Chapter 08 / Capítulo 08

Next-Generation Industrial Engineering: Artificial Intelligence, Smart Manufacturing, and Sustainable Industrial Engineering
ISBN: 978-9915-704-21-0
DOI: 10.62486/978-9915-704-21-0.Ch08
Pages: 103-113

©2026 The authors. This is an open access article distributed under the terms of the Creative Commons Attribution (CC BY) 4.0 License.

Research on the Process of Obtaining Pure Sesame Oil Using Microwave Radiation

Investigación sobre el proceso de obtención de aceite de sésamo puro mediante radiación de microondas

Jasur Farmonov[1] ✉, Mohichehra Sobirova[2] ✉, Erkin Erkinov[3] ✉, Fargan Asadov[4], Zulfiyya Asadova[4]

[1]Department of Food Products Technology, University of Economics and Pedagogy. Karshi, Uzbekistan.

[2]Department of Food Products Technology, Yangi Yer Branch of Tashkent Chemical Technologies University. Syrdarya, Uzbekistan.

[3]University of Economics and Pedagogy. Karshi, Uzbekistan.

[4]Institute of Radiation Problems Ministry of Science and Education Republic of Azerbaijan. Baku, Azerbaijan.

ABSTRACT

This study investigated microwave processing optimization for sesame seed (Sesamum indicum L.) oil extraction efficiency. Sesame seeds underwent controlled microwave treatment at 105W and 2450 MHz with varying exposure times (1-20 minutes), comparing results against conventional thermal processing and combined steam-microwave methods. After unsuccessful attempts with pre-grinding, steam pre-treatment at 250°C for 30 minutes was adopted prior to microwave exposure. Response surface methodology identified optimal processing conditions targeting maximum oil and cake yields. Mass loss analysis revealed no measurable loss during the first 5 minutes of microwave treatment, with gradual increases from 0,25 % at 10 minutes to 1,00 % at 20 minutes. Results demonstrated significant improvements using combined steam-microwave treatment at 10 minutes exposure, achieving 33,72 % oil yield and 68,62 % cake yield—representing 1,32 % higher oil extraction than conventional methods. Optimal conditions through microwave processing alone yielded 32,79 % oil and 66,71 % cake. The combined steam-microwave approach reduced seed moisture content by 3,77 %. Statistical analysis revealed three critical factors significantly affecting extraction: initial seed oil content, microwave power level, and processing duration. Microwave-assisted processing proved superior to traditional thermal methods, offering enhanced extraction efficiency while maintaining cake quality. The steam-microwave combination particularly excelled, demonstrating industrial potential for improved resource utilization. These findings provide practical optimization parameters for commercial sesame processing operations, establishing microwave technology as an effective alternative to conventional extraction methods.

Keywords: Sesame Seeds; Sesame Oil; Microwave Treatment; Drying; Oil Content; Extraction Rate.

RESUMEN

Este estudio investigó la optimización del procesamiento por microondas para la extracción de aceite de semillas de sésamo (Sesamum indicum L.). Las semillas de sésamo se sometieron a un tratamiento controlado por microondas a 105 W y 2450 MHz con tiempos de exposición variables (1-20 minutos), comparando los resultados con el procesamiento térmico convencional

y los métodos combinados de vapor y microondas. Tras intentos fallidos de premolienda, se adoptó un pretratamiento con vapor a 250 °C durante 30 minutos antes de la exposición al microondas. La metodología de superficie de respuesta identificó las condiciones óptimas de procesamiento para obtener los máximos rendimientos de aceite y torta. El análisis de pérdida de masa no reveló ninguna pérdida medible durante los primeros 5 minutos de tratamiento por microondas, con aumentos graduales del 0,25 % a los 10 minutos al 1,00 % a los 20 minutos. Los resultados demostraron mejoras significativas con el tratamiento combinado de vapor y microondas durante 10 minutos de exposición, logrando un rendimiento de aceite del 33,72 % y un rendimiento de torta del 68,62 %, lo que representa una extracción de aceite un 1,32 % mayor que con los métodos convencionales. Las condiciones óptimas, solo mediante el procesamiento por microondas, produjeron un 32,79 % de aceite y un 66,71 % de torta. La combinación de vapor y microondas redujo el contenido de humedad de las semillas en un 3,77 %. El análisis estadístico reveló tres factores críticos que afectan significativamente la extracción: el contenido inicial de aceite de las semillas, la potencia de las microondas y la duración del procesamiento. El procesamiento asistido por microondas demostró ser superior a los métodos térmicos tradicionales, ofreciendo una mayor eficiencia de extracción y manteniendo la calidad de la torta. La combinación de vapor y microondas sobresalió especialmente, demostrando su potencial industrial para una mejor utilización de los recursos. Estos hallazgos proporcionan parámetros prácticos de optimización para las operaciones comerciales de procesamiento de sésamo, estableciendo la tecnología de microondas como una alternativa eficaz a los métodos de extracción convencionales.

