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SYSTEMATIC ANALYSIS METHOD IN COTTON OIL MICELLA REFINING TECHNOLOGY

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Abstract

This scientific article presents an analysis of the technological line for the purification of cottonseed oil in micelles. According to the scheme, technological operations and processes are carried out as follows: the oil-containing plant raw material – (cottonseed) pulp is sent to the extractor I, where it is extracted using an organic solvent. The use of the methodology of systematic analysis in the technology of refining cottonseed oil in micelles allows simplifying technological processes, reducing the amount of costs and expenses for this purpose.

Keywords: *Cottonseed oil, micelle refining methods, systematic analysis*

Introduction

Despite sufficient experience in refining cottonseed oil micelles, the quality and yield of the micelles remain low, which leads to significant oil losses in soap, gasoline, and other substances (Guide to the Technology and Processing of Vegetable Oils and Fats. p. 44; Fedorova V. M., Pashchenko N. K., Blinkova I.Yu., 2005).

The technological regimes presented in the "Current Technology Guide" do not always provide the desired results in terms of the quality and quantity of oil obtained from the micelles (Abdurakhimov A. A., Kadirov Yu.K., Serkaev K. P., 2016; Abdurakhimov A. A., Serkaev K. P., Kadirov Yu.K., 2013).

The cottonseed oil refining process line requires modernization of a number of technological processes and equipment, taking into account the difficulty of separating soaps from the micelles, which leads to the production of relatively low yields and low-quality refined oil (Arutyunyan N. S. et al., 1999; Kuptsov, V. A., 2003).

Finding a rational solution to this problem is, of course, associated with the use of systematic and methodological analysis methods described in scientific research (Rogov, I. A., 1988).

The advantage of the modern approach to the modernization of the cottonseed oil miscellaneous refining technological line is that it allows, taking into account the real conditions of technological processes, to increase production efficiency and improve product quality. This allows determining a number of parameters based on the developed technological regimes, as well as improving the methods specified in the existing "manuals". Therefore, the creation of a systematic analysis methodology in the cottonseed oil miscellaneous refining technology is an urgent issue.

Materials and methods

Modern methods are used in systematic analysis, its implementation methodology, evaluation and analysis (Stopskiy V. S., Klyuchkin V. V., Andreev N. V., 1992; Ismatov S. Sh., Majidov K.Kh., Tojiddinov R.Kh., Zainiev M. F., Bozorov D. Kh., 2002).

The purpose of the work is to develop a systematic analysis methodology for the refining technology of cottonseed oil micella.

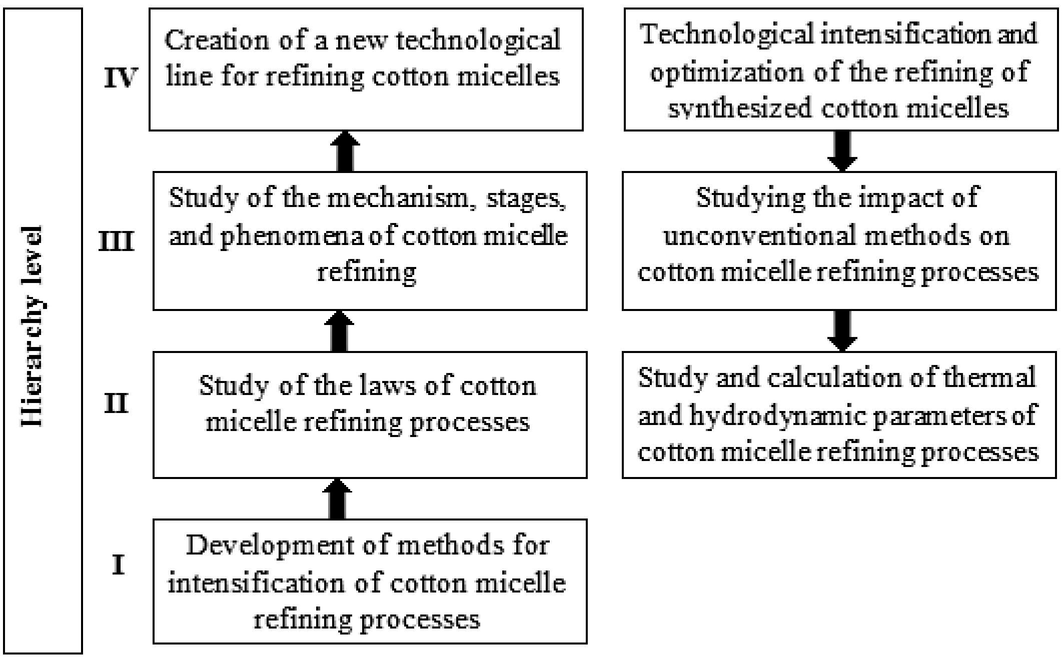
The objects of research are cottonseed oil micelles, technological systems, stages of its refining, their analysis and evaluation.

