EXTRACTION, CHARACTERIZATION, THERMAL STABILITY AND SPECTROSCOPIC STUDIES WITH ALMOND OIL

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BENIN CITY

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A PROJECT SUBMITTED TO THE DEPARTMENT OF CHEMISTRY, FACULTY OF PHYSICAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY. IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE (B.SC) HONORS DEGREE IN CHEMISTRY

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CERTIFICATION

I **IGHODARO PRECIOUS OSARUMWNESE,** a 400L student in the Department of CHEMISTRY University of Benin with the Matriculation **PSC1808523,** has completed the requirements for coursework and research for the Bachelor of Science Degree of the University of Benin for the project work of **EXTRACTION, CHARACTERIZATION, THERMAL STABILITY AND SPECTROSCOPIC STUDIES OF ALMOND OIL.** The work in this Essay is original and all hands have been put together to make this Essay stand out.

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PROF. J. U. IYASELE
Head of Department

Date __________________

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IGHODARO PRECIOUS OSARUMWNESE
Student

Date ____________________

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DEDICATION

With love and gratitude, I dedicate this work to God and to my family, who have been my unwavering support system throughout my educational journey. Their love and encouragement have helped me reach this milestone, and I am forever grateful for their presence in my life.

ACKNOWLEDGMENT.

I give thanks to God Almighty, who has been my ultimate source of strength, guidance, and wisdom throughout my educational journey. I would like to express my gratitude to my project supervisor, Dr Dibie who has been a tremendous source of support and knowledge. I am also grateful to my parents Mr and Mrs Ighodaro, for their unconditional love and encouragement. I would like to thank my friend and laboratory partner Mercy who was so supportive during the period of running the test. Finally, I would like to thank myself for my dedication, perseverance, and hard work throughout this process.

ABSTRACT

Almond oil, a natural product derived from almonds, has garnered attention for its diverse applications in culinary, cosmetic, pharmaceutical, and industrial sectors. This study aimed to characterize almond oil by analyzing its composition, thermal stability, and potential uses. Imported Asian almonds were used to extract almond oil via the Soxhlet method with n-hexane as the solvent. Characterization techniques included Free Fatty Acid (FFA) determination, Fourier-Transform Infrared Spectroscopy (FTIR), and thermal stability tests at normal temperature and 85°C. The results revealed low FFA levels, indicating suitability for culinary use. FTIR analysis identified functional groups, and thermal stability tests demonstrated the oil's resilience to elevated temperatures. These findings suggest almond oil's potential in culinary arts, cosmetics, pharmaceuticals, and industrial applications.

CHAPTER ONE

1.1.1 BACKGROUND OF THE STUDY

Almonds (Prunus dulcis) have a rich historical and cultural significance, dating back thousands of years. These nutrient-dense tree nuts are native to the Middle East, particularly Iran and the Mediterranean region, where they have been cultivated and consumed for centuries. Almonds have played a crucial role in the diets of various cultures and have been associated with health benefits and culinary versatility (Holcapek *et al*., 2005). Historically, almonds were considered a symbol of fertility and were often used in ancient rituals. They were also prized for their longevity and resilience, thriving in arid regions with challenging growing conditions. Over time, almonds have become a staple in both traditional and modern cuisines, finding their way into a wide array of dishes, from sweets and pastries to savory dishes and salads.

One of the most valuable products derived from almonds is almond oil. Almond oil, extracted from the kernels of almonds, possesses a unique set of properties that have made it highly sought after for various applications. Almond oil, scientifically known as Oleum amygdalae, has been extensively utilized in the realm of complementary medicine due to its numerous health advantages. While conclusive scientific evidence may be lacking, almonds and the oil derived from them possess several attributes, including anti-inflammatory, immune-boosting, and anti-hepatotoxic effects. An animal study has demonstrated that almond oil improves colon movement and enhances bowel transit, suggesting a potential beneficial role in managing irritable bowel syndrome. There are associations between almond oil and a reduced risk of colonic cancer and the ‘magic’ oil has been associated with cardiovascular benefits, as it raises levels of "good cholesterol" (high-density lipoproteins or HDL) while reducing "bad cholesterol" (low-density lipoproteins or LDL) (Ahmad, 2010).

This historical use of almond oil for its health and beauty benefits can be traced back to ancient civilizations like India, China, and Greece (Ahmad, 2010). In contemporary times, beauticians, aromatherapists, and massage therapists continue to harness the natural emollient and skin-rejuvenating properties of almond oil. In the field of aromatherapy, almond oil is especially popular, prized for its high concentration of oleic and linoleic essential fatty acids. Moreover, the cosmetic industry leverages almond oil for its capacity to deeply penetrate, moisturize, and rejuvenate the skin. It also serves as an excellent carrier oil in combination with essential oils for aromatherapy purposes.

Recent years have seen an increasing interest in the scientific exploration of almond oil, with researchers delving into its chemical composition, physical characteristics, and potential health benefits with more studies highlighting its nutritional value, antioxidant properties, and potential cardiovascular benefits due to its monounsaturated fatty acid content (Roncero *et al*., 2016).

The extraction, characterization, thermal stability, and spectroscopic analysis of almond oil have emerged as areas of scientific inquiry, shedding light on its structural components, stability under varying conditions, and potential applications in various industries, including food, cosmetics, and pharmaceuticals. Given this growing interest in almond oil and its diverse applications, this research aims to contribute to the body of knowledge about the properties and potential uses of almond oil, with a focus on its extraction, characterization, thermal behavior, and spectroscopic analysis. By doing so, it seeks to provide valuable insights into the utilization of this natural product in both traditional and innovative applications.

1.1.2 STATEMENT OF THE PROBLEM

In the realm of pure chemistry, almond oil presents a unique and intriguing subject of study. The key problem this research aims to address lies in the comprehensive understanding of the chemical composition and properties of almond oil. While almond oil is widely known for its applications in various fields, including culinary arts, cosmetics, and healthcare, its intricate chemical composition and behavior remain incompletely elucidated from a chemistry standpoint.

Almond oil is known to contain a diverse array of chemical compounds, including fatty acids, lipids, phenolic compounds, and other bioactive substances. The exact composition, structure, and concentration of these chemical constituents require detailed analysis. The behavior of almond oil under different chemical and thermal conditions, such as during heating or oxidation, is not thoroughly documented. The study must delve into the chemical reactions, stability, and kinetics of almond oil to gain insights into its reactivity and stability profiles. Identifying and quantifying the myriad chemical components in almond oil necessitates the utilization of sophisticated analytical techniques such as assessing the thermal stability and spectroscopy (Ma *et al.* 2007) . The challenge lies in developing and implementing an effective methodology for the comprehensive analysis of almond oil's chemical composition.

Conducting this research on almond oil offers an opportunity to apply foundational principles of organic chemistry, analytical chemistry, while developing critical laboratory skills and a deeper understanding of chemical processes. By addressing the chemistry of almond oil, this research seeks to bridge the gap between fundamental chemistry and practical applications. It aims to contribute to the body of knowledge that can be applied in industries such as food science, cosmetics, and materials science.

In essence, this research addresses the fundamental problem of understanding the intricate chemistry of almond oil, encompassing its composition, chemical reactions, stability, and the analytical methods required to study it. The knowledge gained not only furthers our understanding of a natural product but also provides a valuable educational experience for budding chemists, paving the way for future applications and research in the field of pure chemistry.

1.1.3 SIGNIFICANCE AND JUSTIFICATION OF THE WORK

This research holds substantial significance within the field of chemistry for several key reasons. Understanding the precise chemical composition of almond oil is fundamental to the study of organic chemistry. Investigating the types and quantities of fatty acids, lipids, and other chemical components in almond oil provides valuable insights into the complex chemistry of natural oils (Roncero *et al.,* 2016).

The thermal stability of almond oil under varying conditions is also a subject of interest in chemical kinetics and thermodynamics. This research allows for the study of chemical reactions and decomposition processes at different temperatures, providing data that contributes to the understanding of reaction mechanisms. Moreover, conducting this research offers the opportunity to utilize a range of analytical techniques commonly employed in chemistry, which are fundamental to understanding and practice in the field of analytical chemistry.

