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Extraction and Characterization of Sesame Seed Oil Using Microwave-Assisted Green Solvent Technology

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ABSTRACT

This research article explores the use of microwave-assisted green solvent technology for the extraction and characterization of oil from sesame seeds. The study highlights the efficiency of this method as an alternative to conventional solvent extraction techniques. The study used five solvents, including ethanol, methanol, ethyl acetate, acetone, and isopropanol, and conducted the extraction with the microwave-assisted method. The results showed that iso-propanol had the highest oil yield of 36.29%, followed by ethyl acetate, which had a yield of 32.39%. Methanol had the lowest yield of 25.79% and was not recommended due to its high toxicity and potential damage to lipid structure. The study demonstrated that the choice of solvent is a critical factor in optimizing oil yield in extraction processes. The use of isopropanol and ethyl acetate as green solvents for oil extraction from sesame seeds could be a promising alternative to traditional solvent extraction methods. The physico-chemical characteristics of the oils extracted using various methods were also compared, and the microwave-assisted green solvent-extracted oil had a lower free fatty acid concentration than the hexane-extracted oil. The refractive index and density of the oils extracted showed no significant solvent effects, while the iodine value, saponification value, and peroxide value showed small differences among the different extraction methods.

Key words : *Sesame seed oil, Green solvent technology, Oil extraction*

Introduction

Sesame seed oil is popular edible oil, widely used in cooking, food preparation, and traditional medicine due to its high nutritional value, antioxidant properties, and health benefits (Uzun *et al*., 2008). However, conventional methods of extracting sesame seed oil involve the use of hazardous organic solvents, such as hexane, which raises environmental and health concerns (Prat *et al*., 2015). In recent years, the development of green solvent technology has gained considerable attention in the field of oil extraction as a sustainable and eco-friendly alternative to conventional solvent extraction methods. Microwave-assisted green solvent extractionis a technique that has been used successfully in extracting various bioactive compounds from plants (Kuo *et al*., 2012). In recent years, this extraction technology has gained increasing interest in oil extraction, as it offers several advantages over conventional methods, such as faster extraction times, lower solvent consumption, and higher extraction yields (Zhang *et al*., 2018). Combining MAE with green solvents has been shown to enhance the extraction efficiency while reducing the environmental impact of the extraction process. In this study, we aim to investigate the use of microwave-assisted green solvent technology for the extraction and characterization of sesame seed oil. The study will focus on optimizing the extraction process to obtain high yields of oil while minimizing the environmental impact of the extraction process. We will also characterize the extracted oil in terms of its physicochemical properties including iodine value, refractive index, Specific gravity, free fatty acids (FFA), peroxide value (PV), and saponification values of the extracted oils. The selection of an appropriate solvent is crucial for maximizing oil yield in extraction processes. In this study, the microwave-assisted extraction method was used to evaluate the efficiency of five solvents for oil extraction from sesame seeds.

Materials and Methods

Microwave-assisted green solvent extraction is a method used to extract oil from plant materials such as seeds, nuts, and fruits. It is a fast and efficient method that uses a combination of microwave radiation and green solvents to extract oil. The following is a detailed experimental procedure for microwave-assisted green solvent extraction:

Materials and preparation of sample

Sesame seeds were collected from ICAR-Indian Institute of Oilseeds Research Hyderabad and thoroughly cleaned using a specific gravity separator for removing unwanted foreign material and undamaged and bold kernels were selected for the study. The cleaned sesame seed grains were dried in a hot air oven with up to 10 % (d.b) moisture content (Sahay and Singh, 2003)**.** In order to smooth the progress of the extraction of oil from the cells of oil-bearing material, it is essential to increase the surface area of contact of the material with the extracting medium (i.e. solvent). For, a maximum yield of oil the cell wall seed needs to rupture. The dried sesame seed was ground in a laboratory mixer-grinder for a period of 30 seconds and the ground sample was allowed to pass through sieve as per the requirement of particle size (<0.4mm) during the experiment. To avoid rancidity and free fatty acid formation, the dehulled ground powder was packed and sealed in airtight polythene bagsand stored in the refrigerator at 4^o C until used for further experiments (Kanitkar *et al*., 2011).

Solvents

The most widely-used solvent to extract edible oil from plant sources is hexane (Brahim *et al.,* 2019). However, n-hexane is the main component of commercial solvent extraction plants. Hexane is listed as No. 1 on the list of 189 hazardous air pollutants by the US Environmental Protection Agency (Kumar *et al*., 2017) and there is vast demand to explore alternative solvents. Hence, polar alcoholic solvents were selected and their effect on the oil yield was studied. Five different green solvents i.e., isopropanol, ethanol, methanol, ethyl acetate, and acetone were taken for the present study.

