Journal of Kerbala for Agricultural Sciences Issue (1), Volume (11), (2024)

Temperature influence variation on extracted oil yield from exported white sesame seed Characterization

Sheraz Zuher Karem *, Safea Sabir Taha

Food Technology Department, Agricultural Engineering Sciences College, University of Salahaddin, Erbil, Kurdistan Region, Iraq.
*Corresponding author e-mail: Sheraz.karem@su.edu.krd
https://doi.org/10.59658/jkas.v11i1.1449

Received: Jan. 14, 2024

Accepted: Feb. 15, 2024

Published: Mar. 18, 2024

Abstract

This study was conducted to find out the effects of various temperatures on the physiochemical and extraction characteristics for oil extracted from white sesame seeds, specifically looking at the yield of extraction, physical analysis, and chemical aspects of the sesame oil that was produced. Using petroleum ether as a solvent, the oil output from sesame seeds was evaluated throughout a temperature range of 100-250°C. Extracted sesame oil had a little aroma, was clear, and had a golden hue; at room temperature, its oil content ranged from 57.49% to 40.79 %. Sesame oil's physical properties were assessed by measuring its density, specific gravity, moisture content, and refractive index. At 250°C, the refractive index reached its maximum, which was in the range of 1.468 to 1.473. At 250°C, the specific gravity was the greatest, however it ranged from 0.9 to 0.98. At 250°C, the moisture content was the lowest, yet it varied from 0.0014% to 0.35%. At 250°C, the density dropped from 0.950 to 0.690 g/cm^3, a decline that was temperature dependent. Sesame oil's chemical evaluation included measures for acidity, free fatty acid concentration, iodine, peroxide, and saponification. A possible indicator of oil deterioration or contaminants is the fact that acid value and free fatty acid content rise with increasing sample levels. Differences in unsaturation levels were suggested by the varying iodine values. The peroxide value rose as the sample concentration rose, suggesting that the oxidation potential rose as well. Variations in triglyceride content or source were reflected in the saponification levels, which likewise showed some fluctuation.

Keywords: sesame seeds,extraction yield,physiochemical properties.

Introduction

Sesame, scientifically known as Sesamum indicum L., is a long-lived oilseed crop that is highly prized for its fragrant oil and many uses in medicine, food, and personal care products [1]. Sesame oil's physiochemical characteristics and its applicability are greatly affected by the extraction procedure, which is very important. Because it has such a significant impact on the yield, quality, and properties of the extracted oil, temperature is an important consideration throughout the extraction process [2].

Recent years have seen an uptick in research on the impact of temperature on white sesame seed extraction and physiochemical characteristics. Improving oil quality, increasing oil production, and guaranteeing product consistency all need optimising the extraction process, which is why this is of importance [3]. For many businesses that depend on sesame oil, including food production, it is crucial to understand the effects of temperature on the extraction process and the qualities of the resultant oil [4].

We want to learn more about the complex interplay between sesame oil's physiochemical properties, the efficiency of its extraction, and temperature in this study. The extraction process may be optimised by methodically testing the effects of different temperatures on white sesame seed oil's composition, stability, and sensory properties [5]. Furthermore, this information may be used to create more sustainable and effective methods of extracting sesame oil, which will help manufacturers keep up with the rising demand for premium sesame oil products while reducing their environmental impact [2].

White sesame seed oil's extraction yield, fatty acid content, oxidative stability, and sensory qualities will be investigated in this research by examining the impacts of various temperature regimes. Our goal in thoroughly investigating these factors is to add to the body of knowledge on the significance of temperature in sesame oil extraction and its potential uses. To ensure sesame oil's continuous quality and adaptability in the global marketplace, this study aims to give significant insights that may guide industry practices and product development.

Materials and Methods

Sample Collection

Sourced at the Show market in Erbil, this sesame seed (Aspy Rash) is from the Kurdistan Region. Following a 6-hour drying period in a desiccator, the seeds were screened to eliminate any remaining stones, sand, or defects. They were then oven-dried at 105 oC. We used a blender to grind the seeds after they were dried.