Knowledge of almond oil's chemical properties can open avenues for further research on chemical modifications like investigating the feasibility of reactions like esterification or hydrogenation of almond oil can lead to the synthesis of novel compounds with industrial applications.

Finally, this research serves as a foundational platform for delving deeper into specialized areas of research in chemistry specifically in areas such as organic chemistry, chemical engineering, or materials science.

1.1.4 SCOPE OF THE WORK

The scope of this research project is defined to encompass a range of investigations and analysis related to almond oil. This research will conduct an extensive analysis of the chemical composition of almond oil with a particular focus on the extraction, characterization, thermal stability, and spectroscopic analysis. It will include the identification and quantification of fatty acids, minor constituents, and unsaponifiable fractions to provide a comprehensive profile of almond oil.

The study will investigate the thermal stability of almond oil under various temperature and processing conditions. This includes analyzing how almond oil reacts to heat and its implications for culinary and industrial applications.

The research will also explore the culinary applications of almond oil, including its role in cooking, baking, and its potential health benefits when used as a cooking oil. It will examine its contribution to flavor, nutrition, and overall culinary practices.

The study will identify and evaluate industrial applications of almond oil, with a focus on sectors such as cosmetics, pharmaceuticals, and skincare products. It will investigate its potential as an ingredient in various formulations and products.

1.1.5 AIM AND OBJECTIVES

The aim of this research is to extract oil from the almond seed, characterize the oil and carry with a specific emphasis on its chemical composition and behavior from a pure chemistry perspective.

1.1.5.2 OBJECTIVES

To achieve the aim of this research work, the following specific objectives were set:

- To extract almond oil from almond samples using a Soxhlet apparatus and a suitable solvent.

- To ensure the efficient extraction of almond oil while maintaining the quality and purity of the extracted oil.
- To identify and quantify the major chemical constituents of almond oil, including fatty acids, lipids, phenolic compounds, and antioxidants.
- To assess the thermal stability of almond oil by subjecting it to controlled temperature variations.
- To observe and record changes in the physical and chemical properties of almond oil under varying temperatures.
- To carry out a spectroscopic analysis on the almond oil.

1.2 LITERATURE REVIEW

1.2.1 INTRODUCTION TO ALMOND AND ALMOND OIL

Almonds, scientifically known as Prunus dulcis, are one of the most widely cultivated and consumed tree nuts globally. These small, oval-shaped nuts are cherished not only for their delicate, nutty flavor but also for their numerous nutritional benefits. Almonds have been an integral part of human diets for centuries, and their historical and cultural significance is deeply rooted in various societies (Ahmad, 2010).

Almonds have a rich history that dates back thousands of years. They are believed to have originated in the Middle East, particularly in the region around the Mediterranean. Ancient civilizations, including the Egyptians and Romans, highly valued almonds for their versatility and nutrition. Almonds were even found in the tomb of King Tutankhamun, underscoring their importance in ancient Egypt. Almonds were carried along the Silk Road, leading to their spread across Asia and eventually to Europe. They became a staple ingredient in Mediterranean cuisine.

In medieval Europe, almonds were used as a symbol of good luck, and they often appeared in traditional wedding ceremonies, such as the tossing of almonds to wish fertility and happiness to the newlyweds (Ahmad, 2010; Roncero *et al.,* 2016).

Almonds hold cultural significance in various societies. In some cultures, almonds are considered a symbol of prosperity, fertility, and longevity. Almonds are a key ingredient in many traditional dishes, desserts, and confections worldwide. They are used to make marzipan, nougat, and almond milk, among other delicacies. In Middle Eastern and Indian cuisines, almonds are frequently used in both savory and sweet dishes, contributing to the complex and aromatic flavors of these cuisines. Almond oil, derived from the pressing of almond kernels, is a prized ingredient known for its culinary, cosmetic, and medicinal uses. It has a light, sweet aroma and a mild, nutty flavor. Almond oil has been used for centuries in traditional medicine and skincare due to its moisturizing and emollient properties. In recent years, almond oil has gained popularity not only for its culinary applications, where it adds depth to various dishes, including desserts and salads, but also for its use in natural cosmetics and skincare products. Its rich content of vitamins, minerals, and essential fatty acids makes it a sought-after ingredient in the beauty industry (Roncero *et al*., 2016).

Almonds and almond oil have a deep-rooted history and cultural significance in various regions around the world. Their versatility, nutritional value, and use in both culinary and cosmetic applications continue to make them valuable commodities today. Almond oil, obtained from the kernels of almond nuts (Prunus dulcis), is a versatile oil known for its numerous properties and characteristics. It is valued for its culinary, cosmetic, and therapeutic uses.

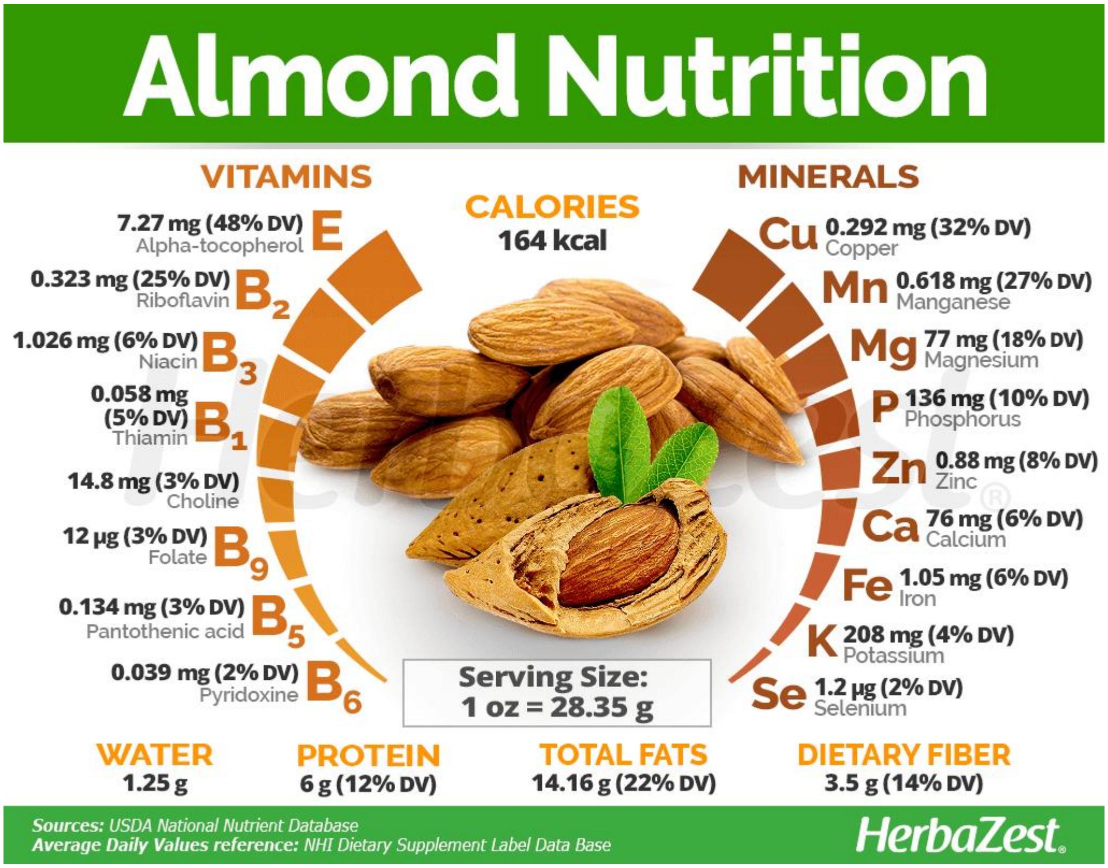


Figure 1: The main nutrition composition and nutrient-based applications of almond.

