NUEJ
Naresuan University
Engineering Journal

The Microwave Pretreatment Effects on Yield and Tocopherol Content of Cold-Pressed Sesame Oil

Patomsok Wilaipon

Mechanical Engineering Department, Engineering Faculty, Naresuan University, Phitsanulok, Thailand

Corresponding author e-mail: patomsok@hotmail.com

(Received: 20 June 2022, Revised: 6 December 2022, Accepted: 19 December 2022)

Abstract

The benefits of black sesame have long been recognized, and black sesame has been used for consumption, cosmetics for hair and skin care, and medication. One process used to produce high quality black sesame oil is the cold pressed process, where temperature is controlled to be lower than 60 °C throughout the process. However, this process results in a lower yield than extraction by solvent. Therefore, with the aim of enhancing efficiency, this study is examining the impact of a microwave pretreatment on the output of cold pressing black sesame oil. The experiment tested three conditions, with different microwave wattages and pretreatment durations, while temperatures were controlled slightly below 60 °C under all conditions. The effects of microwave pretreatment on seed color and weight loss profile of black sesame were studied. Tocopherol, one of the significant compounds of sesame oil, was also examined. It was found that under all conditions, microwave pretreatment increased yields from black sesame cold pressing by 8% relative to pressing with no pretreatment. In addition, higher $\gamma+\beta$ tocopherolin levels were found in the black sesame oil extracted after the pretreatment process, and the highest $\gamma+\beta$ tocopherol levels were found after using low microwave wattage with a longer duration of pretreatment. It was also found that the weight loss rate of black sesame seed increased as the microwave power was increased. Besides, as compared to the non-activated one, 180 W sesame seed showed the highest value of color difference.

Keywords: Cold Pressed Oil, Sesame Oil, Tocopherol, Cold Press Extraction, Microwave Pretreatment

1. INTRODUCTION

Black sesame is a plant with economic value. It is widely consumed, especially in Asia where black sesame has been used for medicine and cosmetics for some time. There are reports of the grain's medicinal benefits, such as its antioxidant and anti-inflammatory properties, as well as its capacity to lower lipid levels in the blood. There is also evidence that consuming black sesame oil for 45 days can reduce hypertension and lipid peroxidation, while helping to increase the antioxidant status of hypertensive patients between 35–60 years old (Sankar et al., 2006). Black sesame is a rich source of nutrition with high levels of biologically active compounds, such as omega-3, tocopherol, sesamin, and sesamolin (Rangkadilok et al., 2010; Gharby et al., 2017; Dogruer et al., 2021). Additionally, sesaminol diglucoside, an antioxidant derived from sesame seed cake, was studied (Nantarat et al., 2020; Eom et al., 2021).

Oil extraction by solvent is one of the most effective processes of extracting oil from plant seeds. However, this process has many disadvantages, especially the quality of the oil products, which is lower because of the high temperature and the numerous procedures that must be applied during extraction. Mechanical press oil extraction, on the other hand, is commonly used for extracting plant oil, is simpler, and can produce higher quality oil products. One reason for this is that it uses a lower temperature in production, especially during the cold-pressed process where temperature is kept below 60 °C. However, mechanical press oil extraction results in a large quantity of remaining oil in the seed waste, indicating low production efficiency. Therefore, applying a pretreatment method prior to extraction aims to reduce the quantity of leftover oil in the seed waste. One of the pretreatment processes conducted to successfully extract most of the oil from the seeds is to use microwave radiation to activate the seeds prior to oil extraction. For example, the production efficiency of purslane seeds that have undergone 400 W microwave radiation is increased by 6% (Hosseini et al., 2017). Gac aril activated by 630 W microwave radiation results in the most efficient production and the highest preservation of beta-carotene and lycopene levels (Kha et al., 2013). In Chilean hazelnut extraction, 400–600 W microwave radiation significantly increases production efficiency relative to hazelnut extraction without microwave activation (Uquiche et al., 2008). Pretreatment of rapeseed using 800 W microwave radiation can increase extraction efficiency relative to rapeseed that has not undergone pretreatment (Wroniak et al., 2016). In addition, activation of rice bran by microwave prior to oil extraction has been shown to be more efficient than activation using steaming, but less efficient than activation using hot air (Thanonkaew et al., 2012).

