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Comparative Analysis of Soybean Oil Bleaching with Carbon Adsorbents

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ABSTRACT: The article discusses the use of various carbon adsorbents for bleaching soybean oil, with an emphasis on experimental research of their effectiveness. Birch activated carbon (BAC) and carbon adsorbents developed based on licorice root, plum shell and walnut shell were studied. The purpose of the study was to evaluate the effect of these adsorbents on color, acid number and other quality characteristics of soybean oil after the bleaching process.

The study included AOCS-Tintometer color analysis, determination of acid number, mass fraction of moisture, volatile and unsaponifiable substances, as well as measurement of peroxide number and flash point. Infrared spectroscopy (IR) has been used to confirm chemical transformations in the oil after bleaching.

The experimental results showed that the use of carbon adsorbents based on licorice root leads to a significant improvement in the quality indicators of soybean oil. Based on the analysis, the effectiveness of carbon adsorbents in removing colorants and improving the nutritional characteristics of oil was emphasized, which makes their use promising for the food industry.

KEYWORDS: coal, adsorbent, sorption abilities, sorption, soybean oil, acid number, oil color.

I.INTRODUCTION

In the modern global vegetable oil market, soybean oil occupies a key position, accounting for approximately 30% of total production, ahead of such types of oils as sunflower and rapeseed (13% each), as well as palm oils (25%). This is due not only to the nutritional and functional properties of soybean oil, but also to its economic availability and high quality, which makes it in demand in the food industry, including the production of mayonnaise, salad dressings and canned foods. The particular importance of soybean oil lies in its content of omega-3 fatty acids, which help prevent cardiovascular diseases. Traditionally, soybean oil is produced by three main methods: pressing, extraction, and a combined pressing method followed by extraction [1, 2].

An important aspect of soybean oil production is bleaching, a process aimed at improving its flavor and stability and removing undesirable components. Today, there are a number of bleaching methods, but the use of carbon adsorbents is an innovative approach that has a number of advantages, including efficiency, environmental friendliness and reusability [3, 4].

Crude soybean oil contains both beneficial and potentially harmful contaminants. Beneficial ones include fat-soluble vitamins such as vitamins K and E, carotenoids, sterols and polyunsaturated fatty acids, including linoleic and linolenic acids, which are essential for the normal functioning of the body. However, crude oil also contains unwanted

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or harmful components that must be removed during the refining process to ensure the safety and quality of the final product.

Soybean oil refining includes several stages: settling, filtration, centrifugation, hydration, alkaline refining, bleaching and deodorization. These processes are aimed at extracting and reducing the content of undesirable components, while maintaining the beneficial properties of the oil [5, 6].

In terms of nutritional properties and fatty acid composition, soybean oil meets the high standards set for vegetable oils and can compete with such well-known oils as olive and corn. This makes it suitable for nutritional, medicinal and prophylactic use, especially in the context of providing the body with essential fatty acids.

Bleaching of soybean oil is a key step in the refining process, which uses various types of adsorbents, including carbon and clay. The effectiveness of these adsorbents in bleaching oil is the subject of this study, which will evaluate their ability to remove various impurities without affecting the beneficial components of the oil. This research aims not only to improve the quality of soybean oil, but also to increase understanding of its purification processes and improve its nutritional profile.

The purpose of this article is to comprehensively study the processes of bleaching soybean oil using various types of carbon adsorbents, the production conditions of which were published in early works [7, 8], and also to evaluate the influence of bleaching processes on the final properties of the product. Particular attention will be paid to research on the effectiveness of removing various contaminants and preserving the beneficial components of the oil, which is key to ensuring a high quality final product and compliance with the requirements of the food industry.

II. SIGNIFICANCE OF THE SYSTEM

The article discusses the use of various carbon adsorbents for bleaching soybean oil, with an emphasis on experimental research of their effectiveness. The study of methodology is explained in section III, section IV covers the experimental results of the study, and section V discusses the future study and conclusion.

III. METHODOLOGY

This study examined the effectiveness of various carbon adsorbents in the soybean oil bleaching process. The following samples were selected as adsorbents: imported activated carbon from birch (BAU), carbon adsorbent based on licorice root (SC), carbon adsorbent based on plum shells (UAS-1) and carbon adsorbent based on walnut shells (UAGA-1).