1.2.2. ALMOND OIL

Almond oil, obtained from the kernels of almond nuts (Prunus dulcis), is a versatile oil known for its numerous properties and characteristics. It is valued for its culinary, cosmetic, and therapeutic uses. Almond oil is primarily composed of fatty acids, with monounsaturated and polyunsaturated fats being the most abundant. Oleic acid (C18:1) is the dominant monounsaturated fatty acid, while linoleic acid (C18:2) is the primary polyunsaturated fatty acid. It is also a good source of fat-soluble vitamins, particularly vitamin E (tocopherol), which serves as a powerful antioxidant. Vitamin E helps protect the oil from oxidation, extending its shelf life.

The oil contains essential minerals like magnesium and potassium, which contribute to its nutritional value (Roncero *et al.,* 2016).

Key Properties and Characteristics:

- Mild, Nutty Flavor: Almond oil has a delicate, nutty flavor that makes it suitable for various culinary applications. It is often used in salad dressings, baking, and as a finishing oil for dishes.
- High Smoke Point: Almond oil has a relatively high smoke point, typically between 420°F to 430°F (216°C to 221°C), making it suitable for cooking methods such as sautéing and stir-frying. Its stability at high temperatures makes it an excellent choice for cooking.
- Light Texture: Almond oil has a light and non-greasy texture, making it a popular choice for skincare and cosmetic products. It is easily absorbed by the skin without leaving a heavy residue.
- Moisturizing Properties: Almond oil is a natural emollient and moisturizer. It helps hydrate and nourish the skin, making it a common ingredient in skincare products like lotions, creams, and massage oils.
- Antioxidant Benefits: The vitamin E content in almond oil provides antioxidant properties that protect the skin from oxidative stress and free radical damage. This can help maintain skin health and a youthful appearance.
- Anti-Inflammatory: Almond oil is known for its anti-inflammatory properties, which can help soothe irritated or sensitive skin. It is often used for massage therapy and aromatherapy.

- Hair Care: Almond oil is used in hair care products for its ability to condition and strengthen hair. It can help reduce hair breakage and promote a healthy scalp.
- Heart Health: The monounsaturated fats in almond oil, particularly oleic acid, are considered heart-healthy fats. Consuming almond oil in moderation as part of a balanced diet may contribute to cardiovascular health.

1.2.3. METHOD OF EXTRACTION OF ALMOND OIL

Different methods for extracting almond oil exist, with solvent extraction being the most efficient for industrial yield. The Cold Pressing method involves mechanically pressing almonds at low temperatures, typically without the use of heat or solvents. It is considered a gentle method that preserves the natural flavor and nutritional qualities of the oil.

Traditional methods, which involve high temperatures and chemicals, can negatively impact oil quality by introducing undesirable flavors and deactivating vitamins and active compounds present in the raw material. This necessitates subsequent refining, precluding the categorization of these oils as virgin oils (Roncero *et al*., 2016).

Matos and Acuña (2010) investigated three crucial parameters—extraction temperature, almond particle size, and solid/solvent proportion—and identified optimal conditions as 90°C, 0.5 mm, and a 1:3 proportion, yielding 44.5% oil. Ultrasonic irradiation at 42 kHz (Sharma and Gupta, 2006) was found to enhance oil yield by creating microfractures and rupturing cell walls, possibly due to reduced particle size. The ammonium sulfate and t-butanol aggregation method (Sharma and Gupta, 2004) involves precipitating proteins as an interphase between the organic and aqueous layers, simultaneously liberating oil in the t-butanol phase.

Enzymes can also be used to break down cell walls and facilitate oil release from almonds. Enzyme-assisted extraction is often combined with other methods for improved yield. Hydrodistillation is another method used for extracting essential oils from almonds, particularly bitter almonds. It involves steam distillation to separate the essential oil from the plant material.

Supercritical Carbon Dioxide (SC-CO2) Extraction uses carbon dioxide in a supercritical state as a solvent to extract oils. It is known for its ability to produce high-quality oils without the use of harsh chemicals. The Supercritical fluid extraction (CO2) has gained recognition as an alternative to conventional solvent extraction (Mendiola *et al*., 2007). Lower temperatures and pressures used in this method result in higher-quality products (Marzouki *et al.,* 2008). Femenia et al. (2001) employed pressures of 330 bar and temperatures of 50°C, achieving oil percentages of 15–16% (raw almonds), 27–33% (raw peeled almonds), and 49–64% (roasted almonds). Leo *et al.* (2005) observed that increased extraction pressure and temperature raised oil yield, with higher temperature having a more pronounced effect due to increased oil solubility in CO2. Higher CO2 flow rates also enhanced oil production.

Ma *et al.* (2007) studied bitter almond oil extraction and identified optimal conditions: 35 MPa extraction pressure, 50°C extraction temperature, 24 l/h CO2 flow rate, 0.6 mm almond particle size, and 2-hour extraction time, resulting in a 53% yield. Hydraulic and screw presses are alternative extraction methods, with hydraulic presses potentially preserving oil quality better, albeit with higher labor demands. Screw presses require preheating, impacting oil separation and yield (Álvarez-Ortí *et al.,* 2012).

Martínez *et al.,* (2013) found that 8% seed humidity and a 40°C preheating temperature produced the highest oil yield (79.3%) with acceptable quality. Extraction using supercritical fluids (CO2) and pressing, either hydraulic or screw press, yields a product suitable for human consumption with the pleasant sensory characteristics of the initial almond, eliminating the need for refining and classifying it as a virgin oil.

1.2.4 COMPOSITION AND CHARACTERIZATION OF ALMOND OIL

Most almond composition research has primarily concentrated on the lipid fraction and fatty acids. there is a substantial variation in oil content, ranging from 30.1% in Portuguese samples to 62.9% in Iranian samples (Roncero *et al.,* 2016). Studies have demonstrated that lipid content primarily depends on the almond cultivar (genotype), although edaphic and climatic conditions have also been found to play a role (Yada *et al.,* 2013; Kodad *et al*., 2014).

FATTY ACIDS

Within the almond lipid fraction, five predominant fatty acids include oleic acid (C18:1), linoleic acid (C18:2), palmitic acid (C16:0), palmitoleic acid (C16:1), and stearic acid (C18:0). These fatty acids make up 95% of the total composition. Additionally, there are eight less common fatty acids (García *et al.,* 1996; Abdallah *et al.,* 1998). Among the most abundant fatty acids, unsaturated fatty acids represent approximately 90%, with monounsaturated fatty acids having a higher proportion than polyunsaturated ones (Roncero *et al.,* 2016).

The greatest variability in fatty acid content has been observed when comparing different almond genotypes. Palmitoleic and stearic acids exhibit the highest variability (coefficient of variation of more than 10%), followed by linoleic and palmitic acids (coefficients of variation of more than 4% and 7%, respectively). Oleic acid, on the other hand, exhibits low coefficients of variation, with contents varying less than 2% . Yada *et al*. (2013) found significant differences among cultivars in saturated and polyunsaturated fatty acids. These variations were also observed when comparing different harvests over two consecutive years.

Kodad *et al.,* (2014) noted that for traditional Spanish cultivars, genotype, year, and genotype x year interaction significantly influenced the variability in stearic, palmitoleic, linoleic, and oleic acids. However, the magnitude of difference among genotypes was insignificant compared to the variability seen among different genotypes. García *et al.* (1996) found variations in oleic and linoleic acid content among different almond tree cultivars, with European cultivars showing higher oleic acid concentrations compared to American ones. This difference was associated with a positive correlation between shell thickness and oleic acid content. García *et al*.'s research also involved classifying almond tree cultivars from different origins based on their fatty acid profiles, incorporating classification criteria, minority fatty acid concentrations and triglyceride compositions (Martín *et al.,* 1999).