Oil Extraction by Soxhlet

Using a soxhlet system [6], sesame oil was extracted from sesame seeds. Once the seeds were dried and powdered, 15 grammes of each sample was removed and put in a thimble. Then, 300 ml of petroleum ether, used as a solvent, was poured to the round-bottom flask of the soxhlet apparatus. As a further step, extraction was performed for four hours at temperatures of 100, 150, 200, and 250 ^{o}C. At 65 ^{o}C, the sesame oil was separated from the solvent using the rotary evaporator. After being filtered under a vacuum and heated to 40 ^{o}C, the residual solvent was evaporated from the separated oil, leaving behind largely light yellow oil samples. We will analyse the extract further after storing it in a dark environment [6].

$$\% \, Yield = \frac{W1-W2}{W1} \times 100$$

W_1= W eight of Sample (g)

W_2 = Weight of remaining sample (g).

Physical analysis

Refractive index

The samples were put on the sample position in the refractometer (Refractometer, ARAGO, Digital Thermo metre, KOICA) with 2, 3 drops of extracted sesame oil each [7].

Moisture content

The AOAC [8] method was used to ascertain the moisture content. 2 gm of oil sample was weighed and dried in a plate. The dish was covered and placed in an oven preheated to 105°C for three hours. After removing the dish from the oven, it was cooled in a desiccator containing phosphorus pentoxide desiccant. Subsequently, its weight was determined. Subsequently, the cover was shut. It was reweighed after cooling after a further hour in the oven. we went through it again.

$$Moisture\ content = \frac{wt.of\ Sesame\ Seed\ sample\ - wt.\ of\ the\ dried\ sample}{wt.\ of\ the\ sesame\ seed\ sample} \times 100$$

Determination of Density

We determined the density using the steps given by A.O.A.C., [7]. The density bottle underwent cleaning and subsequent oven drying. Afterwards, it was cooled using a desiccator. We started by finding the weight of the density bottle, or W1. The weight of the bottle and oil (W3) was determined after filling it with oil. Subtracting W1 from W3 yielded the oil's weight, which was then recorded as W2. This was followed by the recording of the oil quantity. One way to calculate the density of extracted oil is using the following formula:

$$Density\ (\frac{g}{cm^3}) = \frac{wt.of\ Oil\ (W2)}{Volum\ of\ Oil}$$

Specific Gravity Determination by Pycnometer

After removing the side arm cover, carefully fill the dry pycnometer with the 50 ml sesame oil sample, being sure to avoid trapping any air bubbles. Hold for 30 minutes after inserting the stopper and immersing in a water bath set at 22 ^oC. After the capillary hole has released any oil, carefully wipe it off. Take the bottle out of the water and give it a good scrub. Quickly weigh the item while making sure the temperature stays above 30°C after removing the side arm cap [8].

SP.gr at 30 degree C / 30 degree C= $\frac{A-B}{C-B}$

Where:

A= grammes of oil in a 30-degree Celsius container with a specific gravity

B= grammes of the bottle's specific gravity at 30 degrees Celsius

C= grammes of water in a 30-degree Celsius container with a specific gravity.

Chemical Analysis

Acid Value

We used the [7] approach to find the acid value of every sesame oil sample. A 0.1 N potassium hydroxide solution was titrated with 2–3 drops of phenolphthalein indicator after dissolving 1g of sesame oil sample in a 50:50 combinations of ethanol and ether.

This equation quantifies the acid value and the amount of free fatty acid.

Acid Value = $\frac{V\ of\ KOH \times N \times 56}{weight\ of\ sample\ (g)}$

% Free fatty acid = Acid Value × 0.503

Where:

Voltage of the potassium hydroxide titrant (ml), normality of the potassium hydroxide (N), molecular weight of potassium hydroxide (56 g/mol), and percent free fatty acid (%FFA) expressed as oleic acid per 100 g are all variables.

