Study of daily dynamics of cow milk quality indicators

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Abstract. The introduction of modern technological advances and principles of dairy herd management, which were developed in the member countries of the International Committee for Animal Registration (ICAR), contributed to the increase in milk productivity of pedigree cattle at the national level. The harmonization of national regulatory documents with the methodological principles developed in ICAR is a promising area. The study of new methodological approaches to the assessment of milk productivity shows that one of the differences in the assessment of daily milk yield, milk fat and protein yield is the different frequency of performing the corresponding work on the control milking of cows, the formation of a daily milk sample and the necessary mathematical calculations. In the in article various approaches to assessing the daily yield of the main dairy components during 2- and 3-fold milking of cows of a herd of pedigree black-and-white cattle are considered and coefficients are proposed for recalculating the daily content of fat and protein in milk. At the same time, the presented research results, in general, coincide with the main trends in the dynamics of milk fat and protein indicators shown in the ICAR recommendations.

1 Introduction

Dairy farming is one of the main suppliers of protein and fat of animal origin, belongs to the most important branch of agriculture and plays a primary role in ensuring adequate nutrition for the population. The introduction into the practice of Russian dairy cattle breeding of the basic methodological principles for recording the productive qualities of dairy cows, developed by the International Committee for Animal Registration (ICAR), is one of the recognized promising directions for the development of dairy farming [1]. Harmonization of national regulatory documents with international legislation will allow Russian livestock breeders to effectively sell pedigree products and genetic material on the world market, which will help to increase the efficiency of the industry and the attractiveness of the dairy business [2].

2 Materials and methods

Analysis of the ICAR methodological recommendations in the field of accounting for milk production of cows shows that in the practice of many countries of the world the so-called alternative accounting method (AT) is used, which involves a single sampling of milk during the day, followed by recalculation of the average daily content of milk fat and protein using special coefficients [3]. In the Russian practice of pedigree dairy cattle breeding, it is assumed that the traditional sampling of individual milk samples from each milking during the day is assumed, the compilation of an average milk sample, taking into account the milk yield at each milking, and, finally, testing for the content of fat and protein in the average milk sample. Of course, with all the scrupulousness and accuracy, such a technique can be applied mainly for small dairy herds, for example, 150-200 cows, however, in large farms (1-1.5 thousand cows and more), the implementation of this procedure seems to be problematic due to the high labor costs and disruption of technological processes in milk production [2]. At the same time, studies of many authors have shown that daily fluctuations in the content of milk fat and protein in raw milk have a certain biological pattern and can be predicted based on the calculated coefficients [4-10].

3 Results and discussion

The research was carried out with the aim of studying the dynamics of the content of the main dairy components (fat, protein) in raw milk obtained from black-and-white breeding cows with 2- and 3-fold milking. The work was carried out in the Stavropol Territory on the livestock of black-and-white cows with milk productivity, on average, of 8.2 thousand kg of milk per 1 cow per year. Based on the analysis of the materials of the primary zootechnical accounting, groups of cows were formed with 3-fold milking (1st, 2nd and 3rd milking, n = 798) and 2-fold milking (1st

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and 2nd milking, n = 477 cows). The interval between milking with 3-fold milking was
6-8 hours, with 2-fold milking, the interval was 10-12 hours. Individual samples of raw milk were taken together with specialists from breeding farms and a control-assistant service established at the Laboratory for selection control of milk quality of the Stavropol State Agrarian University. This type of work was carried out on a monthly basis, during the planned control milking of cows in breeding farms.

