Thermodynamic Processes of the Cold Extraction of Vegetable Oil

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Abstract: The article is devoted to the methods of cold-pressing of vegetable oil. It is considered the thermodynamic processes for cold-pressing of vegetable oil. It is provided the classification of cold-pressing methods. There were proposed the technological and constructive solution for cold-pressing by extrusion technology which contributes the reduction of compression efforts of oilseed material while the processing temperature of raw material is within the second method of pressure. It was obtained the dependencies of temperature determination of processing of oilseed raw material. The obtained vegetable oil complies with GOST1129-93 unrefined oil, highest grade.

Key words: Vegetable oil · Thermodynamic processes · Cold extraction

INTRODUCTION

One of the most valuable foodstuff are vegetable oils. Vegetable oils are contained a large number of substances, necessary for a human body. They have all biologically important elements in well digestible for our organism a natural form and an optimum ratio.

Oil extraction by method of an extraction has ancient roots it was used in Ancient China, Egypt, India and other countries about 5000 years ago. Initially, the lever method of an extraction, compression by a wedge or manual method of a spiral extraction were used in oil milling apparatuses. Modern ways of extraction of oils, such as a press method and pressing with preliminary moisture thermal treatment and an extraction way with the subsequent processes of refinement and odor-control treatment, bleaching – are promoted decrease in its useful properties.

Pressing with preliminary moisture thermal treatment in braziers is conducted to substantial increase of temperature of raw materials that as the results are losses of vitamins. Besides, such oils need to be filtered that it is raised much more acid number and it is reduced the maintenance of microcells.

There is a method of making oil with the maximum preservation of useful properties of oil (vitamins aren’t collapsed). Such method is called as a cold extraction (a way of pressing with thermoregulating of press). The oil, received by such method, is contained the greatest number of vitamins and useful elements. As a rule, for purification of such oils, barring some, it is enough only sludging therefore it is exposed to oxidation less. It is considered more valuable oil of "the first cold extraction" (From English “first cold press”) though this concept is rather conditional as oil in a varying degree is heated up and at "the first cold extraction".

Now, when it is meanted a cold extraction, usually it is meaning use of a hydraulic or screw press.

It is everywhere used the apparatuses of continuous extraction in the oil milling equipment. Processes can be a little different, but their essence is remained invariable: use of mechanical force for pressing and an extraction of oil from oilseeds. Physical changes are happened in the process of pressing: deformation of oil-bearing crops; separation of oil; friction and calorification; evaporation of moisture. Temperature and humidity changes, microorganisms in oil-bearing crops and other similar factors are caused chemical changes, such as passivation and destruction of enzymes, a denaturation of proteins, etc.

The structure of oil-bearing crops is changed in the process of pressing. Olive raw materials is turned into rigid oilcake at high extent of
compression and thus oil is extracted from it. Oil, first of all, is extracted from a surface of oilcake or from area, close to a surface. The extraction is promoted by the consolidation of structure of a surface of oilcake, which is not passed the oil outside, which remained in olive raw materials. Low viscosity of oil, the closed channels of an exit, a high pressure it is those three factors which influence the oil extraction speed therefore quality of oil-bearing crops and the applied equipment are very important components.

**MATERIALS AND METHODS**

On the basis of various literary data the following interpretation of a method of a cold extraction is offered [1]:

The cold extraction can be divided into three ways conditionally:

1st Way is assumed heating of olive raw materials at the expense of pressure forces and friction, thus temperature of olive raw materials should not exceed 50°C. The effort of compression in the wringing-out device is reached 8 MPas and thus forming heat is needed to delete at the expense of the special refrigerating devices, located in hollow worm shafts of the pressing device or through the external surfaces of the extracting cylinder of a press. That in that and other case extremely complicates a design of the squeezing device

2nd way is assumed to carry out an oil extraction at a temperature of olive raw materials within 50 … 70°C. This way also is difficult achievable at the using of the real worm or hydraulic presses. At an extraction of olive raw materials by traditional devices the degree of pressure put upon raw materials is made 8 … 10 MPas

3rd way is assumed preliminary moisture thermal treatment of olive raw materials or heating of olive raw materials, which is occured in addition in the pressing path of the oil-squeezing press at the expense of specially selected TEs. Thus, temperature of olive raw materials has to be in limits 70 … 90°C and efforts of compression, respectively 10 … 12 MPas.