The findings from the aforementioned studies provide evidence for microwave radiation's impact on activating black sesame seeds prior to using them in a cold-pressed process and for the relative efficiency of oil production when using activated seeds compared to seeds that have not been activated. Since tocopherol is a significant compound of sesame oil, the present study also measured the amount of tocopherol in cold-pressed black sesame oil where the microwave pretreatment method had been applied and compared it to levels found in oil from unprocessed seeds. Therefore, the purpose of this study was to determine how the microwave pretreatment of black sesame affected its yield and tocopherol content. Additionally, the variation in color of microwave-activated sesame was also investigated.

2. Material and Method

The black sesame used in this study originated from raw sesame grown in Thailand. The sesame was kept in a sealed plastic bag and had never been opened before the experiment. The material was kept in storage with a controlled temperature of 25–30 °C. The procedure required the use of an oil pressing unit, which was a cylinder-shaped iron device with a 20-mm inner diameter, a 30-mm outer diameter, and a 70-mm height. The underside had 13 drainage holes, each hole with a 1-mm diameter. The outer part of the tube was equipped with a 220V 150W band heater, used to heat up the cylinder as shown in Figure 1. Temperature measurements and the operation of the heater were controlled by the type K thermocouple with PID Temperature Controller (MaxWell, MTB series). A universal testing machine (UTM: Housefield: H50KS) was used as the starting power of the oil pressing.

For evaluating the weight loss profile of microwave pre-treatment, 10 grams of sesame seed were placed into an 800-W microwave for 360 seconds. Using a digital balance, an Ohaus balance with 0.01 g precision, the weight of the sesame was measured every 30 seconds for 360 seconds. The effects of microwave radiation at three different intensities were studied: 100, 180, and 300 watts. The color of the sesame was then measured using a WR-10QC handheld colorimeter, CIELAB $L^*a^*b^*$ colorimeter system. The color difference between activated and non-activated sesame was computed using the equation below.

$$\Delta E = \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2} \quad (1)$$

Where

ΔE is the colour difference,

L^* is the lightness coordinate,

a^* is the red/green coordinate, with $+a^*$ indicating red and $-a^*$ indicating green,

b^* is the yellow/blue coordinate, with $+b^*$ indicating yellow and $-b^*$ indicating blue.

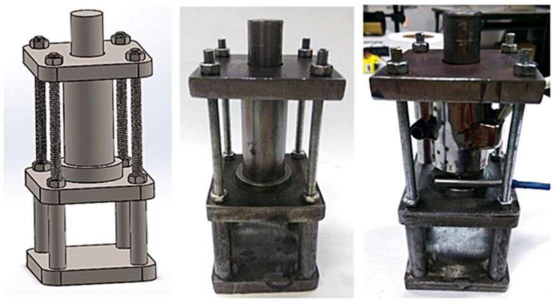

Figure 1 Cold pressed piston-cylinder set (a) drawing (b) cylinder set (c) cylinder set with electric heater

Ten grams of black sesame were baked and activated by microwave radiation. An 800 W 2450 Hz microwave was used, with electric power and duration set at 100 W-330 s, 180 W-150 s, and 300 W-60 s, respectively. The black sesame activated using this method had a temperature slightly lower than 60 °C, which is the controlled temperature required for the cold pressing process. Subsequently, the treated black sesame was loaded into the cylinder equipped with a nylon filter, and the press speed of the UTM machine was set at 1 mm min^{-1}. The press of the UTM was paused for 10 min and the amount of sesame oil produced from the process was measured. Each different condition was tested 3 times with the pressing temperature at 60 °C and the pressure at 70 MPa throughout the experiment.

Tocopherol levels in the treated sesame oil were measured using an HPLC machine and then were compared to the amount of tocopherols already known to be in a standard sample. The measurement process was initiated by dissolving the extracted sesame oil with isopropanol. After that, it was filtered through a 0.45-micron filter and injected into the HPLC machine, SHIMADZU (Japan) model Class-VP with specifications Detector: RF-10A XL Fluorescence Detector (EX 290 and EM 330 nm) Ultra C18, 5 µm, 25 cm x 4.6 mm (Restek).