Results

Modernization of the technological line requires the implementation of an intensive scientific approach and a methodological approach that determines the level of research and development.

The scheme of technological processing of refined components of cottonseed oil in micelles is presented in Figure 1.

Figure 1. *Scheme of a systematic study of the technological line for refining cottonseed oil micella*

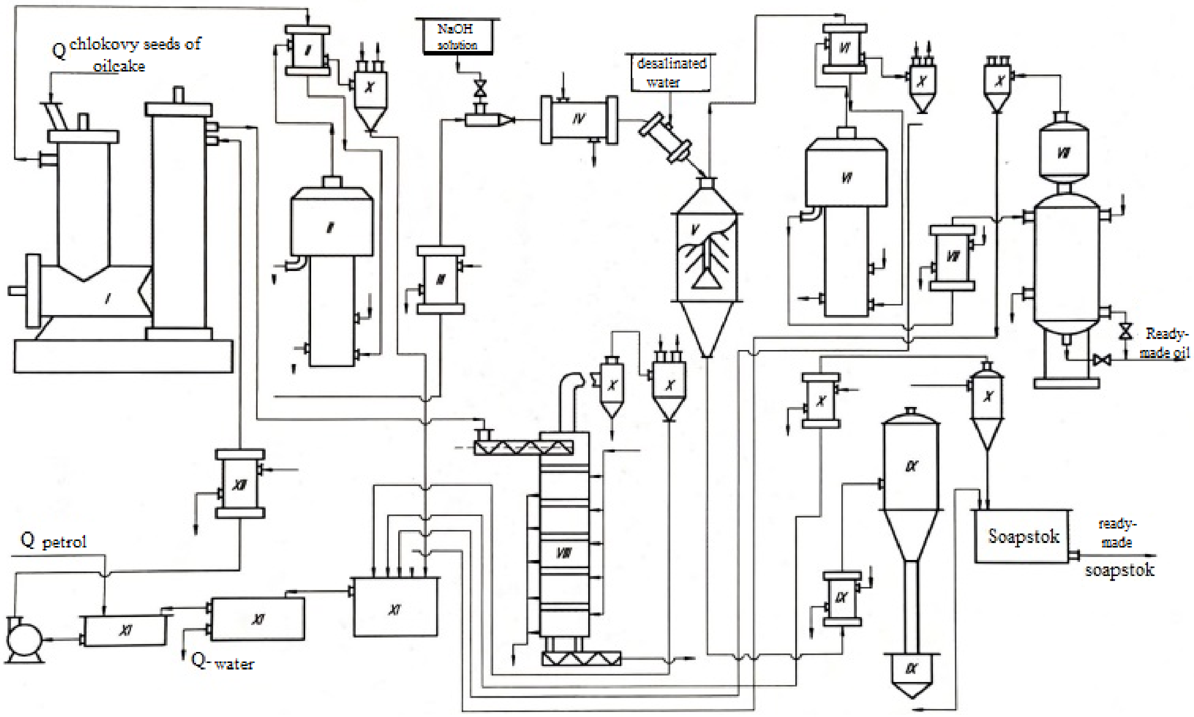


The technological line for the purification of cottonseed oil in micelles was analyzed, the scheme of which is presented in Figure 2.