Palabras clave: Semillas de Sésamo; Aceite de Sésamo; Tratamiento por Microondas; Secado; Contenido de Aceite; Tasa de Extracción.

INTRODUCTION

Oilseed crops play a vital role in supporting global population growth, serving essential functions across the nutraceutical, pharmaceutical, and cosmetic industries. This is particularly relevant for countries like Iran, which currently imports about 94 % of its oilseed requirements.[1] Sesame stands out as a significant oilseed crop, with global production concentrated in four main countries: India, Sudan, China, and Myanmar, which together account for 60 % of worldwide output. The international market shows interesting regional dynamics - for instance, Tunisia sources 80 % of its sesame seeds from Sudan and 20 % from Egypt, with its import volume rising significantly from 3400 tons in 1990 to 10 600 tons in 2005.[2] The composition of sesame oil is notable for its primary fatty acids: linoleic acid (42 %), oleic acid (41 %), palmitic acid (9 %), and stearic acid (6 %). It also contains trace amounts of other fatty acids, including palmitoleic, linolenic, arachidic, gadoleic, behenic, and lignoceric acids. Processing methods vary by scale; smaller producers typically press seeds with 50-60 % oil content, while larger operations employ more sophisticated extraction, refining, neutralization, bleaching, and deodorization processes.[3] A distinctive feature of sesame oil is its remarkable stability, attributed to the conversion of sesamolin into antioxidant phenolic compounds during the bleaching process. Interestingly, oil extracted from whole seeds, including the husk, demonstrates greater stability than oil from dehulled seeds due to additional antioxidants in the seed coat.[4] As an annual herbaceous plant in the legume family, sesame has achieved prominence as one of China's four major edible oilseed crops, alongside soybeans, peanuts, and rapeseed. Its combination of nutritional value, medicinal properties, and distinctive flavor has made it a highly valued crop across traditional and modern applications.[5] Sesame has earned two notable nicknames: the "queen

of oilseeds" due to its exceptional oil quality and resistance to oxidation and rancidity, and the "orphan crop" despite its significant value. The International Plant Genetic Resources Institute (IPGRI) categorizes it as an underutilized crop with substantial development potential.[6] What makes sesame particularly valuable is its rich composition of bioactive compounds, especially lignans (primarily sesamin, sesamolin, and sesamol), phytosterols, tocopherols, and fatty acids. These components contribute to its superior antioxidant properties compared to other edible oils, offering benefits for energy levels and anti-aging.[7] The health benefits of sesame are extensive and well-documented. Research indicates that it can protect heart function, reduce inflammation, regulate lipid metabolism, and exhibit anticancer and antimutagenic effects. Regular consumption may help reduce the risk of viral infections and address malnutrition. Studies have shown that sesame oil can lower low-density lipoprotein (LDL) levels, potentially reducing the risk of atherosclerosis and cardiovascular disease. Additionally, research by Murata et al. suggests that long-term sesamol consumption might help prevent the accumulation of amyloid proteins associated with Alzheimer's disease.[8]

Sesame's versatility extends beyond direct consumption. Its by-products serve various industries, including food production, soap manufacturing, lubricants, industrial goods, medical preparations, and animal feed. In China, the processing industry is evolving from traditional small-scale workshops to larger enterprises with increasing capacity. The country's sesame utilization is distributed across several products: 45 % for oil production, 22 % each for sesame paste and cleaning, and 5 % for baking.[9] This comprehensive profile of uses and benefits, combined with its robust antioxidant properties and health-promoting effects, underscores sesame's significance as both a nutritional powerhouse and versatile industrial resource.[10] Oil extraction from plant materials employs several different techniques, each with its own advantages and characteristics. The main methods include cold pressing, supercritical CO_2 extraction, aqueous enzymatic extraction, and solvent extraction. The industrial sector primarily relies on cold pressing (through screw pressing or continuous mechanical pressing) and solvent extraction methods.[11] Cold pressing stands out as a preferred method when oil quality is paramount, despite its lower yield (55-95 %). This technique operates at lower temperatures and avoids solvents, helping preserve the oil's quality. When using solvent extraction with hexane or screw pressing, additional refining steps are necessary to reduce resin (phospholipid) content, similar to standard edible oil refining processes.[12]

