Analysis of quality indicators of oils during continuous heating before deodorization

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Abstract. The article concerns various types of heating of vegetable oils before deodorization in a continuous process. Experimental methods were used to analyze changes in the physicochemical properties of the samples under study. The main attention is paid to the analysis of changes in the quality characteristics of vegetable oil depending on the type of heater and heating time. The article highlights studies of the main quality indicators, on the basis of which it was concluded that during induction heating the changes occurring in oils are significantly different compared to using a resistance heater.

1 Introduction

The final stage of the refining process of vegetable oils and oils is deodorization [1]. For the processing of oilseed raw materials, modern high-tech equipment is used, which ensures automated compliance with all necessary technological parameters, in particular deodorization [2]. Along with other parameters, temperature is the most important for carrying out this process, which is complex in terms of instrumentation and physical and chemical parameters [3]. And not only its absolute value, but also the conditions and method of heating.

In modern industrial installations, the feedstock is heated to specified temperatures using heat exchangers or electric heaters before being fed into the deodorization column. Under conditions of continuous heating, an increased degree of turbulence is observed, and the mechanics of the process become more complicated [4]. The influence of continuous heating on the quality indicators of oils during the deodorization process has not been studied enough: due attention has not been paid to such indicators as the temperature difference between the heating wall and the heated oil and the heating heat [4]. Today, the study of this problem remains a pressing issue.

The purpose of this article is to study the quality of oils before deodorization under various continuous heating methods.

Tasks:

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1. Analyze the temperature difference between the heating wall and the heated oil.
2. Rate of temperature change per unit time for various methods of continuous heating of oil.
3. Study the influence of various heating methods on changes in their initial parameters.
4. Summarize the experimental data.

2 Methods

At the first stage, a laboratory installation was developed and installed to study the effect of various continuous methods of heating oils on the quality characteristics of vegetable oils.

At the second stage, two heating methods of electrical nature were analyzed. Refined, non-deodorized sunflower oil was subjected to induction heating (IH) and resistance heating (RH). At the same time, the intensity of the thermal effect was analyzed by determining the temperature difference between the heating walls of the heater and the heated oil and the heating temperature. The main physicochemical parameters of sunflower oil heated continuously by the indicated methods were determined. Based on an analysis of quality indicators, the most preferred type of heating was selected. Oil subjected to IH had better characteristics.

In Russian and foreign deodorization devices, steam heating is most common; in this work, IH was considered as an alternative. Based on the results of the experiment, the intensity of the thermal effect and heating temperature were analyzed. Changes in the physicochemical parameters of sunflower oil that occur under the influence of high temperatures at IH and RH were considered and analyzed.

The research objects used were; refined, non-deodorized vegetable oil. Sampling of oils and oils was carried out according to developed methods [5]. Physico-chemical parameters of the feedstock are given in Table 1.

<table>
<thead>
<tr>
<th>Indicator name</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>¹ Indicator name</td>
<td>1st test</td>
</tr>
<tr>
<td>Acid number, mg KOH/g</td>
<td>0.37</td>
</tr>
<tr>
<td>Moisture and volatile content, %</td>
<td>0.12</td>
</tr>
<tr>
<td>Peroxide value, ½ Ommol/kg</td>
<td>8.14</td>
</tr>
<tr>
<td>Refractive index, ηD20</td>
<td>1.4752</td>
</tr>
<tr>
<td>Iodine number, g I2/100g</td>
<td>128</td>
</tr>
<tr>
<td>Content of carbonyl compounds, µmol/g</td>
<td>1.15</td>
</tr>
<tr>
<td>Cargotenoid content, (β-carotene), g/100 ml</td>
<td>–</td>
</tr>
<tr>
<td>Epoxy oxygen content, %</td>
<td>–</td>
</tr>
<tr>
<td>Content of oxidation products insoluble in petroleum ether, %</td>
<td>–</td>
</tr>
<tr>
<td>Mass concentration of iron, mg/kg</td>
<td>0.71</td>
</tr>
<tr>
<td>Mass concentration of copper, mg/kg</td>
<td>0.137</td>
</tr>
<tr>
<td>Mass concentration of lead, mg/kg</td>
<td>0.11</td>
</tr>
<tr>
<td>Mass concentration of zinc, mg/kg</td>
<td>0.15</td>
</tr>
</tbody>
</table>

The studies were carried out according to the following indicators:

1. The acid number was determined by the titrimetric method with visual indication [6]. The discrepancy between parallel determinations did not exceed 0.5%.
2. Iodine number was determined by a chemical method according to [7]. The discrepancy between parallel determinations did not exceed 1% of the iodine number.
3. The refractive index was determined according to [8] using controlled thermostating at a temperature of 20 °C ± 0.1. An IRF-454B refractometer was applied.
4. Peroxide value was determined by the iodometric method according to [9]. The discrepancies between the results of parallel determinations did not exceed 5 % for values of 3.0 1/2O mmol/kg or more and no more than 10 % for values less than 3.0 mmol/kg.
5. The content of carbonyl compounds in sunflower oil was determined by the spectrophotometric method using a UV300/2FD+ spectrophotometer. The difference between parallel divisions was determined did not exceed 10%.

To solve the problems, an experimental laboratory installation was created, including both standard elements and connections, and elements specially designed and made in a single copy [10].

