FOUNDATION OF OPERATING PRACTICES OF SEED MEAL MOISTURE AND HEAT TREATMENT ON OIL EXTRACTION FROM CASTOR BEANS

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Moisture and heat treatment of the castor beans with intensive mixing and bringing its humidity and temperature to optimum values for a given period of time causes a change in a number of physical and chemical properties of the castor-oil seed meal and oil contained in it. This promotes a better oil extraction effect. Moist and heat treatment is one of the most important technological operations in the castor bean preparation for the oil extraction through pressing and has a decisive influence on the quantity and quality of the final products: oil, oilcake or solvent cake. To substantiate the necessary operating practices for moisture and heat treatment of the castor-oil seed meal, an experimental complex was developed to extract oil from oil-bearing raw materials and the experiment procedure was determined.

Experimental researches have established several operating practices of castor-oil seed meal roasting. 1) At steam pressure in a steam generator of 3 kg / cm^2, the seed meal moistening time (at an initial humidity of 5.8%) to a moisture content of 10 ... 13.5% is 30 ... 55 seconds, and the drying time to a humidity of 6 ... 9% is 75 ... 150 minutes; 2) at a steam pressure of 4 kg / cm^2, the seed meal moistening time (at an initial humidity of 5.8%) to a moisture content of 10 ... 13.5% is 35 ... 60 seconds, and the drying time to a humidity of 6 ... 9% is 75 ... 150 minutes; 3) at a steam pressure of 5 kg / cm^2, the seed meal moistening time (at an initial humidity of 5.8%) to a humidity of 10 ... 13.5% is 45 ... 80 seconds, and the drying time to a humidity of 6 ... 9% is 55 ... 100 minutes. As a result of experimental studies, calibration curves have been obtained, which determine the time for the technological operations of seed meal moisture-heat treatment to obtain a target value of its moisture content.

Keywords: castor beans, ground seeds, seed meal, roasting, steam generator, steam pressure, moistening period, drying period, seed meal moisture, seed meal bed height.

INTRODUCTION

The oil in the castor-oil seed meal is distributed in the form of thin films on the surface of particles of ground castor-oil beans (ground seeds) and is held by the forces of intermolecular interaction. Their value is much higher than the pressure gathered by modern presses used for its wringing. Therefore, by oil extraction (pressing) from an unprepared seed meal, a small amount of the final product is obtained. The task of seed meal preparing (moisture and heat treatment or the roasting process) before pressing is to decrease the forces that hold the oil in the seed meal. This is obtained by seed meal moistening. But the moistened seed meal becomes very plastic, and therefore, when pressed, oil is poorly separated from it. To impart it certain elastic properties the moisture is removed from the seed meal, this is obtained by drying [Maslikov V.A., 1974; Goldovsky A.M., 1958]. However, the moistening and drying indices of the castor-oil seed meal according to different sources vary greatly [Didur V.V., Chebanov A.B., Aseev A.A., Shariy A.V., 2016; Didur V.A., 2005]. This makes it difficult to select valid operating practices when oil is squeezed out on the experimental line.

In the industry, there are two types of seed meal roasting: wet and dry [Kopeykovskii V.M., Danilchenko S.I., Garbuzova G.I., 1982; Beloborodov V.V., 1974; Koshevoi E.P., 2001]. The first type roasting proceeds in two

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stages. At the first stage, the seed meal is moistened and heated through adding water, followed by steaming and bringing the moisture content and temperature of the oil-bearing material to optimum values, which are determined by the individual properties of the seed meal. The second stage is drying the moistened seed meal with the optimal structure producing and bringing its humidity and temperature to the values proper for pressing.