Microwave-assisted green solvent extraction procedure

The extraction was performed in a flat bottom flask containing ground sesame seeds and one of the five solvents used in the extraction step. In each experiment, a known mass of ground sesame seeds of about 50 g (particle size <0.4mm) samplewas taken in 500 ml capacity flat bottom flask. 150 ml of solventwas added in the same flask and shaken thoroughly for proper solvent-solid interactionand kept for 40 minutes for soaking later the mixture of solvent and ground seed was in flat bottomed flask and exposed to a microwave at the power levelof 350 watt for 180 second treatment time was used for the oil extraction from the sesame seed. The overhead glass condenser was then fitted on the mouth of the extraction flask and properly sealed. After the completion of desired treatment times, the defatted meal was separated from miscella by means of vacuum filtration using Wattaman No. 1 type of filter paper. Transfer the mixture obtained as filtrate to a rotary vacuum evaporator to separate the oil and solvent. The rotary evaporator works by heating the mixture under reduced pressure, causing the solvent to evaporate and leaving the oil behind. Once the solvent has been removed, collect the oil in a clean glass vial or bottle at reduced pressure (Terigar *et al*., 2011).

Extraction oil yield is the ratio of the amount of oil extracted to the amount of a given sample and expressed in percentage (Li *et al.*, 2004; Kwiatkowski and Cheryan, 2002)

$$\text{Oil yield (\%)} = \frac{\text{Amount of oil extracted(g)}}{\text{Weight of sample(g)}} \times 100$$

Physical and Chemical Analysis of the Extracted Oil

The physico-chemical properties of microwave-assistedgreen solvent extracted using acetone, Ethanol, and Iso-propanol were determined. The oil that was obtained from the seeds was subjected to physical and chemical parameters such as iodine value, refractive index, Specific gravity, free fatty acids (FFA), peroxide value (PV), and saponification values of the extracted oils were determined by AOCS standard methods (1997). The refractive index was measured by a refractometer.

Statistical analysis

The statistical analysis of the data was carried out by analysis of variance (ANOVA) using the statistical software IBM SPSS Statistics 26.0. All experiments were carried out in triplicate. Statistical significance was defined as a probability value of 0.05. Data are presented as mean values and standard deviation based on determinations made in triplicate.

Results and Discussion

Effect of solvent on oil extraction

The experiment was conducted to select the appropriate solvent for maximum oil yield. The selection of the most suitable solvent for extracting the analytes of interest from the sample matrix is a fundamental step in developing any extraction method. Different types of solvents ethanol, methanol, ethyl acetate, acetone, and, iso-propanol were used for oil extraction with microwave-assisted extraction method. Out of these, one solvent was chosen for further experiments. Fig. 1 depicted the mean oil yield percentage for different solvents used for extraction. The highest oil yield was obtained with iso-propanol (36.29%), followed by ethyl acetate (32.39%), acetone (31.32%), ethanol (30.93%), and methanol (25.79%). These results suggest that iso-propanol is the most efficient solvent for extracting oil from the source material. This finding is in agreement with studies that have also reported higher oil yields with iso-propanol compared to other solvents, including ethanol and methanol (Oliveira *et al.,* 2013). Iso-propanol has been shown to have better solvent power for lipids than ethanol and methanol, which can result in higher oil yield. Ethyl acetate, which had the second-highest oil yield in this study, is also a promising solvent for oil extraction. It has been reported to have similar solvent power for lipids as hexane, but with the advantage of being a less toxic and more environmentally friendly solvent. In contrast, methanol, which had the lowest oil yield in this study, is not recommended for oil extraction due to its high toxicity and potential to denature and damage the lipid structure (Li *et al.,* 2006; Wei *et al.,* 2014). Overall, this study demonstrates that the choice of solvent is a critical factor in optimizing oil yield in extraction processes. The use of isopropanol and ethyl acetate as green solvents for oil extraction from sesame seeds could be a promising alternative to traditional solvent extraction methods.

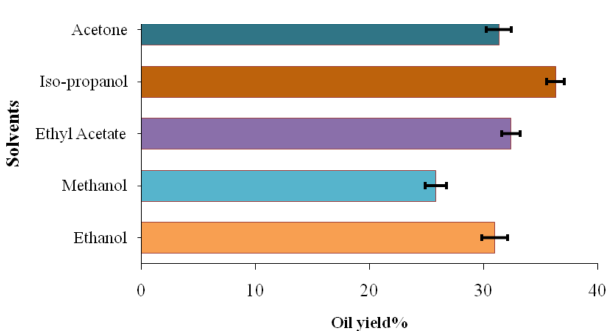

Fig. 1. Effect of different solvents on the extraction of oil from sesame seed

Table 1 shows the mean oil yield percentage for different solvents grouped together. The solvents used are isopropanol, ethyl acetate, acetone, ethanol, and methanol. There are three replicates for each solvent. The mean oil yield percentage for iso-propanol is 36.29%, for ethyl acetate, it is 32.39%, for acetone it is 31.32%, for ethanol, it is 30.93%, and for methanol, it is 25.79%. The groups are labelled A, B, BC, C, and D, respectively. This data is useful in determining which solvent is the most effective for extracting oil from the source material

