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Physicochemical Characterization and Fatty Acid Profiling of Pachira Insignis Seed Oil by Gas Chromatography Mass Spectrometry

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ABSTRACT

Edible fats and oils as important components of food and food products have been commercially sourced for nutritional, industrial and medicinal applications. The demand for quality oils has lately increased due to population growth and education on the numerous health benefits of the so-called good oils. There has, therefore, been a wide gap between demand and supply of quality oils even though there are myriads of underutilized oil producing plants available to be tapped as sources of quality oils. The purpose of this work was to extract oils from the seeds of Pachira insignis, to determine the percentage oil yield, physicochemical properties and fatty acid compositions. The seed oil was extracted using pressurized liquid extraction technique and percentage oil content was determined. Physicochemical properties were characterized using standard methods whilst Fatty acid content of the oil was profiled using Gas Chromatography Mass Spectrometry (GC-MS). The mean percentage oil yields obtained was 38.9 %w/w ± 1.015. The results of physicochemical properties determined gave a range of 0.909 - 0.915 for specific gravity, 0.898 - 0.900 g/cm3 for density, 1.465 - 1.473 for refractive index and 0.670 – 0.674 % respectively for moisture content. The range for free fatty acid and acid value ranged from 3.069 – 3.097 % and 6.107 – 6.163 mg KOH g-1 respectively. Finally, the ranges obtained for iodine value, Peroxide values and saponification number were 47.915 – 50.045 g 100g-1, 0.447 – 0.449 meq O2/kg and 185.492 – 187.498 mg KOH g-1 respectively. The recorded percentage unsaturated fatty acid content of the seed oil was 72.26 %. The results of the analysis show that, Pachira insignis seeds contain enough oil content with physicochemical properties that indicate their suitability for use as domestic and industrial applications. The oils also possess high content of unsaturated fatty acids indicating that the oils are high grade oils. The seed oil can therefore serve as a potential source of commercial oil for nutritional, medicinal and industrial purposes.

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Introduction

Natural vegetable oils and fats play an increasingly vital role in both nutrition and commerce, constituting over 80% of the global supply of oils and fats. Due to rapid population growth and heightened awareness of the numerous health benefits associated with plant oils, there has been a marked increase in demand. This rising demand has exacerbated the gap between production and consumption, highlighting the need to explore alternative sources to bridge the disparity [1,2]. While a diet low in fatty acids is typically considered beneficial for health, the human body requires a certain amount of fats for optimal growth and function. Diets rich in saturated fatty acids are linked to chronic diseases such as cardiovascular disease, diabetes, and cancer, which underscores the recommendation for diets that are higher in unsaturated fatty acids. Polyunsaturated fatty acids (PUFAs), particularly omega-3 fatty acids such as DHA (docosahexaenoic acid) and EPA (eicosapentaenoic acid), are essential dietary nutrients that the body cannot synthesize and must be sourced through the diet. These fatty acids play critical roles in various biological functions, including the synthesis of bioactive compounds, brain and eye development in infants, and the reduction of "bad" cholesterol, thereby contributing to the prevention of coronary heart disease [1,3]. Recently, there has been an increasing focus on the quality of food and its implications for human health, influencing the categorization of oils as either "healthy" or "unhealthy" [4]. The composition of both major and minor compounds in oils is largely influenced by the plant variety, significantly impacting their nutritional properties and economic value. The use and value of oils are influenced by the physicochemical properties intrinsic to their constituents. For example, oils with higher fatty acid content are prone to foam formation, while a high iodine value suggests a higher degree of unsaturation in fats and oils. Other physicochemical properties, such as pH, density, peroxide value, specific gravity, and ester value, provide essential information regarding the suitability of oils for various industrial and nutritional applications. These properties are crucial in determining whether vegetable and seed oils are appropriate for specific uses [1]. The composition of fatty acids within oils can vary, and the relative proportions of these fatty acids play a significant role in determining the oil's quality and economic value. Consequently, it is critical to analyze oils to assess their quality and market value. This analysis typically involves examining both major and minor components of the oil [5]. Despite the increasing importance of natural vegetable oils and fats in nutrition and commerce, many plant species that have potential as oil sources remain underexplored by the scientific community [1]. Vegetable oils have become essential ingredients in a wide range of industrial and nutritional applications due to their beneficial properties and minimal environmental impact [6]. Africa, with its vast biodiversity, is home to approximately 216,634,000 hectares of closed forest areas, which contain over 5,000 plant species. However, efforts to develop edible oils from these indigenous plants to meet the continent's growing oil demand have been limited [7]. Although many African plants have historically been used for oil extraction, their commercial production remains underdeveloped due to insufficient attention given to their cultivation and commercialization. In Ghana, the dominant sources of vegetable oils include palm, corn, coconut, peanut, and shea. However, many tropical oil-bearing plants remain underutilized. Consequently, the country faces a shortage in local oil production, leading to a reliance on imports to meet growing demand. To address this, there is an urgent need to explore alternative sources of plant oils to cater to the expanding local market [8].