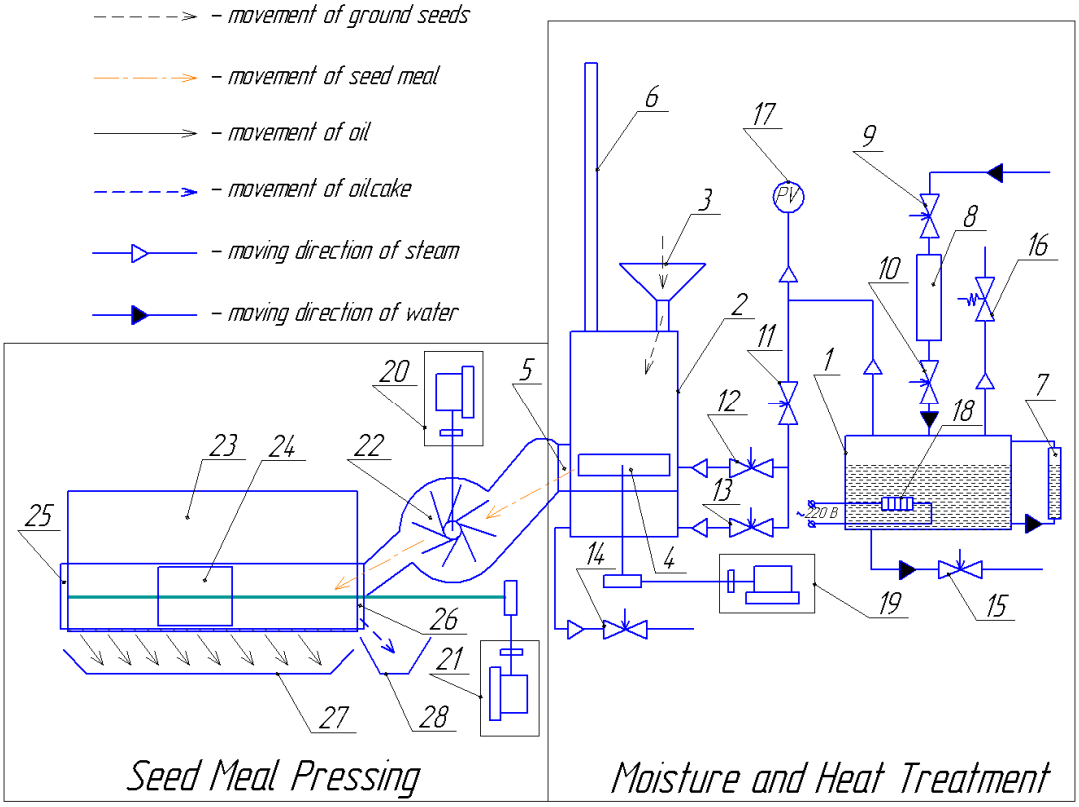
Roasting of the second type is drying and heating the seed meal to certain values without preheating and prior moistening. Thus, the roasting practically begins at once from the second stage. It consists in the exclusion of moisture contained in the material itself, and in bringing the temperature and humidity of the seed meal to the optimum values for pressing.

Roasting of the second type can be recommended in cases where undesired chemical and biochemical processes occur during the seed meal moistening. In addition, this roasting type is recommended when processing raw materials with initial moisture content higher or equal to the humidity limit, which is set for the first roasting stage final.

The first roasting type is more efficient and provides not only the optimum characteristics of the material before its pressing, but also the chemical changes necessary for producing oil, oilcake and solvent cake of the desired quality [Kopeykovskii V.M., 1982]. This is the determining factor in making choice of the roasting method in further studies. The purpose of this work is to found the operating practices of castor-oil seed meal roasting in the roaster of the experimental oil extraction complex.

MATERIALS AND METHODS

The technological process investigations of castor-oil seed meal roasting and the rational values determination of its parameters are performed on an experimental plant, which technological scheme is shown in Fig. 1. The overall view is shown in Fig. 2.



