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Extraction and Characterization of Watermelon (*Citrullus lanatus*) Seed Oil

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Abstract: *This study focuses on employing solvent extraction to extract and characterize watermelon (Citrullus lanatus) seed oil. The physicochemical properties of the oil were investigated to assess its potential applications in the food, cosmetic, and pharmaceutical industries. The extraction process yielded an oil content of 43%. The oil exhibited a pH value of 4.02, refractive index of 1.452 at 25 °C, and specific gravity of 0.934 at 15 °C. The boiling point, cloud point, flash point, and melting point of oil were determined as 326 °C, 7.3 °C, 289 °C, and 2 °C, respectively. The oil's viscosity was measured as 0.04072 Pa.s, and it demonstrated a non-sooty flame nature and solubility in ether. The free fatty acid contents and acid value were determined at 3.339 % and 6.678 mg KOH/g, respectively. The saponification value (S.V) and iodine value (I.V.) were 147.6315 mg/KOH/g and 88.526 mg Iodine/g, respectively. Additionally, peroxide value was 16.40 meq peroxide/g, and the oil exhibited a congealing temperature range of -14 °C to 22 °C. The oil's retention factor during chromatography was determined as 1.6 cm. Fourier-transform infrared (FTIR) analysis revealed the presence of functional groups such as hydroxyl, amine, aliphatic hydrocarbon, carbonyl, carbon-nitrogen bond, and sulfoxide groups in the oil. These findings suggest that the presence of functional groups, such as hydroxyl, amine, aliphatic hydrocarbon, carbonyl, carbon-nitrogen bond, and sulfoxide groups in watermelon oil, indicate its potential suitability for a wide range of applications in the food, cosmetic, and pharmaceutical industries.*

Keywords: *Citrullus lanatus, extraction, FTIR, oil yield, physicochemical properties, watermelon oil.*

1. INTRODUCTION

Vegetable oils have played a crucial role in meeting the world's nutritional needs and finding versatile applications in numerous industries. Over the centuries, plant seeds have been harnessed as a valuable source of vegetable oils. Traditionally, oil from soybeans, cottonseeds, peanuts, corns, palm seeds, and sunflowers has dominated commercial production [1]. These oils have found applications not only in the culinary world but also in manufacturing of soaps, lubricants, varnishes, plastics, and paints, to name a few. Despite extensive research into the traditional sources of plants and seeds oils, there is still untapped potential in the enormous variety of plant seeds to fulfil changing consumer demands. Hence, it is essential to delve into various other forms of seed oils and unveil their yields and industrial applications.

Among the myriad fruits cultivated globally, the watermelon (*Citrullus lanatus*) stands as one of the most extensively grown crops. Belonging to the *Cucurbitaceae* family, watermelons flourish in regions with long, frost-free, and warm periods. There are many different types of watermelons, and they can be identified by their round, oval, or oblong fruit shape. The mesocarp can be white, green, yellow, orange, pink, or red [2]. Beyond their sweet and refreshing taste, watermelon seeds possess hidden potential as they contain essential nutrients such as carbohydrates, fats, insoluble fibre, proteins, and an array of minerals (calcium, iron, sodium, magnesium, phosphorus, potassium, and zinc), along with vitamins A, B, and C [3, 4, 5]. Watermelon seeds oil contains both linoleic and oleic acid in substantial levels [6]. The utilization of watermelon seed oil has gained considerable attention in recent years. While the succulent flesh of the fruit is relished, its seeds have been habitually discarded as waste. However, research has unveiled the bioactive compounds present in these seeds, elevating watermelon seed oil into a valuable resource material. The ever-increasing demands for oils for both residential and industrial sectors cannot be fulfilled solely by traditional sources [7, 8]. Therefore, exploring unconventional sources including *Citrullus lanatus* (watermelon seeds), becomes imperative. This study aims to cast a spotlight on watermelon (*Citrullus lanatus)* oil, its extraction, characterization, applications, and prospects. Seed oil extraction methods have evolved from traditional mechanical techniques to advanced approaches, including supercritical fluid extraction (SFE), enzyme-assisted extraction, and microwave-assisted extraction [9, 10, 11]. These cutting-edge

methods promise improved efficiency, reduced processing time, and enhanced oil quality preservation, rendering them favourable choices for industrial production. In this present research study, Soxhlet extraction technique will be employed. The world's escalating demand for oils necessitates comprehensive research on extracting and characterizing seed oils. By investigating unconventional sources like watermelon seeds and delving into different oil seeds, we can uncover novel avenues for meeting diverse needs. This article aims to shed light on the exceptional worth of watermelon seed oil while promoting a broader exploration of other seed oils and their potential advantages in various industrial applications.

2. MATERIALS AND METHODS

2.1 Materials

The watermelon fruits used for this work were purchased at Otovwodo market in Ughelli North L.G.A, Delta State, Nigeria.

2.2 Equipment

Soxhlet extractor, n-hexane solvent, rotary evaporator, analytical balance, glassware (flasks, beakers.), heating mantle, vacuum pump, filter papers. Water hose, distilled water, bowl, mortar and pestle, n-hexane, sodium hydroxide, hydrochloric acid, stopwatch, tray, plastic sieves, sample bottles, oven, FTIR machine.