According to this scheme, technological operations and processes are carried out as follows: oil-containing plant raw material – (cottonseed) pulp is sent to extractor I, where it is extracted (separated) using an organic solvent.

The deoiled material (meal) leaving the extractor, containing 25–40% solvent, is sent to heater-toaster VIII. Here, the solvent is separated from the meal – using a heater and sharp steam, thus reducing the amount of remaining solvent to approximately 0.02%. After that, the meal is sent to the warehouse for storage.

Figure 2. *Oil extraction production with a cotton oil refining line in missell*



The miscella, leaving the extractor I, is sent to the heater of the first primary distiller. Here, the miscella is heated using solvent vapors coming from the primary distiller II.

The heated micelle is sent to the first primary distiller II, where the micelle is concentrated to 40–60%. The evaporated micelle, at a temperature of 75–80 °C, is sent to the micelle cooler III, where its temperature is reduced to 20–30 °C.

The cooled micelle is sent to a flow reactor-turbulizer (neutralizer), where it is mixed with an alkaline solution with a temperature of 20–30 °C.

The resulting reaction mixture is sent to the heater IV, where the temperature rises to 65–70 °C.

The heated mixture is sent to the micelle separator V, where the mixture is continuously separated into a soap fraction and refined micelle.

The soap fraction is separated from the solvent in the IX apparatus, and the refined micelle, bypassing the heater, is sent to the second primary distiller VI. Here it is concentrated to 95–98% using shell and flash steam.

The highly concentrated refined micelle is sent to the final distiller VII. Here, the organic solvent residues in the refined oil are removed using shell and flash steam.

The finished refined cottonseed oil is obtained at the outlet of the final distiller.

In this scheme, organic solvent vapors from units II, VI, VII, VIII and IX are sent to individual condensers X. After cooling here, the solvent is directed to the water separator XI. The purified circulating solvent is returned to the extractor I through the heater XII at a temperature of 55–60 °C.

The analysis of raw materials, semi-finished products and finished products is carried out directly in the laboratory of the manufacturing enterprise.

Appropriate methods and standards were used for physicochemical studies of raw cotton micelle and its processing products (Ismatov S.Sh., Mamatqulov F.G., 2019).

The "trial refining" method was used to determine the yield of refined cottonseed oil (Abdurakhimov A.A., Serkaev K.P., Pardaev G.E., Yusupkhonov S., 2012).

The yield of neutralized oil according to this method is approximate even in the batch method, since the mixing conditions and processing time differ significantly in laboratory and production conditions.

It is known that the amount of alkali required for refining cottonseed oil with an acidity in the micelle of more than 1.5% was determined by the following formula:

$$Щ = \frac{K}{5,2} + 0,54_{g} \qquad (1)$$

where:

K – acid number of oil in terms of oleic acid, %;

5.2 and 0.54 – experimental coefficients.

The calculation according to the adopted method is based only on the acid number of oils and does not take into account the activity of additives that do not exhibit acidic properties.

Therefore, we used an improved method to determine the optimal amount of alkali required for refining high-black cottonseed oil, taking into account the acidic properties of the additives.

The essence of the methodology is as follows: 30–40 grams of cottonseed oil with a known acid number is mixed with thoroughly refined oil in a ratio of 1 ÷ (1–6) (to facilitate color determination). The resulting sample is heated at a temperature of 120–140 °C for 3–5 minutes and divided into two parts.