In accordance with the physiological state of the cows, in the first 100 days of lactation, cows were milked 3 times, and 2 times in the following days of lactation. The age of the cows was within 3-8 years, the calving period, as a rule, did not exceed 400 days. Individual milk samples, after taking them at each milking (1st, 2nd and 3rd milking), were cooled in the refrigeration compartment of specialized vehicles to a temperature of +6 °C. The average daily milk sample was made by mixing milk samples from 1st, 2nd and 3rd or 1st and 2nd milking, in proportion to the corresponding milk yield. To ensure biological safety, milk samples were mixed with the preservative Bronopol (2-bromo-2-nitropropane-1,3-diol, trade name Microtabs), the use of which does not affect the spectrometric parameters of milk and is approved by ICAR. Milk quality tests were carried out in the Laboratory for selection control of milk quality at the Stavropol State Agrarian University, accredited as per GOST ISO/IEC 17025-2019. At the same time, the determination of the content of milk fat and protein was carried out in accordance with GOST 32255-2013 "Milk and dairy products. Instrumental express method for determining the physical and chemical indicators of identification using an infrared analyzer". The work was carried out on the Milkoscan Mars instrument, manufactured by Foss, Denmark. Milk samples were investigated in 2 replicates, of which the average value was used, the research error did not exceed the instrument error (±1.2%). The mathematical processing of the primary data was carried out using the Excel spreadsheet processor. Changes were considered significant at $p < 0.05$.

The research results showed that the daily dynamics of milk fat and protein in cows with different frequency of milking is somewhat different (Table 1). There was no significant difference between the fat and protein content in average milk samples at 2 and 3 milking times ($p > 0.05$), since these differences were 0.01-0.03 (g 100 g^{-1}), which was at the level of the average statistical error (m). The volatility of changes in milk fat concentration during milking 1, 2 and 3 was at the level of 0.26-5.93%, with the most significant fluctuations observed between milking 1 and 2, where the difference between the absolute values of the fat content was 0.44 (g 100 g^{-1}) and was statistically significant ($p < 0.05$). Between milking 2 and 3, the differences in fat content were 0.20 (g 100 g^{-1}) and were also statistically significant ($p < 0.05$).

Table 1. Daily dynamics of milk fat and protein content at 2- and 3-fold milking of cows

Milking frequency	Results of monitoring fat and protein content in milk							
3x milking	Average indicators per day		I milking		II milking		III milking	
	Fat, g 100 g^{-1}	Protein, g 100 g^{-1}	Fat, g 100 g^{-1}	Protein, g 100 g^{-1}	Fat, g 100 g^{-1}	Protein, g 100 g^{-1}	Fat, g 100 g^{-1}	Protein, g 100 g^{-1}
	3.88 ± 0.03	3.27 ± 0.02	3.65± 0.02	3.25 ± 0.02	4.09 ± 0.03	3.29 ± 0.02	3.89 ± 0.03	3.27 ± 0.02
% of the average daily level	100.0	100.0	94.07	99.39	105.41	100.61	100.26	100.00
2x milking	3.85 ± 0.04	3.28 ± 0.03	3.73 ± 0.04	3.24 ± 0.04	-	-	4.04 ± 0.04	3.30 ± 0.04
% of the average daily level	100.0	100.0	96.88	98.78	-	-	104.94	100.61

Changes in the concentration of milk protein during 1, 2 and 3 milking were significantly less subject to fluctuations ($p > 0.05$), the differences were within 0.02-0.04 (g 100 g^{-1}), which was at the level of the average statistical error (m).

With 2-fold milking, in general, the volatility of the main dairy components was also lower in 1st milking, and higher in 2nd milking. Thus, the differences in the concentration of milk fat between 1st and 2nd milking were 0.31 (g 100 g^{-1}) and were statistically significant ($p < 0.05$). Fluctuations in milk protein concentration were at the level of 0.06 ($p < 0.05$), which was not statistically significant ($p > 0.05$).

The construction of graphical models displaying the daily dynamics of changes in the concentration of milk fat in milk has shown (Fig. 1, 2) that after 3-fold milking, in general, the trend in the indicator is linear, which is described by the following equation:

$$y=0.12x+3.6367 \quad (1),$$

where

y is the measure of milk fat content in raw milk (g 100 g^{-1})

x is the ordinal number of cow milking, for example 1, 2 or 3

At the same time, the dynamics of the milk fat content during milking 1, 2 and 3 is more accurately described by a mathematical equation, which has the character of an exponential approximation:

$$y=-0.32+1.4x+2.57 \quad (2),$$

where

y is the measure of milk fat content in raw milk (g 100 g^{-1})

x is the ordinal number of cow milking, for example 1, 2 or 3

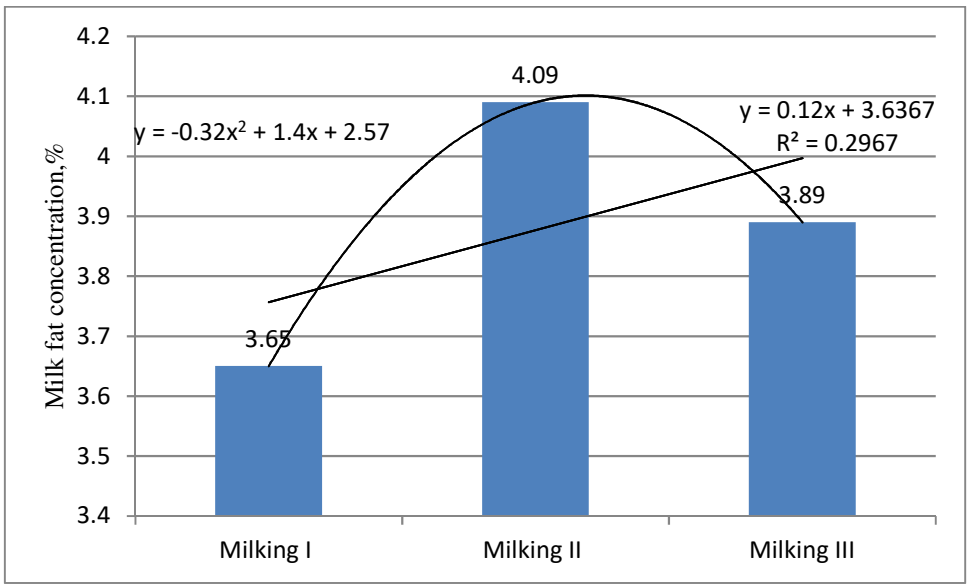

Fig. 1. Daily dynamics of fat in milk in 3-fold milking

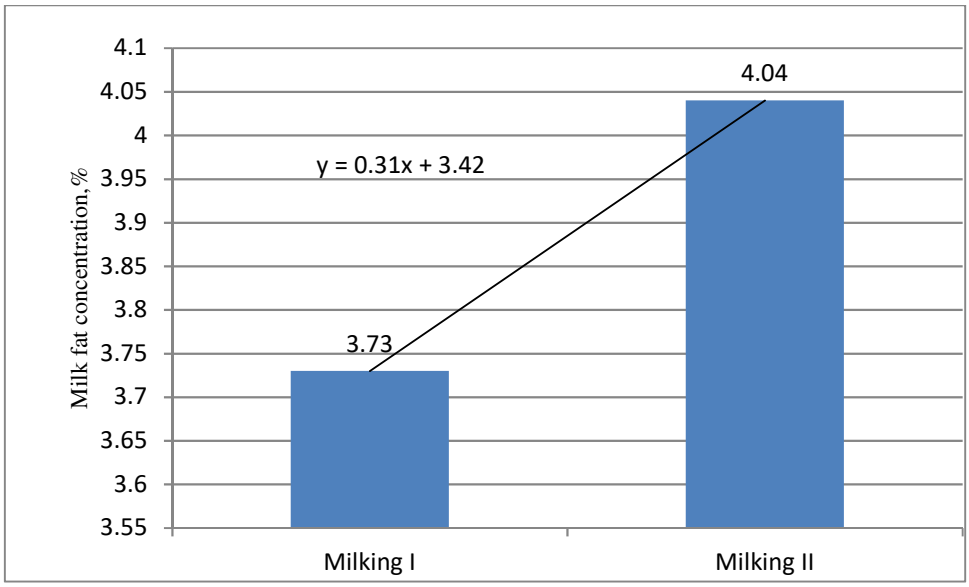

Fig. 2. Daily dynamics of fat in milk in 2-fold milking

Analysis of the graphical model of the dynamics of the fat content in raw milk with 2-fold milking shows (Fig. 2) that the nature of the relationship between the indicators has a linear form and is described by the following mathematical equation:

$$y=0.31x+3.42 \quad (3),$$

where

y is the measure of milk fat content in raw milk (g 100 g^{-1})

x is the ordinal number of cow milking, for example 1, 2 or 3

Analysis of graphical models of the dynamics of milk fat content during 2- and 3-fold milking shows that, in terms of mathematical nature, equations (1) and (3) have the form of a similar linear relationship, the angle of inclination between the straight line representing the change in the milk fat indicator and the axis "X", in both cases less (<) 90º, that is, this relationship has a positive character: the content of milk fat increases in the process of increasing the frequency of milking.

4 Discussion

The issue of simplifying the methods of accounting for milk production in cows has been discussed by many authors and brought up for discussion by ICAR. One of the first to study this issue was Delorenzo, M.A., and G.R. Wiggans (1986), who developed a coefficient for converting milk yield depending on the interval between milking, with a 12-hour interval this coefficient was 2.0, that is, the milk yield of cows would in this case be the same for milking 1 and II. With a reduction in the interval, between 9 and 12 hours, milk fat conversion factors were introduced, which were 0.919-0.997 (or 91.9-99.7%) of the daily fat content, which generally confirms the data obtained in our studies. For instance, with 3 milking, where with 1 milking, the milk fat content was 94.07% of the daily average (or 0.94, when the average daily fat is displayed as 1.0). With 2-fold milking, in our studies this coefficient was 0.968 (96.8%) for the fat content after 1 milking, which also coincides in trend with the studies carried out by ICAR specialists [3]. At the same time, foreign authors point out insignificant fluctuations in the content of milk protein at different intervals between milking, or the order of milking cows, as indicated in our research. These conclusions were also confirmed by us, since fluctuations in the protein content in milk samples obtained from different milking orders (1, 2 or 3) were at the level of a mathematical error and these fluctuations can be neglected. At the same time, the authors point out the need to develop national coefficients for recalculating the fat content in milk, and this conclusion is supported by ICAR.

Studies by Liu, Z., et al. (2000), also conducted within the framework of the developed ICAR recommendations, indicate that it is possible to use calculation methods for assessing the yield of fat content in milk at different, but stable, intervals between milking, expressed in numerical hourly terms: less 10 hours, as well as between 10- and 14-hour intervals with 2-fold milking [9]. At the same time, attention is also paid to lower fat values during morning milking, or 1 milking, which is also confirmed in our studies.

If it is possible to conduct automated accounting of milk production of cows, as shown in the studies of Lazenby, D., et al. (2002, 2004, 2006), it is possible to use multiple regression equations, since accounting is carried out for the maximum possible number of milkings [6-8]. In this case, the measuring equipment must be coordinated with ICAR. In our research, the accounting was carried out with the involvement of specialists in the breeding economy and control-assistant service, and the introduction of automated accounting methods is possible when planning further research.

Research by Peeters, R. and P. J. B. Galesloot (2002) draws attention to the timing of milk sampling or milking order for research and predicting daily milk fat content [10]. The authors draw attention to the fact that when developing a predictive coefficient, the interval between milkings should not be less than 4 hours, which also coincides with the intervals between milkings in our studies, where this indicator was 6-8 hours with 3 milking times, and 10- 12 hours with 2 milkings. At the same time, the authors point out a negative relationship between milk yield and the fat content in it, which may also be an explanation for the increase in the fat content in milk during milkings 2 and 3, as was the case in our studies.

5 Conclusions

1. The dynamics of the concentration of fat in milk at 2- and 3-fold milking, although they have a different mathematical form, have a general tendency: the indicators of fat in milk at 1 milking of cows, as a rule, are 6.19-11.34% lower than that for II and III milkings.
2. The dynamics of protein concentration in milk during 2- and 3-fold milking is similar to the dynamics of fat in milk, although the variability of protein concentration in milk during the day is much less pronounced than in fat and is 1.22-1.83%.

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