Progressive methods of alkaline refining and bleaching of cottonseed oil

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Abstract. The article presents data from a study of the refining process of cottonseed oil, which differs from other vegetable oils in its complex composition and the presence of gossypol, which requires the use of alkali solutions (NaOH) of high concentration and in excess quantities. The use of magnetized solutions of sodium aluminate with a concentration of 15 to 25% has been proposed as an alkaline agent. Studies have shown that with the action of this reagent, a decrease in the acid number and color index of both press oil and oils obtained by extraction is observed.

1 Introduction

When extracting oils into their composition, in addition to triacylglycerols, a lot of related substances are extracted, the quantity and quality of which depend on the method of its production. To purify vegetable oils from impurities that affect their quality and subsequent reprocessing, the technology provides for their refining.

Refining of oils and fats is one of the most important technological processes of their reprocessing.

Refining technology, namely, alkaline neutralization of raw cottonseed oil, consists of a set of complex physical, chemical and physicochemical processes, on which the physicochemical characteristics and quality indicators of refined oil mainly depend. The character and sequence of these processes are determined by the nature of the oils and their quality, as well as the required depth of purification [1-2].

The technique and technology of fat refining is constantly being improved. On the basis of the work of scientists and the experience of production leaders, original technological schemes have been created that provide a high effect of oil purification while significantly reducing waste and losses. Refined production is equipped with modern high-performance continuous equipment, which increases the capacity of workshops and significantly reduces labor costs [1].

So at present, the micelle refining method is used in production. The separation of fatty impurities contained in the miscella (at a concentration of 50-55%), prior to its heat treatment in distillers, favorably affects the color of the resulting oil. This is especially

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noticeable in the production of cottonseed oil, since the gossypol contained in it undergoes great changes in the process of moisture heat treatment.

To improve the efficiency of cottonseed oil refining, the researchers of the Kuban State Technical University developed a new technology in which a mechanochemical activator developed by them was used instead of a reactor-turbulator to mix the oil with an alkali solution [1].

Technological regimes, output and quality indicators of refined cottonseed oil are determined, first of all, by the nature and method of production of crude oil, the composition and quantitative content of impurities in it, as well as related substances.

The refining of cottonseed oils will be complicated due to the presence of gossypol and its derivatives [1,3].

The main method of their purification from unwanted substances is alkaline refining using a solution of alkali (NaOH) of high concentration and in excess. The alkali consumption can be from 150 to 300% of the theoretically required amount. This refining technology is accompanied by a low yield of end products, as well as a significant consumption of material and technological resources.

The neutralization coefficient for such refining, depending on the quality of the oil, ranges from 3 to 6, fat losses in the soapstock increase, the amount of oil in the soapstock can be 30 ... 50%, because the use of high concentrations of alkali leads to saponification and partial hydrolysis of triglycerides. Along with this, the oil and fat industry of the republic is experiencing a shortage of sodium hydroxide due to its high cost.

In order to eliminate the shortcomings of the existing refining scheme for hard-to-refine cottonseed oil, a method of alkaline refining with the addition of urea was proposed. Carbamide with gossypol forms new compounds and passes into the soapstock, which leads to a decrease in the color of the oil. However, in this case, a thick soapstock with high viscosity is formed, which creates difficulties in its processing and transportation [4].

Recently, improved technological processes for alkaline neutralization of raw cottonseed oil have been proposed using new types of alkali-replacing chemical reagents. In this direction, a special place belongs to the use of sodium silicate and other solutions. However, the technological processes of cleaning raw cottonseed oil with these types of alkaline reagents are also not without some drawbacks [1, 4-5].

It should be noted that the chemical and oil refining industries of the republic use various alkaline solutions in their technological processes. This leads to contamination of groundwater, which is partially used for irrigation purposes. At the same time, alkaline compounds of various metals accumulate in wastewater, which is industrial waste.

This is especially noticeable when activating stationary catalysts used in the technological processes of oil refining, cracking and catalytic hydrogenation of oils and fats. Alkaline activation of alloy stationary aluminum containing catalysts is also carried out using sodium hydroxide solutions. As a result of activation of catalysts, alkaline solutions of sodium aluminates are formed, which are subsequently, being industrial wastes, thrown into wastewater [6].

However, alkaline solutions of sodium aluminate have a high neutralizing and adsorption capacity. This is especially important when neutralizing the free fatty acids of raw cottonseed oils. At the same time, alkaline solutions of sodium aluminate react with substances associated with cottonseed oil. In addition, aluminum compounds and aluminosilicates have high adsorption properties, which is important when combining the methods of neutralization and adsorption purification of raw materials.

