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RESULTS OF STUDIES ON JUSTIFICATION OF A DEVICE FOR PRODUCTION OF ECOLOGICALLY PURE CREAM

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Abstract

A device for the production of environmentally friendly cream is presented. A research methodology for substantiating optimal parameters is presented. The regression equation describing the productivity of the milk separation process was determined on the basis of the theory of probability and mathematical statistics. When solving it, the optimal design and kinematic parameters of the device for the production of environmentally friendly cream were identified. Its optimal constructive, kinematic and technological parameters were established, which were: the angle formed by the vector of the relative speed and the reverse direction of the vector of the portable speed for the end of the blades βl2 = - 1 deg; drum angular velocity ω = 1130 s^{-1}; milk temperature t = 44℃. The use of a scraper-cream separator will increase the separation productivity by 14% compared to the serially produced ESB-0.2.

***Key words**: cream, cream separator, drum, milk.*

INTRODUCTION

The main product of dairy cattle breeding of agricultural enterprises is whole milk, which, like its components (cream and skim milk), are raw materials for the production of various dairy products. For this reason, cream separators are used as part of most technological lines for the production of dairy products (Melken, 1991). Analysis of their designs allows us to consider one of the main disadvantages of uneven filling of interplate spaces with milk, which is the main reason for the decrease in their productivity. Therefore, the development of new designs of separators, cream separators, contributing to an increase in their productivity is relevant and is of great national economic importance (Yashin, 2014; Yashin, 2015).

MATERIALS AND METHODS

Milk fat is a valuable component of milk. Its mass fraction is about 30% of milk solids. The efficiency of separation depends on seasonal changes in the composition of milk, which directly depend on the nutritional value of feed, lactation period, etc. (Yashin, 2018-2020).

The efficiency of separation is directly influenced by the technological processes used in milk production, and such technological factors as: separation temperature, milk acidity, pollution milk by mechanical impurities, size and density of fat globules, mass fraction of fat in milk, pretreatment, density and viscosity of milk.

In addition, among the main design factors, one can single out: the number and size of inter-plate spaces, the shape of the plate, the direction of milk supply to the drum, the method of feeding milk into the stack of plates, the type of feeding device, etc. The angular velocity of the drum belongs to the kinematic parameter.

The optimum temperature of milk during separation is considered to be from 35 to 45°C. An increase in milk temperature during separation above the specified range contributes to the denaturation of milk proteins, that is, a decrease in size or complete destruction of fat globules. In this case, part of the small fat globules is carried away into the skim milk, while the mud space of the separator drum is quickly filled with the separator mucus formed. There is also frothing of cream and skim milk, which undoubtedly leads to deterioration in the release of fat. Strong foaming of the cream can negatively affect its further processing, since this leads to the formation of fine oil grains (fat lumps). At the same time, some of the small fat globules that still end up in the cream, for example, during the production of butter, are converted into buttermilk, which reduces the degree of use of milk fat.

When separating milk at a low temperature, energy is saved, the development of microorganisms is slowed down, the fat globules are less affected, therefore, in its structure, the cream is more stable and less susceptible to spoilage. But a significant disadvantage of separating cold milk is a decrease in the efficiency of separating fat, because the viscosity of chilled milk is higher than that of heated milk to a temperature of 35 to 45°C. Since with an increase in the viscosity of milk, the rate of floating of fat globules decreases and, consequently, the possibility of their release from milk.

The acidity of milk, according to GOST R 52054-2003, must be within the range from 16 to 21ºT. Increased acidity leads to partial coagulation of milk proteins. Protein flakes quickly fill the mud space of the separator drum, which entails the carryover of fat globules into skim milk and its contamination with mechanical impurities. To avoid this, with increased acidity of milk, it is necessary to stop the separator for washing more often or use self-emptying separators. To avoid a decrease in the separation efficiency, it is recommended to separate milk with acidity not higher than 20°T.

A constructive diagram of the cream separator (Savvin, 2014, RF patent, 2013) is proposed, the novelty of which is confirmed by the RF patent for invention No. 2539759.

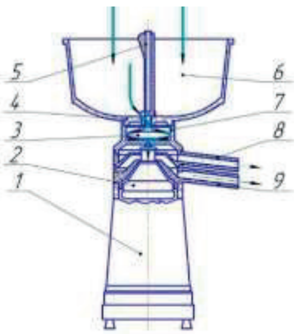

Figure 1. Structural diagram of the cream separator according to the RF patent for invention No. 2539759: 1 - case; 2 - drum, 3 - float; 4 - receiving and output device; 5 - tap; 6 - milk receiver, 7 - float chamber; 8 - cream pipe; 9 - a branch pipe of skim milk

The technical solution is to increase productivity with an admissible sharpness of degreasing, due to the fact that the supply channels of the tray holder of the drum of the separator-cream separator are made expanding towards the periphery and are located along an arc of a circle opposite to the direction of rotation of the drum.

