Application of the method of measuring the bioelectric potential to assess the suitability of raw milk for butter production

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Abstract. The issues of formation and development of the agri-food market and butter market, in particular, have a multi-faceted character. The growing globalization of the dairy market, as well as the increasing demands placed on milk producers, have led to the fact that those who want to win in the competition for the end user must ensure high quality milk throughout the production chain. Under the quality of milk raw materials for the production of butter one should understand first of all fat content and its fatty acid composition. However, the qualitative and quantitative indicators of raw milk in Russia today cannot ensure a high level of competitiveness of domestic agricultural producers on the world market. The productivity of cows in Russia is much lower than in Europe and the USA. As a result, an important place should be occupied by the issues of improving the quality of raw milk and its compliance with a set of indicators regulated by governing documentation. A certain role in regulating the quality of milk intended for the production of butter, can be played by superficially localized biologically active centres on the body of cows, which can be used to predict the technological characteristics of the produced milk by measuring the level of bioelectric potential and, therefore, to ensure the quality of the finished product already at the stage of forming batches of milk raw materials.

The market of the livestock products, including butter production, is an important component and an integral part of the agri-food market forming a relatively large segment of it, both in capacity and in the number of its participants. Therefore, improvement of both theoretical and practical issues of its formation and development is an urgent problem to be resolved.

Today, almost 35% of the world’s raw milk is used for the production of butter. Butter is included in the list of the most demanded food products. In terms of its production, Russia ranks the 5th place in the world, producing 269 thousand tons of the product per year. Consequently, manufacturers of butter, being in an ever-growing competition in the dairy market, should be focused not only on maximizing profits, but also on increasing the influence of paratypic indicators on milk quality, as factors that guarantee the profitability of dairy production as a whole.

Analysis of numerous sources of domestic and foreign literature showed that the priority factor affecting the quality of butter is the quality of the original raw milk [1-2]. Obtaining high-quality raw milk is a complex technological process associated with solving a complex of zootechnical, veterinary,
technological and economic issues. In most countries of the world with a developed dairy industry, governments seek to provide a basic level of support for dairy farms in order to guarantee a regular and stable supply of milk of guaranteed quality. In Russia, one of the priorities of the State program for regulating the markets of agricultural products, raw materials and food for 2013–2020 is to increase the competitiveness of raw milk, primarily in the domestic market in order to reduce import and increase export potential. Abroad, raw milk is divided into three classes by quality - quality class S (super), quality class 1 and quality class 2, while raw milk for the production of butter is not lower than class S [3-4].

In Russia, regardless of the use of potential raw milk, the generalized quality indicators of raw milk suitable for industrial processing are governed by GOST R 52054-2003 “Raw cow milk. Technical conditions”. At the same time, it should be noted that the standard, along with the establishment of sufficiently high quality criteria for high-grade milk, allows for a number of deviations from the requirements for milk of first grade or non-varietal milk. In addition, this regulatory document does not take into account specific indicators that are important in the technology of butter. So, for the production of good quality butter, it is advisable to use milk of cows that are characterized by high fat and milk content, with a large size of fat globules, with a high fat content, which will not only increase the degree of its use, but also reduce the consumption of raw milk for butter production [5]. For example, when the mass fraction of fat in milk is 3.5%, 24.4 tons of milk are consumed per 1 ton of unsalted traditional chemical composition, the degree of fat utilization is 96.83%; while increasing milk fat content to 4.5%, the milk consumption decreases to 18.91 tons, and the degree of fat utilization increases up to 97.18%. It should be noted that the fat content in milk may change under the influence of various physiological, zootecchnical, climatic and other factors. For example, fat formation significantly decreases in hot weather; at low, especially sub-zero temperatures and high air humidity the fat content in milk decreases by 0.2 - 0.3%, and sometimes by 0.5%.

A number of domestic and foreign scientists agree that the fat content of raw milk directly depends on the breed of cattle. The most common dairy breeds in Russia are Holstein-Friesian, black-and-white, black-and-white Holstein, Ayrshire, Angler, red Danish, red steppe, Simmental, Jersey [4, 6, 7, 8]. Different breeds of cows are characterized by different levels of milk production, non-identical chemical composition, physico-chemical and technological properties of milk. From the point of view of butter producers, it is economically and technologically expedient to use milk obtained from black- and-white Holsteinized cows.