The prospects and effective possibility of using alkali-containing industrial wastes, in particular, solutions of sodium aluminate, in the fat-and-oil industry of the republic, namely in technologies for alkaline neutralization of raw cottonseed oil require:
• Study of technological processes of alkaline neutralization of raw cottonseed oil with solutions of sodium aluminate of various concentrations and excess.
• Determination of the possibility and effectiveness of the use of alkaline solutions of sodium aluminate in the industrial technology of refining cottonseed oil.
• Development of technological regimes and conditions for improving the quality, as well as the nutritional value of refined cottonseed oil.

2 Materials and methods

In studies on alkaline neutralization of raw materials with solutions of aluminates and sodium hydroxide, samples of cottonseed oil were used, obtained by prepressing and extracting cottonseeds of different quality.

Raw cottonseed oils obtained from various varieties of cottonseeds under production conditions were evaluated by acid number, color, content of phospholipids, gossypol and its derivatives:
• The acid number of the oil was determined by titration.
• Humidity of vegetable oils was determined by weight method [8].
• Content of phospholipids was determined according to the method [9].
• The content of gossypol was determined according to the method [10].
• Oil absorption of adsorbents was determined according to the procedure [11].
• The color of oils was determined using a Lovibond tintometer (method AOCSCc 13e-92) [11].

Qualitative indicators and physico-chemical characteristics of the original oils are given in Table 1.

Table 1. Characteristics of forpressed cottonseed oil samples.

<table>
<thead>
<tr>
<th>Sample, No.</th>
<th>Cottonseed grade</th>
<th>Acid number, mg KOH/g</th>
<th>Humidity, %</th>
<th>Chromaticity, kr.ed. at 3.5 yellow in Tm.4l</th>
<th>Content in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Phospholipids</td>
</tr>
<tr>
<td>1</td>
<td>I</td>
<td>3.2-4.0</td>
<td>0.20-0.21</td>
<td>17-21</td>
<td>0.5-0.7</td>
</tr>
<tr>
<td>2</td>
<td>I-II</td>
<td>4.8-5.9</td>
<td>0.22-0.24</td>
<td>25-28</td>
<td>0.5-0.7</td>
</tr>
<tr>
<td>3</td>
<td>III-IV</td>
<td>6.9-8.8</td>
<td>0.25-0.27</td>
<td>Not supervised</td>
<td>0.8-1.4</td>
</tr>
<tr>
<td>4</td>
<td>Nonstandard</td>
<td>12.0-14.0</td>
<td>0.28-0.31</td>
<td>Not supervised</td>
<td>1.3-1.7</td>
</tr>
</tbody>
</table>

As the data shown in Table 1 show, the used samples of forpressed cottonseed oils differ in quality and physico-chemical parameters. At the same time, in raw cottonseed oil obtained from low-grade and non-standard oilseeds, an increase in color, the content of free fatty acids and bound gossypol, as well as a decrease in the total amount of tocopherols, is observed.

To obtain the extraction oil, the cakes of the required (Table 1) cottonseeds were extracted under production conditions. It should be noted that the extraction of cottonseed oil with a magnetic solvent accelerates the process of degreasing oil-containing raw materials. An analysis of the extraction of oils showed that, unlike raw forpressed oils, extraction oils are characterized by a higher consumption of fatty acids, phospholipids, free and bound gossypol (Table 2).
3 Results and discussions

The purpose of this work is to study the influence of the concentration of alkaline solutions on the change in the content of the main accompanying substances of raw cottonseed oil during the refining process. As an alkaline reagent, sodium aluminate solutions of various concentrations were used with and without treatment in an electromagnetic field.

Evaluation of technological methods for refining raw cottonseed oil showed that the quality and nutritional characteristics of refined oil mainly depend on the minimum content of free fatty acids, phospholipids, gossypol and its derivatives and other substances in it. Reducing their number and completely removing some of the undesirable oil-related substances can significantly improve the performance of the finished product.

When raw cottonseed oil is treated with an alkaline solution of sodium aluminate of various concentrations, free fatty acids are neutralized and some of the accompanying substances are removed.

The results of the study of the effect of the concentration of aluminate solutions on the content of some related substances contained in the cottonseed oil are presented in Table 3.

Analysis of the presented results showed that with an increase in the concentration of sodium aluminate solutions, the amount of phosphatides, free and bound gossypol decreases. Significant changes occur at a concentration of 15 to 25%.