Physico-chemical properties of extracted sesame oils

The Table 2 shows the results of various analytical parameters for oil extracted using two different methods, hexane-based control solvent and a microwave-assisted green solvent. The values for each

Table 1. Grouping Information Using the Fisher LSD Method at 5% level of significance

Grouping	Mean (Oil yield%)	N	Types of solvents
A	36.29	3	Iso-propanol
B	32.39	3	Ethyl Acetate
BC	31.32	3	Acetone
C	30.93	3	Ethanol
D	25.79	3	Methanol

Table 2. Physico-chemical properties of sesame seed oils

Parameter	Control (Hexane)	Microwave-assisted green solvent-extracted oil				
		Ethanol	Methanol	Iso-propanol	Ethyl acetate	Acetone
Refractive index (40 ^{O}C)	1.4664 ± 0.02	1.4662±0.01	1.4664 ± 0.02	1.4663±0.01	1.4663±0.02	1.4662±0.01
Sp. gravity (20 ^{O}C)	0.92 ± 0.04	0.916 ± 0.04	0.919 ± 0.02	0.920 ± 0.06	0.919 ± 0.03	0.920 ± 0.05
Saponification value (mg KOH/g of oil)	169 ± 3.4	158 ± 3.4	169 ± 2.3	164 ± 1.5	167 ± 1.8	162± 1.4
Free fatty acid contents (% as oleic acid)	1.55 ± 0.03	1.54 ± 0.13	1.47 ± 0.16	1.44 ± 0.12	1.51 ± 0.14	1.46 ± 0.13
Iodine value (g of I/100 g of oil	113 ± 2	108 ± 2	105 ± 4	111 ± 3	110 ± 2	107 ± 5
PV meq O_2/kg	1.73± 0.14	1.77 ± 0.16	1.73 ± 0.12	1.82 ± 0.10	1.79 ± 0.14	1.71 ± 0.11

parameter are presented as mean ± standard deviation for five different solvents: ethanol, methanol, iso-propanol, ethyl acetate, and acetone.For refractive index at 40 °C, the values for the control (hexane) and microwave-assisted green solvent-extracted oil were similar and ranged from 1.4662 to 1.4664. The values for specific gravity at 20 °C were also similar for both solvents, ranging from 0.916 to 0.920 for the microwave-assisted green solvent-extracted oil, and 0.919 to 0.920 for the control (hexane) extracted oil.The saponification value of the microwave-assisted green solvent-extracted oil ranged from 158 to 169 mg KOH/g of oil, while the control (hexane) extracted oil had a saponification value ranging from 162 to 169 mg KOH/g of oil. For free fatty acid content, the values ranged from 1.44% to 1.55% as oleic acid for the microwave-assisted green solvent-extracted oil, and from 1.46% to 1.55% as oleic acid for the control (hexane) extracted oil.The iodine value, which is a measure of the degree of unsaturation in the oil, ranged from 105 to 113 g of I/100 g of oil for the various solvents used in the microwave-assisted green solvent-extracted oil, and from 107 to 113 g of I/100 g of oil for the control (hexane) extracted oil. Lastly, the peroxide value ranged from 1.71 to 1.82 meq O2/kg for the various solvents used in the microwave-assisted green solvent-extracted oil, and from 1.73 to 1.79 meq O2/kg for the control (hexane) extracted oil.

The results of the study showed that microwave-assisted green solvent extraction can be used as an alternative to hexane extraction for obtaining oil from plant material. The values obtained for refractive index, specific gravity, saponification value, free fatty acid contents, iodine value, and peroxide value were comparable between the two methods, indicating that microwave-assisted green solvent extraction can be a viable and more environmentally-friendly option for oil extraction.Several studies have reported on the effectiveness of microwave-assisted extraction for obtaining oil from different plant sources. For instance, a study by Giwa *et al.* (2016) reported that microwave-assisted extraction using ethanol as a solvent was an efficient method for obtaining oil from pumpkin seeds. Another study by Oniya *et al.* (2017) reported that microwave-assisted extraction using a mixture of ethanol and water was an effective method for obtaining oil from flaxseeds. These findings are consistent with the results of the current study, which showed that microwave-assisted green solvent extraction can be a viable option for oil extraction.

Conclusion

Microwave-assisted green solvent extraction can be an effective alternative to the conventional solvent extraction method for the extraction of oil from sesame seeds. The extracted oils had similar physicochemical properties to those extracted using conventional methods. The use of ethanol, methanol, isopropanol, ethyl acetate, and acetone as green solvents also showed promising results in terms of yield and quality of the extracted oil. However, further studies are required to optimize the extraction conditions and evaluate the economic feasibility of this technology on a larger scale. Overall, the study shows that the use of green solvents and microwave-assisted extraction techniques can be a potential alternative to the conventional hexane extraction method. However, the choice of solvent can affect the quality of the extracted oil.

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