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RESULTS OF OIL PRESS STUDIES FOR THE PRODUCTION OF ECOLOGICALLY CLEAN BUTTER

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Abstract

Introduced an oil press for the production of environmentally friendly butter. A research methodology for substantiating optimal parameters is presented. Based on the theory of probability and mathematical statistics, the regression equation describing the complexity of the production of environmentally friendly butter was determined. When solving it, the optimal design and kinematic parameters of the oil press. Its optimal parameters were established, which were: the value of the angular velocity of the screw 6.3 s^{-1}, the change in the pitch of the screw winding in the zones of 17.7 mm and the utilization factor of the throughput of the loading zone of the screw 0.6. At the same time, the technological labor intensity of the oil press per cycle was 18.385 man-hours. Research in production conditions has confirmed the correctness of finding the optimal values for the parameters of the oil press. The resulting technological labor intensity per cycle was 18.4 man-hours. with a productivity of 3.85 kg/h, which confirms the convergence of research results in laboratory and production conditions. The mass fraction of moisture in the original oil grain was 24-27.8%, and butter - less than 20%, but more than 16%, which meets all the requirements for peasant unsalted sweet cream butter.

Key words: *auger, butter, butter grain, casing, environmentally friendly, oil press.*

INTRODUCTION

The main task of the country's agriculture and dairy farming in particular, there is a further increase in the production of dairy products necessary for the population, on the basis of reducing their cost and creating generally available solutions for the mechanization of processing dairy products with minimized labor costs (Yashin et al., 2018).

The most important parameter that determines the labor intensity of devices for the production of butter and energy consumption for compaction is the speed of rolling. Back pressure in screw machines with an open chamber is created as a result of friction of the compressed mass against the channel walls. In presses with a closed chamber, the material fed into the seal channel is compressed between the stamp and the stop.

The processed material is pushed out of the chamber by the subsequent stroke of the stamp with the retracted stop. It is obvious that the energy intensity of the process is much lower here than when pressing in an open chamber, however, presses with spiral working bodies received the greatest distribution due to their cheapness, durability, simplicity and low energy consumption, in contrast to roller ones.

According to the operating mode, oil presses are also divided into three groups, differing in the number of working bodies.

A single-screw press in comparison with a multi-screw press has a number of advantages: higher productivity, reduced load on bearings, transmissions and drives, greater reliability in operation, low cost, proven technology, simple design.

In a single-screw press, the entire screw channel is filled with material: the conditions for forming are more favorable than in a two-screw analogue.

By the location of the working body, oil presses are also divided into three groups, which differ in the position and direction of the working bodies in space, the unconditional advantage of installations with an inclined arrangement of the working body is that, unlike horizontal presses, there is no partial mixing of the processed material -la with the removed liquid, which indicates the expediency of using inclined presses due to the absence of partial mixing of the squeezed material with the removed liquid (oil grain and a layer of butter with the removed buttermilk).

In the direction of winding the auger working body, oil presses come with both left and right winding, this, of course, an important criterion plays a major role when choosing a working body during the assembly of the machine, since the direction of winding will depend on the direction supply and processing of material (Yashin, 2021).
By the type of the screw surface of the working body, oil presses are also divided into three groups, depending on the geometric parameters of the screw winding.
Existing, serially produced devices for the manufacture and processing of butter are focused on high throughput and their use when processing small batches of dairy products in conditions of farms with a small production program is not advisable. Therefore, promising devices are those with a relatively low power consumption, with minimized labor intensity, highly economical, easy to operate and maintain, capable of performing several technological operations, and most importantly, having a low cost (Yashin, 2020).
The production of butter is carried out mainly according to two technologies: conversion of high-fat cream and churning (discontinuous and continuous), the use of which is determined by the volume of production and grade of oil (Yashin et al., 2019; Melken, 1991).
Based on the foregoing, it can be concluded that the work devoted to the development and aimed at finding and determining the optimal parameters of the oil press, which ensures a decrease in the labor intensity of the manufacture of butter, while observing quality indicators, are relevant and practically significant for agricultural production.

MATERIALS AND METHODS

The oil press (Figure 1) consists of three main parts [PF patent, 2013, 2017, 2018). The first part is recording and includes a laptop ASUS X540S 2 and an electronic multimeter MAS-345 5.
The second part is a control one and has an IEK 7 automatic switch and a Vesper E2-8300 6 speed converter. The third part is an executive part and contains an AIR71A2SU 3 electric motor, an SG80N 4 worm gearbox parts.

The oil press works as follows (Figure 2). The oil grain to be processed into butter is loaded into the hopper 5, while the shutter 6 is in the closed position. Then the electric motor 2 is started, transmitting the torque through the gearbox 3 and the clutch 4 to the screw shaft 8.