Pachira insignis, commonly referred to as tree nut or wild chestnut, is part of the Bombacaceae family and is one of the two edible species within the Pachira genus [9]. This deciduous, perennial plant is primarily found in the coastal and forest zones of Ghana and other parts of West Africa, where it grows both in the wild and in cultivation. In Ghana, it is regarded as a wild plant, with local names such as '*asiato*' among the Ewe and '*bonbonfradaa*' among the Akan. The seeds of Pachira insignis are utilized in a similar manner to groundnuts: roasted, boiled, or dry-fried, and serve as thickening agents in stews and soups. They are also used to prepare a popular dish called 'eto,' made from mashed yam, plantain, or cocoyam. Although the seeds of *Pachira insignis* are rich in oil and used for cooking locally, commercial production of its oil has not been established. Despite the plant's traditional significance, there is a dearth of research on its seed oil's content, physicochemical properties, and fatty acid profile. This paper aims to analyze these characteristics of *Pachira insignis* seed oil using Gas Chromatography-Mass Spectrometry.

Materials and Methods

Sample and Sampling Collection

Pachira insgnis fruits were collected from the Botanic Garden of the University of Cape in the Central region of Ghana. The fruits were opened to get the seeds. The samples were authenticated by a Botanist at the Department of theoretical and Applied Biology of the College of Science at Kwame Nkrumah University of Science and Technology, Kumasi.

Sample Treatment

The collected seeds were dried and ground using a well cleaned and sterilized miller at the Chemical Engineering Department of Kwame Nkrumah University of Science and Technology, Kumasi and kept in a dry air-tight polythene bag prior to extraction.

Extraction Technique

The oils were extracted using the pressurized liquid extraction (PLE) technique, employing a Pressurized Liquid Extractor (DMS-6000, Fluid Management Systems Incorporated, Watertown, Massachusetts, USA) with hexane as the solvent. After extraction, the oils were separated from the hexane using a concentrator (DMS-6000, Fluid Management Systems) under a nitrogen gas stream. The percentage oil content was calculated, and the oils were then stored in an air-tight, Teflon-lined container at 4°C in a refrigerator for subsequent analysis.

Determination of Physicochemical properties

The oil content percentage and physicochemical properties of the extracted crude oil were assessed using the procedures described by [1]. The parameters analyzed included oil content (%), specific gravity, density (g/ml), refractive index (D, 25°C), moisture content (%), free fatty acid content (% Oleic), acid value (mg KOH/g), iodine value (g/100g), peroxide value (meq O_2/kg), and saponification number (mg KOH/g). All recorded data were the mean values from triplicate determinations.

Determination of Fatty Acid Composition by GC-MS

Preparation of Fatty Acid Methyl Esters (FAMES) for Analysis by GC-MS

An oil sample of 0.1g was mixed with 2mL of 0.1N methanolic KOH and subjected to centrifugation at 4000 rpm for 20 minutes. After centrifugation, 5mL of n-hexane was added, and the mixture was vortexed for 2 minutes. It was then allowed to settle, following the procedures outlined in [10,11].

GC-MS Analysis of Fatty Acids

A 1 µl aliquot of the hexane layer from the FAMEs preparation was subjected to fatty acid analysis using a PerkinElmer GC Clarus 580 Gas Chromatograph coupled with a PerkinElmer Clarus SQ 8 S Mass Spectrometer. The system was equipped with an Elite-5MS capillary column (5% diphenyl/95% dimethyl polysiloxane; 30 × 0.25 mm ID × 0.25 µm DF). The temperature program for the oven was initiated at 70°C (isothermal for 1 minute), followed by a ramp of 3°C/min to 240°C, with a final hold at 250°C for 1 minute. The electron ionization system was operated in electron impact mode at 70 eV for mass spectrum acquisition. Helium gas (99.999%) was employed as the carrier gas at a constant flow rate of 1.6 mL/min, and the injection volume was 1 µl. The injector temperature was maintained at 200°C, while the ion-source temperature was set at 150°C. Mass spectra were recorded at a scan rate of 0.5 seconds, with ion fragments ranging from 50 to 450 Da. The solvent delay was set to 2 minutes, and the total GC-MS analysis time was 59 minutes. Data acquisition and analysis were performed using Turbo-Mass software (version 6.1.0), with mass spectrum interpretation facilitated by comparison with the National Institute of Standards and Technology (NIST) database, which includes over 62,000 reference spectra. Fatty acid compositions were quantified using the built-in data handling program, with the results expressed as relative percentages of the total peak area.