1 - steam generator; 2 - a roaster; 3 - the feeding box; 4 - a stirrer; 5 - the discharge opening; 6 - a steam pipe; 7 - a gauge glass of the steam generator; 8 - an additional water tank; 9-15 - through control valve; 16 - a safety valve; 17 - pressure sensor; 18 - a heating element; 19-21 - an electric motor with a reducer; 22 - beater; 23 - a press; 24 - a press piston; 25-26 - a press valve; 27 - oil collection reservoir; 28 - container for oilcake collection.

Figure 1. Technological scheme of the experimental complex for oil extraction from oil-bearing raw material

Figure 2. Overall view of the experimental complex for oil extraction from oil-bearing raw material

Roasting (moistening and drying) of the castor-oil seed meal occurs in the roaster 2. According to the manufacturing method, the water is fed in the steam generator 1 through an open through control valve 9, an additional water tank 8 and a through control valve 10. The water level monitoring is performed using a gauge glass 7.

After the required water level in the steam generator 1 is obtained, the valves 10 and 9 are closed. The water is heated by three heating elements 18, which are located in the tank of the steam generator. The pressure in the steam generator 1 is controlled by a pressure-gauge 17. The emergency pressure is controlled by a safety valve 16.

The ground seeds are fed into the roaster 2 through the feeding box 3. The necessary ground seed level is provided by means of a measuring scale inserted into the feeding box. Stirring during the roasting process is performed by a stirrer 4 driven by an electric motor with a reducer 19. The steam is removed during the roasting process through a steam pipe 6. The seed meal moistening is carried out by the steam, which is fed to the roaster tank 2 through the open valves 11 and 12. The valve 13 is thus closed. Moreover, the valve 12 is fully open, and the valve 11 is open in such a position that the vapor pressure, controlled by the pressure sensor 17, remains unchanged. Seed meal drying is carried out by the indirect heating vapour fed to the lower part of the roaster through the valves 11, 13 and 14. To obtain this, the valve 12 is closed and the valves 13 and 14 are opened completely. The valve 11 position does not change for the preset pressure value. The seed meal roasting ends with the material

unloading through the discharge opening 5. The through valve 15 is necessary for water drain from the steam generator.

For experimental investigation conducting the castor-oil bean variety *Khortitskaya 7* was used. Refinement of castor-oil beans to ground seeds was carried out by a special roller press. The gap between the grinding rolls was set taking into account the physical and mechanical characteristics of the beans (length, width and thickness). Determination of these characteristics was carried out using the methods recommended in accordance with [DIDUR V.A., 2004].Before the experiments, the initial ground seed moisture was determined according to [GOST 5947-68, 1968]. In this case, the mass of water in the test material (g_m) was determined as follows:

$$g_m = g - g_{d.sub}, \qquad (1)$$

where g is the total mass of wet material, kg;

$g_{d.sub}$ is the weight of dry substance, kg.

The moisture content of the test material with respect to the total mass (in %) was determined as follows:

$$w = \frac{g_m}{g_{d.sub}} \cdot 100. \qquad (2)$$

When preparing the ground seeds for roasting in the roaster, the determining parameters are: the heating steam pressure $p_{h.s}$, the seed meal bed height H, the initial seed meal moisture content W_{in}, the finite seed meal moisture separately for the moistening periods $W_{f.m}$ and drying $W_{f.d}$.. The roaster of the experimental plant has one tank, the number of revolutions of the roaster stirrer 4 does not change and is 32.5 rpm.

As already noted in various sources, the values of the finite moisture content during moistening and drying of the castor-oil seed meal are different, therefore, in order to carry out further studies on oil pressing, the maximum values with the obligatory examination of several average values are accepted. That is, the finite castor-oil seed meal moisture content for the moistening period will be controlled to the level $W_{f.d}$=13,5%, the finite castor-oil seed meal moisture content for the drying period will be controlled to the level $W_{f.d}$=6%. The heating steam pressure during the studies is assumed to be $p_{h.s}$ = 3 kg / cm^2, 4 kg / cm^2 and 5 kg / cm^2. The ground seed bed height in the roaster can vary from H = 0 mm to H = 240 mm. Carrying out preliminary experiments allowed determining the parameters for loading the ground seeds into a roaster. So, in order to provide the necessary amount of castor-oil seed meal, which is fed to the castor-oil extracting press, a sufficient ground seed bed height in the roaster is 160 mm.