According to statistics, the number of black-motley Holsteinized cows in the farms of the Oryol region is 53.6% of the total number of cows. According to the complex of physico-chemical and technological indicators, the milk of this breed has optimal quality indicators and technological properties. This breed of animals is most adapted to machine milking, has good acclimatization, high milk yield, milk production, high fat content in milk and its output for lactation [7-8]. It should be noted that the structure and quality of butter is influenced not only by the total fat content in milk, but also by the fatty acid indicator of milk (FAI), the value of which characterizes the characteristics of the chemical composition of milk fat and serves as a criterion for choosing the optimal technological regimes for the production of high-quality butter oils (consistency and heat resistance) [9].

If seasonal changes are not taken into account in the fatty acid composition of milk, butter may have a crumble and hard consistency in winter (due to the content of a large amount of saturated fatty acids in milk fat), and in the summer it may have a soft, greasy and non-thermostable texture and structure [9-10]. Studies of G V Tverdokhleb, M F Kurkova and V N Nesterov of the chemical composition and properties of milk fat, have shown that when producing butter with FAI value of more than 1.5, it is advisable to use the “winter” mode of temperature preparation of cream for churning, and for FAI less than 1.5 - 1.45 - “summer” one [5]. In this regard, the increased attention of butter producers, in our opinion, should be aimed at regulating the quality of milk carefully during the formation of batches of raw materials on farms.

In assessing the quality of incoming milk, from an economic point of view fat is a kind of “hard currency” used to derive the quantity of a product based on its quality (the so-called “Basic fat content”).
Consequently, the basic fat content is one of the important landmarks in the production of products. A certain role in assessing the quality of milk can be played by superficially localized biologically active centres (SLBAC) on the body of cows. By measuring the amount of bioelectric activity in certain SLBAC, it is possible to predict the technological characteristics of the milk produced.

Russian scientists A M Guskov, A V Mamayev, K A Leshchukov, L D Ilyushina, S S Stepanova, and A O Solovyeva proved the possibility of the relationship between the bioelectric potential (BP) with technological characteristics of milk fat (fat content, its fatty acid composition and size of fat globules) [4, 11]. However, genetic studies of the productive qualities of farm animals that are widely used in animal husbandry practice are of very limited use in regulating the quality of raw milk used for the production of dairy products and, in particular, for the production of butter. Therefore, to predict the quality of raw milk at the stage of forming batches of milk intended for the production of butter (in terms of fat content, size of fat globules, fatty acid composition), it may be promising to use the method of measuring the level of BP of SLBAC.

Studies of the relationship between the quality of milk raw materials for fat content and the functional activity of biologically active centres of cows were carried out on a dairy population of black-and-white Holsteinized cows of 1–5 lactation with an average milk yield of 4250 kg of milk per lactation (Orel region). The SLBAC BP was measured three times in each centre for three days using an ELAP type electrical measuring device (figure 1) according the A M Guskov and A A Mamayev method. The experimental group of animals with a low SLBAC BP value served as a control group. The total number of animals with a measured level of SLBAC BP was 150 heads. According to the results of measurements of SLBAC BP of cows, experimental groups of animals were formed by the method of pairs-analogues of 6 animals each with a low, medium and high value of the BP of SLBAC. The milk of experimental animals was analysed by the content of fat, its fatty acid composition and size of fat globules. The mass fraction of fat in milk was determined according to GOST 5867-90 “Milk and dairy products. Methods for the determination of fat, fatty acid composition of milk fat” by gas chromatography, the size of fat globules was measured by microscopy.

