Application of microwave technology to extract pure sesame oil

Jasur Farmonov[1], *Dulangana* Hunupolagama[2], *Kasun* Dissanayake[3], *Yulduz* Boynazarova[4], *Kamar* Serkaev[3], *Murodjon* Samadiy[4], and *Mohamed* Rifky[2,3*]

[1]University of Economics and Pedagogy, Karshi, 180100, Uzbekistan
[2]Eastern University, Sri Lanka, Chenkalady, 30350, Sri Lanka
[3]Tashkent Chemical Technological Institute, Tashkent, 100000, Uzbekistan
[4]Karshi Engineering-Economics Institute, Karshi, 180100, Uzbekistan

Abstract. The purpose of the study was to use microwave technology to extract pure sesame seed oils. The findings of investigations on how microwave treatment affects sesame seed yields for oil and cake are reported. It has been demonstrated that the radiation strength and duration of processing have a major impact on oil production. Studies have shown the possibility of increasing the yield of sesame oil, compared to obtaining oil with preliminary heat treatment of sesame seeds, by 1.97% by treating them with steam and subsequent treatment with microwave radiation for 12 minutes. In these circumstances, the oil output is 33.72%, the cake yield is 66.28%, and the moisture content is reduced to 3.77%. The oil content of the seeds, the intensity of the microwave radiation, and the length of the process are the primary factors affecting the amount of oil released. The best technical parameters have been determined, at which 33.72% of the oil and 66.28% of the cake are extracted.

1 Introduction

Essential food products are important for the growing world population and the extraction of oils from economical and health-promoting plant resources, which are required not only in the pharmaceutical but also for cosmetic industries, revealing the importance of oilseeds. Increasing research in this field in Iran seems to be very important since almost 94% of oilseeds are imported from abroad [1].

Many nations, including China, India, Sudan, and Burma, are known to be the primary producers of sesame, accounting for 60% of global output [2]. Sudan provides 80% of the necessary sesame seed produced in Tunisia, with the remaining 20% coming from Egypt. Between 1990 and 2005, the amount of imports rose from around 3,400 to 10,600 tons.

Sudan, Burma, India, and China are the countries that cultivate sesame seeds. Trade between countries is not very large. Sesame oil mostly comprises the fatty acids palmitic acid (9%), stearic acid (6%), oleic acid (41%), and oleic acid (42%) [3]. It also has trace quantities of linolenic acid (18:1) and palmitoleic acid (16:1) lignoceric acid (24:0),

* Corresponding author: rifkyalm@esn.ac.lk

behenic acid (22:0), gadoleic acid (20:1), arachidic acid (20:0). Larger operators remove the cake and refine, neutralize, bleach, and deodorize the crude oil; small operators restrict their oil output to pressing seeds that contain 50–60% oil. Because the sesamolin in the oil is changed during bleaching into several phenolic compounds with antioxidant qualities, the oil is very durable. Since oil extracted from intact seeds is known to be more stable than oil extracted from hulled seeds, sesame seed hulls also contain antioxidants [4].

Sesame is a popular and widely used traditional medicinal plant that has a high nutritional value and excellent flavour. Sesame, a historic oilseed crop, is one of China's four main edible oilseed crops, along with peanut, soybean, and rapeseed [5]. Because of its high oil content, pleasant scent, and degree of resistance to oxidation and rancidity, sesame is referred to as the "queen of oilseeds" and the "orphan crop" [6-7]. In addition, thermal oxidation is also possible type of autoxidation, which yield some primary products like peroxides [8]. TBA value could be measured for secondary products of lipid oxidation [9].

Currently, the processing capacity of businesses is steadily rising, even though tiny sesame processing firms are still widely available [10-13]. Sesame oil is made in China from around 45% of the seed, while 22% is used to manufacture sesame paste, 22% is used to peel sesame, and 5% is used to bake [14]. Antioxidants and bioactive substances such as lignans, phytosterols, fatty acids, and tocopherols are abundant in sesame. Compared to other edible oils, sesame oil has a greater antioxidant content, which boosts vitality and delays the ageing process [15-17].