In order to obtain a constant amount of steam, it is necessary to calibrate the through control valve 11 for a different pressure. To do this, the steam generator is filled with water, all the heating elements 18 are switched on and steam pressure $p_{h.s}$ = 5 kg / cm$_2$ is produced. The valves 13 and 14 are opened completely, and the valve 11 is opened to such a position that the steam pressure, which is controlled by the pressure gauge 17, does not change. When this position of the valve is fixed, a mark is made. The same marks are made for pressure values $p_{h.s}$ = 4 kg / cm$_2$ and $p_{h.s}$ = 3 kg / cm$_2$.

For the moistening period of the seed meal, it is also necessary to determine the capacity of the steam generator (kg / sec). To do this, a container with water was taken. It was weighed. The hose beyond valve 14 was installed into this container with water and compacted. In the steam generator, a vapor pressure $p_{h.s}$ = 5 kg / cm$_2$ was generated. The valves 13 and 14 were fully open, and valve 11 was open at the required mark. At that, the time was controlled, which made up 30 seconds. After 30 seconds, valves 11, 13 and 14 were closed, and the container with water was weighed again.

The productivity of the steam generator was determined using:

$$Q_{sg} = \frac{m_c - m_{s.c}}{t}, \qquad (3)$$

where m_c is the mass of the container with water before the research, gr;

$m_{c.s}$ is the mass of the container with water and steam after the research, gr;

t is time while the studies were conducted, sec.

The same experiments were carried out for pressure values $p_{h.s}$ = 4 kg / cm$_2$ and $p_{h.s}$ = 3 kg / cm^2.

To ensure the ground seed bed height which is fed into the roaster, it is necessary to calibrate the tank of the roaster. To do this, a depth of the roaster tank was measured with a measuring scale through the feeding box 3 and the value was recorded. Then the ground seeds were fed into the roaster tank. Periodically, the electric motor with a reducer 19 was turned on and ground seeds were mixed with a stirrer 4. The ground seeds were fed so that the measured value on the measuring scale was reduced by 160 mm and the mark was made on the scale at the upper border level of the feeding box.

In order to determine the amount of steam, to moisten the castor oil ground seeds to the finite moisture content (13.5%), it is necessary to determine the ground seed weight for the appropriate bed height. To do this, weighed ground seeds were fed into the roaster. At the same time, the bed height of the ground seeds being fed was controlled. For a bed height of 160 mm, the mass was fixed.

The amount of steam necessary to moisten the ground seeds to the finite moisture content was determined by means of formula

$$\Delta g_m = g_1 \frac{w_2 - w_1}{100 - w_1}, \qquad (4)$$

where g_1 is the castor oil ground seed mass with initial humidity w_1, kg;

w_1 is the initial moisture of the ground seeds, %;

w_2 is the finite moisture of the ground seeds,%.

The time required to moisten the ground seeds to the finite moisture w_2 at a given pressure $p_{h.s}$ was determined using:

$$T = \frac{\Delta g_m}{Q_{s.g}}, \qquad (5)$$

To carry out the research on the experimental plant (Figure 1), the following equipment and materials should be provided:

- an oven;
- scales graduated to 0.001 g;
- aluminium weighing bottles for samples with the test material;
- the material under examination (castor-oil seed meal).

The algorithm for carrying out the experiments is as follows:

1. Weigh each empty weighing bottle on the scales graduated to 0.001 g.

2. Generate a steam pressure in the steam generator 1 equal to $p_{h.s}$ = 5 kg / cm_2, which is controlled by a manometer 17. If there is a high steam pressure, it should be released. To do this, the valves 11, 13 and 14 are opened.