A crucial preprocessing step involves thermal treatment of the oilseeds. This can be done through traditional methods like pan and oven roasting, or modern techniques such as microwave roasting, continuous forced convection drum roasting, revtech, and infrared roasting. These roasting processes serve multiple purposes: they increase bioactive components, enhance flavor, and improve overall oil quality.[13] The intensity of roasting significantly impacts the final product characteristics. Light roasting (low temperature, short duration) results in minimal changes to the oil's color and flavor, while dark roasting (high temperature, long duration) produces oil with a darker color and stronger flavor. Research has shown impressive improvements in oil yield after roasting: mechanical extraction yield increased from 41,18 % to 46,28 %, while solvent extraction yield rose from 47,77 % to 55,35 %. Roasting also positively affects other oil properties, including color, acid value, oxidative stability, Maillard reaction products, and antioxidant activity.[14]

Cold pressing represents a distinct category, performed without heat or at minimal temperatures. The resulting oil typically has low temperature and acidity levels. A key advantage of cold-pressed oil is that it usually doesn't require refining - after settling and filtering, it's ready

for use.[15] Cold pressing is characterized by processing temperatures below 80°C and does not involve seed roasting before pressing. This method offers two key advantages: it produces clear, transparent oil (making it ideal when oil color standards are strict) and preserves the nutritional quality of the resulting cake. Since the process avoids high temperatures, the proteins in the cake maintain their original properties, ensuring high nutritional value in the byproduct.[16] The incorporation of functional ingredients in cheese is a new technology application in the food industry. Onion oil is considered a functional oil that is obtained by cold pressing of onion.[17] In contrast, hot pressing operates at temperatures above 80°C and typically incorporates a roasting stage before pressing. The roasting device serves multiple purposes: controlling temperature and moisture content of the oilseeds, raising their temperature, and ultimately improving oil yield. Hot pressing offers three main benefits: enhanced oil extraction efficiency, development of distinctive aromatic and taste properties due to the high-temperature roasting process, and minimal residual oil content in the cake.[18] The choice between these methods should be tailored to specific oilseed crops, as each has unique characteristics that affect processing requirements.[19] Recent technological developments have introduced microwave (MW) processing, also known as super high frequency (SHF) processing. This technique operates in the electromagnetic spectrum between 300 MHz and 300 GHz (wavelengths from 1 m to 1 mm), falling between infrared and radio waves. Industrial applications, including food processing, typically use a frequency of 2450 MHz.[20] A growing focus in the field is the development of deep processing methods for oil-containing materials to produce environmentally safe fatty products. Deep processing represents an advanced approach that aims to utilize all raw material components without waste while ensuring ecological cleanliness of the final products.[21] The incorporation of functional ingredients into cheese is a new technological application in the food industry. Onion oil is considered a functional oil obtained by cold pressing onions.[22]

METHOD

The research focused on Central Asian sesame varieties containing 38,10 % oil content. Standard methods were employed for chemical analysis throughout all stages of processing - from raw materials to final products.

The study defined oil content as the total amount of crude fat and associated fat-like substances that could be extracted into ether from the seeds. Quality assessment was conducted using near-infrared spectroscopy, which simultaneously measured several key parameters within specific ranges:

- Fat content: 1-60 %
- Moisture and volatile substances: 1-18 %
- Protein content: 5-80 %
- Fiber content: 2-50 %

RESULTS AND DISCUSSION

The experimental phase investigated how microwave radiation affected sesame seeds' mass loss, oil yield, and cake production. The setup centered around a microwave oven operating at 2450 MHz, with power settings ranging from 100 to 300 W over 15-minute intervals. A significant finding was that seed roasting began to occur at power levels of 120 W and above.