When oil seeds are fed into a press at a temperature higher than 80 °C, hot pressing takes place. Usually, there is a single fryer in front of the press, whose primary duties include controlling the oil seeds' water content and temperature, raising their temperature, and increasing the oil production in the end. The hot pressing method's high oil yield is one of its features. More oil is extracted from the oil seeds when they are roasted and pressed; the resulting oil tastes well and has a distinct aroma, leaving little oil residue in cakes. Each oilseed crop has specific characteristics, and the cake's residual oil concentration is quite low following hot pressing. Every oilseed crop requires a specific pressing technique [18-20]. In recent years, the word "microwaves" (MW) has been used interchangeably with the previously used term "ultrahigh frequency" (UHF), which describes the same wave spectrum [21]. The microwave (MW) spectrum of electromagnetic radiation encompasses frequencies ranging from 300 GHz to 300 MHz (wavelengths from 1 mm to 1 m), which fall between infrared and radio waves. The frequency utilized in industry, including food, is 2450 MHz [22].

In this context, an essential issue is to develop ways for deep processing of the Republic's oil-containing raw materials to produce ecologically beneficial fatty products. Deep processing entails developing and using innovative technologies that enable the waste-free usage of all raw material components while producing ecologically favourable products [23-24]. Thus, microwave technology was employed to extract pure oils from sesame seeds.

2 Methods

The experimentation was done using 38.10% oil-level Central Asian sesame. Using known protocols, chemical analyses of the starting, intermediate, and final products were carried out [13–15]. The quantity of crude fat and other fat-like substances that enter the ethereal extract from the seeds under investigation is known as the oil content of seeds.

Oil seeds, cakes, and meals may all benefit from this moisture and volatile chemical detection methodology, which also develops a near-infrared spectroscopy method for the simultaneous evaluation of the following quality indicators:

- Mass fraction of fat (1%- 60%).

- Mass fraction of moisture and volatile chemicals (1%-18%).
- Mass fraction of protein (between 5% - 80%).
- Mass fraction of fibre (between 2% to 50%).

The effect of microwave radiation on weight reduction, oil yield, and cake production from sesame seeds was investigated in an installation that included a microwave oven as its major component. The radiation power ranged from 100 to 300 W at a frequency of 2450 MHz. The processing time is 15 minutes. Studies have demonstrated that frying of seeds occurs at radiation power levels of 120 W or higher. To determine the influence of microwave radiation duration on sesame oil yield, seeds were placed in a microwave oven with a study power of 105 W, a frequency of 2450 MHz, and a study time of 1- 20 minutes. Moisture content was tested according to the method mention in previous article [9, 19, 24].

Sesame seeds did not perform better after being pre-ground. Consequently, more research was done on unground seeds by pretreating them with steam at 250°C for half an hour at the first instance and to increase the oil yield, sesame seeds were first subjected to coarse grinding (splitting) and then subjected to microwave radiation treatment. Under optimal conditions - study power 105 W, frequency 2450 MHz and duration process 15 minutes did not give positive results. Therefore, uncrushed sesame seeds were pre-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 2450 MHz, depending on the duration of treatment. The results were compared to get the decision on the oil extraction.

3 Results and Discussions

Sesame seeds did not perform better after being pre-ground. Consequently, more research was done on unground seeds by pretreating them with steam at 250°C for half an hour. Table 1 demonstrates that no weight loss is seen when sesame seeds are processed for longer periods (1-8 minutes). The weight loss rises from 0.28% to 1.00% when the microwave treatment technique is extended from 12 to 20 minutes shown in Table 1 .

Table 1. The influence of microwave radiation on oil extraction.

Time duration, Min	Weight loss, %	Oil yield, %
-	-	18.61
4	-	28.15
8	-	29.23
12	0.28	31.75
16	0.54	32.49
20	1.00	25.08

The oil output rises from the initial minutes of processing sesame seeds when the processing time is extended. As a result, the oil output rises by 9.54% and goes from 18.61% to 28.15% after processing for 4 minutes. Before treatment, the maximum oil extraction degree which ranges from 31.75 to 32.49% is monitored for 12 to 16 minutes. A 20-minute processing time increase results in an additional drop in oil yield to 25.08%. With the best processing conditions, a 12 to 16 minutes processing time, the lowest cake yield (68.25–67.51%) is achieved.

If we compare the performance of sesame oil production by pre-heat treatment at the temperature of 110-120°C for about 30 minutes, (oil yield is 33.72-31.74% and weight loss

 https://doi.org/10.1051/e3sconf/202449404025

is 3.77- 4.71%), it can be seen that the oil yield during preliminary heat treatment of sesame seeds is approximately the same.