Sathe *et al.* (2008) analyzed Californian cultivars and found that palmitic, oleic, and linoleic fatty acids were predominant in the lipid composition, regardless of the cultivar, crop origin, or harvest year. The oleic/linoleic ratio, important for its nutritional value, exhibited a wide range of variation depending on the author's consideration, ranging from 1.96 to 3.05, 2.35 to 6.56 , or 1.8 to 3.8 . The correlation between these two fatty acids is highly negative, with r values ranging from -0.92 to -0.99 (Sathe *et al.,* 2008). Aside from fatty acids, Almond oil is a good source of fat-soluble vitamins, particularly vitamin E (tocopherol), which serves as a powerful antioxidant. Vitamin E helps protect the oil from oxidation, extending its shelf life. It also contains essential minerals like magnesium and potassium, which contribute to its nutritional value.

TRIGLYCERIDES

In mature almonds, fatty acids primarily exist in the form of triglycerides (Nassar *et al*., 1977). Notably, almond oil is the nut oil with the highest triglyceride content, comprising approximately 98% of its composition . This high triglyceride content contributes to a low acidity index in almond oil . However, the composition of almond oil has not been extensively studied. The type and quantity of oil triglycerides play a critical role in determining the final physical and functional properties of the oil (Jahaniaval *et al.,* 2000).

Another research also identified nine triglycerides in ten different almond cultivars from various production zones, observing the following order of content from highest to lowest: OOO > OLO > OLL > POO > PLO > SOO = LLL = PLL > PLP, where O represents oleic acid, L linoleic acid, P palmitic acid, and S stearic acid. The first five triglycerides are the most predominant, while the last four are less common. Due to the abundance of oleic acid, triglycerides containing this fatty acid are more prevalent. OOO has the highest content, ranging from 11.3 to 31.3 mg·100 g−1 of dry sample, while OLO content varies from 15.7 to 6.9 mg·100 g−1 of a dry sample. Following these, OLL and POO triglycerides appear, with PLP triglycerides present in the smallest quantities. OOO triglyceride exhibits the highest correlation with other triglycerides, generally with a negative sign, except for POO and SOO, which is expected since they are the most abundant triglycerides in almond oil (Roncero *et al*., 2016).

Similarly, Martín (1999) studied 19 representative almond cultivars from major production regions worldwide and found the same triglycerides in the same order of concentration. Triglycerides OOO and OLO together accounted for 60% of the total triglyceride content. Triglyceride composition in almond oil was remarkably similar among different cultivars. Holcapek *et al*. (2003) detected 18 triglycerides in almond oil, possibly due to improved resolution in their analysis method. However, the order of triglycerides by content differed from other studies: OLO (28.0%), OLL (27.6%), OOO (13.3%), LOP (11.3%), LLL (8.7%), LLP (4.8%), OOP (2.7%), SLO (1.8%), SOO (0.6%), PLP (0.5%), OOMo (0.5%), OLLn (0.1%), LLMo (0.1%), OLMo (0.1%), GLO (0.1%), POP (0.1%), OOMa (0.05%), and GOO (0.05%), where Mo represents heptadecanoic acid, Ln is linolenic acid, Ma is margaric acid, and G is gadoleic acid.

Cherif *et al.* (2004) discovered 10 triglycerides, including LOO, which had not been identified by previous authors. Their research focused on the evolution of fatty acids and triglycerides throughout the development and ripeness of almond seeds. While triglyceride profiles varied slightly among cultivars, the overall composition of triglycerides in almond oil remained similar for all the cultivars studied.

Holcapek *et al*. (2005) identified 24 triglycerides in almond oil, representing one of the highest numbers of triglycerides reported in oil analyses. These findings were consistent with values obtained in previous literature. Barreira *et al.* (2012) conducted a study on almonds collected over three months in Trás-os-Montes, Portugal, to differentiate between Protected Designation of

Origin (DOP) Amêndoa Douro and non-DOP commercial cultivars. Results indicated that DOP Amendoa Douro cultivars had higher content of OLL and LLP triglycerides. Nonetheless, OOO and OLO triglycerides remained prevalent, consistent with prior research. Overall, the triglyceride profiles observed were similar to previous studies. A research using wild almonds in Iran yielded the following triglyceride composition: OOO (47.27%), POO+SOL (26.25%), and OOL+PLnP (10.67%). This triglyceride profile closely resembled that of olive oil (Givianrad *et al.,* 2013).

Analyzing triglycerides provides an advantage over the fatty acid profile because the stereo-specific distribution of fatty acids in the glycerol molecule is genetically controlled. Consequently, intact triglycerides generally offer more information (Aparicio and Aparicio-Ruiz, 2000; Bail *et al*., 2009).

LIPOSOLUBLE BIOACTIVE COMPOUNDS

Pasini *et al.* (2013) introduced a lipid classification that encompasses the unsaponifiable fraction and complex lipids, such as phospholipids and glycolipids. Although these fractions make up a relatively small portion of the total composition, they hold significant biological and nutritional importance. In almonds, these compounds, collectively referred to as fat-soluble bioactives, include tocopherols, tocotrienols, phospholipids, sterols, phytosterols, phytostanols, sphingolipids, squalene, and terpenoids. Several authors have incorporated this group of compounds into the phytochemical concept (Alasalvar and Pelvan, 2011).

The unsaponifiable fraction primarily consists of sterols, methyl sterols, aliphatic alcohols, and fat-soluble vitamins. Among these, the more prevalent sterols are sitosterol (80-86%) and campesterol (2-4%), with trace amounts of stigmasterol (Garcia *et al.,* 1978). General studies on nuts have reported unsaponifiable substance contents in extracted oil ranging from 0.35 to 0.53 g·100 g−1, with an average of 0.44 g·100 g−1 (Kornsteiner *et al.,* 2006).

1.2.5 IMPLICATIONS OF ALMOND OIL COMPOSITION

Almond oil's composition has significant implications for its health benefits and potential applications across various industries.

- Almond oil's composition, characterized by high levels of monounsaturated fats (e.g., oleic acid), makes it a healthier alternative to some traditional cooking oils high in saturated fats. Substituting almond oil in cooking can potentially lower the risk of heart-related issues.
- Almond oil's mild, slightly nutty flavor can enhance the taste of various dishes, making it suitable for use in salad dressings, marinades, and sautéing.
- The high monounsaturated fat content in almond oil has been associated with heart health benefits, including reducing bad cholesterol levels (LDL) and promoting good cholesterol (HDL).
- Almond oil contains antioxidants such as vitamin E, which can help combat oxidative stress, reducing the risk of chronic diseases and supporting overall well-being.
- Almond oil's composition includes fatty acids like oleic acid and linoleic acid, which may have anti-inflammatory effects when consumed as part of a balanced diet.
- Almond oil's composition, rich in oleic and linoleic acids, makes it an excellent natural moisturizer for the skin. It can help alleviate dryness and maintain skin hydration.

- Almond oil contains tocopherols and tocotrienols (vitamin E forms), which possess antioxidant properties that can help reduce the signs of premature aging, such as wrinkles and fine lines (Roncero *et al.,* 2016).
- The use of almond oil in hair products is due to its composition's ability to nourish and condition hair, making it smoother and shinier.
- Almond oil's hypoallergenic nature and ability to carry other compounds make it suitable as a carrier oil for topical medications, facilitating the delivery of active pharmaceutical ingredients.
- In traditional medicine systems like Ayurveda, almond oil is used for its therapeutic properties, including its potential to soothe skin conditions and improve overall health.
- Almond oil's composition makes it a candidate for use as a natural lubricant in certain machinery and equipment where non-toxic and biodegradable lubricants are preferred.
- The mild, pleasant aroma of almond oil makes it a popular choice as a carrier oil for essential oils used in aromatherapy.
- Almond oil can be used in soap and detergent formulations due to its ability to contribute to lathering and cleansing properties.
- Almond oil's nutritional composition may make it a suitable ingredient in dietary supplements aimed at improving heart health and overall well-being.
- Almond oil's natural composition makes it biodegradable, reducing its environmental impact compared to synthetic alternatives.

1.2.6 THERMAL STABILITY OF ALMOND OIL

Almond oil, a versatile and nutrient-rich oil, exhibits varying degrees of thermal stability when subjected to heat, a property of significant importance in both culinary and industrial applications.