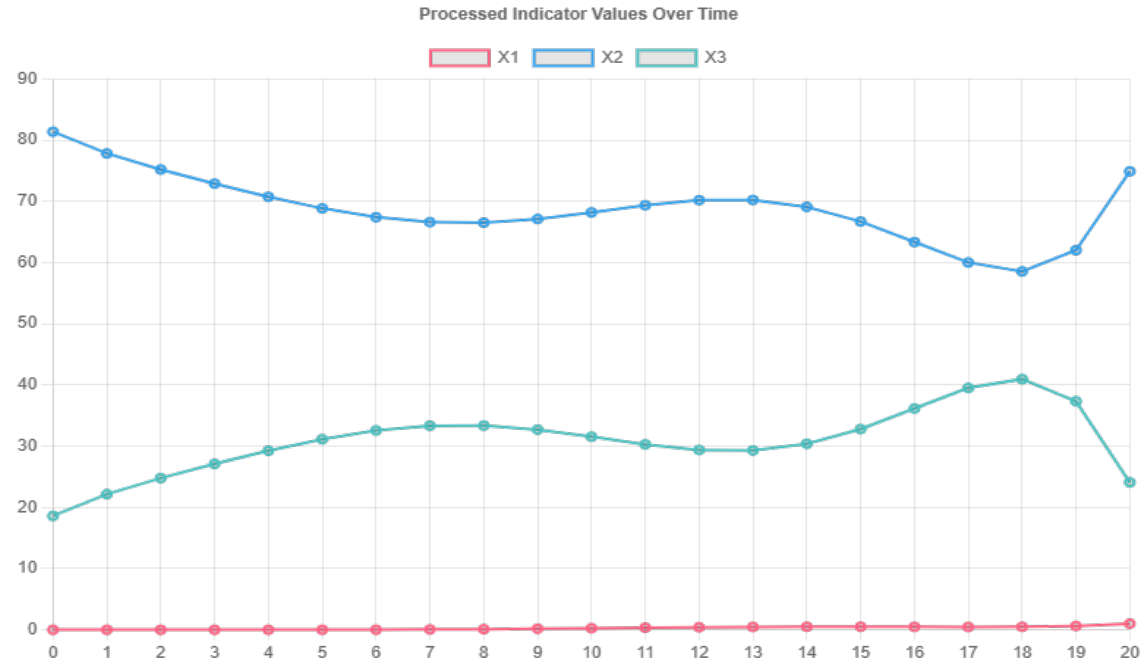
To understand the relationship between microwave exposure time and oil yield, researchers conducted tests at 105 W and 2450 MHz, varying exposure times from 1 to 20 minutes. Initial attempts to pre-grind the sesame seeds proved unsuccessful, leading researchers to adopt an alternative approach using steam pre-treatment at 250°C for 30 minutes.

The time-dependent effects of microwave processing revealed interesting patterns: no measurable mass loss occurred during the first 5 minutes of treatment. However, as processing time increased from 10 to 20 minutes, mass loss gradually increased from 0,25 % to 1,00 %. These findings demonstrate a clear correlation between exposure duration and mass loss in sesame seed processing.

Table 1. Effect of Microwave Radiation on Oil Extraction and Cake Yield

No	Time (t), min	Mass Loss (X1) %	Cake Yield (X2) %	Oil Yield (X3) %
1	-	-	81,39	18,61
2	1	-	77,84	22,16
3	3	-	72,90	27,10
4	5	-	68,86	31,14
5	10	0,25	68,20	31,55
6	15	0,50	66,71	32,79
7	20	1,00	74,92	24,08

The impact of microwave processing duration on oil yield becomes evident from the earliest stages of treatment. A significant increase in oil yield occurs after just 3 minutes of processing, jumping from 18,61 % to 27,10 % - an improvement of 8,49 %. The process reaches peak efficiency during the 10-15 minute window, when oil yields reach their maximum levels of 31,55-32,79 %. However, extending the processing time beyond this optimal window proves counterproductive, as demonstrated by the decline in oil yield to 24,08 % after 20 minutes of processing.



Source: https://claude.site/artifacts/e7a1bc2c-8302-4594-8e9f-24edfc973f12

Figure 1. Processed indicator values over time Data points at every minute from 0 to 20

The optimal processing period of 10-15 minutes also corresponds with the lowest cake yield measurements, ranging between 68,20 % and 66,71 %. These results were compared with traditional thermal treatment methods (110-120°C for 30 minutes), which produced similar oil yields of 31,15-32,40 % and cake yields of 66,83-65,48 %, with mass losses of 2,02-2,11 %.