For the purposes of the experiment, soybean oil was selected with the following initial indicators: color - 1.5 red, 6.0 yellow and 0.7 blue units, acid value - 1.09 mg KOH/g, peroxide value - 4.8.

The main purpose of the experiment was to evaluate the effectiveness of adsorbents in changing the content of colorants in oil (measurement of light transmittance and color number), as well as in reducing the content of free fatty acids and substances titrated with alkali (assessment by acid number).

The experimental procedure was as follows: 100 g of soybean oil, heated to a temperature of 70-80 ºC, was mixed with 1% of the selected carbon adsorbent. This mixture was intensively stirred at a speed of 500 rpm for 20 minutes. After completing the mixing process, the mixture was filtered through a paper filter in a muffle furnace at a temperature of 50-60ºC.

Experiments were conducted to determine optimal conditions and select the most effective adsorbent for bleaching soybean oil, which is important for improving the quality of the final product.

IV. EXPERIMENTAL RESULTS

This section presents the results of experimental studies conducted to evaluate the effectiveness of using various carbon adsorbents for the soybean oil bleaching process.

During the experiments, changes in the color, acid and peroxide numbers of soybean oil were studied after treatment with various adsorbents. These indicators are key when assessing the quality of bleached oil and its suitability for further use in the food industry. The results obtained for bleached oils are given in table. 1.

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Table 1.
Analytical characteristics of soybean oil after treatment with various carbon adsorbents.

The name of indicators	Carbon adsorbents			
	BAU (control)	SK	UAS-1	UAGA-1
Color according to AOCS-Tintometer Colour	0.9R 6.8Y	0.7 R 3.8 Y	0.8 R 4.8Y	0.9 R 4.8Y
Acid number, mg KOH/g	0.8	0.5	0.6	0.7
Mass fraction of moisture and volatile substances, %	0.15	0.13	0.18	0.14
Mass fraction of non-fat impurities, %	0.06	0.05	0.08	0.05
Mass fraction of non-saponifiable substances, %	1.3	1.2	1.4	1.3
Peroxide value, mmol O/kg	5	4	6	5
Flash point, ºC	225	223	227	228

Analysis of the presented table allows us to evaluate the effectiveness of various coal adsorbents (BAU, SK, UAS-1, UAGA-1) in the process of bleaching soybean oil.

Better color improvement was observed when using adsorbent SK (0.7R 3.8Y), indicating more effective removal of colorants compared to other adsorbents. For adsorbents UAS-1 and UAGA-1, the color remains comparable to the control sample (BAU), which may indicate similar efficiency.

The SA adsorbent has the lowest acid number (0.5 mg KOH/g), which indicates the greatest reduction in the content of free fatty acids. This may indicate a higher cleaning ability of this adsorbent. Also, the lowest mass fraction of moisture and volatile substances is observed for this adsorbent (0.13%). This may indicate its ability to more effectively remove water and volatiles from oil.

The slight differences in the mass fraction of non-saponifiable substances between the adsorbents indicates similar efficiency in removing non-saponifiable substances. The SA adsorbent has the lowest peroxide number (4 mmol O/kg), which may indicate less oil oxidation when using this adsorbent.

Based on these data, SA adsorbent demonstrates the greatest effectiveness in improving the quality of soybean oil compared to other adsorbents in many aspects, including reducing color, acid value, moisture and volatile matter content, and peroxide value.

Figure 1 shows the change in light transmittance (Kras. units) of soybean oil depending on the bleaching temperature (T, °C)