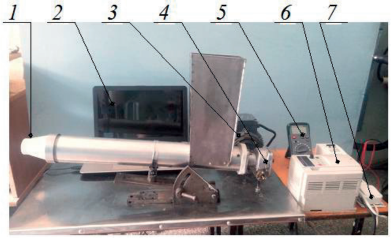

Figure 1. General view of the laboratory installation of the oil press: 1 - model of the oil press; 2 - ASUS X540S laptop; 3 - AIR71A2SU electric motor; 4 - worm gearbox SG80H; 5 - electronic multimeter MAS-345; 6 - frequency converter Vesper E2-8300; 7 - automatic circuit breaker IEK

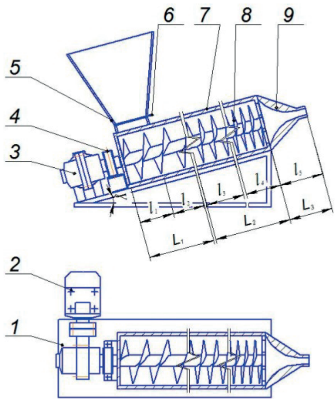

Figure 2. Structural diagram of the oil press: 1 - frame; 2 - electric motor; 3 - reducer; 4 - clutch; 5 - loading hopper; 6 - damper; 7 - casing; 8 - auger; 9 - forming nozzle; γ - auger ascent angle; l_1 - loading area; l_2 - primary mixing zone; l_3 - primary compression zone; l_4 - secondary compression zone; l_5 - forming zone; L_1 - section for loading and separating excess moisture; L_2 - compression section; L_3 - forming section

When the nominal angular velocity is reached, the shutter 6 opens and the oil grain from the loading hopper 5, enters the loading zone of the oil press auger and moves to the next zone with the separation of excess moisture and its removal from the hole in the casing 7, where mixing and texturing of the oil grain occurs.

Then the processed product, passing through the compression zones, undergoes compaction and plasticization with mixing. Towards the end of the secondary compression zone, the processed product acquires a continuous homogeneous structure, which is facilitated by the ongoing processes of intensified compression and the stepwise execution of the screw. From the secondary compression zone, the compressed mass leaves the screw and enters the molding zone in the form of a swirling flow, which is exposed to the forming nozzle 9 with a profile.
When using a polymer sleeve for food products on a forming nozzle, it is possible to pack and pack butter, which will reduce the labor intensity of making butter from the resulting oil grain when churning, since this oil press allows you to perform several technological operations - processing of oil grains and packaging.
The three-factor experiment was based on D - the optimal plan, carried out in order to obtain regression equations for the process of making butter and determine the optimal values of the parameters of the oil press.
When carrying out a three-factor experiment, the evaluation criterion was the labor intensity of processing oil grain, and the moisture content and consistency were used as limitations.
To implement a three-factor experiment, in order to give the factor x2 (change of the screw pitch in sections) an intermediate (zero) value of the level of variation, a set of replaceable screws with the first pitch t = 0.06 m was made (Figure 3).

Figure 3. A set of augers with a variable pitch in the sections: 1 - a screw with a pitch change of 20 mm, at t0 = 0.06 m; 2 - auger with a step change of 15 mm, at t0 = 0.06 m; 3 - auger with a step change of 10 mm, at t0 = 0.06 m

Mathematical processing of the results was carried out using the computer programs Statistica 6.0, MathCAD 2001RUS, Microsoft Excel on a PC. In this case, the statistical processing of the results of the three-factor experiment was carried out first by the Multiple Regression module of the Statistica 6.0 program when attempting to describe it by a linear model and by the Nonlinear Estimation module of the Statistica 6.0 program when describing by higher-order models. When determining the adequacy of the model (by multiple correlation coefficient and F-test), we used the data of statistical processing and the Microsoft Excel program. When determining the optimal values of the factors, the program MathCAD 2001 RUS was used, for which its listing was developed for solving the problem of finding the extremum of a function (an adequate model of the regression equation).

RESULTS AND DISCUSSION

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	ω	Changing the pitch of the auger in sections	Throughput ratio	Labor intensity, man-h.
	x_1	x_2	x_3	T
1	1	1	1	40.74
2	1	1	-1	46.34
3	1	-1	1	43.83
4	1	-1	-1	48.58
5	-1	1	1	46.51
6	-1	1	-1	41.72
7	-1	-1	-1	59.53
8	-1	-1	-1	53.92
9	1	0	0	26.77
10	-1	0	0	32.22
11	0	1	0	20.63
12	0	-1	0	28.27
12	0	0	1	33.95
14	0	0	-1	30.1

The volume of oil grain to be processed for each experiment was the same and amounted to the volume of the loading hopper equal to 3.85 liters. The processing time was defined as the time from the opening of the feed hopper flap to the end of the outflow of butter from the hole of the forming nozzle.
During the experiments, butter grains were produced from cream of constant fat content of 38%, temperature - 10°C, is corresponding to the requirements of GOST R 53435-2009 “Raw cream. Technical conditions”.