Let us to consider the last two ways as the most widespread and often used in farms.

Obviously, than less temperature of processing of olive raw materials, it is made especially qualitative oil. The unstable condition of vitamins (A, D, E, K) in raw materials is the reason of poor quality of the developed oil, the more processing temperature, the less vitamins remains in the final product.

In Figures 1 and 2 are presented oil-squeezing presses of firm Andromeda Rasma 150U (Bulgaria), working on the second way of an extraction and at which heat supply from the outside by means of thermal elements (TE) is made.
Fig. 1: Oil squeezing press Andromeda Rasma 150U (Bulgaria), working on technology of a cold extraction

Fig. 2: Oil squeezing press Andromeda Rasma 150U (Bulgaria), with a double pressing head where heating elements on the external case of a pressing tract are established

Thus, the most important on influence on quality indicators of vegetable oil is temperature of its processing. Heat in the process of processing is appeared as a result of deformation, friction and material compression, mechanical energy is turned in thermal, it is shown the principle of dissipation.

According to the first law of thermodynamics and the principle of equivalence of heat and operation (law of energy conservation), amount of heat which the system is maked and exchanged with environment, \( dQ \) is equal to number of the done mechanical work \( A \) [2]:

\[
dQ = dU + pdV - dl,
\]

where

\( dU \) is change of internal kinetic energy of a body;

\( pdV \) is a change of potential energy of the body connected with volume of system; \( dl \) is friction work.

The thermal energy of \( dQ \), received as a result of transformation of mechanical energy, is spent for heating of an olive material and heat loss in environment:

\[
dQ = Q_t + Q_n. \tag{2}
\]

Heat exchange, at the same time thermal balance in thermodynamic systems, is caused by conditions of distribution of temperature and thermal streams in material bodies.

The amount of heat, received by a body as a result of dissipation of energy (J), is equal to change of internal energy of the olive material, located in worm tract and the extracting case, in time from \( \tau = 0 \) to \( \tau = \infty \):

\[
Q_t = \pi (r_2^2 - r_1^2) l \frac{\lambda}{\alpha} (T_k - T_h) \tag{3}
\]

where

\( r_2, r_1 \) are external and internal radiuses of worm cylinder, m;

\( l \) is length of the extracting cylinder, m;

\( \lambda \) is coefficient of heat conductivity, W/m * degree;

\( \alpha \) is coefficient of heat diffusivity, m²/s;

\( T_h, T_k \) is first and final temperature of heated olive material, °C.

Losses of heat \( Q_n (\text{Joule}) \) are from expression

\[
Q_n = \frac{8\lambda(\tau - T_f) \pi^2 l^2 (r_2^2 - r_1^2)}{0.2na^2 \frac{Bi}{a} \left[ 1 - \left( \frac{r_1}{r_2} \right)^2 \right] + 1 - \left( \frac{r_1}{r_2} \right)^2 - 2 \left( \frac{r_1}{r_2} \right)^2 \ln \frac{r_2}{r_1} } \tag{4}
\]

where \( (\tau - T_f) \) is temperature distribution between the internal volume of olive raw materials and an external surface of the extracting cylinder;

\( Bi = \frac{\alpha r_2^2}{\lambda} \) criterion of Bio.

The equation of heat conductivity and thermal losses of \( Q_{oh} (\text{J}) \) with an internal source of heat in this case looks as follows

\[
Q_{oh} = Q_t - Q_n = \pi (r_2^2 - r_1^2) l \frac{\lambda}{\alpha} (T_k - T_h) - \frac{8\lambda(\tau - T_f) \pi^2 l^2 (r_2^2 - r_1^2)}{0.2na^2 \frac{Bi}{a} \left[ 1 - \left( \frac{r_1}{r_2} \right)^2 \right] + 1 - \left( \frac{r_1}{r_2} \right)^2 - 2 \left( \frac{r_1}{r_2} \right)^2 \ln \frac{r_2}{r_1} } \tag{5}
\]
Temperature of an olive material in the extracting cylinder of a oil-squeezing press is solved from conditions of the equation of thermal balance of work of installation (5) and (8). At multiplication of the right and left parts of equation of thermal balance (5) on the frequency of rotation of the worm shaft of \( n \), the equation assumed the following air, (W):

\[
(Q_T - Q_x)m = (A_s - A_h)n = N_{cw} \cdot N_{h,ma}.
\]