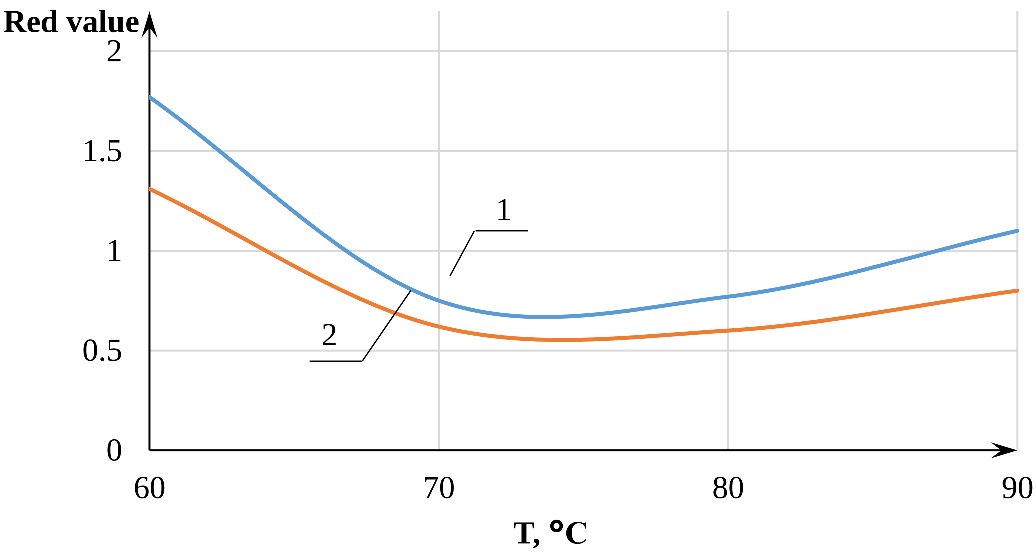

Fig. 1. Dependence of color on bleaching temperature
1-control sample BAU; 2- SK

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Curve 1 starts with a higher transmittance at about 60 °C, which decreases with increasing temperature until about 75 °C, after which it begins to increase gradually. This indicates that the optimum temperature for bleaching this oil sample, leading to minimum color, is in the range of around 75°C.

Curve 2 shows a slower decrease in light transmittance with increasing temperature, reaching a minimum at approximately 80 °C, after which it also begins to increase. This may indicate that the maximum bleaching efficiency for this sample is achieved at a higher temperature than for the first.

Both curves demonstrate that there is a certain temperature at which bleaching efficiency is maximum, and that as heating continues, efficiency decreases. This may be due to the fact that at higher temperatures, processes are activated that can degrade the color of the oil, such as oxidation or polymerization of oil components.

Data indicate that temperature control is an important factor in the oil bleaching process, and that each type of oil and adsorbent used may have a different optimal processing temperature.

Next, the dependence of the degree of purification on the amount of introduced adsorbent was studied.

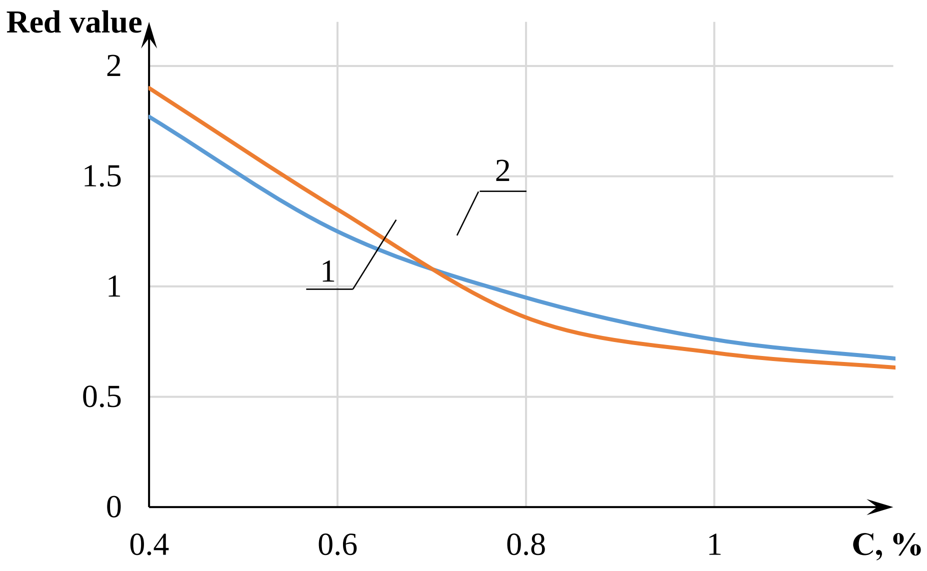

Fig. 2. Dependence of color on the amount of adsorbent introduced: 1) BAU control sample; 2) SK.

In the provided fig. Figure 2 shows the dependence of the degree of oil purification (expressed in terms of light transmittance, Kras. units) on the adsorbent concentration (C, %). Light transmittance is an indicator of the color of the oil after bleaching, with lower values indicating better purity and lighter color of the oil.