Results and Discussion

Table 1: Physicochemical Properties of Pachira Insignis Seed Oil

PARAMETER	Recorded range	Acceptable range (CODEX, 2009; CODEX-STAN, 1999; CODEX, 1993; 2001; WHO/FAO, 1994))
Oil Content (%)	38.851 ± 1.015	N/A
Specific gravity	0.912 ± 0.003	0.919-0.925,
Density (g/ml)	0.899 ± 0.001	0.919-0.925
Refractive index (D, 25°C)	1.469 ± 0.004	1.4677- 1.4707
Moisture Content (%)	0.672 ± 0.002	Not more than 0.2%
Free Fatty Acid (%, Oleic)	3.083 ± 0.014	Not less than 2.0%
Acid value (mg KOH g-1)	6.135 ± 0.028	Not more than 0.6 mgKOH/g
Iodine value (g 100g-1)	48.98 ± 1.065	<100 for non-drying oils, ≥130 for drying oils
Peroxide Value (meq O2/Kg)	0.448 ± 0.001	<10 mEq/kg
Saponification number (mg KOH g-1)	186.495 ± 1.003	190-209mg KOH/g fat (palm oil), 230-254 mg KOH/g fat (Palm Kernel oil) and 248-265 mg KOH/g fat (coconut oil)

Physicochemical Properties

The results of the physicochemical Properties are reported in Table 1.

Percentage Yield

The oil yield of *Pachira insignis* was determined to be 38.851 ± 1.015% (Table1), which is higher than the 30.0 ± 0.9% yield reported for Agushi seeds, but exceeds the 27.5 ± 0.5% and 28.0 ± 0.4% yields obtained from Wrewre and Desert Melon seeds, respectively, as noted by [12]. This yield surpasses the Codex guideline of 20-22% for soybean oil and is comparable to the oil yields of groundnut (40-45%) and sunflower (40-50%). Moreover, the oil yield of *Pachira insignis* is consistent with the 38.9% reported by Yeboah [13]. Given this relatively high oil yield, *Pachira insignis* shows promise as a potential source for commercial oil production.

Specific Gravity/Relative Density

The specific gravity of oil is defined as the ratio of its density to the density of an equal volume of water, which reflects the oil's relative density compared to water. Oils with a specific gravity of less than one is typically advantageous for use in cream formulations, as they facilitate easy spreading and flow on the skin [13]. The specific gravity of *Pachira insignis* seed oil was found to range from 0.909 to 0.915, which is consistent with the Codex-recommended specific gravity range for olive oil (0.910–0.916), groundnut oil (0.912–0.914), and palm kernel oil (0.899–0.914). However, this value is slightly lower than the Codex-recommended specific gravity ranges for soybean oil (0.919–0.925) and sunflower oil (0.918–0.923), but higher than that of palm oil (0.891–0.899) [14,15]. Although the specific gravity of *Pachira insignis* seed oil is slightly below the FAO/WHO recommended range of 0.919–0.925 for oil densities, it remains within a generally acceptable range [14,15].

Density

The density of an oil is defined as its mass per unit volume and serves as an important indicator of its purity, fatty acid composition, and whether it is refined or unrefined [16]. The density of oils generally increases with molecular weight and decreases as the degree of unsaturation rises [1]. Higher-density oils are typically more effective as lubricants, while oils with lower density values tend to be lighter and may possess a higher degree of unsaturation. Elevated density values may also suggest the presence of particulates in crude oil samples [16]. The density of Pachira insignis seed oil was found to range from 0.898 to 0.900 g/cm³, with a mean value of 0.899 g/cm³ (Table 1). This value aligns with the density of 0.913 g/cm³ reported by Yeboah, et al., 2012 [16]. The recorded density range is consistent with that of palm oil (0.891–0.899 g/cm³) but is lower than the densities of coconut oil (0.908–0.921 g/cm³), rapeseed oil (0.910–0.920 g/cm³), sesame oil (0.950 g/cm³), and cottonseed oil (0.918–0.926 g/cm³). Moreover, the recorded density range for Pachira insignis seed oil (0.898–0.900 g/cm³) is comparable to the 0.913–0.916 g/cm³ range for olive oil and falls within the general density range of 0.840–0.960 g/cm³ for mineral oils [15]. However, it is below the Codex-recommended range of 0.919–0.925 g/cm³, which suggests that Pachira insignis seed oil is a relatively lighter oil. This characteristic could make it particularly suitable for use in cream production [13]. The lower density also suggests the presence of unsaturated fatty acids in the oil [17]. Overall, the density of Pachira insignis seed oil is comparable to that of commercially available oils, highlighting its potential as a viable source of oil with properties similar to those of established commercial oils.