During the experiment, the laboratory setup was assembled in 2 versions, differing from each other by the use of different flow-type heaters in the circuit. In the first variant, the research objects were heated using IH and HS before setting temperatures. In the second option, an induction heater and a high-pressure steam heater (3.0-4.0 MPa) were used.

When calculating and manufacturing various heaters, the following was taken into account:
1. Heaters must be similar in design and have the same areas of heated surfaces.
2. The thermal power consumed by the heaters and the oil consumption must be equal.

When the above conditions are met, the same hydrodynamic regimes are provided with different heating methods. With the help of a system of shut-off valves, conditions are created such that each heater can be used autonomously, independently of the other.

When passing the study through each system, the following measurements were taken:
1. Final temperature to which the oil was heated;
2. Thermal exposure duration;
3. Temperature of the heater walls.

The same flow rate (oil consumption) was regulated by changing the pump rotation speed, which in turn was determined by the voltage supplied to the electric motor windings.

In accordance with the developed methodology, samples were taken when the oil was heated to 175, 190 and 200°C. In the selected samples, the acid number, peroxide number, content of carbonyl compounds, as well as the content of metals: iron, copper, lead, zinc were determined.

3 Results

To determine the intensity of thermal effects during IH and HS, the temperature difference between the walls of the heaters and the heated oil was calculated. The experimental data are presented in Figure 1-2. Average data on temperature difference and heating temperature are presented in table 2, where the following values are used.

\[ \Delta t_{av1} \] - average temperature difference between the wall of the inner cylinder of the working chamber and the oil temperature at the outlet;

\[ \Delta t_{av2} \] - average temperature difference between the wall of the outer cylinder of the working chamber at the outlet and the oil temperature at the outlet;

\[ \frac{dT}{d\tau} \] - heating rate (average rate of temperature change)
An analyzing the data in Figures 1-2, it should be noted that with HS, the average difference between the heating walls and heated oil is 4.0-9.4 times higher than with IH. At the same time, the rate of temperature change with HS is slightly higher than with IH (3.8 versus 3.7 degrees/min). The temperature difference between the inner and outer cylinders of the heaters ($\Delta t_3$) at IH is 20-30°C, at HS 40-45°C. The data obtained give grounds to assert that with HS the oil experiences a stronger thermal effect compared to IH.

### 4 Discussion

As it is known [11], none of the stages of the refining process ensures the complete removal of metals from vegetable oils and fats. Since during IH the oil is exposed to a low-frequency electromagnetic field, it can be assumed that this field can influence the content of metals in the oil under study. Data on metal content are presented in Figure 3.
As can be seen from Figure 3 at IH and at HS there is an increase in the content of metals compared to the original oil. Obviously, this is due to the fact that metals can enter the oil from the installation material. A pattern is visible: with IH, the mass concentration of metals increased less than with HS. However, it is premature to draw final conclusions, since the oil was initially heated using an electric heater.

When heated to high temperatures, oxidative and hydrolytic processes occur in the oil. One of the main indicators of oil quality is the acid number, since the change in this indicator characterizes the degree of hydrolysis of acylglycerols. With a relatively short heating of sunflower oil, the destruction of unstable primary oxidation products (peroxides, hydroperoxides) and the formation of secondary oxidation products, among which there are compounds containing a carbonyl group (aldehydes, ketones), occur. Only by changing the content of these compounds one cannot judge the mechanism of oxidative processes, however, an increase in the amount of carbonyl compounds gives an idea of the intensity of the thermal effect on a given product during IH and HS.

The results of the study are shown in Figure 4-6.
Figure 4 shows that the acid number for both heating methods increases with increasing temperature. The acid number values in comparison with the original oil increased by 41% with IH, and by 64% with HS. With the growth of carbonyl compounds, a decrease in the peroxide number is observed for both heating methods (Figure 5). With HS, the content of carbonyl compounds increased by 28.5 times compared to the original oil (Figure 6), which is 2.8 times more than with IH (10.2 times increase). When fats are heated, both destruction and formation of new peroxides and hydroperoxides occur. As a rule, the value of the peroxide number changes chaotically during the heating process. With IH, a decrease in the peroxide number is observed, which leads to a decrease in this indicator by 3.2 times; with NS, after a decrease in the peroxide number by 3.2 times, its slight increase is observed.

This study also contributes to ensuring the safety of the deodorization process, as a technospheric object from the point of view of obtaining a quality product, and having a systemic impact on the environment [12-13].

5 Conclusion

Based on the research conducted, it was established:

1. The temperature difference between the heating walls of the working chamber and the heated oil at I is, on average, 3.7 times lower than at NS, therefore, this type of heating is “softer”. Analysis of the temperature difference between the inner and outer cylinders of the heating chambers showed that the IH is more uniform.
2. Analysis of the quality indicators of oil subjected to various heating methods confirms the advantages of IH compared to HS.
3. Considering that with continuous heating of the oil using an induction heater and a resistance heater for the same time (35, 40, 45 minutes), approximately to the same temperatures (170-175, 185-190, 200-205°C), different values of the temperature difference between the heating walls of the heater and the heated oil and significantly different quality indicators were found, which tend to deteriorate with increasing values of $\Delta t_{av1}$ and $\Delta t_{av2}$, it should be noted that the so-called “burn” effect is observed.
4. Thus, the quality of oils heated before deodorization using HS and IH differs significantly in favor of the latter, which may serve as justification for further research

References
1. G.F. Vasilieva, Deodorization of oils and fats (SPb., GIORD, 2000)