3. Feed the weighed ground seeds into the roaster 2 to a bed height of 160 mm. Calculate from the formulas (4) and (5) the amount of steam and the time required to moisten the ground seeds to the finite moisture w_2.

4. Switch on the electric motor with a reducer 19, which rotates the stirrer 4 of the roaster 2.

5. For the moistening period. Open fully the valve 12 and open the valve 11 at the corresponding mark (the valve 13 is closed). The time, calculated from formula (5) to moisten the ground seeds to the finite moisture, must be proportionally divided into four periods. After each period, open the throttle of the discharge opening 5 and take a ground seed sample in the weighing bottle.

6. For the drying period. Open fully the valve 13, and close the valve 12. Do not change the position of the valve 11. Carry out drying until the water level in the steam generator 1 controlled by the measuring glass 7 reaches the lower level. This time interval is divided into several periods. After each period, open the throttle of the discharge opening 5 and take a ground seed sample in the weighing bottle.

7. Weigh each weighing bottle on a scales graduated to 0.001 g.

8. Determine the moisture content of the samples by drying them to perfectly dry mass by the procedure mentioned in [GOST 5947-68, 1968]. At that, the mass of water in the test material and the moisture content of the material with reference to the total mass are calculated from formulas (1) and (2).

9. It is necessary to take samples of the ground seeds throughout the bed height (in order to determine how the ground seeds are steamed throughout the bed height). To do this, divide the bed height by the graduated scale into 4 segments. Insert the scale into the feeding box 3. Open the throttle of the discharge opening 5 and unload the ground seeds to the

appropriate mark. At each mark, take a ground seed sample in the weighing bottle.

10. Repeat experiments 1-9 with steam pressure in the steam generator 1 $p_{h.s}$ = 4 kg / cm_2 and $p_{h.s}$ = 3 kg / cm_2.

RESULTS AND DISCUSSION

The seed meal moisture curves from moistening time at a steam pressure of 3 kg / cm_2, 4 kg / cm_2 are shown in Fig. 3. The dependence analysis results that with an increase in the heating steam pressure, the moistening time increases. Thus, for example, at a steam pressure of 3 kg / cm2, the time necessary for seed meal moistening (at an initial moisture content of 5.8%) to a moisture content of 13.5% is 55 seconds. At a steam pressure of 5 kg / cm_2, the same seed meal moisture is obtained in 75 seconds. The explanation of this is that disparity of specific weight of steam and liquid decreases with pressure increase.

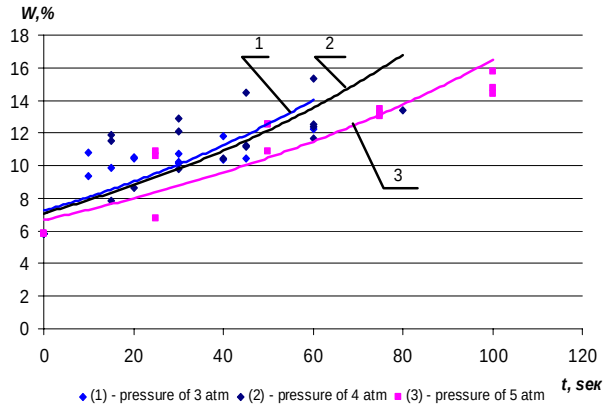


Figure 3. Dependence of the seed meal moisture content on the moistening time

The seed meal moisture curves at the bed height in the roaster tank immediately after moistening at steam pressure of 3 kg / cm_2, 4 kg / cm_2 and 5 kg / cm_2 are shown in Fig. 4. With an increase in the bed height, the seed meal moisture decreases, which is a consequence of the design features of the roaster (steam is brought about to the roaster bottom).

