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Optimizing Garlic Oil Extraction: A Comparison of Microwave Heating and Traditional Drying Method

Syahril Ishmir Hasim[1*], and Sitinoor Adeib Idris[1,2*]

[1]*School of Chemical Engineering, College of Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia*
[2]*Integrated Separation Technology Research Group, School of Chemical Engineering, College of Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia*

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ABSTRACT

Pre-treatment, such as drying, is important in producing high-quality essential oil from plants. Due to a lack of pre-processing treatment, heavy losses are incurred in terms of both the quality and quantity of garlic oil. These losses could be attributed to respiration, transpiration, or microbiological spoilage. This study aimed to investigate the effect of oven drying and microwave heating on the oil yield of garlic. The nutraceutical industry is currently keen on obtaining garlic extracts using mild extraction processes to recover high levels of labile allicin. Therefore, the oil is extracted using a modern method, microwave-assisted extraction (MAE). In this study, MAE was conducted to determine the optimum extraction conditions, including extraction time and sample-to-solvent ratio, to achieve the highest yield of garlic oil. MAE can significantly reduce extraction time and solvent consumption compared to conventional methods such as solvent extraction and maceration. Based on the results obtained, garlic heated using a microwave yielded a higher oil yield than oven-dried garlic, with percentages of 11.18% and 6.78%, respectively. The best extraction time using MAE was found to be 20 minutes, and the optimal sample-to-solvent ratio was 1:1.5. Moreover, the efficiency of extraction obtained from microwave-heated garlic exceeded that of oven-dried garlic, with percentages of 31.94% and 12.91%, respectively.

INTRODUCTION

Essential oil is a highly volatile substance isolated by a physical process from an odoriferous plant of a single botanical species. The essential oil that was produced all bears the name of the plant from which it is extracted. For example, rose oil is extracted from the rose plant, specifically the rose flower [1]. These oils were called essential because they were thought to represent the very essence of odor and flavor [2], [3]. Essential oils have been used in a variety of domestic applications, such as in perfumery [4], cosmetics [5], feed, food [6], and beverages.

[1*] Corresponding author. *E-mail address*: adeib@uitm.edu.my
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Few researchers have demonstrated the possibility of utilizing essential oils in cooking, which give the food a pleasant taste and are mostly used in processed food [7]. Recently, there has been much interest in using essential oils in aromatherapy for their curative properties. Plant oils were largely used in pharmaceutical and other related medical uses as essential oils, one of the most important and effective ingredients [8].

Essential oil can be extracted from a variety of aromatic plant parts. The chosen extraction method is determined by the characteristics and components required. In some cases, ineffective extraction techniques can alter the biological activity of the essential oils' chemical compounds, resulting in a loss of active compounds, staining, off-flavor, and, in some cases, causing physical changes in essential oils [9]. Low-cost and time-consuming extraction methods are required to obtain high-quality essential oils with a high production yield. Essential oils can be extracted from various parts of plants using various methods [10]. Various essential oil extraction methods are used to obtain the oil. Each method applies a different temperature and pressure that ultimately impacts essential oil quality. Steam distillation normally works by passing hot steam through raw plant materials, while for solvent extraction, to isolate the oils, food-grade solvents, such as ethanol, benzene, dimethyl, or hexane, are used [11]. However, few modern methods were implemented that surpass the traditional method [12], such as microwave-assisted) [13], solvent extraction under pressure, supercritical fluid extraction [14], and ultrasound-assisted extraction [15]. MAE provides numerous benefits, including reduced extraction time and solvent consumption, the ability to extract multiple samples simultaneously, and significantly improved sample throughput [16].

In this study, the essential oils will be obtained from garlic extraction. Garlic, also known as *Allium sativum* L., is a member of the onion family, Lamiaceae. Garlic is thought to have originated in Central Asia, and it is now used all over the world for both culinary and medicinal purposes [17]. Garlic oil is high in sulphurate organic compounds and contains several sulfides, including diallyl disulfide and diallyl trisulphide [18]. It treats and prevents various illnesses, flavorings, and food preservatives. It is widely known and used in the pharmaceutical industry due to its antithrombotic, antiplatelet aggregation, and anticarcinogenic qualities [19]. Garlic essential oils are extracted by hydro-distilling garlic or garlic extracts. Garlic essential oils contain compounds that are primarily classified as main compounds (20%-95%), secondary compounds (1%-20%), and trace compounds with less than 1% concentration [20]. This research extracted garlic oil using MAE with ethanol as a solvent. The objective was to determine the effect of heating, drying, and operating parameters on the oil yield of garlic.

EXPERIMENTAL

Sample preparation

Fresh garlic was procured from a local market in Shah Alam, Selangor, Malaysia was crushed and chopped into small pieces before extraction. The oven-dried garlic samples were prepared by dehydrating sliced fresh garlic for 8 h in a vacuum oven at 60°C and 1 bar vacuum pressure. The oven-dried garlic samples were kept in polystyrene bags and a refrigerator at 4°C until further use.