The proposed separator-cream separator (Figure 1) includes a drive located in the housing 1, drum 2, inlet and outlet device 4, consisting of a tap 5 located in a milk receiver 6, a float chamber 7 with a float 3, a cream pipe 8 and a skim milk pipe 9.

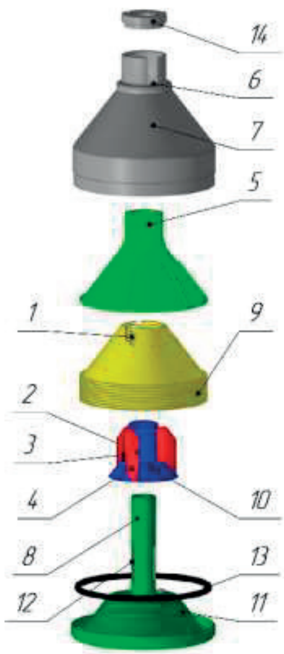

Figure 2. Drum of the separator-cream separator according toRF patent for invention No. 2539759: 1 - slot; 2 - supply channels; 3.4 - blades; 5 - a hole for the withdrawal of cream; 6 - opening for skim milk output; 7 - drum cover; 8 - central tube; 9 - a package of plates; 10 - blade plate holder; 11 - drum bottom; 12 - rectangular hole; 13 - a sealing ring; 14 - nut

The drum of the separator-cream separator (Figure 2) has a cover 7, a central tube 8 with a bottom 11, on which a hollow blade plate holder 10 is placed with a removable package of plates 9, in which rectangular holes 12 are made in the upper part along the height of the package of plates 9, communicating with supply channels 2, formed by blades 3 and 4.

Each plate 9, mounted on a blade plate holder 10, has slots 1 according to the number of supply channels 2 of the blade plate holder 10. Blades 3 and 4 of the plate holder 10 are made expanding towards the periphery and are located opposite to the direction of rotation of the drum along the arc of a circle. In the lid 3 of the drum there are holes 5 and 6 for the output of cream and skim milk, respectively.

RESULTS AND DISCUSSION

The volume of milk to be separated for each experiment was the same and made up the volume of the receiver equal to 5.5 liters.

The separation time was determined as the time from the beginning to the end of the outflow of separation products (skim milk and cream) from the branch pipes.

The milk used in the experimental studies corresponded to GOST R 52054-2003 "Natural cow's milk - raw material". The milk temperature was changed in a water bath. The fat content of the milk was 3.8%. If the requirements for milk in terms of fat content were not met, it was normalized by adding cream with a known fat content or skim milk.

The matrix and the results of the three-factor experiment are presented in Table 1. The results are defined as the average of triplicate

Table 1. Matrix and results of a three-factor experiment

Experience number	Angle between vector the relative velocity and the reverse direction of the vector carrying velocity at the end of the blades	Angular velocity drum	Milk temperature	Performance separator-cream separator m3 / s
	x1	x2	x3	Q
1	1	1	1	0.0000157
2	1	1	-1	0.0000093
3	1	-1	1	0.0000118
4	1	-1	-1	0.0000047
5	-1	1	1	0.0000153
6	-1	1	-1	0.0000093
7	-1	-1	1	0.0000118
8	-1	-1	-1	0.0000047
9	1	0	0	0.0000136
10	-1	0	0	0.0000147
11	0	1	0	0.0000150
12	0	-1	0	0.0000098
13	0	0	1	0.0000148
14	0	0	-1	0.0000108

As a result of the calculations, a two-dimensional section of the response surface was obtained (Figure 3) from the drum angular velocity x^2 and milk temperature x3 at the optimal value angles formed by the vector of the relative velocity and the reverse direction of the vector of the portable velocity for the end of the blades x1.

The obtained values of the factors indicate the finding of an extremum and obtaining the maximum productivity of the separator-cream separator with a paddle plate holder. According to the obtained values, interpolation was carried out for each factor according to Table 1.

Optimal values of factors in the decoded form were: the angle formed by the vector of the relative velocity and the reverse direction of the vector of the portable velocity for the end of the blades $\beta_{л2} = -1$hail; drum angular velocity $\omega = 1130$ from^{-1}; milk temperature $t = 44$ ºC. In this case, the performance of the separator-cream separator is $Q_{с.э.} = 0{,}0000165$ m^3/s.

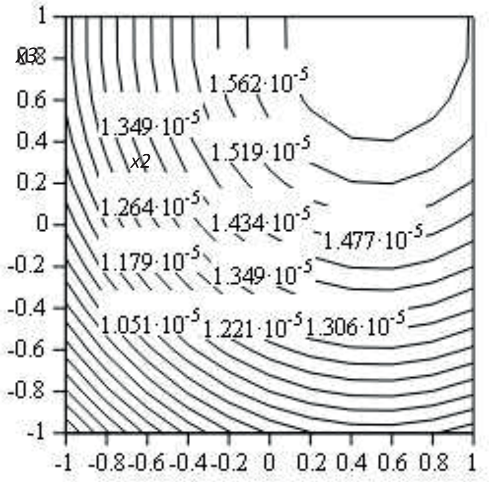

Figure 3. Two-dimensional cross-section of the surface of the response of the performance of the separator-cream separator from the angular speed of the drum x2 and milk temperature x3 at the optimal value of the angles formed by the vector of the relative speed and the reverse direction of the vector of the portable speed for the end of the blades x1

The density of the original milk during the research ranged from 1029 kg/m^3 to 1032 kg/m^3 with a fat content of 3.8%.

