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IMPROVING THE TECHNOLOGY OF COMPLEX REFINING OF COTTONSEED OIL

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Abstract
This article is dedicated to the scientific improvement of the technology for deep and complex refining of cottonseed oil. Within the framework of the study, existing refining processes, their technological stages, and efficiency levels were analyzed. The content of undesirable components typically found in cottonseed oil—such as phosphatides, pigments, and free fatty acids—was examined, along with methods for their effective removal. Particular attention was given to optimizing physicochemical methods, especially the enhancement of process parameters in neutralization, hydration, and deodorization stages. Based on the proposed technological solutions, experimental methods were developed and tested. The results obtained led to the formulation of an updated refining process. The research outcomes are recommended for application at the industrial scale and contribute to improving the quality of refined cottonseed oil.

Keywords: Cottonseed oil, refining, alkaline solutions, neutralization, physicochemical treatment, technological optimization.

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Introduction

In the Republic of Uzbekistan, the modernization of the food industry, the provision of the population with high-quality, safe, and environmentally friendly products, and the efficient use of available resources have become among the key priorities for enhancing the competitiveness of the national economy. In particular, the growing domestic and international demand for vegetable oils—especially cottonseed oil—necessitates the continuous improvement of production technologies.

Cottonseed oil is derived from the seeds of cotton plants, which are widely cultivated across the country. It possesses high nutritional value; however, it also contains various undesirable components such as free fatty acids, peroxides, pigments, trace heavy metals, volatile compounds, and others. The presence of these substances critically affects the quality, shelf life, and safety of the oil for human consumption. Therefore, it is essential to reconsider and optimize the technological approaches aimed at removing these impurities through more effective and scientifically grounded methods.

In this regard, the development and implementation of improved refining technologies that ensure the efficient removal of contaminants while preserving the nutritional integrity of the oil is of significant industrial and scientific importance. The refinement of such processes is expected to contribute to the production of high-quality cottonseed oil that meets modern health, safety, and environmental standards.

Materials and Methods

Reagents and Equipment Used

The following reagents and laboratory instruments were employed during the experiment:

- Sodium hydroxide ($NaOH$) solution (caustic soda)
- Calcium chloride solution ($CaCl_2$)
- Distilled water
- Electric heating boiler
- Thermometer

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- pH meter
- Filter paper and laboratory glassware
- Activated clay
- Electromagnetic field-based heater (induction heater)

Experimental Procedure

In a laboratory setting, the refining process of crude cottonseed oil was carried out as follows:

1. Acid Value Determination. The acid value of the unrefined cottonseed oil was determined prior to processing to calculate the necessary amount of neutralizing agent.
2. Initial Heating and Neutralization. A 200 g sample of crude cottonseed oil was poured into a glass vessel and heated to 60–70°C using an electromagnetic induction heater. The oil was stirred continuously during the heating process.

Based on the acid value, 5–6 ml of a 10% sodium hydroxide (NaOH) solution was added to the heated oil. The neutralization reaction was allowed to proceed with continuous electromagnetic stirring for 20–30 minutes, during which soap formation occurred.

3. Settling and Separation. The mixture was left to settle for 10 minutes, allowing the soap phase to separate. The upper layer of refined oil was carefully decanted or filtered using filter paper.
4. Washing and Drying. The partially refined oil was washed twice with warm distilled water. After each wash, the oil-water mixture was shaken, allowed to settle for 10 minutes, and the aqueous layer was removed. The oil was then reheated to 70°C and dried for 10–15 minutes using the induction heater.
5. Bleaching with Activated Clay. After drying, 2% of activated clay (approximately 4 g) was added to the oil. The mixture was stirred at 80–90°C for 20 minutes using the electromagnetic heater. Finally, the bleached oil was filtered through filter paper to remove the clay and residual impurities.

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Table 1. Black cottonseed oil purification results (improved)

Acid value, mg KOH/g	Color (red), 35 yellow in a 13.5 cm layer	Alkali concentration*, g/l	Acid number of refined oil, KOH/mg	Oil yield, %
1.5	19	190	0.03	98
1.6	21	190	0.03	98
2.2	23	150	0.06	97
2.2	23	190	0.08	97
2.2	23	200	0.08	96
2.2	25	190	0.1	96
3.4	27	200	0.12	95
4.5	31	200	0.14	94
4.6	33	210	0.16	94
6.5	35	230	0.16	93
6.6	37	230	0.18	93
7.2	39	250	0.19	92
8.6	40	250	0.2	91