Refractive Index

The refractive index of an oil is defined as the ratio of the speed of light in a vacuum to the speed of light within the oil. This parameter is influenced by several factors, including wavelength, temperature, the degree and type of unsaturation in the oil, and the structural characteristics of the constituent fatty acids [18]. Refractive index is an important metric in quality control, as it aids in determining the purity of oils and serves as a method of identification, given that each substance has a unique refractive index. A higher refractive index generally indicates a greater number of carbon atoms in the fatty acid composition and is often associated with increased unsaturation [19]. The refractive index of Pachira insignis seed oil was found to range between 1.465 and 1.473, with mean refractive index of 1.469±0.004 which falls within the Codex-recommended range of 1.4677–1.4707 for virgin oils, 1.4677–1.4705 for olive oil, and 1.467–1.469 for sunflower oil [20]. Furthermore, this value aligns with the FAO/WHO recommended range of 1.466 to 1.470 for oils. However, the refractive index of Pachira insignis seed oil is slightly higher than the Codex-recommended range of 1.460–1.465 for groundnut oil, 1.454–1.456 for palm oil, and 1.448–1.452 for palm kernel oil, as well as slightly above the recommended range of 1.466–1.467 for soybean oil. This suggests that the fatty acid profile of Pachira insignis seed oil contains a greater number of carbon atoms and a higher degree of unsaturation compared to these oils, with values that are comparable to sunflower and olive oils [15]. The refractive index is linearly correlated with both the number of carbon atoms and the degree of unsaturation in the fatty acid composition [21]. Consequently, the higher refractive index observed for Pachira insignis seed oil indicates a higher degree of unsaturation, suggesting that it is of high quality and, therefore, a potentially valuable oil source.

Moisture Content

Moisture content in oils and fats refers to the weight loss observed when the sample is heated at 105–110°C under specified conditions. It is a critical parameter as it indicates the presence of water in the oil, which can significantly affect the rate of oxidation and rancidity. Lower moisture content is generally preferred, as it enhances the oil's stability by inhibiting oxidative processes and prolonging its shelf life [22]. In contrast, high moisture content can promote hydrolysis [23]. and it also implies that a greater quantity of oil is required for its intended applications [22]. The moisture content of *Pachira insignis* seed oil was found to be 0.672%, which exceeds the Codex standard limit of 0.2% [15]. The high moisture content suggests an increased susceptibility to oxidation, potentially leading to rancidity and a reduction in the oil's shelf life. Moreover, the elevated moisture content implies that a larger volume of oil would be necessary for its applications, as higher moisture levels necessitate the use of greater amounts of the oil for effective use [22].

Acid Value

The acid value of an oil is defined as the amount of potassium hydroxide (KOH) in milligrams required to neutralize the free fatty acids (FFA) in 1g of oil, serving as an indicator of its free fatty acid content [24]. It is an important measure of the breakdown of triglycerides into free fatty acids, which adversely affects the quality of the oil. An increase in free fatty acids typically indicates hydrolysis of triglycerides [21]. The acid value also reflects the extent of hydrolysis by lipolytic enzymes and oxidation [25]. A low acid value suggests that the oil is stable and resistant to rancidity and peroxidation over time, often due to the presence of natural antioxidants such as vitamins C and A, as well as other phytochemicals like flavonoids. The acid value serves as an indicator of the oil's suitability for consumption and its potential industrial uses, such as in the production of soap and paint [6]. High acid values generally suggest that an oil may not be suitable for cooking, though it may be appropriate for industrial applications like the production of paints, soaps, and shampoos [6]. Additionally, high acid values may indicate that the plant could be toxic to livestock. According to the Codex Alimentarius Commission, the acid value should be below 0.6 mg KOH/g for edible oils. The *Pachira insignis* seed oil exhibited an acid value of 6.135 mg KOH/g, which is comparable to the 4.44 mg KOH/g [18]. While this value exceeds the Codex standard for edible oils, it aligns with the acid values found in commonly consumed oils, including soybean, sunflower, groundnut, palm, and palm kernel oils, which generally fall in the range of 4.0 mg KOH/g [12,15]. The acid value of *Pachira insignis* seed oil is similar to that of olive oil, soybean oil, sunflower oil, groundnut oil, palm oil, and palm kernel oil, suggesting that this oil shares characteristics such as quality, stability, and resistance to triglyceride hydrolysis, lipolytic enzyme activity, and oxidation, all of which contribute to oil deterioration and rancidity [6,18]. This acid value further suggests that *Pachira insignis* seed oil could be suitable for both culinary uses and industrial applications, such as the production of paints, liquid soap, shampoos, and even livestock feed [6,21].