3. Result and Discussion

Figure 2 depicts the weight loss profile of black sesame after microwave pretreatment for 0 to 360 seconds. It has three different microwave power levels: 100, 180, and 300 W. The weight loss rates of 100, 180, and 300 W appear to be consistent from the beginning to 180 s: 0.027, 0.061, and 0.111 % per second, respectively. After that time, the graphs' slopes are somewhat reduced to 0.027, 0.033, and 0.025 % per second, respectively. As the microwave power level increased, it produced a higher value of the pressure difference between the surface and the inside of the seed, resulting in a higher weight loss rate (Younces et al., 2016).

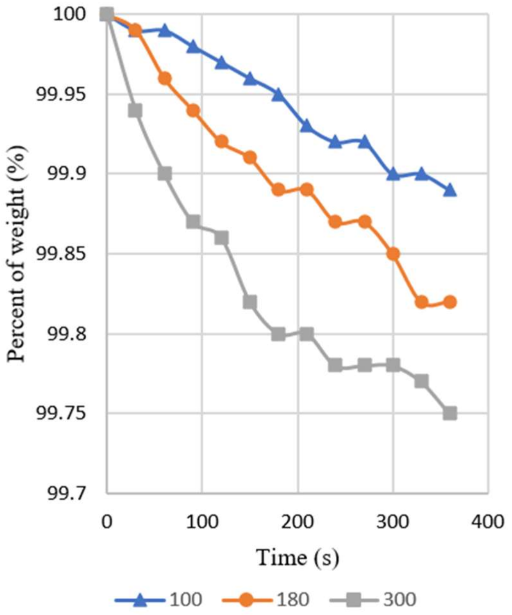

Figure 2 Percentage of remaining weight after microwave radiation

Figure 3 shows the color of black sesame after microwave pre-treatment. For 100 W microwave radiation, the *L**, *a**, and *b** values were found to be 13.71, 0.55, and 0.17, respectively. In comparison to the as-received sesame, the *L** value, lightness, was somewhat enhanced while the *a** and *b** values were decreased. These values were 13.22, 0.8, 0.09 for 180 W and 14.64, 0.35, 0.31 for 300 W, respectively. According to the calculations, when the microwave power increases, the color difference values, ΔE, increase. When compared to non-activated sesame, the ΔE values for 100, 180, and 300 W sesame were 0.29, 0.32, and 1.25, respectively.

The output of black sesame oil from the seeds that had undergone microwave-pretreatment extraction and the common seeds that had not undergone activation was 34.50–37.67% by weight. The yields from the black sesame seeds that had undergone microwave pretreatment at 100 W-330 s, 180 W-150 s, and 300 W-60 s showed a significant difference from yields from common seeds without microwave pretreatment, with a significance level at 95% at about 8% higher than common seeds, shown in Figure 4. The reason for increased yield may be the vaporization of seed moisture after microwave treatment. This causes an increase in pressure in the seed interior, leading to cell wall and membrane disruption, which facilitates the oil passage and affects the oil yield (Bose et al., 2020).

However, when comparing among the three microwave-pretreatment conditions, no statistical difference ($P < 0.05$) was found. The findings from this study are consistent with research in Chile (Uquiche et al., 2008) which found that activating hazelnuts by 400W and 600W microwave radiation prior to mechanical pressing for oil extraction increases yields from those of hazelnuts that have not undergone pretreatment. This is because the cell membrane of the seed is altered by the microwave radiation, which heats up the object from the inside. The present findings also relate to other studies (Wroniak et al., 2016; Bakhshabadi et al., 2017) which mention the use of microwave pretreatment resulting in membrane disruption and in an increase in oil extraction yields.