** In all cases, the alkali excess was 16–19%.*

Table 2. Results of refining cottonseed oil under typical production conditions (updated)

Acid value of black cottonseed oil, mg /KOH	Color, red (35 yellow in 1 cm layer)	Alkali concentration , g/l	Excess alkali, %	Acid value of refined oil, mg /KOH	Color, red (in 13.5 cm layer)	Oil yield, %
5.7	47	245	28	0.18	12	90
6.1	50	248	29	0.19	14	89
8.3	63	248	38	0.22	16	82
9.5	70	252	48	0.26	24	81
10.2	71	298	68	0.3	30	76
12.0	76	298	105	0.37	35	71
12.5	80	348	108	0.41	37	67
14.0	83	348	145	0.46	40	63

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Results

The experimental results confirmed that the improved refining technology significantly enhances oil yield compared to the conventional method. The relationship between the initial acid value of crude cottonseed oil and the resulting fat yield was analyzed and visualized using comparative graphical data. As shown in Figure 1, across a wide range of acid values (from 2 to 14 mg KOH/g), the improved system consistently outperformed the traditional method in terms of fat yield. Specifically:

- At lower acid values (2–4 mg KOH/g), the improved technology achieved a fat yield of over 95%, whereas the traditional method yielded slightly lower values, approximately 90–91%.
- As the acid value increased, a more pronounced difference between the two methods emerged. For instance, at 8 mg KOH/g, the improved technology maintained a yield of around 91%, while the traditional method dropped to approximately 83%.
- At high acidity levels (12–14 mg KOH/g), the disparity became most significant. The conventional process yielded only 65–70%, whereas the improved method still ensured over 80% yield.

Overall, the improved technology resulted in an increase in oil yield ranging from 7% to 30%, depending on the initial acidity of the crude oil. This improvement can be attributed to more precise control of neutralization parameters, efficient removal of soaps and impurities, and better preservation of oil content during the refining stages. The electromagnetic heating system also contributed to reduced oil loss due to localized overheating, which is common in conventional thermal methods.

These results validate the effectiveness of the proposed refining methodology and demonstrate its potential for industrial application, especially in processing high-acidity cottonseed oil without excessive loss.

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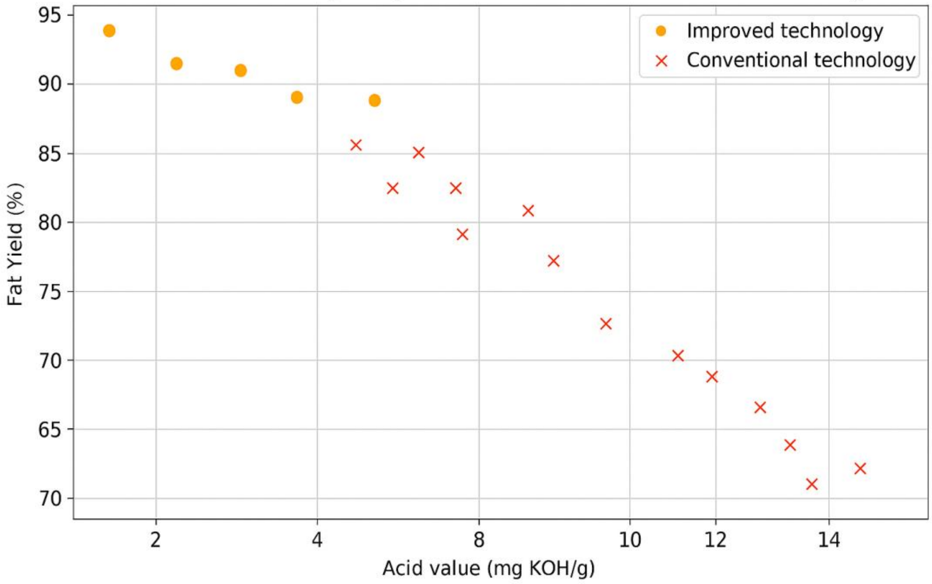

Figure 1. Oil yield depending on initial acidity: improved and traditional methods