The seed meal moisture curves from the drying time are shown in Fig. 5. As dependencies indicate, with drying time increase, the seed meal moisture decreases. This process is influenced by the steam pressure. Thus, at the initial moisture after the seed meal moistening process at 13.5% and the steam pressure of 5 kg / cm_2, the seed meal moisture content of 6% is obtained after 100 minutes. At a steam pressure of 3 kg / cm_2, the same seed meal moisture is obtained after 150 minutes only, which accounts for a steam temperature decrease and, correspondingly, by drying rate increase [Maslikov V.A., 1974; Maslikov V.A., 1965].

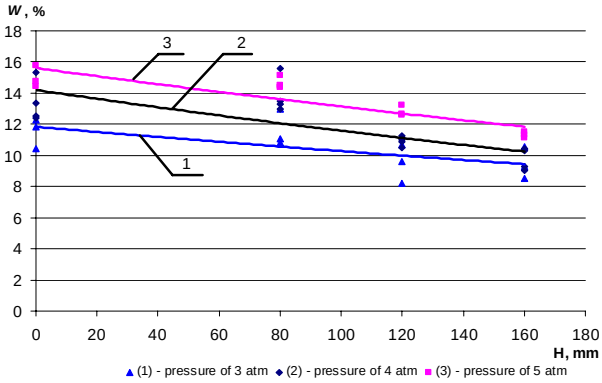


Figure 4. Dependence of the seed meal moisture on the bed height in roaster tank after moistening

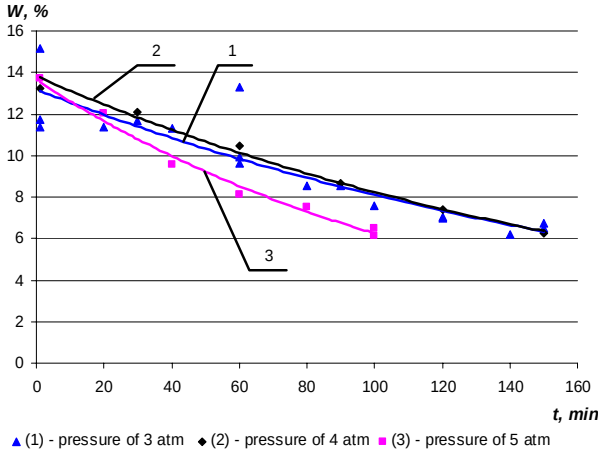


Figure 5. Dependence of the seed meal moisture content on the drying time

The drying process is due to thermal diffusion, which causes moisture transfer in the direction of heat, that is, from the more heated part to the colder one. The moisture transfer occurs as a result of moisture differential in the different seed meal layers: from the layers with more moisture the moisture moves into layers with less moisture. The moisture differential is created by the temperature difference. The more the temperature difference is, the more intensive drying takes place. This is confirmed by the curves of the seed meal moisture content throughout the bed height in the roaster tank after drying at a steam pressure of 3 kg / cm_2, 4

kg / cm_2 and 5 kg / cm_2 in Fig. 6. If, after moistening (Fig. 4), for example, at a pressure of 5 kg / cm_2, the moisture content throughout the bed height varied from 15.5% in the lower part of the roaster to 12% at the top, then after drying (Figure 6), the moisture content varied from 6.2 to 6.3%. That is, it can be asserted that after drying there is a uniform steaming of the seed meal layers at any roaster height.

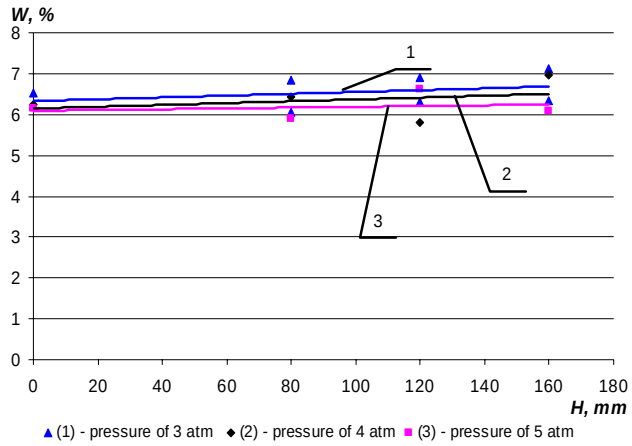


Figure 6. Dependence of the seed meal moisture content change on the layer in the roaster tank after drying

