dairy products with a normalized SNF content, and the protein to SNF ratio corresponds to the norm and indicates that it is quite raw.

The results of the conducted research allowed to identify reserves for increasing the dairy productivity of cattle, and can be used to further increase the profitability of the industry. The obtained results on increasing the level of fat in diets are recommended for use in agricultural production as a reference material for organizing full-fledged feeding of cattle, for rational consumption of feed and more complete realization, on this basis, of potential opportunities to increase the productivity of animals.

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