Curve 1 shows a decrease in light transmittance with increasing adsorbent concentration up to a certain point, after which a further increase in adsorbent concentration does not lead to a noticeable improvement in purification (plateau on the graph).

Curve 2 also shows a decrease in light transmittance with increasing adsorbent concentration, however, this curve reaches a plateau at lower transmittance levels, indicating higher efficiency of the adsorbent compared to the adsorbent of Curve 1.

These results may indicate that there is an optimal adsorbent concentration at which the best oil purification is achieved. As the concentration is further increased, the bleaching effect improves up to a certain point, after which there is little or no further improvement.

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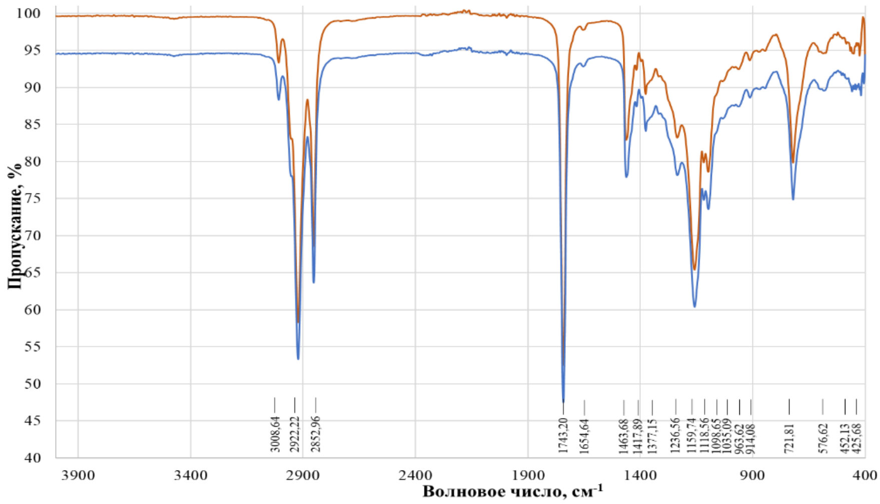

Fig 3. Spectra of original and bleached soybean oil.

The presented infrared spectroscopy spectrum shows the spectrum corresponding to the original (unbleached) and bleached soybean oil. Peaks in the region of about 3000 cm^{-1} correspond to the stretching of C-H hydrogen bonds in alkyl groups (methyl and methylene groups). The strong peak around 1740 cm^{-1} usually corresponds to stretching vibrations of the carbonyl group (C=O) in esters, which is characteristic of fatty acids in oils. The peaks at 1460 and 1375 cm^{-1} are attributed to C-H bending vibrations in alkyl chains. Bands around 1150-1000 cm^{-1} may correspond to stretching C-O-C vibrations in etheric connections.

The blue graph (bleached oil) shows lower transmittance in the region of the peaks associated with C-H and C=O bonds, which may indicate a decrease in the concentration of the corresponding groups after bleaching. This may indicate the removal or conversion of some fatty acids or other components containing these groups during the bleaching process.

The orange graph (original oil) shows higher transmittance, indicating a higher concentration of unmodified chemical groups.

V. CONCLUSION AND FUTURE WORK

Based on the research conducted in this article, we can conclude that the use of various carbon adsorbents, including birch activated carbon (BAC), as well as carbon adsorbents based on licorice root (SC), plum shell (UAS-1) and walnut shell (UAGA) -1), had a significant impact on improving the quality indicators of soybean oil after the bleaching process.

A comparative analysis showed that all studied carbon adsorbents effectively remove coloring matter from soybean oil, reduce the acid number and other indicators of oil quality, which contributes to its discoloration and improvement of consumer properties.

The study of the influence of bleaching temperature on the color of the oil and the dependence of the degree of purification on the amount of introduced adsorbent confirmed that the selection of optimal process parameters allows one to achieve the best bleaching results.

Analysis of the IR spectra of bleached and unbleached soybean oil revealed changes in oil chemistry associated with the bleaching process, highlighting the effectiveness of the adsorbents used in removing undesirable components.

Overall, the results confirm that carbon adsorbents, including those developed based on natural components, are effective and cost-effective materials for bleaching soybean oil, which is important for the food industry. Further research can be aimed at optimizing the composition and conditions of use of adsorbents to increase the efficiency of the bleaching process and improve the quality of the finished product.

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