Iodine Value

The sesame oil samples were tested for their iodine value using the method described in reference [7]. Using 1 litre of glacial acetic acid, dissolve 18.2 grammes of iodine. To raise the halogen level, add 3 ml of bromine water. Combine 1 gm of sesame oil with 0.5 millilitres of chloroform solvent to generate the Hansus solution. Half a millilitre of potassium iodide and five millilitres of distilled water are then added to the mixture. After that, the solution is allowed to settle for half an hour after adding two or three drops of starch. Then, a sodium thiosulfate solution is used for titration to estimate it. The iodine value was calculated using the following equation:

Iodine value = $\frac{[(B-S)\times N \times 126.9]}{sample\ wt.g}$

Where:

The molecular weight of iodine is 126.9, and N is the normality of the Na2S2O3 solution. S= millilitres of titrant with sample and B= millilitres of titrant without blank.

Peroxide Value

The technique described in [7] was used to assess the peroxide value of sesame oil samples. After adding 1g of sesame oil to a combination of 25 ml each of glacial acetic acid (16.6 ml), chloroform (8.4 ml), and KI (1 g), stir for 1 minute in a dark location until the mixture is homogeneous. Thirty-five millilitres of distilled water, two or three drops of starch for colour, and finally, sodium thiosulfate for titration.

The measurement was given in milligrammes of peroxide oxygen equivalents per kilogramme of oil (meq/kg).

$$PV\ (meqO2/kg\ oil) = \frac{[\ (S-B)\ *\ N]\ x1000}{sample\ wt.g}$$

Where S= Volume of titrant (ml) with sample, B= Volume of titrant (ml) with blank, $N = Normality$ of sodium thiosulfate

Saponification

The number of saponification degrees found in sesame oil samples according to [7]. To prepare the solution, dissolve 30 grammes of potassium hydroxide in 20 millilitres of water. Add 12.5 millilitres of 0.5 N alcoholic potassium hydroxide. Add 2-3 drops of phenolphthalein as an indicator. Titrate with hydrochloric acid to estimate the saponification number.

Saponification Number = $\frac{56.1\ (B-S)\times N\ of\ HCl}{Weight\ of\ sample\ (g)}$

Where

B: ml of HCl required by Blank, S: ml of HCl required by sample, $N =$ Normality of hydrochloric acid

Statistical Analysis

The data from the Factorial in a Completely Randomised Design (FCRD) experiment was analysed statistically using the computer programme SPSS (SPSS software, version 26, 2019). We used Duncan's multiple range tests to compare the averages at a significance level of ($P \leq 0.05$).

Results and Discussion

Oil yield

The oil content of the seeds was measured using a Soxhlet extractor using petroleum as the solvent. Figure 1 shows that the oil content of sesame seed samples ranged from 57.59% to 40.79% when tested at temperatures between 100 and 250 °C. Oily liquid at room temperature with a faint aroma and a golden color; it is clear and unhazy. Oil yields are greatest at the lowest temperature and lowest at the maximum temperature, with 57.49% and 40.79 percent, respectively.

