Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 1, 2020
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

RESULTS OF RESEARCH ON JUSTIFICATION THE DEVICE FOR PRODUCING ECOLOGICALLY PURE BUTTER

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Abstract

A device for the production of environmentally friendly butter with a rotary-blade working body is presented. The research technique for substantiating the optimal parameters is presented. Based on the theory of probability and mathematical statistics, the regression equation describing the energy intensity of the process of whipping butter is determined. When solving it, the optimal design and kinematic parameters of the device for the production of environmentally friendly butter were revealed with a churning capacity of 13.4 kg/h, a butter yield of 59.5% and a fat loss of less than 0.4%. The rotational speed of the rotor-blade working body is np=422 min^{-1}*; the number of blades of the rotor-blade working body zp=3; the capacity filling factor φzap=0.57. Evaluation of the economic efficiency of introducing a device for the production of environmental friendly butter will reduce the energy intensity of churning by 24% compared with the mass-produced EMB-01 Salyut.*

Key words: *butter, environmental friendly, rotary-blade working body.*

INTRODUCTION

At the present stage of the production of butter, the question of preserving traditional technologies that allow the production of various types of butter from cow's milk, as well as the use of innovative technologies that contribute to the intensification of the churning process, remains relevant for the butter industry. An important factor for obtaining a high-quality product is the use of modern oil-smelting equipment, which allows to obtain the maximum amount of the best product with the minimum energy intensity of whipping. As a result of the analysis of various designs of oil manufacturers from domestic to imported, it could be concluded that the most promising and productive are devices with non-moving horizontally mounted tanks and rotating working bodies of various designs. Their use leads to greater turbulization of the entire cream content, a decrease in stagnant zones and an increase in productivity.

In this case, the most promising are the mechanisms of knocking down with horizontally located blades, since during the churning process they provide a more thorough and intensive mixing of the cream.

MATERIALS AND METHODS

A batch-type oil producer with a rotor-blade working body (Figure 1) consists of a cylindrical horizontally located container 1, mounted on supports 2 and a rotor-blade working body 3, located with an eccentric relative to the axis of the tank (Yashin et al., 2018).

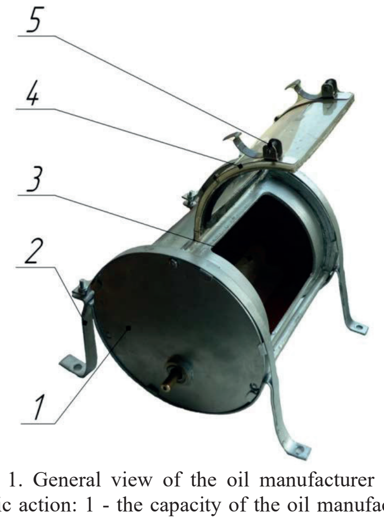

Figure 1. General view of the oil manufacturer of the periodic action: 1 - the capacity of the oil manufacturer; 2 - supports; 3 - rotor-blade working body; 4 - loading hatch; 5 – clamp

A loading hatch 4 is installed in the tank, made of transparent material (plexiglass) in order to control the churning process, as well as to supply cream before churning. The loading hatch is pressed against the container with clamps 5.

The degree of filling the tank during churning was 40-80% based on the fact that when filling the working tank with more than 80%, the cream churning process slows down and the waste of fat to buttermilk increases due to a decrease in the boundary surface of the air cream, and when filling the tank below 40 % of its volume of cream is sprayed with a rotary-blade working body onto the walls of the container and the churning process is not carried out.

The rotational speed of the rotor-blade working body was chosen at 200 min^{-1} and 600 min^{-1} based on the fact that the wave motion of the cream begins at 200 min^{-1} and ends at 600 min^{-1}. At a rotation frequency of more than 600 min^{-1}, in addition to the wave motion along the profile of the rotor-blade working body, its blades begin to be ejected by its blades (Yashin et al., 2018).

Based on the fact that the degree of collapsing and reduction of stagnant zones depends on the location of the rotor-blade working body, the eccentricity of the rotor-blade working body relative to the center of the tank was chosen to be 21.5 and 43 mm, respectively (Yashin, Polivyannii et al., 2018; Polivyannii et al., 2017).

The principle of operation is the following. Before starting work, the installation is connected to the network via a switch.