And the right part of the presented equation (8) is given a difference of power at compression of an olive material and power of friction of rounds of the worm with raw materials and at its viscous-plastic current in a pressing tract of the wringing-out device. The left part, after substitution of values of changes of heat, can be considered as follows:

\[
dQ = Q_T + Q_n
\]

The equation of heat conductivity and thermal receipt in an olive material in a press from an external source of heating of raw materials (TEH, moisture thermal treatment) is from the following expression

\[
Q_{CB} = Q_T + Q_n = \pi(r_2^2 - r_1^2) \frac{\alpha(T_K - T_H)}{\alpha} + \frac{2\pi\lambda(T_1 - T_2)}{T_2 + 1} \ln \frac{r_2}{r_1}
\]

\[
\pi \cdot (r_2^2 - r_1^2) \cdot l \cdot \frac{\lambda_{HE}}{a} (T_K - T_H) \cdot n = \frac{8\lambda_3(T_1 - T_2)}{\lambda_3} \cdot l \cdot \pi^2 \cdot \frac{r_2}{r_1} \cdot \frac{r_2^2 - r_1^2}{\ln \frac{r_2}{r_1}},
\]

where

- \( T_f \) is temperature of a surface of the extracting cylinder of oil press, °C;
- \( T_r \) is temperature of olive raw materials, °C;
- \( T_H \) is ambient temperature (air \( T_H = +10°C \));
- \( \lambda_3 \) is coefficient of a heat transfer steel extracting strips, \( \lambda_3 = 40 \text{ W/m * degree} \);
- \( \lambda_{HE} \) coefficient of a heat transfer of an olive material, \( \lambda_{HE} = \frac{a l}{N_u} \);
- \( N_u = 0.57Re^{0.5} \) [3].

The conducted researches on various ways of receiving vegetable oil and on a way of a cold extraction, are allowed to reconsider existing traditional technologies of a oil production and on its basis to develop a number of technologies, allowing to receive more high-quality oil with smaller expenses. The principle of processing of seeds without violation of their natural packing and preparation of a kernel for oil extraction without change of its localization due to preservation lipid spheroses in a bio-protective membrane state [1] is the basis for the latest technologies. The oil-squeezing extrusive press was designed and made on this technology of processing (Figure 3).

By results of researches of the author [4] it is supposed that the new technology of the oil production will be dominated in the XXI century, its essence is that by preparation of oilseeds for oil extraction they will be subjected to rough crushing by way of spalling on a natural large intercellular oscules. Thus, there is no destruction of natural organoids, contact between oil and oxygen of air is excluded because of preservation of natural packing by spheros and oils and oscules are not created a new (adverse from the point of view of extraction of oil), which are formed at thin crushing of material by an attrition method. Conditions for decrease in temperature thresholds of moisture thermal action are created at application of technology of rough crushing of material.

Feature of extrusive process of oil is that crushing and getting of oil is occurred due to shift efforts, but not volume compression and extent of compression thus...
Fig. 4: Scheme of extrusive worm oil-press

1 – extracting strips; 2 – composite worm shafts; 3 – winding of worm; 4 – output hoop gap; 5 – regulation hoop; 6 – zone of formation of oilcake; 7 – loading worm; 8 – regulation device; 9 – loading bunker; 10 – slide gate

Work of installation is carried out in the following parameters: humidity of the processed olive material is in W limits $W = 5 \ldots 8\%$; pressure created in the worm tract is in limits $p = 1 \ldots 3.5$ MPas; frequency of rotation of the worm shaft will be in n limits $n = 350 \text{ min}^{-1} \ldots 450 \text{ min}^{-1}$: temperature of an extraction of olive raw materials is in t limits $t = 60^\circ \ldots 65^\circ C$, that is allowed to speak about a cold extraction of oil and to receive vegetable oil with good quality indicators.