The first part is cooled to 40 °C, and the second part is heated for 7–12 minutes in the above temperature range, then it is also cooled to 40 °C. The color and interfacial tension of the prepared samples are determined and the product of the following ratios is calculated:

$$\frac{Ц_{E1}}{Ц_{E2}} \times \frac{\sigma_2}{\sigma_1} \qquad (2)$$

Then, based on formula (2), the optimal amount of alkali required for refining high-black cottonseed oil in micelles is determined:

$$P_{ш} = К.ч. \times 0,714 \left(1 + \frac{Ц_{E1}}{Ц_{E2}} \times \frac{\sigma_2}{\sigma_1}\right), kg/m^t \qquad (3)$$

where:

К.ч. – acid number of the oil under study, mg KOH;

0.714 – conversion coefficient from KOH to NaO H.

Це1 and σ1 – color and interfacial tension when the sample is heated for 3–5 minutes;

Це2 and σ2 – color and interfacial tension when the same sample is heated for 7–12 minutes.

To simplify the methodology and reduce its duration, the following formula can be used to determine σ1:

$$\sigma = K\left(d_1 - d_2\right) \times P_{cp} \qquad (4)$$

Because:

$$\frac{\sigma_2}{\sigma_1} = \frac{K\left(d_1 - d_2\right) \times P_{cp2}}{K\left(d_1 - d_2\right) \times P_{cp1}} \qquad (5)$$

In this case, the interfacial tension is determined in micrometer units.

To determine the relative error in indirect measurement of the amount of alkali required for refining vegetable oils, the function РшP_{ш}Рш is logarithmized and the following expression is obtained:

$$\ln P_{ш} = \ln 0,714 + \ln К.ч. + \ln(Цв_1 P_{cp2} + Цв_2 P_{cp1}) - \ln Цв_2 - \ln P_{cp1} \qquad (6)$$

Then, by differentiation, we get:

$$\frac{dP_{ш}}{P_{ш}} = \frac{dK_{ч}}{K_{ч}} + \frac{dЦв_1}{Цв_1} + \frac{dP_{cp2}}{P_{cp1}} + + \frac{d(Цв_1 P_{cp2} + Цв_2 P_{cp1})}{Цв_1 P_{cp2} + Цв_2 P_{cp1}} \qquad (7)$$

Replacing the differentials with the corresponding mean square errors, and based on the rules for adding errors in subtraction, addition, and multiplication, the following formula is obtained:

$$\frac{\delta P_{ш}}{P_{ш}} = \frac{\delta K_{ч}}{K_{ч}} + \frac{\delta Цв_1}{Цв_1} + \frac{\delta P_{cp2}}{P_{cp1}} + + \frac{\delta(Цв_1 P_{cp2+} Цв_2 P_{cp1})}{Цв_1 P_{cp2} + Цв_2 P_{cp1}} \qquad (8)$$

$$\delta^2\left(Цв_1 \times P_{cp2}\right) = = \delta^2 Цв_1 \times P_{cp2}^2 + \delta^2 P_{cp2} \times Цв_1^2 \qquad (9)$$

In this calculation, the relative error of the new methodology is determined as follows.

$$\frac{\delta P_{ш}}{P_{ш}} = \frac{\delta K_{ч}}{K_{ш}} + \frac{\delta Цв_1}{Цв_1} + \frac{\delta P_{cp2}}{P_{cp1}} + \frac{\sqrt{Цв_1^2 \delta^2 P_{cp2} + P_{cp2}^2 \delta^2 Цв_1 + Цв_2^2 \delta^2 P_{cp1} + P_{cp1}^2 \delta^2 Цв_2}}{Цв_1 \times P_{cp2} + P_{cp1} \times Цв_2} \qquad (10)$$

To determine the errors of the improved method, 40 measurements were performed on the same sample. The measurement results were processed in the following way:

- The arithmetic mean of the measurements was determined:

$$Ш = \frac{Ш_1 + Ш_2 + \ldots + Ш_{40}}{40} = \frac{1}{40}\sum_{n-1}^{40} Ш_n \quad (11)$$

Deviations from the mean were calculated for each experiment:

$$\varepsilon_i = \bar{x} - x_i \quad (12)$$

where x_i re the observed values;

The root mean square error was found:

$$\delta_s = \sqrt{\frac{\Sigma_{i=1}^{40} Ш_i^2}{39}} \quad (13)$$

These results were inserted into formula (9), and the relative error of this methodology was found to be ±4.8%.