Free Fatty Acid (% Oleic)

Free fatty acids (FFAs) represent the weight percentage of specific fatty acids (such as oleic acid) in an oil [26]. The level of FFAs is a key factor in determining the oil loss during the refining process, as they must be removed from crude oils [27]. High FFA concentrations in crude vegetable oils are undesirable because they lead to greater loss of neutral oil during refining. Furthermore, elevated FFA levels, especially of linoleic acid, can result in off-flavors and a reduced shelf life of the oil. As such, the FFA content serves as a crucial indicator of oil quality; oils with lower FFA concentrations are considered of higher quality [28]. High levels of FFAs also lower the smoke point of oil and may cause splattering during cooking [28]. Generally, oils with lower FFA content are considered higher quality [29]. Additionally, in refined oils, a low FFA content is preferred for improved palatability. The FFA content is directly linked to the acid value of the oil, and an increase in FFA levels indicates the hydrolysis of triglycerides [21]. In the case of *Pachira insignis* seed oil, the FFA content was measured at 3.083%. This value exceeds the threshold for edible oil and suggests its suitability for nutritional purposes [22]. This percentage is also above the Codex Alimentarius Commission's (1993) minimum limit of 2.0% for high-grade oils, indicating that the oil meets the standard for quality. Although high FFA content can lower the smoke point and cause splattering during cooking, the FFA level in *Pachira insignis* seed oil suggests it is still appropriate for cooking applications [28]. Moreover, the relatively low FFA content implies that minimal oil will be lost during refining and the oil remains edible and suitable for nutritional [29].

Iodine Value

The iodine value of an oil or fat represents the amount of iodine (in grams) absorbed by 100 grams of the oil or fat when measured using Wijs solution. This value is an indicator of the degree of unsaturation, reflecting the number of double bonds present in the fat [1]. The iodine value is a key characteristic for identifying seed oils, making them ideal raw materials for industries such as soap and cosmetics [16]. Additionally, the iodine value provides information about the oil's susceptibility to oxidation, with higher iodine values indicating a higher degree of unsaturation and greater vulnerability to rancidity [25]. Oils with iodine values below 100 gI2/100g are classified as non-drying oils, which are unsuitable for the production of ink and paint, but are useful for soap production and are considered liquid oils. On the other hand, oils with iodine values above 130 are considered drying oils [15]. High iodine values suggest a higher content of unsaturated fatty acids, which absorb more iodine and are valuable for applications like vegetable oil-based ice cream. In the present study, the iodine value of *Pachira insignis* seed oil was 48.98, which is consistent with the value of 46.99 [18]. This relatively low iodine value indicates that the oil has a lower degree of unsaturation, making it less prone to oxidation and rancidity [25]. As a result, the oil has a longer shelf life due to its reduced susceptibility to deterioration. The iodine value of *Pachira insignis* seed oil is below 100, classifying it as a non-drying oil [15] which makes it unsuitable for ink and paint production but suitable for use in soaps and cosmetics [30]. This value is similar to the Codex recommended range for palm oil (50-55) but lower than the iodine value for olive oil (75-94). Thus, *Pachira insignis* seed oil is expected to have applications comparable to those of palm and olive oils, positioning it as a versatile and useful oil.