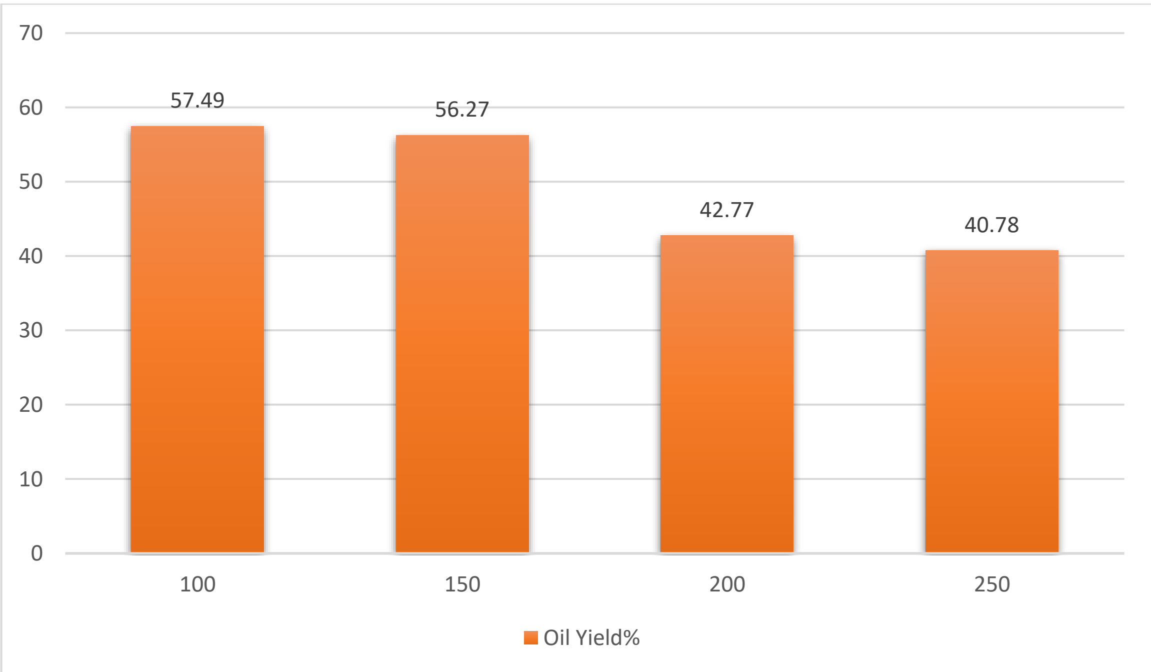

Figure (1): Effect of heat treatment on sesame seed oil extraction using petroleum either

Physical analysis

Refractive index

Table (1): Refractive index, specific gravity, moisture and density of sesame oil parts

sample	RI	SP.gr	Moisture	D
100	**1.468±0.21[c]**	**0.9±0.02[d]**	**0.35±0.12[d]**	**0.950±0.018[d]**
150	**1.4695±0.018[b]**	**0.902±0.21[c]**	**0.24±0.01[c]**	**0.890±0.15[c]**
200	**1.47±0.17[a]**	**0.96±0.012[b]**	**0.010±0.013[b]**	**0.850±0.13[b]**
250	**1.473±0.15[a]**	**0.98±0.15[a]**	**0.0014±0.03[a]**	**0.690±0.12[a]**

How fast light travelling through oil at a certain wavelength compares to how fast it travels through air is called the oil's refractive index (RI). Wavelength, temperature, unsaturation degree and type, component fatty acid replacement type, and surrounding chemicals all have an effect on the refractive index. Quality control, material purity, and the monitoring of hydrogenation and isomerization are all areas that make extensive use of the refractive index [9]. Refractive index values ranged from 1.468 to 1.473, with the maximum value observed in 250 °C sesame seed oil samples (1.468) and the lowest value in 100 °C sesame oil samples (1.473), as shown in table (3.1). This study's RI results at room temperature are in agreement with [10,11]: melon seed oil, both white and yellow (1.47).

Specific gravity

A pycnometer is a non-destructive tool for measuring the volume and density of solids. When it comes to gas pycnometers, this is achieved by using Boyle's law of volume-pressure correlations [11] and Archimedes' theory of fluid displacement [12]. The sesame oil samples had a specific gravity ranging from 0.9 to 0.98, which was heavier than the water table at (1) The sample with the greatest specific gravity was the one made at 250 °C, while the one with the lowest specific gravity was the one made at 100 °C. These results were in agreement with those of Rahman et al. [12] and ranged from 0.91 to 0.913.

Moisture content

Table (1) displays the results showing that the moisture content of the sesame seed samples varied substantially from one another. Moisture content ranged from 0.0014% in the 250 oC sample to 0.35% in the 100 oC sample of sesame seed. Inadequate storage conditions or problems during extraction and manufacture might lead to sesame oil containing undesirable levels of moisture. Concerns with extraction, processing, storage, packaging, quality control, and rancidity might arise with sesame oil, which is mostly a lipid product but may include small levels of water [13].