The results obtained for the stream-treated sesame seeds and the oil extractions are shown in Table 2.

Table 2. Effects of microwave radiation on cake production and oil extraction during sesame seed first steam treatment.

Time, min	Increase in weight after steam treatment, %	Mass loss after microwave radiation, %	Oil output, %
-	-	-	18.61
1	6.11	0	20.76
4	6.10	0.57	21.93
8	6.10	2.35	24.81
12	6.11	3.77	33.72
16	6.10	4.71	31.74
20	6.10	5.66	29.22

When 200 g of uncrushed sesame seeds are treated with steam, the weight of the seeds increases by an average of 6.1% and amounts to 211-212 grams.

With further treatment of seeds with microwave radiation, weight loss increases from 0.57%, with a process duration of 4 minutes, to 5.66%, with a processing duration of 20 minutes. The highest oil output of 33.72% is found while processing uncrushed seeds that have been exposed to steam and microwave radiation for 12 minutes. The production of sesame oil decreases as the length of the microwave radiation treatment increases.

GX analyses of sesame oil obtained by exploration with preliminary microwave radiation. The chromatogram of sesame oil has differential maxima related to fatty acids. A chromatographic study of the resulting sesame oil showed that it contains 15 fatty acids are shown in Table 3 and Figure 1.

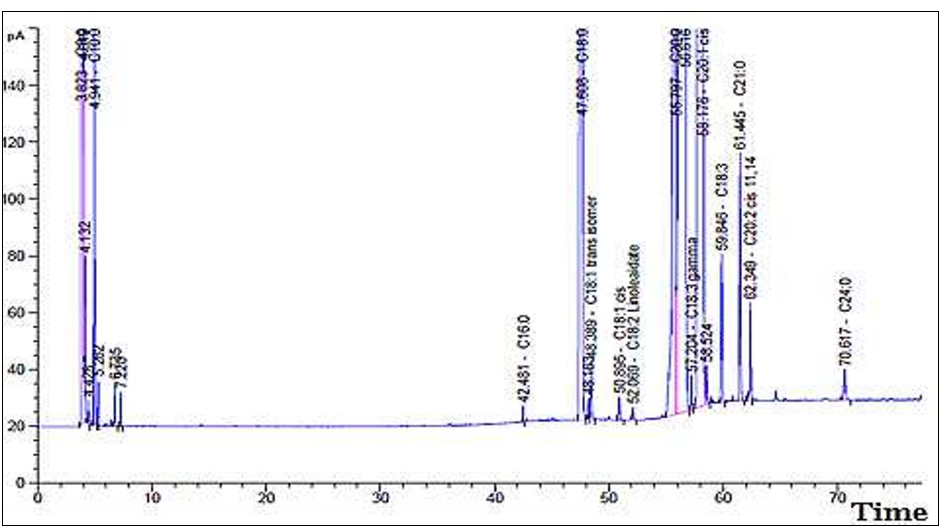

Fig. 1. Chromatogram of sesame oil obtained by preliminary microwave radiation.

Sesame oil contains the most oleic (32.35%) and linoleic (29.56%), palmitine (12.0%) and decanoic (11.08%) acids. The content of heneicosinidic acid was determined to be 4.14%, which is not found in the literature. Also, sesame oil contains linolenic, the socalled ω3 fatty acid in an amount of 2.4% and its especially valuable γ-form in a small amount (0.03%). It contains arachidonic, eicosinic, and caprylic acids in small quantities.

Table 3. The fatty acid content of vegetable oils and quantitative measurement of fatty acids by gas chromatography.

Names of the fatty acids	The fatty acid content in sesame seeds oil, %
C8:0	0.08
C10:0 decanoic (capric)	11.08
C14:0	-
C15:0	-
C16:0	12.00
C16:1 cis	-
C18:0	5.14
C18:1 olein	32.35
C18:1 trans isomer	0.82
C18:2 linol	29.56
C18:2	0.45
C18:3 linolene	2.40
C18:3 gamma	0.03
C20:0	0.03
C20:1 cis	0.03
C21:0	4.14
C20:2 cis 11.14	1.47
Undefined	0.02
Total:	100

The presence of the trans isomer of oleic acid was determined to be 0.82% and the cis isomer to be 0.40%. Until now, many researchers believed that trans isomers do not exist in natural vegetable oils. An exception has recently been considered flame oil, where the content of trans isomers of fatty acids reaches up to 5%.