These findings indicate that microwave processing can achieve comparable oil extraction efficiency to conventional thermal treatment methods. To provide a more detailed understanding of these relationships, the study proceeded with mathematical modeling using Lagrange formulas to analyze the dynamics of variables x1, x2, and x3 over time.

$X_3(t)=18,61+4,364t-1,053t^2+0,275t^3-0,038t^4+0,0022t^5-0,000047t^6$ (1)
$X_1(t)=0,005t+0,00863t^2-0,004t^3+0,0007t^4-0,000045t^5+0,000001t^6$ (2)
$X_2(t)=100-X_1(t)-X_3(t)$ (3)

The chart shows three lines: X2 (blue line) starts at 80 %, decreases to around 59 % at 18 minutes, then rises to 74 %. X3 (turquoise line) starts at 18 %, increases to a peak of 41 % at 18 minutes, then drops to 24 %. X1 (pink line) remains at or very close to 0 % throughout. Added features include grid lines for better readability, interactive tooltips for precise values, a y-axis scale from 0 to 90 %, and a clear legend for identifying each line.

Since the arguments are linearly dependent, the optimization problem can be formulated using just a single variable, which in this case is X3X_3X3. Therefore, we focus on the following equation:

$(\partial X_3(t))/dt=0$
$4,364-2,106t+0,895t^2-0,152t^3+0,011t^4-0,00028t^5=0$

The value 17,338429 is the root of the equation being discussed. This means that the maximum value of X_3 is 40,35 %.

Therefore, the optimal observation occurs between 17 and 18 minutes, where: X_3 equals 40,35 %, X_1 equals 0,46 %, X_2 equals 59,19 %. Additionally, during the experiment, our ability to more fully reflect the changes in arguments X_2 and X_3 increases.

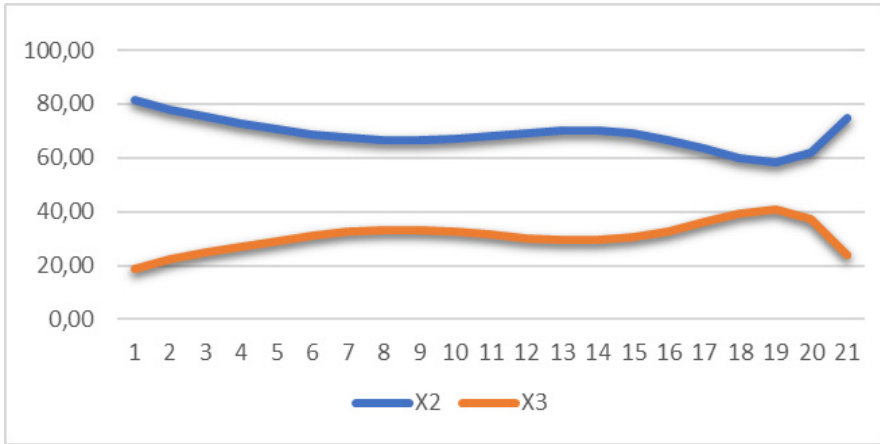


Figure 2. Analog curves of the arguments X2 and X3

Two lines only - X2 (blue line) - starting at 80 % and ending at 75 %, X3 (orange line) - starting at 18 % and ending at 25 %. Key features - X-axis from 1 to 21 with all integers marked, Y-axis from 0 to 90 with increments of 10, smooth lines without data points, grid lines for better readability, similar curve shapes to the original, showing the dip in X2 around time 18 and peak in X3 around time 19. Style changes - removed dots/markers on the lines for a cleaner look, used thicker lines (2px) for better visibility, changed the X3 color to orange to match the original, and maintained the professional graph styling with grid lines.

To increase oil yield, sesame seeds were initially subjected to coarse grinding (splitting) and then treated with microwave radiation. Under optimal conditions - radiation power of 105 W, frequency of 2450 MHz, and process duration of 15 minutes - did not yield positive results. Therefore, whole sesame seeds were preliminarily treated with steam for 30 minutes at a steam temperature of 250°C, followed by treatment of the moistened seeds with microwave radiation at a power of 105 W, frequency of 2450 MHz, varying the duration of treatment. The results obtained are shown in Table 2.