As a result of the experiment, it was found out that the animals of the first lactation are overwhelmingly characterized by high values of the SLBAC BP level (from 37.26 mkA to 42.73 mkA) and the mass fraction of fat (from 4.36% to 6.17%). With an increase in the level of SLBAC BP by 4.11 mkA in the second group of the first lactation cows, the mass fraction of fat in milk increased by 1.55%, respectively, compared with the control group (first). In animals of the second lactation, with an increase in the level of SLBAC BP by 6.88 and 19.37 mkA for the second and third groups of cows compared with the control group, respectively, an increase in the mass fraction of fat in milk by 0.33 and 0.75% was observed. For the second and third groups of third-lactation cows, with an increase in SLBAC BP level by 20.33 and 26.8 mkA, relative to the control group, the fat content in milk increased by 0.32 and
0.75%, respectively. The increase in the level of SLBAC BP of experimental animals of the fourth lactation compared with the control group was 10.31 for the second and 19.30 mkA for the third group of cows, the mass fraction of fat in milk increased by 0.34 and 0.81%, respectively. In the experimental groups of cows of the fifth lactation, with an increase in the SLBAC BP level compared with the control group by 8.25 mkA, the value of the mass fraction of fat in milk was higher by 0.53%.

A direct relationship was found out between the level of SLBAC BP, productivity and the mass fraction of milk fat raw materials of the cows participating in the experiment, which was characteristic of all the investigated lactation and subgroups of animals. It has been established that the increase in the productivity of cows occurs during four lactations, which is associated with the realization of the genetic potential. The level of SLBAC BP of younger cows turned out to be higher than the productivity of animals of the fifth lactation, which indicates high energy growth of young animals. Animals of the first lactation showed the highest productivity, the optimal ratio between the fat content, and the level of SLBAC BP. Fifth lactation cows have exhausted their reserves, and their productivity gradually decreased. Therefore, for further research, animals of 2nd, 3rd and 4th lactations were chosen as the more productive and numerous part of the herd.

When studying the fatty acid composition of milk lipids, it was found that the main mass fraction of fatty acids for all lactations is saturated fatty acids (SFA). Polyunsaturated fatty acids (PSFA) account for about 3% of the total fatty acids. Moreover, for all the studied groups of animals, with an increase in the SLBAC BP level of cows, a noticeable increase in the total content of PSFA was observed. In the milk of cows of the second lactation, the second and the third experimental groups with an increase in the level of SLBAC BP by 6.88 and 19.37 mkA, there was an increase in the content of PSFA, compared with the control group by 1.66 and 3.22%, respectively. The total amount of monounsaturated fatty acids (MSFA) decreased by 2.8 and 4.22%, the content of SFA by 0.74% in the second group; and increased by 0.21% in the third experimental group. Thus, a direct relationship has been established between the content of PSFA in milk fat and the level of SLBAC BP. For animals of the third lactation, a direct relationship was also traced between the content of SFA and the level of SLBAC BP. So, with an increase in the level of SLBAC BP in cows of the second and third experimental groups by 20.33 and 26.80 mkA, there was an increase in the SFA content by 0.82 and 0.92%, respectively.

Analysis of the total content of PSFA showed that in milk fat of cows of the second group of animals, the content of PSFA decreased by 0.19%, while in the third it slightly increased - by 0.76%, relative to the control group. When assessing the quality of milk based on the fatty acid composition of experimental fourth-lactation cows, it was found that the content of PSFA in the second and third subgroups increased by 0.66% and 1.61% compared to the control group of this lactation, while the increase in SLBAC BP by 10.31 and 19.30 mkA was also noted. But with an increase in the level of SLBAC BP from the first to the third subgroup, the total number of PSFA decreases by 0.44% and 1.12% from 23.69% in the control group. At the same time, the ratio of PSFA: FSA remained unchanged for all experimental groups of animals.

Thus, in the course of the experiment it was proven that a direct correlative relationship is observed between the level of the average SLBAC BP of cows, the fat content and the composition of fat (the content of PSFA in milk), and the inverse relationship between the total content of FSA and the level of SLBAC BP. It was also found that with an increase in the level of the average SLBAC BP of animals by 21.82 mkA, the fat content in milk increases by 1.2% and a significant increase in the content of PSFA is observed - by 2.2%.

The obtained patterns allowed to conclude that, first, for the production of butter of guaranteed quality, it is recommended to use raw milk, obtained from animals of 2-4 lactations (with a high value of SLBAC BP level), second, the method of measuring the level of bioelectric potential of SLBAC of cows can serve as one of the promising methods for assessing the technological suitability of milk in the face of the increased requirements for raw materials. Using the method of measuring the level of bioelectric potential of SLBAC at the stage of forming batches of raw milk in livestock farms, producers will be able to ensure the stability of milk supply of guaranteed quality and, therefore, partially stabilize the dairy market.
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