Pre extraction

Garlic samples of 50 g were placed in a beaker with 75 mL of ethanol added (sample to solvent ratio: 1:1.5 (wt/wt)) for a 30-minute maceration process. The same process was conducted for the 1:0.5 and 1:0.75 sample-to-solvent ratio for fresh and oven-dried garlic.

Extraction

The main extraction process occurred at the Gas Processing lab in the School of Chemical Engineering utilizing a microwave oven (Panasonic, NNST651M, Malaysia) with a frequency of 2,450

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MHz and a maximum delivery power of 1,000 W. The interior cavity dimensions of the oven are 35.5 (W) cm × 25.1 (H) cm × 35.6 (D) cm. During the experiment, power and time were under control. The microwave power was set at 200 W. The experiment was conducted with different sample-to-solvent ratios (1:0.5, 1:0.75, and 1:1.5), extraction time (20 min, 30 min, and 40 min), and garlic samples (fresh and oven-dried garlic). A total of 18 runs were conducted using the one factor at one time (OFAT) method, as stated in Table 1.

Determination of oil yield

The calculation for the oil yield from each sample was using Equation (1) as follows:

$$\text{Oil yield (\%)} = \text{Mass of garlic oil (g)} / \text{Mass of garlic (g)} \times 100 \quad (1)$$

Table 1. Design of experiment by using OFAT for extraction of garlic oil

Run	Type of garlic	Sample to solvent ratio (wt/wt)	Time of extraction (min)
1	Microwave-heated	1:0.5	20
2	Microwave- heated	1:0.5	30
3	Microwave- heated	1:0.5	40
4	Microwave- heated	1:0.75	20
5	Microwave- heated	1:0.75	30
6	Microwave- heated	1:0.75	40
7	Microwave- heated	1:1.5	20
8	Microwave- heated	1:1.5	30
9	Microwave- heated	1:1.5	40
10	Oven-dried	1:0.5	20
11	Oven-dried	1:0.5	30
12	Oven-dried	1:0.5	40
13	Oven-dried	1:0.75	20
14	Oven-dried	1:0.75	30
15	Oven-dried	1:0.75	40
16	Oven-dried	1:1.5	20
17	Oven-dried	1:1.5	30
18	Oven-dried	1:1.5	40

RESULTS AND DISCUSSION

Table 2 shows the oil yield obtained at different sample-to-solid ratios for various extraction times for microwave-heated and oven-dried garlic. The lowest oil yield was collected at a 1:0.5 sample-to-solvent ratio for both oven-dried garlic and microwave-heated garlic with 2.26% (mean = 2.39, SD = 0.20%) and 2.93% (mean = 3.31, SD = 0.33%), respectively. However, the lowest oil yield was collected at different extraction times for oven-dried and microwave-heated garlic with 30 and 20 min of extraction, respectively.

The highest oil yield was collected at a 1:1.5 sample-to-solvent ratio for both oven-dried and microwave-heated garlic with 5.30% (mean = 4.92, SD = 0.39%) and 11.18% (mean = 9.17, SD = 2.14%), respectively. The highest oil yield was collected at different extraction times for oven-dried and microwave-heated garlic with 30 and 20 min of extraction, respectively. The low value of standard deviation was

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obtained for oven-dried garlic at both the lowest and highest sample-to-solvent ratio. This meant that the amount of oil extracted from oven-dried garlic was insignificant at 20 min to 40 min of extraction.

In Table 2, the oil yield obtained from oven-drying was lower than the microwave-heated garlic at all parameters. It suggested that the oven-dried samples required a pre-extraction procedure, such as soaking the sample in solvent to improve the extraction. According to Feng et al. (2021), the extraction of the dried matrix can be improved by pre-treating it with water before subjecting it to microwave-assisted extraction. Furthermore, Feng et al. (2021) explained that the rotation of molecules generates heat, and the heating of moisture inside the plant cell causes the development of pressure, which leads to the disruption of plant cells and so enhances the flow of bioactive phytochemicals from the plant cells [18]. Water is a polar molecule and can be partially aligned by the electric fields, which increases the chances of collision between water and other molecules and substances [21].

Furthermore, from Table 2, the oil yield shows an increasing trend with an increasing sample-to-solvent ratio for all extraction times. The authors performed a t-test: Paired Two Sample for Means to compare the means of microwave-heated and oven-dried samples on garlic oil yield. There was a significant difference between the means of microwave-heated and oven-dried samples on garlic oil yield ($t(df) = 2.306004135$, $p = 0.012918665$). The mean of the microwave-heated sample was 5.75, higher than the mean of the oven-dried sample at 3.63.