Density

A substance's density is defined as its mass/volume ratio. Seed and vegetable oils vary in density according to temperature, minor components, and the content of fatty acids [14]. Based on the data in Table 3.1, the density of sesame seed was determined to be 0.950±0.018d. As the temperature increases up to 250°C, the density drops to 0.690±0.12a. This change in density might be caused by the oil expanding when heated. Though it was lower than 1.16 in sesame seed, the density value of sesame oil in this research was more than 0.847 in cotton seed oil [15]. Possible explanations for the discrepancy in density levels between the seseme seed oil samples included in this analysis and others include differences in the proportion of fatty acids and the presence of trace amounts of other components [16].

Chemical Analysis

Table (2): Chemical properties of sesame oil parts

Sample	AV	FFA	IV	PV	SP
100	1.796±0.131^{c}	0.903±0.2^{d}	108.18±0.12^{a}	4.4±0.11^{c}	24.29±0.012^{b}
150	2.113±0.19^{b}	1.063±0.131^{c}	85.09±0.012^{b}	4.621±0.015^{c}	22.416±0.31^{c}
200	2.796±0.17^{a}	1.406±0.12^{b}	76.8±0.13^{c}	5.113±0.103^{b}	26.121±0.23^{a}
250	3.112±0.015^{a}	1.565±0.115^{a}	112.13±0.031^{a}	5.921±0.122^{a}	27.651±0.18^{a}

Acid Value

Based on the data shown in table (2)The Acid Value rose with increasing sample level, reaching its maximum at 250 (3.112±0.015a) and its lowest at 100 (1.796±0.131c). As the breakdown of chemical bonds in oils increases at higher temperatures, a rise in acid value indicates that the oil is deteriorating, which is the case with seeds. While [17] (2015) reported a room temperature acid value of 5.00 mg/g for palm oil, the result in our investigation was somewhat higher. But it was less than the 10.7 mg/g found in [18]. You can tell how much fatty acid is in the oil sample by looking at the acid value. It is the acidity value that determines whether seed oil is suitable for human consumption or for use in industry. Acid values are the milligrammes of potassium hydroxide (KOH) needed to neutralise one gramme of free fatty acid in one gramme of fat or oil. It is common practice to utilise the acid values as a rough indicator of the oil's quality and edibleness, and they also serve to represent the amount of free fatty acid in the oils. In other words, the acidity of the oil is directly proportional to the quantity of free fatty acids in it. [17]. An indication of oil deterioration or contaminants might be the greater amounts of free fatty acids shown by an increasing Acid Value and Free Fatty Acid content with increasing sample levels. Variations in sample processing or quality may account for the discrepancies in these figures.

Free Fatty Acid

The proportion of a given fatty acid by weight is known as its free fatty acid. More samples resulted in a higher concentration of free fatty acids. At a value of 250, the maximum was noted at 1.565±0.115a, while at 100, the minimum was recorded at 0.903±0.2d. The FFA levels at room temperature in this investigation were higher than the following values reported in the literature: sesame seed oil (2.33) [19], castor seed oil (0.14), and several types of melon seed oil (3.30-3.80). Unwanted effects on taste, oil shelf life, and smoke point might result from a high free fatty acid content. Oils with low quantities of free fatty acids are considered to be of high grade [20].

Iodine Value

One measure of a substance's iodine absorption capacity is its "iodine value." This includes oils and fats. One way to tell whether unsaturated fats are oxidizable is by seeing how iodine reacts with their double bonds. The iodine value is expressed as grammes of iodine per 100 grammes of sample because it is important for forecasting the stability of oil, which might be more unstable if it contains more double bonds [7]. See table 3.2 for details. Depending on the sample level, the iodine value varied somewhat. According to another research, the iodine value ranged from 100 (108.18±0.12a) to 250 (112.13±0.031a) and 200 (76.8±0.13c), with a value between 103 and 116.

Peroxide Value

As a measure of oxidation or rancidity, peroxide value is important. As a measure of the main byproducts of lipid oxidation, the peroxide value is helpful for identifying moderate rancidity in its early stages. It also provides a measure of the degree of primary oxidation in an oil sample, while the p-anisidine test can identify the degree of secondary oxidation [22]. The peroxide value likewise rose as the sample level increased, as seen in Table 3.2. At 250, the Peroxide Value was recorded as the greatest (5.921±0.122a), while at 100, it was recorded as the lowest (4.4±0.11c). Research has shown that sesame oil has a peroxide value that is within the range specified by [23].