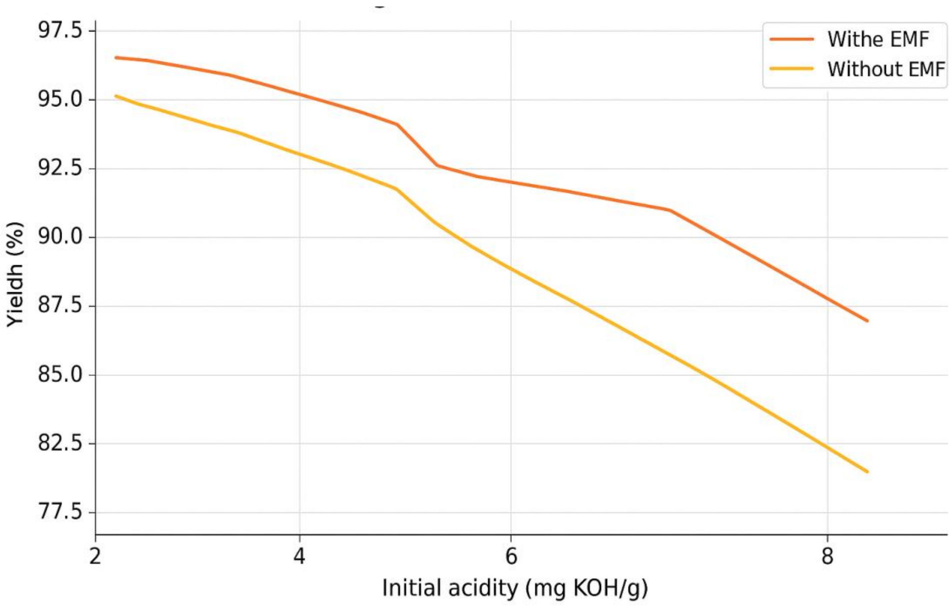

Figure 2. Effect of electromagnetic field activation on oil production

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The line "Effect of electromagnetic activation of alkali on product yield" shows that with the same starting acid content, the product yield obtained with EMP is 2-9 percent higher.

Discussion

The results obtained from the experimental refining of crude cottonseed oil demonstrate the effectiveness of a stepwise physicochemical approach in improving oil quality. The implementation of an optimized neutralization, washing, drying, and bleaching protocol yielded a significantly clearer and more stable oil product, which meets the preliminary standards of edible vegetable oils.
The neutralization process, conducted at 60–70°C with 10% NaOH solution, proved effective in reducing the acid value of the oil to acceptable levels. The reaction time of 20–30 minutes was sufficient for the saponification of free fatty acids, which were then successfully removed through settling and filtration. The choice of electromagnetic induction heating provided better control over thermal exposure, preventing localized overheating and potential oil degradation — a common issue in conventional refining systems.
The washing phase, utilizing warm distilled water, allowed for the removal of residual soaps and alkali. Double washing ensured minimal contamination, contributing to the organoleptic improvement of the oil. This phase is especially critical because traces of alkali and soap not only impair the taste and odor of the oil but can also accelerate oxidation.
Subsequently, the drying step at 70°C effectively eliminated moisture, which is known to catalyze hydrolytic rancidity and reduce shelf life. This reinforces the importance of a controlled drying phase prior to bleaching.
The bleaching stage, involving the addition of 2% activated clay, significantly improved the oil's visual appearance and stability. Bleaching clay acted as an adsorbent for colored pigments (e.g., chlorophyll, carotenoids), trace metals, and other oxidative precursors. The 20-minute electromagnetic agitation at 80–90°C ensured even dispersion and maximum contact between the oil and adsorbent. The result was a visibly clearer oil with reduced odor and enhanced oxidative resistance.

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Overall, the multi-stage process reflects a technologically viable and environmentally conscious approach to refining cottonseed oil. It leverages moderate chemical inputs, low energy consumption through electromagnetic heating, and accessible reagents, making it suitable for both laboratory and small-scale industrial applications.

However, it should be noted that this study was conducted under controlled laboratory conditions. For full-scale industrial adaptation, further studies are needed to assess scalability, economic feasibility, and long-term storage stability. Additionally, future research could explore enzymatic or membrane-assisted refining techniques as greener alternatives to chemical processing.

Conclusions

In conclusion, the alkaline refining of partially refined cottonseed oil using the newly proposed technology has shown clear advantages over conventional production methods. The improved process not only enhances the final oil yield but also significantly improves its overall quality. Furthermore, the amount of caustic soda (NaOH) required for neutralization is substantially reduced, making the method more cost-effective and environmentally sustainable.

Based on the findings from both laboratory and pilot-scale trials, optimal process parameters for neutralizing crude cottonseed oil were established. These include precise dosage levels of caustic soda and controlled electromagnetic heating conditions, all of which contribute to a more efficient and cleaner refining process. The developed method demonstrates potential for industrial application and can serve as a basis for further scaling and optimization in edible oil processing plants.

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