The cream obtained during research in industrial conditions (Figure 4) had a fat content of 18 to 41.5%. The severity of degreasing was%, which meets the requirements of GOST 18113-2013 (%).

Figure 4. Cream obtained during research in production conditions

The proportion of fat globules present in skim milk with a radius of $r = 0.5 \cdot 10^{-6}$ m (Figure 5) is at least 97%, which is in good agreement with the calculated value of the critical radius of the fat globule. At the same time, the number of fat globules in cream reaches 150 billion pieces (Figure 6) in 1 ml, and in skim milk 2 billion pcs.

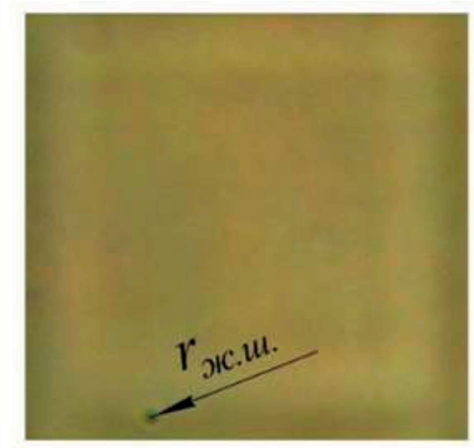

Figure 5. Fat ball in a small square of the grid of the Goryaev chamber when analyzing skim milk

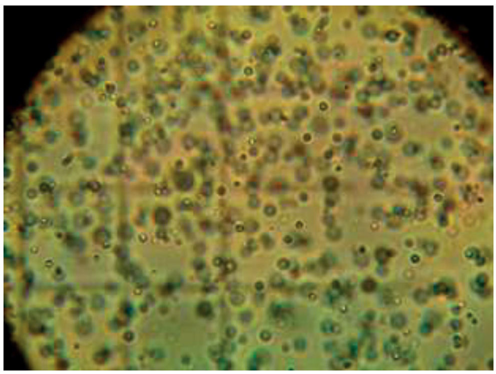

Figure 6. Fat globules in small squares of the grid of the Goryaev chamber when analyzing cream

To determine the mathematical dependence of the performance of the separator-cream separator with a paddle tray on the design, kinematic and technological parameters, and the matrix of experimental studies was decoded with subsequent processing by the Nonlinear Estimation module of the Statistica 6.0 program. The mathematical dependence of the performance of the separator-cream separator with a paddle plate holder in a decoded form is obtained:

$$Q = -0.0001153 - 0.0000000017 \cdot \beta l2 + 0.00000019 \cdot \omega + 0.00000104 \cdot t - - 0.0000000009 \cdot \beta l22 - 0.0000000001 \cdot \omega 2 - 0.000000012 \cdot t2... \quad (1)$$

With optimal design, kinematic and technological parameters, the dependence of the performance of the separator-cream separator with a paddle tray-holder on the number of inter-tray spaces was established when processed by the Non-linear Estimation module of the Statistica 6.0 program. As a result, a mathematical dependence of the performance of the separator-cream separator with a paddle plate-holder on the number of inter-plate spaces was obtained:

$$Q_C = 0{,}000001342 \cdot z \quad (2)$$

The multiple correlation coefficient is R = 0.99, and the F-test = 0.99, which shows the degree of density (spread) of the experimental and calculated values. Consequently, the obtained mathematical dependence (2) adequately describes the results. Thus, the productivity of each individual interplate space is a constant value, which confirms the uniformity of filling the interplate spaces with milk.
The multiple correlation coefficient is R = 0.99 and the F-test = 0.97. Consequently, the resulting model adequately describes the results of the experiments.
The divergence of the performance values of the separator-cream separator with a paddle plate holder obtained from the results of a three-factor experiment with optimal values of design, kinematic and technological parameters $Q_{с.э.} = 0{,}0000165$ m^3/s, as well as according to the theoretical relationship $Q_C = 0{,}0000159$ m^3/does not exceed 4%.

CONCLUSIONS

A prototype of a separator-cream separator with a paddle tray has been developed and manufactured, and the optimal values of the angles formed by the vector of the relative velocity and the reverse direction of the vector of the portable speed for the end of the blades have been determined −1o; drum angular velocity 1130 s^{-one}; milk temperature 44ºC at performance of the separator-cream separator with paddle plate holder 0.0000165 m^3/s. The productivity of each individual interplate space has been established, which is a constant value, which confirms the uniformity of filling the interplate spaces with milk.

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