The influence of the concentration of sodium aluminate solutions on the acid number and color of pressing and extraction cottonseed oils was also studied. The obtained data are shown in tables.

Table 2. Characteristics of cottonseed oil samples.

<table>
<thead>
<tr>
<th>Sample, № (On the Table 2)</th>
<th>Acid number, mg KOH/g</th>
<th>Humidity, %</th>
<th>Chromaticity, kr救.ed. at 35 yellow in 1 cm std</th>
<th>Phosphatides</th>
<th>Free gossypol</th>
<th>Bound Gossypol</th>
<th>General tocopherol content, mg 100</th>
<th>The residual content of the solvent, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.0-5.9</td>
<td>0.21-0.26</td>
<td>34-41</td>
<td>0.7-0.9</td>
<td>0.11-0.20</td>
<td>0.14-0.25</td>
<td>70-80</td>
<td>traces</td>
</tr>
<tr>
<td>2</td>
<td>6.1-7.7</td>
<td>0.26-0.30</td>
<td>46-52</td>
<td>1.3-1.6</td>
<td>0.25-0.35</td>
<td>0.25-0.35</td>
<td>60-70</td>
<td>traces</td>
</tr>
<tr>
<td>3</td>
<td>7.9-12.5</td>
<td>0.33-0.35</td>
<td>Not supervised</td>
<td>1.9-2.6</td>
<td>0.35-0.40</td>
<td>0.40-0.55</td>
<td>50-90</td>
<td>traces</td>
</tr>
<tr>
<td>4</td>
<td>12.6-14.8</td>
<td>0.37-0.41</td>
<td>Not supervised</td>
<td>2.0-2.8</td>
<td>0.35-0.40</td>
<td>0.60-0.70</td>
<td>40-50</td>
<td>traces</td>
</tr>
</tbody>
</table>

Table 3. Influence of sodium aluminate solution concentration on the composition of forpressed cottonseed oil.

<table>
<thead>
<tr>
<th>Concentration of sodium aluminate solution, %</th>
<th>Phosphatide</th>
<th>Free gossypol</th>
<th>Bound gossypol</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.00</td>
<td>0.25-0.40</td>
<td>0.016-0.020</td>
<td>0.010-0.012</td>
</tr>
<tr>
<td>40.00</td>
<td>0.25-0.30</td>
<td>0.015-0.020</td>
<td>0.012-0.010</td>
</tr>
<tr>
<td>45.00</td>
<td>0.20-0.23</td>
<td>0.014-0.017</td>
<td>0.015-0.030</td>
</tr>
<tr>
<td>50.00</td>
<td>0.22-0.24</td>
<td>0.012-0.015</td>
<td>0.017-0.030</td>
</tr>
</tbody>
</table>

Studies have shown that under the action of sodium aluminate solutions of various concentrations, a decrease in the acid numbers of both forpressed and extraction cottonseed oils is observed. This is due to the interaction of free fatty acids with sodium aluminate:
The decrease in the color of oils is explained by the adsorption properties of sodium aluminate, which sorbs the coloring substances contained in the oils.

An analysis of the data obtained showed that a higher concentration of sodium aluminate solution (from 22 to 25%) is required to reduce the acid number and color indices of extraction oils. This is due to the fact that extraction oils contain a greater amount of related substances compared to press oils.

However, it should be noted that sodium aluminate solutions show their reactivity up to a certain indicator of the acid number and the content of substances accompanying the original oil.

This reagent can be used for cleaning mainly for pressed oils containing a smaller amount of related substances compared to extraction oils.

4 Conclusions

Technological parameters have been established that make it possible to significantly reduce the content of substances associated with the oil and improve its color.

The chemical interactions of the main components of crude oil with an alkaline solution of sodium aluminate were determined and their correspondence with known phenomena was established.

A technology is proposed for intensifying the partial alkaline neutralization of raw cottonseed oil with a solution of sodium aluminate activated by treatment in an electromagnetic field. Optimization of technological parameters has been carried out and modes have been determined that improve the quality of partially neutralized oil.

Obviously, the final process of alkaline refining of raw materials with reduced acidity and improved color can be achieved by reducing the consumption of sodium hydroxide, which increases the yield of refined oil and improves its quality.

High quality refined cottonseed oil is characterized by taste, smell, color, transparency, iodine, acid and peroxide values, the amount of phosphorus-containing and unsaponifiable substances and moisture.

References

9. S. Shomuratova, *Improving the energy efficiency of a solar air heater with heat accumulator using flat reflectors*, E3S Web of Conferences 411, 01026 (2023)