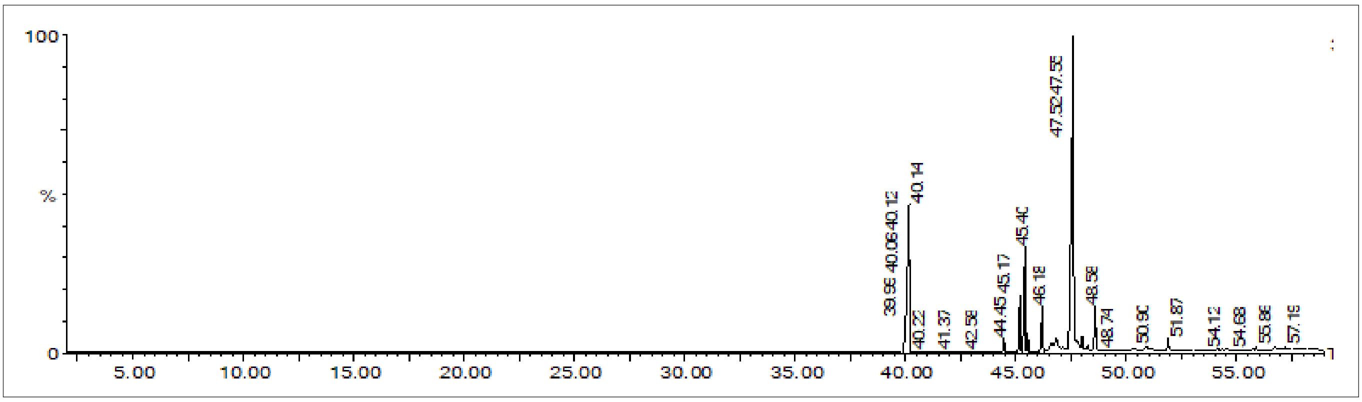
Peroxide Value

Peroxide value is a key indicator of lipid oxidation and is expressed as milliequivalents of peroxide oxygen per kilogram of sample (meq/kg). Unrefined vegetable oils typically have higher peroxide values than refined oils. Elevated peroxide values indicate higher levels of oxidative rancidity, which suggests low or absent antioxidants in the oil. As a measure of rancidity and oxidation susceptibility, a low peroxide value signifies resistance to peroxidation during storage [3]. Peroxide value is also useful for determining the shelf life of oils, with fresh oils typically having values below 10 meq O2/kg, as recommended by WHO/FAO (1994). A rancid flavor usually becomes detectable when the peroxide value reaches between 20 and 40 meq/kg. In this study, the peroxide value of *Pachira insignis* seed oil was found to be 0.448 meq O2/kg, which is considerably lower than the 4.04 meq O2/kg [18]. This value is well below the WHO/FAO (1994) recommended maximum of 10 meq O2/kg, indicating that the oil is fresh [4]. The low peroxide value suggests that *Pachira insignis* seed oil is resistant to lipid peroxidation and rancidity during storage, meaning it can be stored for extended periods without significant degradation [3]. Additionally, this low peroxide value suggests that the oil contains natural antioxidants that help prevent lipid peroxidation and enhance its stability.

Saponification Value

The saponification value refers to the quantity of potassium hydroxide (KOH) in milligrams required to saponify 1 gram of oil or fat. It serves as an indicator of the average molecular weight of the fatty acids in the glycerides of the fat. A lower saponification value suggests a higher molecular weight of the fatty acids, while a higher saponification value indicates a lower molecular weight. This value is inversely related to the chain length of the fatty acids in the oil or fat; longer fatty acid chains result in a smaller saponification value [22]. An increase in saponification value enhances the volatility of oils, improving their quality by indicating the presence of lower molecular weight components, which generate more energy during combustion [31]. A higher saponification value is also associated with the oil's suitability for soap production. Conversely, a low saponification value may imply that the oil is unsuitable for soap making, oil-based ice cream, and shampoos. It could also indicate lower foaming ability, a characteristic important for surfactants used in emulsions, soaps, and detergents [25]. The saponification value of *Pachira insignis* seed oil was determined to be 186.495 mg KOH/g, which aligns closely with the value of 189.49 mg KOH/g [18]. This value suggests that the oil is appropriate for use in soap formulation, oil-based ice creams, and shampoos. Additionally, the high foaming ability of the oil makes it suitable for emulsions and detergent formulations [3]. The saponification value of *Pachira insignis* seed oil is comparable to that of soybean oil, sunflower oil, palm oil, olive oil, and groundnut oil, indicating that it shares similar characteristics with these commercially available oils [12,15].

Fatty Acid Composition in Pachira insignis Seed Oil using GC



S.No	RT	Scan	Height	Area	Area %	Norm %
1	40.144	762	1,565,231,3	166,478,384	17.599	40.88
2	44.445	8486	152,819,856	11,012,132.0	1.164	2.70
3	45.171	8631	587,489,024	43,520,596	4.601	10.69
4	45.401	8677	1,084,373,504	77,169,656	8.158	18.95
5	45.521	8701	187,711,1	9,358,315	0.989	2.30
6	46.181	8833	482,242,784	35,175,044	3.719	8.64
7	46.606	8918	86,069,208	12,669,361	1.339	3.11
8	46.816	8960	125,746,672	21,810,366.0	2.306	5.36
9	47.096	9016	32,082,132	3,868,003.2	0.409	0.95
10	47.591	9115	3,318,212,096	407,217,760	43.049	100.00