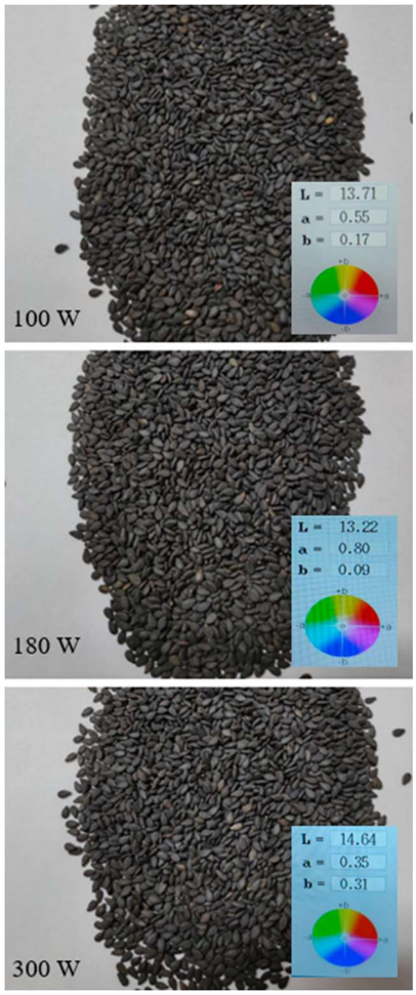

Figure 3 Sesame seed color after microwave pre-treatment

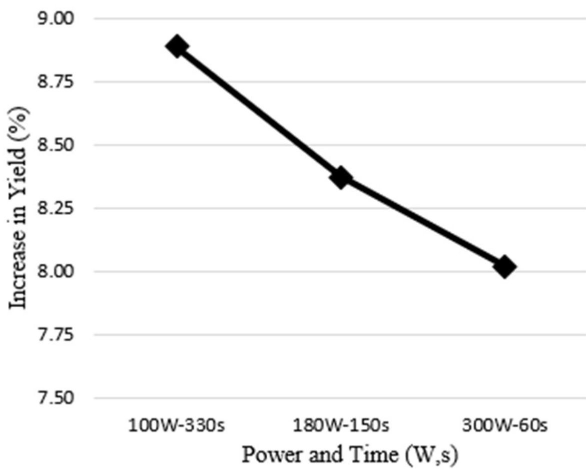

Figure 4 Increase in yield of pre-treatment sesame oil

High performance liquid chromatography separates the components of a liquid mixture by injecting the mixture into a stream of solvent flowing through a column packed with a separation medium. As the sample components separate from one another while flowing through the column, the detectors deliver a voltage response as a function of time, which is called a chromatogram. The moment each peak appears identifies the sample constituent with respect to a standard. The present study found γ+β tocopherol in every sample without α and δ tocopherol, as presented in Figure 5. This is consistent with other studies conducted in Thailand (Rangkadilok et al., 2010) which have reported that both types of tocopherols cannot be found in most black sesame. In Figure 5, when comparing tocopherol levels between the black sesame seeds that underwent microwave pretreatment at 100 W-330 s, 180 W-150 s, and 300 W-60 s with the controlled sample, or the common seeds that had not undergone microwave pretreatment, it was found that the seeds that had undergone microwave pretreatment had higher tocopherol levels than the controlled sample. The seeds that underwent pretreatment at a low wattage and for a longer time (100 W-330 s) had the highest tocopherol levels, followed by pretreatment conditions of 180 W-150 s and 300 W-60 s, respectively. These levels were higher than those observed in the corresponding controlled samples (20.33%, 17.47%, and 3.20%, respectively).

This result is consistent with a previous study on microwave pretreatment of kana rapeseed, which indicated that after a 7-min microwave treatment, α-tocopherolis levels decreased while γ and δ tocopherolis levels were found to be higher than rapeseed that had not undergone microwave treatment (Wroniak et al., 2016). Research on Sea Buckthorn leaves also found that γ tocopherol levels in microwave-dried samples were higher than those of samples which had undergone the conventional drying method (Gornas et al., 2014).