CONCLUSIONS

Experimental researches established operating practices of castor-oil seed meal roasting:

- at a steam pressure of 3 kg / cm_2, the time of seed meal moistening (at an initial moisture content of 5.8%) to a moisture content of 10 ... 13.5% is 30 ... 55 seconds; drying time to moisture content of 6 ... 9% is 75 ... 150 minutes;

- at a steam pressure of 4 kg / cm_2, the time of seed meal moistening (at an initial moisture content of 5.8%) to a moisture content of 10 ... 13.5% is 35 ... 60 seconds; drying time to moisture content of 6 ... 9% is 75 ... 150 minutes;

- at a steam pressure of 5 kg / cm_2, the time of seed meal moistening (at an initial moisture content of 5.8%) to a moisture content of 10 ... 13.5% is 45 ... 80 seconds; drying time to moisture content of 6 ...9% is 55 ... 100 minutes/

The presented curves serve as calibration curves when the oil extraction in the reamed channel.

REFERENCES

Maslikov V.A. Tekhnologicheskoe oborudovanie proizvodstva rastitel'nyh masel / V.A. Maslikov. – M.: Pishchevaya promyshlennost', 1974. – 439 s.

Goldovskij A.M. Teoreticheskie osnovy proizvodstva rastitel'nyh masel / A.M. Goldovskij. – M.: Pishchepromizdat, 1958. – 446 s.

Didur V.V. Termodynamichni kharakterystyky elementiv nasinnia rytsyny / V.V. Didur, A.B. Chebanov, A.A. Aseiev, A.V. Sharii // Naukovyi visnyk Natsionalnoho universytetu bioresursiv i pryrodokorystuvannia Ukrainy. Seriia «Tekhnika ta enerhetyka APK». – Kyiv, 2016. – Vyp. 254. – S. 278-285.

Rozrobka tekhnolohii, eksperymentalnoho ustatkuvannia tekhnolohichnoi linii po hlybokii pererobtsi nasinnia rytsyny v kastorovu oliiu dlia vyrobnytstva mastyl dlia silskohospodarskoi tekhniky: zvit pro NDR; ker. V. A. Didur. – Melitopol: TDATA, 2005. - 99 s.

Kopejkovskij V.M. Tekhnologiya proizvodstva rastitel'nyh masel / V.M. Kopejkovskij, S.I. Danil'chenko, G.I. Garbuzova i dr. – M.: Legkaya i pishchevaya promyshlennost', 1982. – 416 s.

Podgotovitel'nye processy pererabotki maslichnyh semyan / pod red. V. V. Belobo-rodova. - M.: Pishchevaya promyshlen-nost', 1974. -337 s.

Koshevoj E.P. Tekhnologicheskoe oborudo-vanie predpriyatij proizvodstva rastitel'nyh masel / E.P. Koshevoj. – SPb: GIORD, 2001. – 368 s.

Didur V.A. Analiz i doslidzhennia fizyko–mekhanichnykh vlastyvostei nasinnia rytsyny / V.A. Didur, K.V. Zubkova // Pratsi / Tavriiska derzhavna ahrotekhnichna akademiia. – Vyp.19, Melitopol: TDATA, 2004. – S. 18-21.

GOST 5947-68. Semena hlopchatnika. Tekhnicheskie usloviya. – M.: Standartinform, 1968. – 22 s.

Maslikov V.A. Kinetika zhareniya podso-lnechnoj myatki / V.A. Maslikov, S.G. Tarasov // Pishchevaya tekhnologiya. – Krasnodar, 1965. – S. 147-150.