11	48.007	9198	135,261,296	8,639,164	0.913	2.12
12	48.577	9312	458,571,6	32,936,564	3.482	8.09
13	50.908	9778	43,366,072	5,942,683	0.628	1.46
14	51.873	9971	112,326,008	7,450,202	0.788	1.83
15	55.860	10768	39,781,128	4,234,027.5	0.448	1.04
16	56.690	10934	44,114,776	15,191,147	1.606	3.73
17	57.185	1103	44,378,472	7,253,111	0.767	1.78
18	57.590	1111	42,114,672	7,225,428	0.764	1.77
19	57.906	1117	22,420,046	6,904,141	0.730	1.70
20	58.461	1128	24,209,570	14,709,820	1.555	3.61

Table 2 Fatty Acid profile of Pachira insignis Seed Oil from GC-MS

Number	Retention time/min	Chemical Name	Common Name	Carbon: double bond Number	Mwt	Fatty Acid Type	Percentage Comp. /%
1	40.144	Hexadecanoic acid	Palmitic Acid	C16:0	270	SFA	17.599
2	44.445	6,9-Octadecadienoic acid	Linoelaidic acid	C18:2 (6,9)	294	PUFA	1.164
3	45.171	9,12-Octadecadienoic acid	Linoleic Acid	C18:2 (9,12)	294	PUFA	4.601
4	45.401	9-Octadecenoic acid	Oleic acid	C18:1 (9)	296	MFA	8.158
5	45.521	11-Octadecenoic acid	Asclepic/ CisVaccenic	C18:1 (11)	296	MFA	0.989
6	46.181	Octadecanoic acid	Stearic acid	C18:0	298	SFA	3.719
7	46.606	Hexacosenoic Acid		C26:1	408	MFA	1.339
8	46.816	Pentacosanoic acid	Pentacosylic Acid	C25:0	396	SFA	2.306
9	47.096	Heptacosanoic Acid	Carboceric Acid	C27:0	424	SFA	0.409
10	47.591	5,9-Octadecadienoic Acid	Taxoleic, T	C18:2(Z5,9)	294	PUFA	43.049
11	48.007	Tetracosatrienoic Acid		C24:3	376	PUFA	0.913
12	48.577	Docosahexaenoic acid, DHA	Cervonic acid	C22:6	342	PUFA	3.482
13	50.908	Nonacosadienoic Acid		C29:2	448	PUFA	0.628
14	51.873	Tricosanoic acid	Tricosylic acid	C23:0	368	SFA	0.788
15	55.860	Octacosahexaenoic acid		C28:6	426	PUFA	0.448
16	56.690	Octacosapentaenoic		C28:5	428	PUFA	1.606
17	57.185	Docosanoic acid	Behenic acid	C22:0	354	SFA	0.767
18	57.590	Hexacosanoic acid	Cerotic acid	C26:0	410	SFA	0.764
19	57.906	Octacosadienoic acid		C28:2	434	PUFA	0.730
20	58.461	Octacosatetraenoic Acid		C28:4	430	PUFA	1.555

Key: SFA Saturated Fatty Acid, MFA Monounsaturated Fatty Acid, PUFA Polyunsaturated Fatty Acid