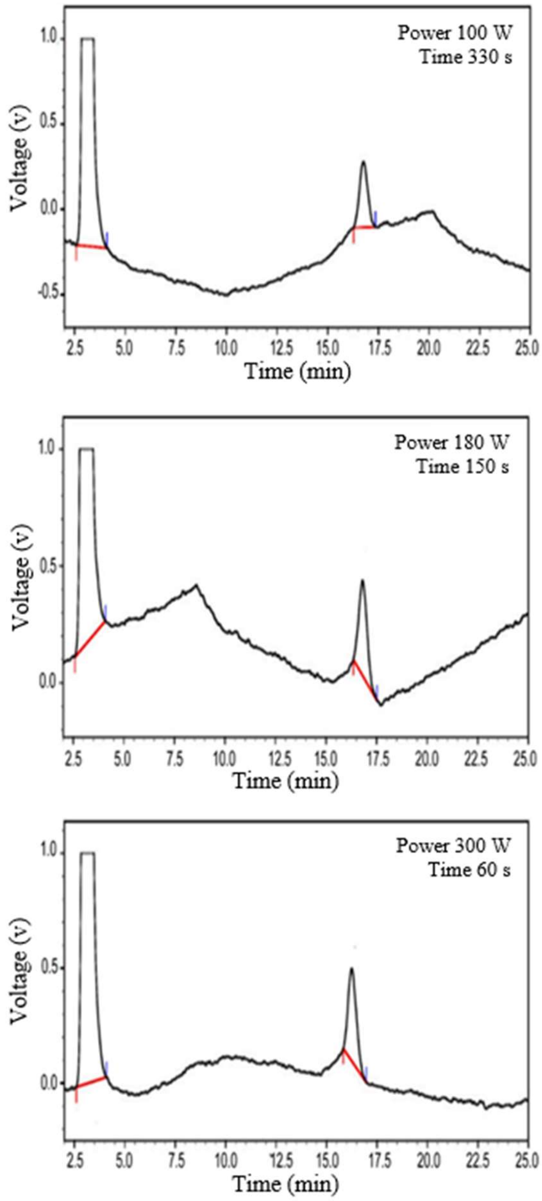

Figure 5 Tocopherol analysis result of pre-treatment sesame oil

4. Conclusion

This study investigated the impact of microwave pretreatment of black sesame on the seed's yield and on tocopherol levels in sesame oil extracted using the cold pressed process. The temperature was controlled to remain below 60 ºC throughout the process. The study found that this method can be applied prior to pressing oil from sesame in order to increase the yield from pressing. In terms of levels of the tocopherol compound, the study showed that pretreatment at all tested electrical powers and durations was able to increase the yield from the cold pressing process about 8%, with no statistically significant differences between the different conditions of pretreatment. Regarding levels of γ+β tocopherol in the cold pressed oil, using the microwave at a low wattage and with longer pretreatment duration at a temperature under 60 ºC yielded the highest levels of tocopherol, 20.33%, compared to other pretreatment conditions. Besides, the sesame seed that underwent 180 W of microwave treatment showed the highest value of color difference.

5. Acknowledgment

This research work was financially supported by Engineering Faculty, Naresuan University.

6. References

Bakhshabadi, H., Mirzaei, H., Ghodsvali, A., Jafari, S. M., Ziaiifar, A. M. & Farzaneh, V. (2017). The effect of microwave pretreatment on some physico-chemical properties and bioactivity of black curmin seed's oil. *Industrial Crops and Products,* 97, 1–9. http://dx.doi.org/10.1016/j.indcrop.2016.12.005

Bose, P., Pradhan, D., Sonawane, A., Pathak, S. S., Anupriya, S. & Pradhan, R. C. (2020). Optimization of hot air and microwave pretreatment for enhancing the mechanical expression yield of Simarouba glauca oil. *J. Agric. Res*., 2, 100024. https://doi.org/10.1016/j.jafr.2020.100024

Dogruer, I., Uyar, H. H., Uncu, O. & Ozen, B. (2021). Prediction of chemical parameters and authentication of various cold pressed oils with fluorescence and mid-infrared spectroscopic methods. *Food Chem*., 345, 128815. https://doi.org/10.1016/j.foodchem.2020.128815