Through the loading hatch, the tank 3 is filled with cream to 40-80% of its content. After that, the loading hatch is closed with the help of clamps. The churning mechanism 3 is brought into rotation by an electric motor, while setting the necessary rotational frequency with a frequency converter. When the rotary-blade working body 3 rotates, the cream stream is turbulized. As a result of the action of the blades, two wave fronts are formed. The front of the wave displaces the cream into their main stream, and the back pumps them out, which leads to the appearance of a “traveling wave”, which makes the cream layer move along the generatrix of the rotor. With an increase in the peripheral speed of the cream, the resistance to mixing decreases and when the equality of the peripheral speed of the traveling wave and the cream is achieved, it decreases significantly, which leads to a decrease in the resistance to rotation of the churning mechanism (Yashin et al., 2018).

RESULTS AND DISCUSSIONS

The matrix of the three-factor experiment and its results are presented in Table 1.

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

№	x_1	x_2	x_3	$Y, \frac{W*h}{butter,kg}$
1	1	1	1	14.16
2	1	1	-1	11.45
3	1	-1	1	14.87
4	1	-1	-1	17.16
5	-1	1	1	16.06
6	-1	1	-1	12.2
7	-1	-1	1	15.16
8	-1	-1	-1	12.56
9	1	0	0	10.42
10	-1	0	0	13.11
11	0	1	0	10.41
12	0	-1	0	12.78
13	0	0	1	11.89
14	0	0	-1	9.53
15	0	0	0	7.36

Table 2. Significance Levels of Factors on Churning Energy Intensity

	a0	a1	a2	a3	a12	a13	a23	a11	a22	a33	a1122
Estimate	7.36	-0.103	-0.825	0.924	-0.87	-0.755	0.7825	4.405	4.235	3.35	-5.148

The results of experimental studies were processed by the Multiple Regression module of the Statistica 6.0 program.

As a result of processing the experimental data, a second-order regression equation is obtained that describes the dependence of the energy intensity of the whipping (W in h/kg) on the selected factors $E = f\,(z_л\,,\cdot n_p,\ \varphi_{зап})$ in encoded form:

$$E = 7,36 - 0,103000 \cdot x_1 - 0,825000 \cdot x_2 + 0,924000 \cdot x_3 - 0,870000 \cdot x_1 \cdot x_2 - 0,755000\, x_1 \cdot x_3 + 0,782500 \cdot x_2 \cdot x_3 + 4,405 \cdot x_1^2 + 4,235 \cdot x_2^2 + 3,35 \cdot x_3^2 - 5,148 \cdot x_1^2 \cdot x_2^2 \quad (1)$$

The decoded regression equation (1) takes the form:

$$E = 17,67 - 0,193 \cdot z_л + 0,026 \cdot n_p - 15,205 \cdot \varphi_{зап} - 0,028\, z_л \cdot n_р - 3,419\, z_л \cdot \varphi_{зап} + 0,021 \cdot n_p \cdot \varphi_{зап} + 1,286 \cdot z_л^2 + 0,000003 \cdot n_p^2 + 18,193 \cdot \varphi_{зап}2 + 0,000005 \cdot z_л^2 \cdot n_p^2 \quad (2)$$

The adequacy of the obtained regression equations (1) and (2) is confirmed by the multiple correlation coefficient $R_k = 0.97$ and the convergence of the calculated and experimental data *F-мест* = 0.968.

To determine the optimal constructive and kinematic parameters of the periodic oil producer with a rotor-blade working body, the extremum was determined when solving equation (1).

In this case, the optimal values of the factors in encoded form were: x1 = 0; x2 = 0.112; x3 = - 0.15. The obtained two-dimensional cross-sections (Figures 2, 3, 4) indicate the location of the extremum and obtaining the minimum energy capacity of knocking down the oil producer of periodic action with a rotor-blade working body.

The obtained values were interpolated for each factor according to the table. In decoded form, the optimal values of the factors are: the number of blades of the rotor-blade working body $z_р$ = 3; rotor-blade working body rotation frequency $n_р$ = 422 min^{-1}; capacity factor $\varphi_{зап}$ = 0.57. The energy intensity of the knocking down of the periodic manufacturer of oil with a rotor-blade working body is *E* = 7.24 W·h/kg (Yashin et al., 2018).