Table 2 provides the fatty acid composition of Pachira insignis seed oil, revealing the presence of twenty distinct fatty acids. The major fatty acids in the oil are Taxoleic acid (C18:2, Z5,9), which constitutes 43.049%, and Palmitic acid, accounting for 17.599%. Oleic acid is also present in a smaller, yet significant amount of 8.158%. Other fatty acids present in smaller quantities (1-5%) include Linoleic acid (4.601%), Stearic acid (3.719%), Docosahexaenoic acid (DHA) or Cervonic acid (3.482%), Pentacosanoic acid (2.306%), Octacosapentaenoic acid (1.606%), Octacosatetraenoic acid (1.555%), Hexacosenoic acid (1.339%), and Linoelaidic acid (1.164%). Fatty acids present in trace amounts (less than 1%) include Asclepic/Vaccenic acid (0.989%), Tetracosatrienoic acid (0.913%), Tricosanoic acid (0.788%), Behenic acid (0.767%), Cerotic acid (0.764%), Octacosadienoic acid (0.730%), Nonacosadienoic acid (0.628%), Octacosahexaenoic acid (0.448%), and Carboceric acid (0.409%). The most abundant fatty acid, Taxoleic acid (C18:2, Z5, Z9), makes up 43.049% of the oil. This omega-9 polyunsaturated fatty acid contributes significantly to the polyunsaturated fatty acid content of the oil, thereby enhancing its quality. Taxoleic acid is a delta5-unsaturated polymethylene-interrupted fatty acid (delta5-UPIFA) commonly found in gymnosperm seed oils such as Pine oil, which is known for a variety of applications [32]. The high concentration of Taxoleic acid in Pachira insignis oil suggests that it shares some characteristics with Pine oil, indicating potential for similar applications. Therefore, Pachira insignis oil can be considered for commercial use. The 17.599% presence of Palmitic acid, a saturated fatty acid, suggests that the oil is less susceptible to rancidity and may have a longer shelf life. Furthermore, Palmitic acid is known for its analgesic and anti-inflammatory effects, which implies that the oil could be used as a natural anti-inflammatory and analgesic agent [33]. The presence of Palmitic acid also indicates the oil's suitability for the soap industry. Additionally, the high content of Palmitic acid in Pachira insignis oil places it in line with oils such as palm oil, palm kernel oil, and coconut oil [34]. The oil also contains 4.601% Linoleic acid, which further contributes to its health benefits [35]. Omega-3 fatty acids, including Docosahexaenoic acid (DHA)/ Cervonic acid (3.482%), Tetracosatrienoic acid (0.913%), and Octacosahexaenoic acid (0.448%), are present in notable amounts. Omega-3 fatty acids are essential because the body cannot produce them, and they must be obtained through the diet [4]. DHA, in particular, has been associated with various health benefits, including the prevention of coronary heart disease, cancer, stroke, asthma, regulation of cholesterol levels, diabetes, and osteoporosis [36]. The presence of omega-3 fatty acids in Pachira insignis seed oil indicates its potential to serve as a valuable source of essential fatty acids, offering numerous benefits when formulated into products for infants, pregnant women, and adults to promote overall health. Other trace fatty acids, such as Vaccenic acid (0.989%), Behenic acid (0.767%), Tricosanoic acid (0.788%), Cerotic acid (0.764%), and Carboceric acid (0.409%), also contribute to the oil's characteristics. The relatively low level of Behenic acid (0.767%) is beneficial because higher concentrations could interfere with digestive enzymes in humans and animals [37]. The fatty acid profile of Pachira insignis seed oil, which is rich in polyunsaturated and omega-3 fatty acids, positions it as a promising candidate for various industrial and nutritional applications.

Table 3: Percentage Composition of Fatty Acid Classes in Pachira insignis Seed Oil

Fatty Acid Type	Percentage Content (%)
SFA	27.735
MFA	11.036
PUFA	61.229
TOTAL UFA (MFA+ PUFA)	72.265
SFA/UFA index	0.384
% OMEGA-3 FATTY ACIDS	4.843
% OMEGA- 6 FATTY ACIDS	47.374
OMEGA-3/OMEGA-6 Index	0.102

Table 3 outlines the percentage composition of fatty acid classes in Pachira insignis seed oil, showing that the oil contains a significantly higher proportion of unsaturated fatty acids (72.265%) compared to saturated fatty acids (27.735%). Oils with a high level of unsaturated fatty acids are considered beneficial from both a nutritional and health standpoint, as their consumption helps lower the risk of heart disease. In contrast, oils high in saturated fatty acids are linked to cardiovascular conditions such as atherosclerosis, aging, and cancer [38]. Additionally, oils rich in unsaturated fatty acids are particularly advantageous for individuals with coronary heart disease and may contain little to no cholesterol [39]. Oils with an unsaturated-to-saturated fatty acid ratio greater than 0.4 are regarded as healthy and effective in reducing the risk of heart disease [40]. Pachira insignis seed oil has an unsaturated-to-saturated ratio of 2.61, which is more than double the recommended value, indicating that the oil is both healthy and suitable for consumption. The fatty acid composition, unsaturated-to-saturated fatty acid ratio, and the presence of omega-3 and omega-6 fatty acids in Pachira insignis seed oil align with the characteristics of several commercially available oils [18]. This highlights the potential of Pachira insignis seed oil as a high-quality product with diverse applications in nutritional, industrial, and pharmaceutical sectors.

Conclusion

It can be concluded from this work that extraction and subsequent determination of oils from the seeds of Pachira insignis have been done which revealed that the percent oil content is high enough to be exploited as commercial oil. The physicochemical properties of Pachira insignis seed oil characterized indicate that they can potentially be used for nutritional, medicinal and industrial purposes. Fatty acid profile of Pachira insignis seed oils performed using GC-MS indicates the presence of essential fatty acids in sufficient amounts set by the WHO/FAO for healthy oils and can thus be used as sources of essential fatty acids and for prevention of heart diseases when consumed.

Data Availability

All the data has been included in the manuscript.

Conflict of Interest

The authors have no conflict of interest to declare.

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