Eom, S. J., Zu, H. D., Lee, J., Kang, M. C., Park, J., Song, K. M. & Lee, N. H. (2021). Development of an ultrasonic system for industrial extraction of unheated sesame oil cake. *Food Chem*., 354, 129582. https://doi.org/10.1016/j.foodchem.2021.129582

Gharby, S., Harhar, H., Bouzoubaa, Z., Asdadi, A., Yadini, A. E. & Charrouf, Z. (2017). Chemical characterization and oxidative stability of seeds and oil of sesame grown in Morocco. *Journal of Saudi Society of Agricultural Sciences,* 16, 105–111. https://doi.org/10.1016/j.jssas.2015.03.004

Gornas, P., Sne, E., Siger, A. & Seglina, D. (2014). Sea buckthorn (hippophae rhamnoides L.) leaves as valuable source of lipophilic antioxidants: the effect of harvest time, sex, drying and extraction methods. *Industrial Crops and Products,* 60, 1–7. http://dx.doi.org/10.1016/j.indcrop.2014.05.053

Hosseini, S. D., Nayebzadeh, K., Mirmoghtadaie, L., Kavosi, M. & Hosseini, S. M. (2017). Effect of extraction process on composition, oxidative stability and rheological properties of purslane seed oil. *Food Chem.,* 222, 61–66. http://dx.doi.org/10.1016/j.foodchem.2016.11.150

Kha, T. C., Nguyen, M. H., Roach, P. D. & Stathopoulos, C. E. (2013). Effect of gac aril microwave processing conditions on oil extraction efficiency, and β-carotene and lycopene contents. *J of Food Engineering,* 117, 486–491. http://dx.doi.org/10.1016/j.jfoodeng.2012.10.021

Nantarat, N., Mueller, M., Lin, W. C., Lue, S. C., Viernstein, H., Chansakaow, S., Sirithunyalug, J. & Leelapornpisid, P. (2020). Sesaminol diglucoside isolated from black sesame seed cake and its antioxidant, anti-collagenase and anti-hyaluronidase activities. *Food Biosci,* 36, 100628. https://doi.org/10.1016/j.fbio.2020.100628

Rangkadilok, N., Pholphana, N., Mahidol, C., Wongyai, W. , Saengsooksree, K., Nookabkaew, S. & Satayavivad, J. (2010). Variation of sesamin, sesamolin and tocopherols in sesame (sesamum indicum L.) seeds and oil products in Thailand. *Food Chem.,* 122, 724–730. https://doi.org/10.1016/j.foodchem.2010.03.044

Sankar, D., Rao, R. M., Sambandam, G. & Pugalendi, K. V. (2006). Effect of sesame oil on diuretics or β-blockers in the modulation of blood pressure, anthropometry, lipid profile, and redox status. *Yale J Biol Med,* 79(1), 19–26. PMID: 17876372; PMCID: PMC1942178.

Thanonkaew, A., Wongyai, S., McClements, D. J. & Decker, E. A. (2012). Effect of stabilization of rice bran by domestic heating on mechanical extraction yield, quality, and antioxidant properties of cold-pressed rice bran oil (oryza saltiva L.). *LWT – Food Science and Technology,* 48, 231–236. https://doi.org/10.1016/j.lwt.2012.03.018

Uquiche, E., Jerez, M. & Ortiz, J. (2008). Effect of pretreatment with microwaves on mechanical extraction yield and quality of vegetable oil from Chilean hazelnuts (gevuina avellana mol). *Innovative Food Science and Emerging Technologies,* 9, 495–500. https://doi.org/10.1016/j.ifset.2008.05.004

Wroniak, M., Rekas, A., Siger, A. & Janowicz, M. (2016). Microwave pretreatment effects on the changes in seeds microstructure, chemical composition and oxidative stability of rapeseed oil. *LWT – Food Science and Technology,* 68, 634–641. http://dx.doi.org/10.1016/j.lwt.2016.01.013

Younces, O. S., Sorour, M. A. & Mohamed, E. N. (2016). Effect of microwave on drying of parsley plant. *Middle East J. Appl. Sci*., 06(04), 1100-1109. www.curresweb.com/mejas/mejas/2016/1100-1109.pdf