Table 2. The Effect of Microwave Radiation on Oil Extraction and Cake Yield After Pre-steaming Sesame Seeds

No	Time, min.	Increase in mass after steaming, %	Mass loss after microwave radiation, %	Cake yield, %	Oil yield, %
1	-	-	-	81,39	18,61
2	1	6,11	0	79,24	20,76
3	3	6,10	0,57	83,60	21,93
4	5	6,10	2,35	78,94	24,81
5	10	6,11	3,77	68,62	33,72
6	15	6,10	4,71	69,65	31,74
7	20	6,10	5,66	71,22	29,22

Oil extraction and cake production over time

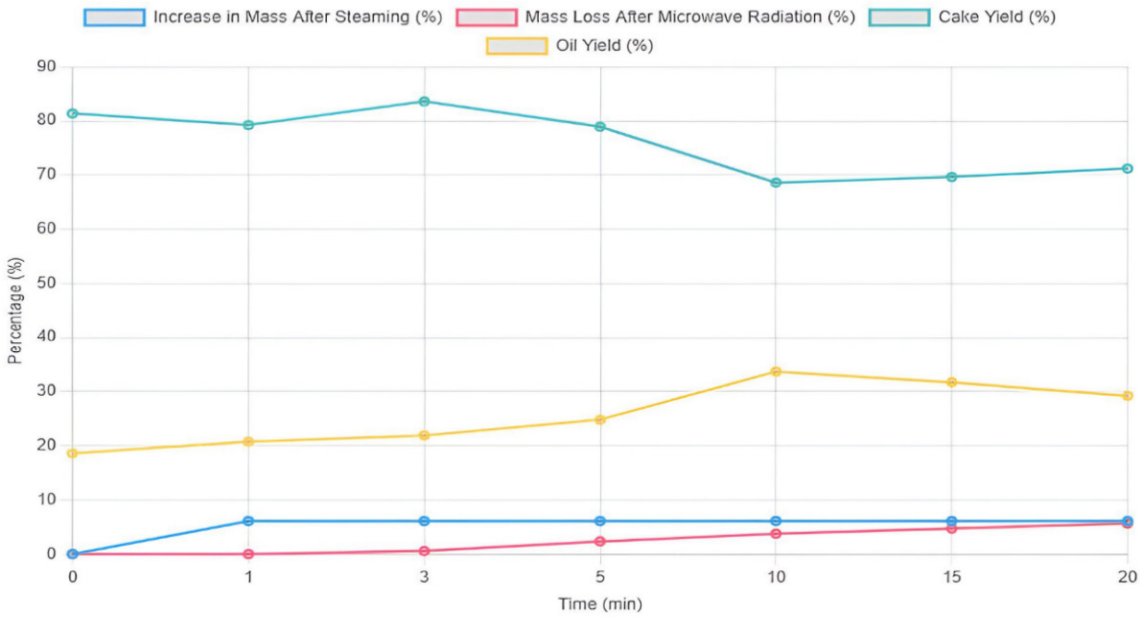
When 200 g of unground sesame seeds are steamed, the seed mass increases by an average of 6,1 %, reaching 211-212 grams. After further microwave radiation treatment, the mass loss increases from 0,57 % after 3 minutes of processing to 5,66 % after 20 minutes. The highest oil yield occurs when unground seeds, previously steamed, are treated with microwave radiation for 10 minutes, reaching 33,72 %. Extending the microwave treatment duration beyond this point leads to a decline in sesame oil yield. Under these conditions, the cake yield is at its lowest, 68,62 %.

Gas chromatography (GC) analysis of sesame oil obtained through expeller pressing after preliminary microwave treatment reveals differential peaks corresponding to fatty acids.

Four distinct lines showing - cake yield (turquoise) - starting at 80 % and ending around 71 %, oil yield (yellow) - starting at 18 % and increasing to peak around 33 %, increase in mass after Steaming (blue) - starting at 0 % and stabilizing around 6-7 %, mass loss after microwave radiation (pink) - starting at 0 % and gradually increasing to 5 %, time axis from 0 to 20 minutes, percentage axis from 0 to 90 %.