The thermal stability of almond oil plays a crucial role in determining its suitability for different cooking methods and its shelf life in various industrial processes.

Understanding the thermal behavior of almond oil is essential for optimizing its applications in both culinary and industrial settings, ensuring that its valuable properties are preserved while minimizing quality degradation due to heat exposure

BEHAVIOR UNDER HEAT:

When almond oil is exposed to high temperatures, its thermal stability is influenced by several factors, including the composition of fatty acids present in the oil. Almond oil is primarily composed of unsaturated fatty acids, with oleic acid (C18:1) and linoleic acid (C18:2) being the predominant ones. Unsaturated fatty acids are more susceptible to heat-induced oxidation compared to saturated fatty acids.

A study by Bolling *et al*. (2010) investigated the oxidative stability of almond oil during heating and found that almond oil, rich in monounsaturated fats and antioxidants, exhibited good resistance to oxidative degradation when compared to oils with higher polyunsaturated fatty acid content. During heating, almond oil undergoes oxidative reactions, primarily lipid oxidation, which can lead to the formation of undesirable compounds such as free radicals, peroxides, and aldehydes. These reactions not only degrade the oil's quality but also result in off-flavors and reduced nutritional value. Therefore, understanding the thermal stability of almond oil is crucial for maintaining its quality in culinary applications.

IMPLICATIONS:

Almond oil's relatively high smoke point, typically around 420°F (216°C), makes it suitable for various cooking methods, including sautéing, frying, and roasting. Its mild, nutty flavor adds a pleasant note to dishes. However, while almond oil can withstand moderate to high cooking temperatures, it is essential to avoid overheating to prevent excessive oxidation and the development of off-flavors.

To preserve the thermal stability of almond oil during cooking, it is recommended to use it for light sautéing and as a finishing oil for drizzling over dishes. Additionally, combining almond oil with more heat-stable oils, such as canola or grapeseed oil, can help mitigate the negative effects of high-temperature cooking.

To enhance thermal stability in industrial applications, manufacturers may employ techniques such as cold pressing, which minimizes heat exposure during oil extraction, or the addition of antioxidants to the oil to inhibit oxidation. These measures help maintain the oil's quality and extend its usability in various products. Sharma and Gupta (2006) examined the effect of ultrasound treatment on almond oil extraction. Ultrasound-assisted extraction was found to improve oil yield while minimizing the detrimental effects of heat during traditional extraction methods.

1.2.7 USE OF ALMOND OIL IN CULINARY ARTS

Almond oil's unique composition has far-reaching implications for its health benefits and its suitability for diverse industrial applications (Roncero *et al.,* 2016). The distinct blend of fatty acids, vitamins, and bioactive compounds found in almond oil makes it a valuable resource in various sectors.

Culinary Applications:

- **Nutritional Value:** Almond oil is renowned for its healthful monounsaturated fats, particularly oleic acid, which can help reduce the risk of cardiovascular diseases when incorporated into a balanced diet.

- High Smoke Point: With a smoke point of around 420°F (216°C), almond oil is suitable for high-heat cooking methods like sautéing and stir-frying.
- Flavor Profile: The oil's mild, nutty flavor enhances the taste of dishes and makes it an excellent choice for salad dressings, drizzling over roasted vegetables, or as a finishing oil for various culinary creations.
- The monounsaturated fats in almond oil may contribute to improved heart health by reducing LDL cholesterol levels and inflammation.
- Weight Management: Despite its calorie content, almond oil may help with weight management when consumed in moderation due to its ability to promote satiety.
- Digestive Health: Almond oil can be used to soothe and protect the digestive tract, potentially aiding in the relief of mild gastrointestinal discomfort.

1.2.8 INDUSTRIAL APPLICATIONS OF ALMOND OIL

Almond oil finds diverse industrial applications due to its beneficial properties, such as its moisturizing, emollient, and antioxidant characteristics (Ahmad, 2010) ;

1. Cosmetics and Skincare:

Skin Moisturizer: Almond oil is a common ingredient in cosmetics and skincare products like creams, lotions, and moisturizers. It is renowned for its ability to hydrate and nourish the skin. Its emollient properties help lock in moisture, making it particularly suitable for dry and sensitive skin.

-Makeup Remover: Almond oil is an effective and gentle makeup remover. It can dissolve makeup, including waterproof mascara, without harsh chemicals or excessive rubbing, leaving the skin soft and moisturized.

Massage Oil: Due to its excellent slip and glide properties, almond oil is widely used as a massage oil in spas and wellness centers. It provides a smooth and soothing massage experience while moisturizing the skin.

Anti-Aging Products: Almond oil's vitamin E content and antioxidant properties make it a valuable ingredient in anti-aging products. It may help reduce the appearance of fine lines and wrinkles by protecting the skin from free radical damage.

2. Haircare:

Hair Conditioner: Almond oil is used in hair conditioners and serums to promote soft, shiny, and manageable hair. It can help reduce frizz, repair split ends, and improve overall hair health.

Scalp Treatment: Massaging almond oil into the scalp can nourish hair follicles and help alleviate dryness and dandruff. Some hair products contain almond oil to address these scalp concerns.

3. Pharmaceuticals:

Carrier Oil: In pharmaceutical formulations, almond oil serves as a carrier oil for various medicinal compounds and active ingredients. It helps disperse these substances evenly and aids in their absorption into the skin.

Topical Medications: Almond oil is used as a base in some topical medications, including dermatological creams and ointments. Its hypoallergenic nature makes it suitable for sensitive skin.

4. Food Industry:

- Flavoring Agent: Almond oil with a mild, nutty flavor is sometimes used as a flavoring agent in the food industry. It can add a subtle almond taste to baked goods, confectionery, and culinary creations.

Salad Dressings: Almond oil's delicate flavor makes it a desirable component in salad dressings and vinaigrettes, contributing to their taste and texture.

5. Aromatherapy:

Almond oil is a popular choice as a carrier oil in aromatherapy. It serves as a neutral base for diluting essential oils before applying them to the skin during massage or as part of relaxation therapy.

6. Industrial Lubricants:

Machinery Lubrication: In certain industrial applications, almond oil can be used as a biodegradable and eco-friendly lubricant. Its natural viscosity and lubricating properties make it suitable for machinery components.

CHAPTER TWO

METHODOLOGY AND MATERIALS

2.1 SOURCING OF MATERIALS

The almonds utilized in this research were bought from a local supermarket in benin and comprised 500 grams of imported Asian almonds. Specific details about the origin, such as the precise location and variety of the almonds, were not available. Nevertheless, these almonds were selected as the study's raw material due to their availability and suitability for the intended extraction process.

FIGURE 2.1 ALMOND NUTS

2.2 SAMPLE PREPARATION AND EXTRACTION OF OIL FROM SAMPLE NUT

2.2.1 MATERIALS

- Soxhlet extractor
- Thimble
- Condenser
- Round distillation flask (1 liter)
- N- Hexane
- Almond nuts

- Anti bumping stones
- Rotary evaporator

FIGURE 2.2 : THE MASHED ALMOND NUTS

2.2.2. METHOD AND PROCEDURE

The extraction of almond oil was carried out using a Soxhlet apparatus, a widely recognized and effective technique for oil extraction from various solid materials. The choice of this method was driven by its efficiency in extracting oil while minimizing the loss of key components. The almond nuts were crushed using a mortar and ninety six grams of the sample was weighed and packed into the thimble and covered with a cotton ball to avoid falling into the extractor.

The extraction solvent used in this research was n-hexane, a common solvent in oil extraction processes known for its effectiveness in separating lipids from solid matrices. The rationale for selecting n-hexane lies in its ability to efficiently dissolve lipids, facilitating the extraction of almond oil. 60cl of n-hexane was weighed into the round bottom flask. Then the apparatus was set up for a reflux of 6-8 hours as shown in figure 3. After the reflux was completed, the shaft (solid) portion in the thimble was removed and the round bottom flask containing the solvent and oil extracted was moved to the rotary evaporator.