Fig. 1 and Fig. 2 show the effect of the extraction time for microwave-heated and oven-dried garlic on oil yield at different sample-to-solvent ratios, respectively. For each sample-to-solvent ratio, microwave-heated garlic yielded higher than oven-dried garlic. The trend for all extractions was different for each operating condition. For example, microwave-heated garlic extracted using a solvent ratio of 1:1.5 showed a decreasing trend of oil yield collected at increasing extraction times. No better results were obtained with increasing extraction time due to the degradation of compounds by microwaves. This was due to the solvent's concentration, which resulted in a decrease in bioactive diffusion and dissolution force from the plant matrix [17]. The oil yield was 38%, reduced from 20 to 40 min of extraction. Oven-dried garlic at 1:1.5 and 1:0.75 sample to solvent ratio; microwave-heated garlic at 1:0.75 showed the same trend of oil yield from 20 min to 40 min of extraction time. The oil yield increases at 30 min of extraction and decreases at 40 min.

Moreover, it can be seen from the graph that at 20 minutes of extraction of oven-dried garlic at 1:1.5, the sample-to-solver ratio yielded the same oil as that of microwave-heated garlic at 1:0.75. The oil yield collected from microwave-heated garlic (Fig. 1) was higher at all operating conditions than oven-dried garlic (Fig. 2). The difference may be related to the drying treatment. The sliced garlic was dehydrated for 8 hours at 60 °C in a vacuum oven at 1 bar vacuum pressure. The combined effect of the time duration and temperature of drying and extraction might be the effects of loss of garlic oil. The long drying time of hot air drying could result in a higher thermal load, which is considered responsible for the degradation of bioactive compounds [12]. The low moisture content of the oven-dried garlic sample was likely to explain this event, which contributed to a relatively low evaporation rate of the essential oil, resulting in inefficient extraction.

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Table 2. Design of experiment by using OFAT for extraction of garlic oil

Sample to solvent ratio (wt/wt)	**Time of extraction (min)**					
	Microwave-heated garlic			Oven-dried garlic		
	20	30	40	20	30	40
1:0.5	2.93	3.51	3.49	2.29	2.26	2.62
1:0.75	4.52	5.18	4.59	3.34	3.89	3.53
1:1.5	11.18	9.4	6.92	4.52	5.3	4.94

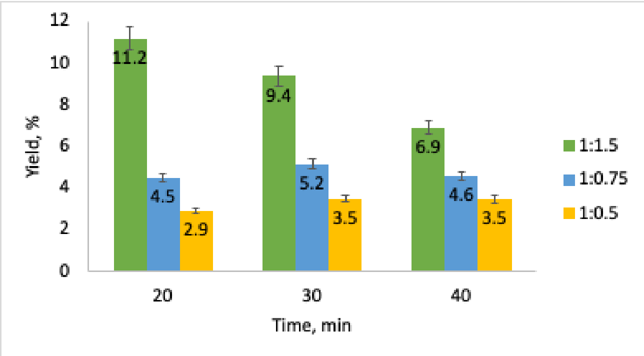

Fig. 1. Effect of extraction time for microwave-heated garlic on oil yield at different sample-to-solvent ratios (Microwave power: 200W)

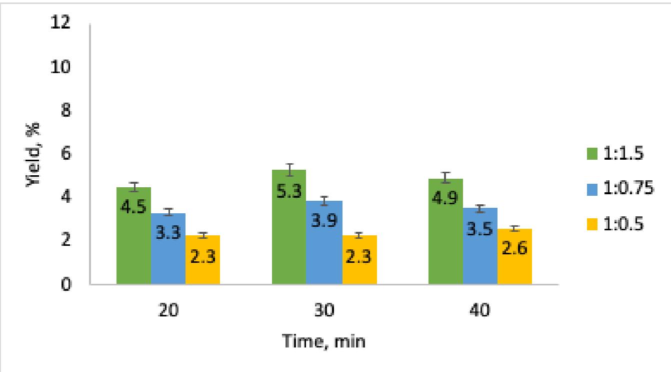

Fig. 2. Effect of extraction time for oven-dried garlic on oil yield at different sample-to-solvent ratios (microwave power: 200W)

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CONCLUSION

Drying methods and extraction time significantly impact the yield of garlic essential oil. The best parameter is a 1:1.5 sample-to-solvent ratio of microwave-heated garlic with an extraction time of 20 min to obtain the maximum yield of 11.18%. Further sample quality analysis should be conducted to identify the drying methods that produce the best quality garlic essential oil.

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AUTHOR'S CONTRIBUTION

Syahril Ishmir carried out the research and wrote the article. Sitinoor Adeib designed the research, supervised the research progress, anchored the review and revisions, and approved the article submission.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted without any self-benefits, commercial, or financial conflicts and declare the absence of conflicting interests with the funders.

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