Added features - grid lines for better readability, data points marked with dots, interactive

tooltips for precise values, a clear legend with descriptive labels, and proper axis labels.



Source: https://claude.site/artifacts/16568368-1f01-46ee-9a09-e12763519651

Figure 3. Influence of Steaming and Microwave Treatment on Sesame Cake and Oil Yields Over Time

Chromatographic analysis of the sesame oil revealed the presence of 15 fatty acids (figure 1 and table 3). The oil is primarily composed of oleic acid (32,35 %) and linoleic acid (29,56 %), followed by palmitic acid (12,0 %) and decanoic acid (11,08 %). The amount of gondoic acid was found to be 4,14 %, a value not previously reported in the literature. Additionally, sesame oil contains 2,4 % linolenic acid, known as the ω-3 fatty acid, along with a small amount (0,03 %) of its valuable γ-form. Arachidonic, *eicosanoid*, and caprylic acids are found in trace amounts.

CONCLUSIONS

The research conducted has demonstrated that sesame oil extraction can be significantly optimized through microwave-assisted processing. The combined steam-microwave treatment, employing steam pre-treatment at 250°C for 30 minutes followed by 105W microwave radiation at 2450 MHz for 10 minutes, achieved the highest extraction efficiency with 33,72 % oil yield and 68,62 % cake yield—representing a 1,32 % improvement over conventional thermal processing methods. This optimized process reduced seed moisture content by 3,77 %.

Time-dependent analysis revealed critical processing dynamics: no mass loss occurred during the first 5 minutes of microwave exposure, while extended treatment (10-20 minutes) resulted in progressive mass loss from 0,25 % to 1,00 %. Microwave processing alone (without steam pre-treatment) at optimal parameters yielded 32,79 % oil and 66,71 % cake, confirming the superiority of microwave technology over traditional methods.

Statistical analysis identified three critical factors governing extraction efficiency: initial seed oil content, microwave power level (105W), and processing duration (optimal at 10 minutes). The steam-microwave combination method demonstrates substantial industrial potential,

offering improved resource utilization, reduced processing time, and enhanced product quality.

These findings establish practical optimization parameters for commercial sesame processing operations: steam pre-treatment at 250°C for 30 minutes, followed by microwave treatment at 105W and 2450 MHz for 10 minutes. This approach positions microwave technology as an economically viable and technically superior alternative to conventional extraction methods. Further industrial-scale validation is recommended to facilitate technology transfer and commercial implementation.

Declaration of AI

Artificial intelligence tools were used for mathematical modeling and analysis of technological processes.

BIBLIOGRAPHIC REFERENCES

1. Iran Nezhad H, Hoseini Mazinani S. Investigating the effects of planting date on the performance of three varieties of oil Flax seed in Varamin. J Agric Sci. 2017;11(4):10.

2. Abou-Gharbia HA, Shehata AAY, Shahidi F. Effect of processing on oxidative stability and lipid classes of sesame oil. Food Res Int. 2000;33:331-340.

3. Institut National de la Statistique. Republique Tunisienne Ministre du Developpement Economique ISSN 0330-163X. Statistiques du Commerce Exte´rieur. 1990-2005;N 21-32.

4. Dijkstra AJ. Vegetable Oils: Types and Properties. In: Encyclopedia of Food and Health. 2016. p. 381-386. doi:10.1016/b978-0-12-384947-2.00706-6

5. Afroz M, Zihad SMNK, Uddin SJ, Rouf R, Rahman MS, Islam MT, et al. A systematic review on antioxidant and antiinflammatory activity of sesame (Sesamum indicum L.) oil and further confirmation of antiinflammatory activity by chemical profiling and molecular docking. Phytother Res. 2019;33:2585-2608. https://doi.org/10.1002/ptr.6428

6. Ahmad SR, Ghosh P. Benefits of dietary sesame seed and flaxseed to strengthen immune system during COVID-19 pandemic and prevent associated comorbidities related health risks. Ann Phytomed Int J. 2020;9. https://doi.org/10.21276/ap.2020.9.2.5

7. Cardoso CA, de Oliveira GMM, de Almeida Vittori Gouveia L, Moreira ASB, Rosa G. The effect of dietary intake of sesame (Sesamum indicum L.) derivatives related to the lipid profile and blood pressure: a systematic review. Crit Rev Food Sci Nutr. 2018;58:116-125. https://doi.org/10.1080/10408398.2015.1137858