The general design of the worm tract of an extrusive oil-squeezing press is presented in Figure 4. The worm with a variable diameter of a shaft in installation is used as well as in offered of the installation earlier [5].

Solving the found equations (8) and (9) concerning temperature of processing of an olive material $T_k(\circ C)$, we find dependence of temperature of processing on installation power:

$$T_k = T_m + \frac{N_{cp} \cdot \tau}{\pi (r_1^2 - r_2^2) l s} - \frac{N_{s.m}}{8 \pi \rho c \eta (r_1^2 - r_2^2)} \cdot \frac{0.2 I^2}{B i} \left[ 1 - \left( \frac{r_2}{r_1} \right)^4 \right] + 1 - \left( \frac{r_2}{r_1} \right)^2 - 2 \ln \frac{r_2}{r_1}$$

(10)

RESULTS AND DISCUSSION

Results of calculation of theoretical dependence of temperature from the power of installation (10) are presented in Figure 5. In this figure the results of pilot studies on measurements of temperature of an olive material depending on installation power are presented also. Results of comparison of experimental and theoretical functions are shown that at a significance value 0.05 with probability $P = 100 - 5 = 95\%$ and degree of freedom $m = 4$ tabular criterion of a consent of Pearson is more settlement and therefore, the empirical curve will be coordinated with theoretical ($x^2 = 0.71 > x^2 = 0.701$).

The analysis of the received dependences is shown that the average temperature of the recycled olive material is not exceed 64$\circ C$. At small values of power and small values of pressure discrepancy of experimental and theoretical temperatures is explained by a small pressure the olive raw materials and it is behaved as a loose product that the received equation (10) is not considered too.
Fig. 5: Dependence of temperature of an oil material on the power of process of processing of an oil material

Table 1: Indicators of quality, received on extrusive technology of the cold extraction of oil

<table>
<thead>
<tr>
<th>№</th>
<th>Name of indicators</th>
<th>Unit of measure of indicators</th>
<th>Method, definition of indicators State Standard, ISO</th>
<th>Indicators</th>
<th>Norm of unrefined oil, extra, State Standard 1129-93</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Moisture and volatiles</td>
<td>%</td>
<td>State Standard 1129-93</td>
<td>0,09</td>
<td>0,2</td>
</tr>
<tr>
<td>2</td>
<td>Acid number</td>
<td>mOe l/g</td>
<td>State Standard 1129-93</td>
<td>0,19</td>
<td>1,5</td>
</tr>
<tr>
<td>3</td>
<td>Peroxide number</td>
<td>mOe O /kg</td>
<td>State Standard 1129-93</td>
<td>0,12</td>
<td>5,0</td>
</tr>
<tr>
<td>4</td>
<td>Saponification number</td>
<td>mOe O /g</td>
<td>State Standard 1129-93</td>
<td>178,4</td>
<td>188-194</td>
</tr>
<tr>
<td>5</td>
<td>Refraction coefficient. n</td>
<td>LOVIBOND</td>
<td>State Standard 1129-93</td>
<td>1,465</td>
<td>1,461-1,468</td>
</tr>
<tr>
<td>6</td>
<td>Relative density D</td>
<td></td>
<td>State Standard 1129-93</td>
<td>0,9183</td>
<td>0,918-0,923</td>
</tr>
<tr>
<td>7</td>
<td>Color number</td>
<td>ppm</td>
<td>State Standard 547793,ISO 15305</td>
<td>1,0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>- the red</td>
<td></td>
<td></td>
<td>1,0</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>- the yellow</td>
<td></td>
<td></td>
<td>4,0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Chlorophyll- carotene</td>
<td>ISO 15305</td>
<td></td>
<td>0,01612,11</td>
<td></td>
</tr>
</tbody>
</table>

Quality indicators of the received oil are presented in Table 1. As follows from the obtained data the quality indicators of the received oil on technology of extrusive processing are corresponded to the norm not refined oil, an extra sort State Standard 1129-93 and on some indicators, such as the acid and peroxide number is surpassed by norms of the extra sort.

REFERENCES