4 Conclusion

Thus, the studies have shown the possibility of increasing the yield of sesame oil, compared to obtaining oil with preliminary heat treatment of sesame seeds, by 1.97% by treating them with steam and subsequent treatment with microwave radiation for 12 minutes. Under these conditions, 3.77% of the moisture is removed, the cake yield is 66.28%, and the oil yield is 33.72%.

References

1. N.H. Iran, S. J. Hoseini, Agric. Sci. **11**, 4 (2017)
2. H.A. Abou-Gharbia, A.A.Y. Shehata, F. Shahidi. Food Rese. Intl. **33**, 9 (2000)
3. M.G. Agidew, A.A. Dubale, M. Atlabachew, W. Abebe, Chem. Biol. l tech. Agri. 8, 10 (2021)
4. A.J. Dijkstra. Encyclopedia of Food and Health, 381–386, (2016)
5. M. Afroz, S.M.N.K Zihad, S.J. Uddin, R. Rouf, M.S. Rahman, M.T. Islam, I.N. Khan, E.S. Ali, S. Aziz, J.A. Shilpi, et al, Phytother Res. **33**, 24 (2019)
6. X. Ma, Z. Wang, C. Zheng, C. Liu, Oil Crop Science, **7**, 7 (2022)

7. C.A. Cardoso, G.M.M. de Oliveira, V.G.L. de Almeida, A.S.B. Moreira, G. Rosa, Crit. Rev. Food Sci. Nutr. **58**, 10 (2018)
8. K. Dissanayake, M. Rifky, M. Jesfar, J. Makhmayorov, S. Rakhimkulov, B. Abdullayev, IOP Confe. Series: Earth and Envir. Sci. **1275**, 1 (2023)
9. K. Dissanayake, M. Rifky, M. Jesfar, J. Makhmayorov, S. Rakhimkulov, B. Abdullayev, M. Samadiy, IOP Confe. Series: Earth and Envi. Sci. **1275**, 7 (2023)
10. L. Gouveia, C.A. Cardoso, G.M.M. de Oliveira, G. Rosa, A.S.B Moreira. J. Med. Food **19**, 9 (2016)
11. E. Hsu, S. Parthasarathy, Cureus **9** (2017)
12. J. Murata, E.Ono, E. Yoroizuka, H. Toyonaga, A. Shiraishi, S. Mori, M. Tera, T. Azuma, A.J. Nagano, M. Nakayasu, et al, Nat. Commun. **8**, 2155 (2017)
13. J.W. Shao, G.X. Zhang, J.X. Fu, B.W. Zhang, Int. J. Food Prop. **23**, 12 (2020)
14. J. Lee, M.J. Kim, M.Y. Jung, Seed Oil (Sesame Seed, Perilla Seed). In Korean Functional Foods, CRC Press (2018)
15. L.G. Wang, Agric. Prod. Mark. **960,** 5 (2021)
16. Y.W. Qu, C.L. Ren, Y.Z. Jiang, J. Agric. Henan. **1**, 3 (2021)
17. M. Namiki, Crit. Rev. Food Sci. Nutr. **47**, 23 (2007)
18. O. Ziyodullo, D. Absattorov, M. Rifky, S. Rakhimkulov, I. Usmanov, D. Ramazonova, Z. Matkarimov, M. Samadiy, E3S Web of Conf. **411**, 10 (2023)
19. F. Aljuhaimi, M.M. Ozcan, J. Food Proc. Prese. **42**, 2 (2018)
20. K. Suri, B. Singh, A. Kaur, N. Singh. J. Food Sci.Tech, **56**, 10 (2019)
21. Q. Dun, L. Yao, Z. Deng, H. Li, J. Li, Y. Fan, et al, Lebensmittel-Wissenschaft & Technologie, **112**, 107648 (2019)
22. A.N. Ostrikov, state. technol. Acad. 40-51 (2011)
23. D.M.P. Mingos, D.R. Baghursi, Chem. Soc. Rev. **20** (1991)
24. B. Abdullayev, M. Rifky, J. Makhmayorov, I. Usmanov, T. Deng, M. Samadiy, Intl. J. Engi. Tren. Tech. **71**, 9 (2023)