8. Afroz M, Zihad SMNK, Uddin SJ, Rouf R, Rahman MS, Islam MT, et al. A systematic review on antioxidant and antiinflammatory activity of sesame (Sesamum indicum L.) oil and further confirmation of antiinflammatory activity by chemical profiling and molecular docking. Phytother Res. 2019;33:2585-2608. https://doi.org/10.1002/ptr.6428

9. Gouveia L, Cardoso CA, de Oliveira GMM, Rosa G, Moreira ASB. Effects of the intake of sesame seeds (Sesamum indicum L.) and derivatives on oxidative stress: a systematic review. J Med Food. 2016;19:337-345. https://doi.org/10.1089/jmf.2015.0075

10. Hsu E, Parthasarathy S. Anti-inflammatory and antioxidant effects of sesame oil on atherosclerosis: a descriptive literature review. Cureus. 2017;9:e1438. https://doi.org/10.7759/cureus.1438

11. Murata J, Ono E, Yoroizuka S, Toyonaga H, Shiraishi A, Mori S, et al. Oxidative rearrangement of (+)-sesamin by CYP92B14 co-generates twin dietary lignans in sesame. Nat Commun. 2017;8:2155. https://doi.org/10.1038/s41467-017-02053-7

12. Shao JW, Zhang GX, Fu JX, Zhang BW. Advancement of the preparation methods and biological activity of peptides from sesame oil byproducts: a review. Int J Food Prop. 2020;23:2189-2200. https://doi.org/10.1080/10942912.2020.1849276

13. Afroz M, Zihad SMNK, Uddin SJ, Rouf R, Rahman MS, Islam MT, et al. A systematic review on antioxidant and antiinflammatory activity of sesame (Sesamum indicum L.) oil and further confirmation of antiinflammatory activity by chemical profiling and molecular docking. Phytother Res. 2019;33:2585-2608. https://doi.org/10.1002/ptr.6428

14. Wang LG. Investigation and analysis report of sesame market and industry in China. Agric Prod Mark. 2021;960(6):48-51.

15. Qu YW, Ren CL, Jiang YZ. Thought about the development of the sesame industry in Henan Province. J Agric Henan. 2021;1(1):11-12. https://doi.org/10.15904/j.cnki.hinny.2021.01.008

16. Namiki M. Nutraceutical functions of sesame: a review. Crit Rev Food Sci Nutr. 2007;47:651-673. https://doi.org/10.1080/10408390600919114

17. Lampi AM, Heinonen M. Berry seed and grapeseed oils. In: Moreau RA, Kamal-Eldin A, editors. Gourmet and health-promoting specialty oils. Urbana, Illinois: AOCS Press; 2009. p. 215-235.

18. Sobirova M, Rifky M, Dissanayake K, Farmonov J, Boynazarova Y, Meyliyev A, et al. Technology Development to incorporate Onion (Allium cepa L) oil as a functional ingredient in Cheese spread. BIO Web Conf. 2024;95:01039. https://doi.org/10.1051/bioconf/20249501039

19. Aljuhaimi F, Ozcan MM. Influence of oven and microwave roasting on bioproperties, phenolic compounds, fatty acid composition, and mineral contents of non germinated peanut and germinated peanut kernel and oils. J Food Process Preserv. 2018;42(2):e13462. https://doi.org/10.1111/jfpp.13462

20. Suri K, Singh B, Kaur A, Singh N. Impact of roasting and extraction methods on chemical properties, oxidative stability and Maillard reaction products of peanut oils. J Food Sci Technol. 2019;56:2436-2445. https://doi.org/10.1007/s13197-019-03719-4

21. Dun Q, Yao L, Deng Z, Li H, Li J, Fan Y, et al. Effects of hot and cold-pressed processes on volatile compounds of peanut oil and corresponding analysis of characteristic flavor components. LWT - Food Sci Technol. 2019;112:107648. https://doi.org/10.1016/j.lwt.2018.11.084

22. Sobirova M, Rifky M, Dissanayake K, Farmonov J, Boynazarova Y, Meyliyev A, et al. Production of spread cheese by incorporating microencapsulated pepper oil with corn oil. BIO Web Conf. 2024;95:01046. https://doi.org/10.1051/bioconf/20249501046