Table 1. *Types of processes in the SEED MICELLA refining process line and their levels of systematic research hierarchy*

Process type	Process name in the technological line	Research hierarchy levels
Dosing	Feeding NaOH solution	Levels II + IV
	Feeding demineralized water	Levels II + IV
Mechanical	Mixing seed micelles with NaOH solution	Levels I + III
	Mixing neutralized micelles with water	Levels II + IV
	Separation of soapy sediment from neutralized seed micelles	Levels II + IV
Heat	Cooling raw seed micelles	Levels II + IV
	Heating the mixture of micelles and NaOH solution	Levels II + IV
Chemical	Interaction of seed micelles with alkali	Levels I + III
Change in the aggregate state of substances	Processing of soapy sediment	Levels II + IV
	Coagulation of soapy sediment	Levels II + IV

Table 2. *System analysis tasks in the main subsystems (A1, B1 and C1) of the seed micelle refining technological line*

Name of the technological line subsystem	Levels of the systematic research hierarchy
Neutralization of crude seed micelles (C1)	–
Separation of soap residues from neutralized micelles (B1)	+
Obtaining refined seed micelles (A1)	–

Table 2 lists the main subsystems of the process line (A1, B1 and C1) and their levels of the system analysis hierarchy.

Discussion and Conclusion

The use of the systematic analysis methodology in the technology of refining cottonseed oil in micelles allows for the simplification of technological processes and the reduction of costs and expenses for this purpose.

This diagram shows the purpose of the systematic analysis at each hierarchical level and the corresponding research tasks. For example, at the first hierarchical level, the purpose of the study is to study the mechanism, stages and phenomena of the refining process, and the corresponding research task is to determine the kinetic parameters of the refining process. At the fourth level, the goal is to create a new technological line for refining cotton micellas.

The tasks of studying the technological line for cleaning cotton micellas also include the selection of optimal technological parameters for the technological line for cleaning cotton micellas. In this case, the interrelation and influence of these goals are carried out both in the vertical and horizontal directions.

The technological line for cleaning cotton oil in micelles is a complex and multi-stage production. Analysis of such systems allows you to identify the correlation of technological processes with the parameters under consideration and "bottlenecks" in the devices.

Thus, this work reduces the amount of research being done and brings it closer to the goal that should logically be achieved.

Thus, the use of the improved methodology for calculating alkali consumption allows optimizing the yield of refined oil from cottonseed oil micelles.

At present, there are multiple processes used in the current cottonseed oil MISSELLA refining technological line. These processes can be studied based on a typical scheme. For example:

- mixing raw cottonseed oil micelles with an alkali solution,
- mixing neutralized micelles with softened water, etc.

In such cases, it is possible to increase the levels of the systematic analysis hierarchy, which will expand the amount of data on this study.

Optimization of processes helps to group similar processes in the refining of cottonseed oil micelles and determine the minimum volume of scientific research work.

As can be seen from Table 1, in the current technological line for refining seed oil, the following types of processes are used in micelles: dosing, mechanical, thermal, chemical and changing the aggregate state of substances. All of these affect the formation and quality of the obtained refined micelles and the quality of the final product. At the indicated levels of the systematic analysis hierarchy, these processes were studied within the framework of the specified research tasks and subject to achieving the specified quality indicators.

Note: The "+" sign indicates the need to perform systematic analysis tasks at the appropriate hierarchical level, and "–" indicates that it is not necessary.

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