There, it undergoes a process of distillation under vacuum. The water-bath of the rotary evaporator was set to 68.7°C (the boiling point of n-hexane). After the solvent is completely removed using evaporation and condensation, only the almond oil is left remaining in the initial round bottom flask. The almond oil obtained from the process was 250ml.

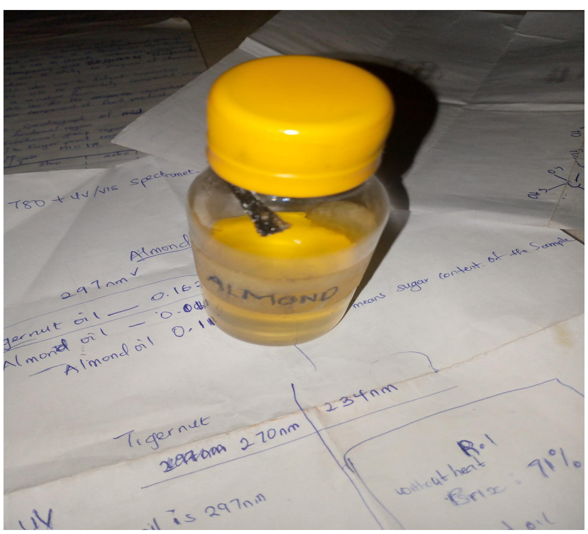


FIGURE 2.3 THE ALMOND OIL EXTRACTED

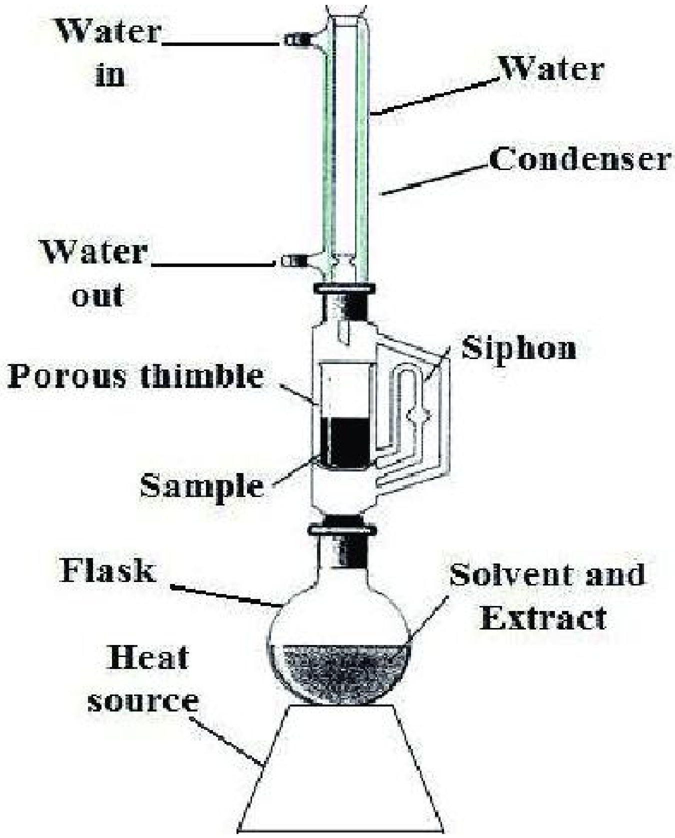


FIGURE 2.4 DIAGRAM OF THE SOXHLET APPARATUS SOURCE: (Mitra, 2003)

FIGURE 2.5 SOXHLET EXTRACTOR ATTACHED TO A COOLER OF WATER.

2.3 CHARACTERIZATION TECHNIQUES USED IN ALMOND OIL

2.3.1 FREE FATTY ACID DETERMINATION

Materials

- Ethanol
- Sodium Thiosulphate
- Distilled Water
- Phenolphthalein
- Almond oil
- Chloroform
- Glacial Acetic Acid
- Starch Indicator
- Iodine Solution
- O.In Naoh
- Glacial Acetic
- Potassium Hydroxide
- 50ml Burette
- Weighing Balance
- 50ml measuring cylinder
- Funnel
- 250ml Conical flask

PROCEDURE

Ten grams of almond oil was weighed into a 250ml conical flask. Then 50 ml of ethanol was added to the conical flask containing the almond oil, till the oil was dissolved in ethanol. Prepare a solution of sodium thiosulphate (Na2SO3) by dissolving an appropriate amount in distilled water. This solution will be used as a titrant to determine the free fatty acids. Add a few drops of phenolphthalein to the conical flask to serve as an indicator.

Set up a burette with the sodium thiosulphate solution. Slowly titrate the ethanol-almond oil solution with the sodium thiosulphate solution from the burette. The solution will change color from pink (phenolphthalein) to colorless as the titration progresses. This color change indicates the neutralization of the free fatty acids.

Record the volume of sodium thiosulphate solution required to reach the endpoint of the titration. The endpoint is the point at which the pink color disappears completely.

We can then calculate the amount of free fatty acids in the almond oil using the following formula:

Free Fatty Acids (FFA)

Free Fatty Acids (FFA)(%)= $\frac{(V \times M \times F)}{W} \times 100$

Where:

V = Volume (in ml) of sodium thiosulphate solution used for titration.

M = Molarity of the sodium thiosulphate solution.

F = Factor to account for the presence of multiple acidic sites (typically around 0.1 for oils).

W = Weight (in grams) of the almond oil sample used.

2.4 THERMAL STABILITY TEST

To conduct the thermal stability analysis, we use the following parameters

- Peroxide Value
- Refractive Index
- UV analysis

2.4.1 MATERIALS USED IN THE THERMAL STABILITY TEST

PEROXIDE VALUE TEST

- Glacial Acetic Acid
- Saturated Potassium Iodide
- Distilled Water
- 0.01N Sodium Thiosulphate Solution
- Starch Indicator
- Filter Paper

UV ANALYSIS

- Heated oil sample
- Sample at room temperature
- UV Spectrometer

REFRACTIVE INDEX

- Refractometer
- Oil sample
- Tissue paper

2.3.2 PROCEDURE

The thermal stability analysis was carried out using the specialized equipment designed for controlled heating and monitoring of chemical changes in almond oil (see 2.4.1). This setup included:

- Heating apparatus with precise temperature control.
- Analytical instruments for measuring FFA, conducting FTIA, and determining Peroxide Value.

- Sample containers designed for uniform heating and accurate measurements.

Almond oil samples were carefully prepared, ensuring they were free from contaminants and moisture. The samples were divided into two sets: one maintained at normal temperature (control), and the other exposed to elevated temperature conditions (85°C) to induce thermal stress.

FTIA was conducted on both control and thermally stressed almond oil samples. FTIR spectra were recorded at various time intervals during the heating process to observe any structural changes or chemical transformations.

Peroxide value was determined by a standardized iodometric titration method. The control and thermally stressed samples were titrated with an iodine solution to quantify peroxide formation as an indication of oxidative degradation.

After this the data regarding FFA levels, FTIR spectra, and peroxide values were collected and analyzed. The results were compared between the control and thermally stressed samples to assess the thermal stability of almond oil and the extent of chemical changes induced by heating.

2.5 SPECTROSCOPIC STUDIES

Fourier-Transform Infrared Spectroscopy is a spectroscopic technique used to investigate chemical changes in almond oil during heating. It provides insights into alterations in functional groups and molecular structures caused by thermal degradation.

The principle behind FTIR is the measurement of the absorption of infrared light by chemical bonds within a sample. Molecules absorb specific wavelengths of IR radiation, leading to characteristic absorption peaks in the resulting spectrum.

The FTIR instrument operates by first passing an IR beam through a Michelson interferometer, which splits the beam into two paths. One path travels through the sample while the other serves as a reference. These two beams recombine, and the resulting interferogram is converted into an IR spectrum using a mathematical algorithm called a Fourier transform. The resulting spectrum displays absorbance (or transmittance) as a function of wavelength or wavenumber.

CHAPTER 3

RESULTS AND DISCUSSION.