Saponification

One gramme of oil may be saponified using a certain amount of potassium hydroxide or sodium hydroxide; this quantity is called the saponification value or number. The average molecular weight (or chain length) of triglycerides is used to get this estimation. A higher saponification score is indicative of shorter average fatty acid chains and lighter average triglyceride weights.

The data in Table 3.2 show The saponification values rose as the sample size increased. At 250, the Saponification value was 27.651±0.18a, whereas at 150, it was 22.416±0.31c, the lowest. It is possible that the triglyceride composition of the samples differed because the Saponification values varied with sample levels. This can be because different sesame seeds come from different places or undergo different processing techniques. The findings of a research conducted by [24] ranged from 20.89 to 31.91 mg KOH/g of oil.

Testing sesame oil in a controlled environment provided valuable information about its characteristics, including its density, moisture content, specific gravity, and refractive index. The sesame oil tests showed a refractive index (RI) ranging from 1.468 to 1.473, with the highest RI seen in samples given at 250°C and the lowest at 100°C. Consistent RI values across different seed oils are shown by these results. The explicit gravity values ranged from 0.9 to 0.98, with higher temperatures resulting in better quality samples, in line with the assumptions made based on the standards for liquid elements. Examples demonstrated the need of proper stockpiling and assembly cycles to avoid undesirable moisture levels, with moisture content ranging from 0.0014% to 0.35%. The expansion of oil particles upon heating explains why density exhibited a decreasing trend with increasing temperature. Although there are differences in viscosity levels compared to other oils, such as cotton seed oil, possible explanations should keep in mind differences in unsaturated fat organization and subsequent components. Sesame oil's corrosive, free unsaturated fat, iodine, peroxide, and saponification values were further investigated using chemical analysis. Essential indicators of oil quality, edibleness, and stability are these criteria. Notable trends in these chemical characteristics provide useful information for determining if sesame oil is suitable for use in a variety of contexts, from contemporary cycles to the kitchen. Sesame oil's properties and potential uses in several domains are better understood thanks to the comprehensive physical and chemical investigations.

References

1) Afolabi, I. S. (2008). Chemical qualities of oils from some fresh and market vegetable crops within Kwara State of Nigeria. *Biokemistri*, 20(2).
2) Afshar, S., Ramezan, Y., & Hosseini, S. (2022). Physical and chemical properties of oil extracted from sesame (*Sesamum indicum* L.) and sunflower (*Helianthus annuus* L.) seeds treated with cold plasma. *Journal of Food Measurement and Characterization*, 1-13.
3) Akinoso, R., Aboaba, S. A., & Olayanju, T. M. A. (2010). Effects of moisture content and heat treatment on peroxide value and oxidative stability of unrefined sesame oil. *African Journal of Food, Agriculture, Nutrition and Development*, 10(10).
4) Al-Bachir, M. (2015). Quality characteristics of oil extracted from gamma-irradiated peanut (*Arachis hypogaea* L.). *Radiation Physics and Chemistry*, 106, 56-60.
5) Amos-Tautua, B. M. W., & Onigbinde, A. O. (2013). Physicochemical properties and fatty acid profiles of crude oil extracts from three vegetable seeds. *Pakistan Journal of Nutrition*, 12(7), 647.
6) Andrew, C., Itodo, A. U., & Etim, E. E. (2012). Thermoxidative degradation of commonly used vegetable oils: a comparative study. *Journal of Emerging Trends in Engineering and Applied Sciences*, 3(6), 924-928.

7) AOAC (Association of Official Analytical Chemists). (2000). *Official Methods of Analysis* (17th ed.). AOAC International.

8) AOAC (Association of Official Analytical Chemists). (2005). *Official Methods of Analysis* (18th ed.). AOAC International.