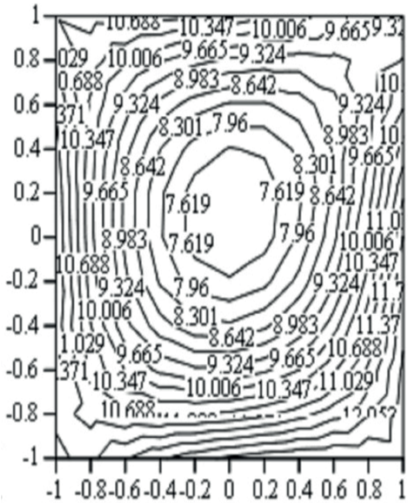

Figure 2. Two-dimensional sections of the response surface, characterizing dependence of the energy intensity of whipping butter on the number of rotor blades (pcs) and rotor speed (min^{-1})

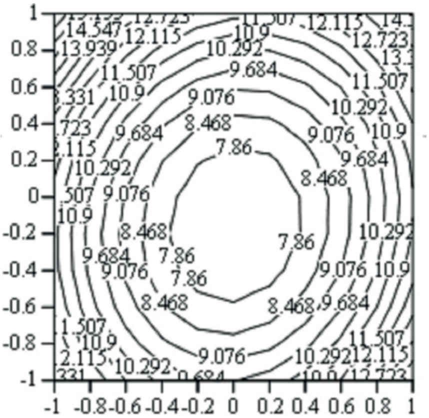

Figure 3. Two-dimensional sections of the response surface, characterizing dependence of the energy intensity of whipping butter on: the number of rotor blades (pcs) and the capacity filling factor

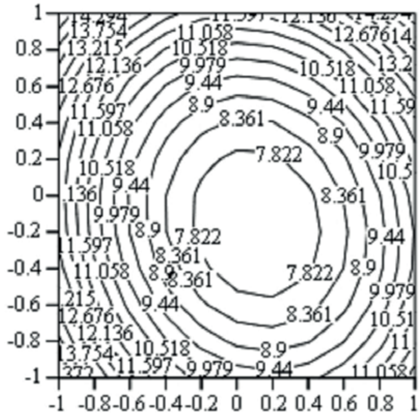

Figure 4. Two-dimensional sections of the response surface characterizing dependence of the energy intensity of whipping butter on rotor speed (min^{-1}) and fill factor capacities

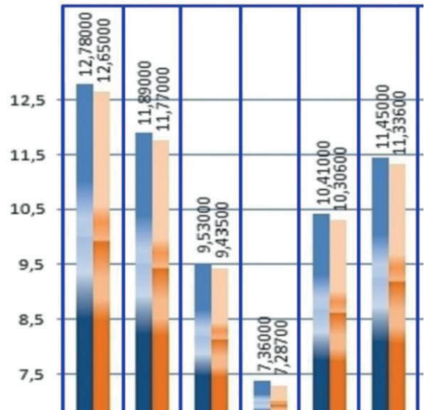

Figure 5. The dependence of the energy intensity of the churning oil manufacturer periodic action on the rotational speed of the rotor-blade working body (left columns according to the regression equation (2), right columns according to the theoretical dependence

The dependences of the energy intensity of knocking down the oil producer of periodic action on the rotational speed of the rotor-blade working body, determined by the regression equation (2) and theoretical dependence, are shown in Figure 5 (Yashin et al., 2018). The proposed oil producer can be used both at enterprises with a large production capacity, and in farms with a small production program.

With small dimensions and weight, simplicity of the device of the oil manufacturer and its reliability in operation, it will be in demand especially for small volumes of production.

CONCLUSIONS

The analysis of theoretical and experimental values established sufficient convergence

F-test = 0.982, and the spread of values does not exceed 1.02%. As a result, it could be argued that the application of theoretical dependence is fair. An experimental sample of a batch-type oil manufacturer with a rotor-blade working body was developed and laboratory studies were carried out, after analysis of which the optimal design and kinematic parameters of the oil manufacturer were identified with a mass production of 13.4 kg/h, an oil yield of 59.5% and a waste of fat in buttermilk not more than 0.4%.

REFERENCES

Polovyannii, Y.V., Parfenov, V.S., Chugunov, V.A., Yashin, A.V. (2017). *Patent* 2624925, The Russian Federation, МПК A 01J15/00. Butter maker, № 2016104701; Published 11.07.2017, Bulletin № 20.

Yashin, A.V., Polovyannii, Y.V., Kuderkin, N.S. (2018). *Patent* 182020, The Russian Federation, МПК A 01J15/02, A 01J17/00. Oil press, № 2017145823; Published 31.07.2018, Bulletin № 22.

Yashin, A.V., Polovyannii, Y.V., Mishanin, A.L., Horev, P.N. (2018). Determination of power on the drive of an oil manufacturer with a flexible vibrodrive. *Izvestiya of Samara State Agricultural Academy*, *4*. 92–101.