3.1 RESULTS AND FINDINGS

TABLE 3.1 SELECT PHYSIO-CHEMICAL PROPERTIES OF RAW AND TREATED OIL

The table below shows the result of the tests and procedure carried out in the research.

Characteristics of Almond Oil				
Free Fatty Acid %			0.10	
	Normal temperature		At 85°C	
Peroxide value	1.8		2.60	
Refractive Index (Brix %)	71		71.5	
	UV test			
Wave length(nm)	297 nm	234 nm	297 nm	234 nm
Absorbance	0.112	0.933	0.012	0.001

3.1.1.CHARACTERIZATION OF THE ALMOND OIL

The characterization of almond oil reveals a crucial property: The sample Almond oil contains approximately 0.10% free fatty acids. The low percentage of free fatty acids in almond oil is a positive characteristic. High levels of free fatty acids can indicate oil degradation and affect its sensory qualities and shelf life. This low value suggests that the sample almond oil is of good quality and suitable for various applications, including culinary and cosmetic uses.

3.1.2 THERMAL STABILITY TEST

Normal Temperature (25°C) vs. 85°C Thermal Stability Test:

At normal temperature (25°C), the peroxide value is 1.8, while at 85°C, it increases to 2.60. This indicates that heating almond oil to 85°C has led to an increase in peroxide value. The increase in peroxide value at higher temperatures suggests that almond oil undergoes oxidation when exposed to heat. This is important information for industries that use almond oil in high-temperature processes, as it may affect the oil's quality and shelf life.

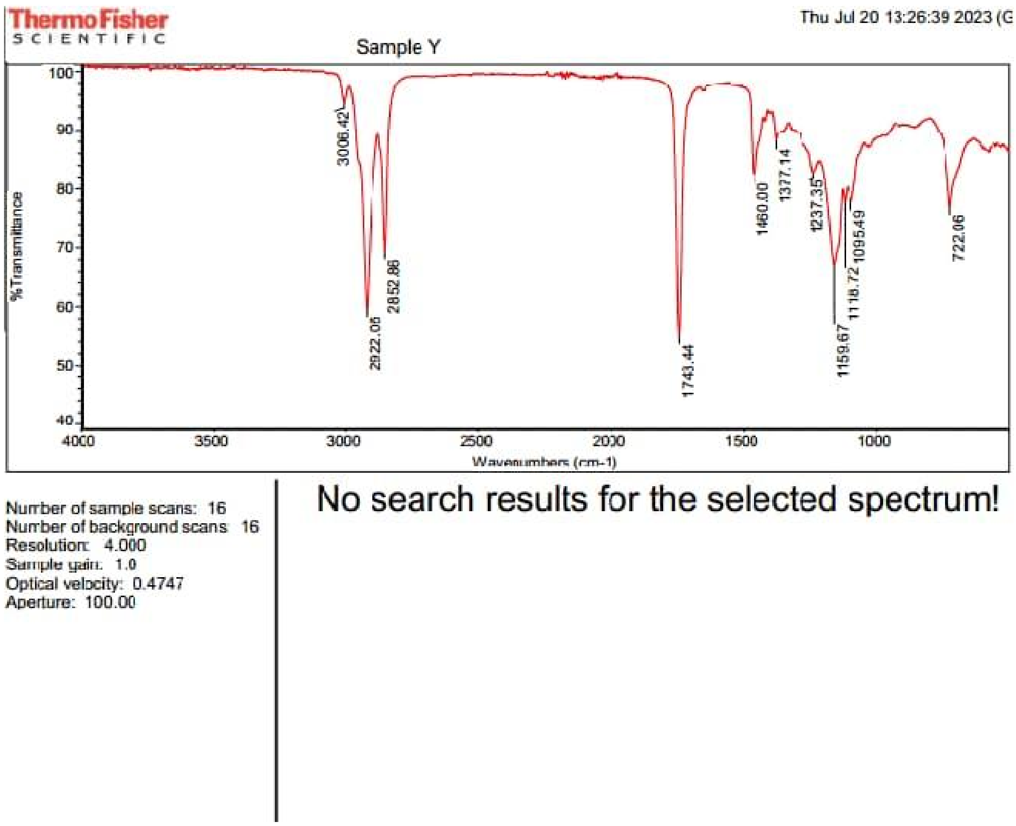
Refractive Index (Brix %):

The refractive index remains relatively consistent at both normal temperature (71 Brix %) and 85°C (71.5 Brix %). The stable refractive index indicates that there is no significant change in the composition or purity of almond oil when subjected to these temperature conditions. This is a positive sign for the oil's usability in various applications.

UV Test Results:

At normal temperature (25°C), the UV absorbance at 297 nm is 0.112, while at 85°C, it increases significantly to 0.933. Similarly, at 234 nm, the absorbance goes from 0.012 at normal temperature to 0.001 at 85°C. This sharp increase in UV absorbance at 85°C indicates that almond oil is undergoing changes in its chemical composition, likely due to thermal degradation. This could involve the formation of degradation products or changes in the concentration of certain compounds.

3.1.3.FITR ANALYSIS



The FTIR machine with model number Cary 630+set at revolution of 4,000 with number of sample scans and background of 16, optical velocity of 0.47 and aperture of 100 presented the spectrum above, the peak in the spectrum is interpreted below.

WAVENUMBER cm-1	ABSORPTION BAND RANGE cm-1	FUNCTIONAL GROUP	APPEARANCE
3006.42	3100- 3000	C-H stretch of alkene (=C-H)	medium
2922.06	3000- 2840	N-H stretch of amine salt	strong
2852.86	3000- 2840	C-H stretch of alkane (C-H)	medium
1743.44	1750- 1735	C-O stretch of ester (=C-O)	strong
1460.00	1465- 1415	C-H bend of alkene (-	medium

		C=H)	
1377.14	1380- 1370	C-H bend of alkane (C=H)	medium
1237.35	1250- 1020	C-N Stretch of amine	medium
1159.67	1160- 1120	S=O stretch of sulfonic acid	strong
1118.72	1124- 1087	C-O stretch of secondary alcohol (C-OH)	
1095.94	1124- 1087	C-O stretch of secondary alcohol (C-OH)	
722.06	730 -665	C-C bend of alkene (-C=C)	strong

These interpretations represent the chemical bonds and functional groups in the almond oil sample that are responsible for the observed absorption peaks in the FTIR spectrum. The appearance indicates the relative intensity or strength of the absorption bands.

C-H Stretch of Alkene (=C-H) at 3006.42 cm^{-1}: This peak suggests the presence of alkene functional groups in almond oil. Alkenes contain double bonds between carbon atoms. In almond oil, this might be indicative of unsaturated fatty acids. The medium appearance indicates a moderate concentration of this group. Almond oil is known for its high content of unsaturated fatty acids, including oleic acid. This peak confirms the presence of such unsaturated compounds, which are beneficial for health.

N-H Stretch of Amine Salt at 2922.06 cm^{-1}: The detection of amine salt could indicate the presence of certain compounds, possibly related to the extraction process or impurities..

This peak indicates the presence of amine salts in almond oil. It suggests the presence of organic compounds containing amine groups. This could be related to the composition of almond oil or its processing. The presence of amine salts might be related to the almond oil's quality or processing method. Further investigation is needed to understand its significance fully.

C-H Stretch of Alkane (C-H) at 2852.86 cm^{-1}: This peak indicates the presence of alkane functional groups, which typically represent saturated hydrocarbons. These can be found in various organic compounds, including fats and oils.

Relevance to Research: The presence of alkane functional groups is expected in almond oil, as it contains a mixture of saturated and unsaturated fatty acids. This result aligns with the known composition of almond oil.

C-O Stretch of Ester (=C-O) at 1743.44 cm^{-1}: This peak indicates the presence of ester functional groups. Esters are common in natural oils and fats and are usually associated with triglycerides, which are the primary constituents of almond oil. This finding confirms the expected chemical composition of almond oil as almond oil is primarily composed of triglycerides, and the presence of ester groups is consistent with its chemical structure.