Before each experiment, the oil press was disassembled and assembled with washing of the parts in contact with oil grain and butter. For each experiment, according to the research matrix (Table 1), the adjustment was made to the specified parameters.

Analyzing the obtained values of Table 2, it can be noted that, with the exclusion of factors and their interactions x_2, $x_2 \cdot x_3$ from the considered dependence, the values of the regression coefficients for the factors and their interactions did not change in comparison with the results of table 4.3, in contrast to the Student's criteria for them. However, the tabular values of the Student's test at a confidence level of P = 0.95, t (6) = 2.447, which is lower than the obtained values for all factors and their interactions, which means they are statistically significant.

Table 2. Levels of significance of factors (parameters) on the labor intensity of making butter for the second order dependence (refined)

Factors	Coefficient regressions		Standard error	Student's criterion	Error severity level
	a		*Std. Err.*	*t (6)*	*p-level*
	a0	19.16188	0.725047	26.4284	0.000000
x_1	a1	-2.76400	0.359724	-7.6837	0.000254
x_2	a2	-3.81900	0.359724	-10.6165	0.000041
$x_1 \cdot x_2$	a12	2.48625	0.402184	6.1819	0.000824
$x_1 \cdot x_3$	a13	-2.59375	0.402184	-6.4492	0.000658
x_1^2	a11	10.33312	0.725047	14.2517	0.000007
x_2^2	a22	5.28812	0.725047	7.2935	0.000339
x_3^2	a33	12.86313	0.725047	17.7411	0.000002

According to the data obtained in Table 2, the mathematical dependence of the labor intensity of making butter of the parameters of an oil press finally in coded form will take the form:

$$Tts = 19.16188 - 2.76400\,x1 - 3.81900\,x2 + 2.48625\,x1\,x2 - 2.59375\,x1\,x3 + 10.33312x_1^2 + 5.28812x_2^2 + 12.86313x_3^2 \quad (1)$$

Moreover, the multiple correlation coefficient R = 0.995, and the F-test = 0.893. Consequently, the obtained mathematical relationship (1) adequately describes the results of the experiments.

To determine the optimal parameters of the oil press for the laboriousness of making butter, the data obtained were processed in the MathCAD program to find the extremum of the dependence (1). Why the obtained mathematical dependence (1) was differentiated by the variables x_1, x_2, x_3 and got a system of equations:

$$\begin{cases} -2,764 + 2,486 \cdot x_2 - 2,594 \cdot x_2 + 20,666 \cdot x_1 = 0 \\ -3,819 + 2,486 \cdot x_1 + 10,576 \cdot x_2 = 0 \\ -2,594 \cdot x_1 + 25,726 \cdot x_3 = 0 \end{cases} \quad (2)$$

By solving the system of equations (2), the optimal values of the parameters of the oil press in coded form were determined:

$$\begin{cases} x_1 = 0,094 \\ x_2 = 0,339 \;.. \\ x_3 = 0,0095 \end{cases} \quad (3)$$

With optimal values of the parameters of the oil press, the labor intensity of making butter (1) would be:

$$T_ц^{min} = 19,162 - 2,764 \cdot (x_1 = 0,094) - 3,819 \cdot (x_3 = 0,339) + 10,333 \cdot (x_1 = 0,094)^2 + $$
$$+ 2,486 \cdot (x_1 = 0,094) \cdot (x_2 = 0,339) - 2,594 \cdot (x_1 = 0,094) \cdot (x_3 = 0,0095) + + 5,288 \cdot (x_2 = 0,339)^2 + 12,863 \cdot (x_3 = 0,0095)^2 = 18.385$$, people - hours (4)

The optimal values of the factors in the decoded form were: $\omega = 6{,}3$ s-1, $\Delta t = 17{,}7$ mm and $k_{загр} = 0{,}6$. In this case, the technological labor intensity per cycle of the oil press is $T_{тц} = 18{,}385$ people - h. The spread in the values of the labor intensity obtained from experimental studies in laboratory conditions at the optimal values of the parameters and according to the theoretical expression does not exceed 5%.

CONCLUSIONS

An experimental design model of an oil press has been developed and manufactured. Experimental studies in laboratory conditions made it possible to determine the optimal values of the angular velocity of the screw 6.3 s^{-1}, changing the pitch of the auger winding in the zones of 17.7 mm and the utilization factor of the throughput of the feeding zone of the auger 0.6. At the same time, the technological labor intensity of the oil press per cycle was 18.385 man-hours.

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