9) Aremu, M. O., & Akinwumi, O. D. (2014). Extraction, compositional, and physico-chemical characteristics of cashew (*Anacardium occidentale*) nuts reject oil. *Asian Journal of Applied Science and Engineering*, 3(2), 227-234.

10) Chakrabarty, M. M. (2013). *Chemistry and technology of oils & fats* (Vol. 1). Allied Publishers.

11) Duduyemi, O., Adebanjo, S. A., & Oluoti, K. (2013). Extraction and determination of physico-chemical properties of watermelon seed oil (*Citrullus lanatus* L.) for relevant uses. *International Journal of Scientific & Technology Research*, 2(8), 66-68.

12) Evbuowman, B. O., Lawson, J. N., & Atuka, M. M. (2013). Some physicochemical properties of cashew nut (*Anacardium occidentale*) and palm kernel (*Elaeis guineensis*) oil using straight run gasoline. *International Journal of Science and Engineering Investigations*, 2(20), 82-84.

13) Fakhri, N. A., & Qadir, H. K. (2011). Studies on various physico-chemical characteristics of some vegetable oils. *Journal of Environmental Science and Engineering*, 5(7).

14) Hamitri-Guerfi, F., Ouahrani, S., Benbouriche, A., Bey, M. B., Boulekbache-Makhlouf, L., & Madani, K. (2020). Impact of the extraction method on physico-chemical properties, phytochemicals, and biological activity of sesame seeds oil. *The Annals of the University Dunarea de Jos of Galati. Fascicle VI-Food Technology*, 44(1), 82-103.

15) Hobani, A. I., & Tolba, M. H. (1995). Bulk thermal conductivity and diffusivity of barley. *Research Bulletin*, 53, 5-17.

16) Langyan, S., Yadava, P., Sharma, S., Gupta, N. C., Bansal, R., Yadav, R., … & Kumar, A. (2022). Food and nutraceutical functions of sesame oil: An underutilized crop for nutritional and health benefits. *Food Chemistry*, 389, 132990.

17) Mohammed, M. I., & Hamza, Z. U. (2008). Physicochemical properties of oil extracts from *Sesamum Indicum* L. seeds grown in Jigawa State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 12(2).

18) Oboulbiga, E. B., Douamba, Z., Compaoré-Sérémé, D., Semporé, J. N., Dabo, R., Semde, Z., … & Dicko, M. H. (2023). Physicochemical, potential nutritional, antioxidant, and health properties of sesame seed oil: a review. *Frontiers in Nutrition*, 10, 1127926.

19) Parthasarathy, U., Nandakishore, O. P., Senthil Kumar, R., & Parthasarathy, V. A. (2014). A comparison on the physico-chemical parameters of seed butters of selected Indian *Garcinia* spp.

20) Rahman, M. S., Hossain, M. A., Ahmed, G. M., & Uddin, M. M. (2007). Studies on the characterization, lipids, and glyceride compositions of sesame (*Sesamum indicum* L.) Seed Oil. *Bangladesh Journal of Scientific and Industrial Research*, 42(1), 67-74.

21) Serna-Saldivar, S. O., & Jacobo-Velázquez, D. A. (2022). Quality Control and Assurance in the Snack Food Industry. In *Snack Foods* (pp. 477-518). CRC Press.

22) Van Vlierberghe, S., Graulus, G. J., Samal, S. K., Van Nieuwenhove, I., & Dubruel, P. (2014). Porous hydrogel biomedical foam scaffolds for tissue repair. In *Biomedical foams for tissue engineering applications* (pp. 335-390). Woodhead Publishing.

23) Visavadiya, N. P., Soni, B., & Dalwadi, N. (2009). Free radical scavenging and antiatherogenic activities of *Sesamum indicum* seed extracts in chemical and biological model systems. *Food and Chemical Toxicology*, 47(10), 2507-2515.

24) Wang, J., Yang, Z. J., Wang, Y. D., Cao, Y. P., Wang, B., & Liu, Y. (2021). The key aroma compounds and sensory characteristics of commercial Cheddar cheeses. *Journal of Dairy Science*, 104(7), 7555-7571.