(C-H bend of alkene (-C=H)) at 1460.00 cm^{-1} : This peak suggests the presence of alkene functional groups, particularly bends in their structure. It complements the information from the first peak, confirming the existence of unsaturated compounds. The confirmation of unsaturated compounds reinforces the nutritional value of almond oil, which is rich in monounsaturated fats.

(C-H bend of alkane (C=H)) at 1377.14 cm^{-1}: This peak indicates the presence of bends in alkane functional groups. Alkanes are typically saturated hydrocarbons. Similar to the earlier alkane peak, this result reaffirms the presence of saturated hydrocarbons, which are a common component of almond oil.

(C-N Stretch of amine) at 1237.35 cm^{-1}: This peak suggests the presence of amine groups in almond oil. Amines are organic compounds containing nitrogen atoms. The presence of amine groups might be linked to specific compounds or processing methods. Further analysis is required to determine their exact nature and significance.

(S=O stretch of sulfonic acid) at 1159.67 cm⁻¹ : This peak indicates the presence of sulfonic acid groups. Sulfonic acids are strong acids and are not typical in natural oils. Their presence may result from processing or contaminants. The presence of sulfonic acids raises questions about the quality or processing of almond oil. Further investigation is necessary to understand its origin.

(C-O stretch of secondary alcohol (C-OH) at 1118.72 cm^{-1}): This peak suggests the presence of secondary alcohol functional groups, which can be found in various organic compounds. The presence of secondary alcohols is consistent with the complex composition of almond oil, which contains various types of compounds.

(C-O stretch of secondary alcohol (C-OH)) at 1095.94 cm^{-1} : This peak also indicates the presence of secondary alcohol functional groups, reinforcing the previous observation. The presence of secondary alcohols adds to the complexity of almond oil's composition, which can have implications for its properties and applications.

(C-C bend of alkene (-C=C)) at 722.06 cm^{-1} : This strong peak suggests the presence of bends in alkene functional groups, indicating the presence of double bonds in the structure. The presence of double bonds is consistent with the unsaturated nature of almond oil. It contributes to its nutritional value and potential health benefits.

CONCLUSION

The almond oil characterized in this research has a low percentage of free fatty acids, which is a favorable trait indicating its overall quality and stability for different applications. The result further aligns with the desirable properties of almond oil for both industrial and consumer purposes.

The UV test results strongly suggest that almond oil is not thermally stable at 85°C. The significant increase in absorbance at specific wavelengths indicates chemical alterations, which may affect the oil's sensory properties, nutritional value, and shelf life. It is crucial for industries and culinary applications to be aware of these changes when using almond oil in high-temperature processes.

The thermal stability test results reveal that almond oil undergoes oxidation and chemical changes when exposed to higher temperatures, as evidenced by the increase in peroxide value and UV absorbance. While the refractive index remains stable, indicating no major impurities, the UV test highlights the need for caution when subjecting almond oil to elevated temperatures. Further research could delve into the specific chemical changes and their implications for various applications, including culinary and industrial uses of almond oil.

The FTIR spectrum confirms the presence of both saturated and unsaturated compounds in almond oil, aligning with its known composition.

The presence of amine salts, sulfonic acid, and secondary alcohols raises questions about almond oil quality or processing and warrants further investigation. A probable cause of the presence of sulfonic acid and secondary alcohol could arise from the process of extraction using solvents and other procedures on the sample of almond oil during the research.

The FTIR analysis provides valuable information about the chemical composition of almond oil, which is essential for understanding its properties and potential applications. Further research can help clarify the origin and significance of specific functional groups.

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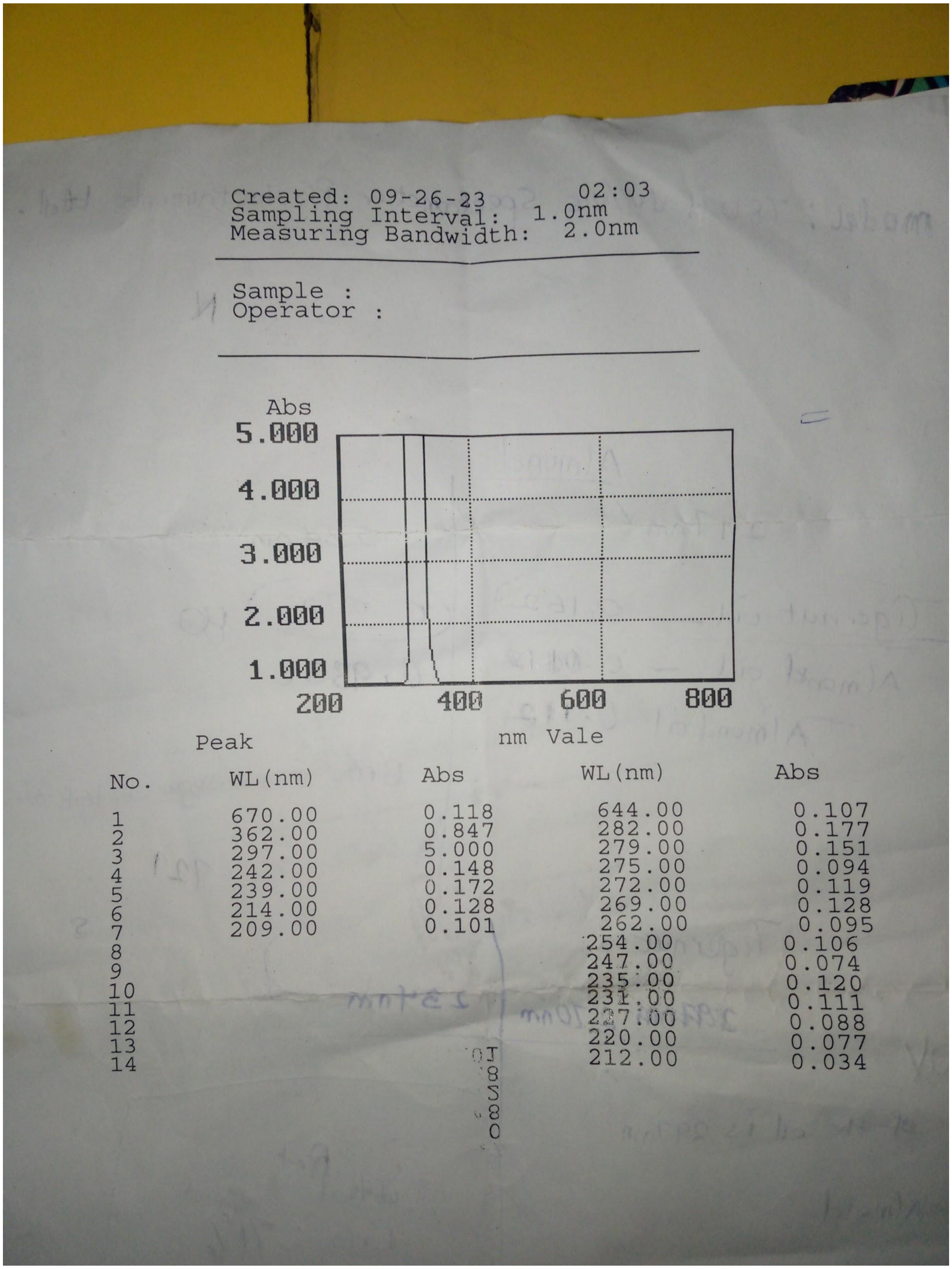
APPENDIX



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Sampling Interval: 1.0nm
Measuring Bandwidth: 2.0nm

Sample :
Operator :

	Peak		nm Vale	
No.	WL(nm)	Abs	WL(nm)	Abs
1	670.00	0.118	644.00	0.107
2	362.00	0.847	282.00	0.177
3	297.00	5.000	279.00	0.151
4	242.00	0.148	275.00	0.094
5	239.00	0.172	272.00	0.119
6	214.00	0.128	269.00	0.128
7	209.00	0.101	262.00	0.095
8			254.00	0.106
9			247.00	0.074
10			235.00	0.120
11			231.00	0.111
12			227.00	0.088
13			220.00	0.077
14			212.00	0.034