2.3 Extraction Procedure

The seeds from watermelons (*Citrullus lanatus*) were gathered and thoroughly washed to remove any impurities. After being thoroughly cleaned, watermelon seed samples were washed and oven dried at 50 °C for 24 hours until a constant weight was attained. Thereafter, dried watermelon seed samples were milled with a mill and pestle into a fine powder weighing 523.15 g. A Soxhlet extractor was assembled with the ground watermelon seed powder placed in a Soxhlet extractor thimble. The ratio of watermelon to n-hexane was 1:10. N-hexane was measured and placed in the flask of Soxhlet extractor. The temperature was kept between 60-70 °C to ensure efficient extraction without excessive breakdown of extracted oil. The solvent vapour travelled up the column, condensed and dripped onto watermelon seed powder in Soxhlet extractor thimble, allowing extraction of watermelon oil. The extraction process continued until the solvent in the flask became clear, indicating the oil extraction was complete. The solvent-oil mixture was collected in a flask upon completion of the extraction process. The contents of the round bottom flask were cautiously transferred to a quick-fit bottom flask for rotary evaporation. The heating pan of the rotary evaporator was filled with cold water and set to a temperature of 60 °C. A quick-fit receiver flask was attached at the receiver end of the rotary evaporator. Once the heating pan and rotary evaporator were activated, the solvent began to evaporate and subsequently condensed into the quick-fit receiver. The process was closely monitored until all the solvents had been condensed into the receiver flask. The resulting crude oil remaining in the quick-fit bottom flask was then transferred to an Erlenmeyer flask. It was left uncorked for approximately 30 minutes before being securely corked. The weights of extracted crude oils from the samples were recorded for further analysis. Equation 1 was used to calculate the oil yield in per cent.

$$\text{Percentage yield} = \frac{\text{Weight of extracted seed oil}}{\text{Weight of oven-dried seed sample}} * 100 \quad (1)$$

2.4 Determination of Physiochemical Properties of Watermelon Seed Oil

1) Acid-Value (A.V.) determination

An Erlenmeyer flask was dried and filled with 2.5 g of watermelon oil, 50 ml of absolute ethanol, and 1 ml of phenolphthalein. The mixture was heated for 3 minutes and titrated with 0.1 N KOH to determine the acid value (acid number), which was subsequently used to calculate the free fatty acids (FFA) content of the oil using Equation (2).

$$\text{Acid value} = \frac{ml\ of\ KOH \times N \times 56}{Weight\ of\ sample\ used}\ \text{mg of KOH} \quad (2)$$

FFA was calculated by applying Equation (3).

$$\%\text{free fatty acid (FFA)} = \frac{\text{Acid value(A.V.)}}{2} \quad (3)$$

2) Determination of saponification value (S.V.)

A conical flask was filled with 2 g of oil. Following that, 25 ml of an alcoholic potassium hydroxide solution was added to the flask. The flask was heated for one hour while being repeatedly shaken in boiling water with a reflux condenser attached. Next, 1 ml of a 1% solution of phenolphthalein was added. The hot excess alkali was then titrated with 0.5M hydrochloric acid, and the volume of hydrochloric acid used in titration was recorded as ‘a’ (in ml). Simultaneously, a blank titration was conducted, and the volume of hydrochloric acid used in blank titration was recorded as 'b' (in ml). The saponification value was estimated using Equation (4).

$$\text{Saponification value (S.V.)} = \frac{(b-a) \times 28.05}{weight\ of\ sample} \quad (4)$$

In this equation, 'b - a' represents the difference between volumes of hydrochloric acid (HCl) used in blank and actual titration, while 28.05 is a conversion factor.

3) Determination of iodine value (I.V.)

The iodine value was determined using a method described in reference [12]. To begin, approximately 0.3 g of dry watermelon oil was accurately measured and placed in a 250 ml Erlenmeyer flask. Next, 25 ml of carbon tetrachloride (CCl_4) was added to the flask, and the contents were thoroughly mixed. The weight of the watermelon oil sample was checked to ensure an excess of 50-60% of the required Wijs solution. Subsequently, 25 ml of Wijs solution was pipetted into the mixture, and the glass stopper was reinserted after dampening it with potassium iodide solution. The mixture was then thoroughly mixed and placed in a dark cabinet for 30 minutes. A blank test was also conducted without adding watermelon oil. After the 30-minute incubation period, 15 ml of potassium iodide (KI) solution was added, followed by 100 ml of freshly boiled and cooled water. The stopper was rinsed, and the released potassium iodide (KI) solution was titrated with sodium thiosulfate ($Na_2S_2O_3$) solution using a starch indicator. The titration process was continued until the blue colour disappeared with vigorous shaking. Finally, the iodine value was calculated using Equation (5),

$$\text{Iodine Value (I.V.)} = \frac{(12.69\,(B-S)N)}{W} \quad (5)$$

where,
B = volume of sodium thiosulfate ($Na_2S_2O_3$) solution used for the blank test,
S = volume of sodium thiosulfate ($Na_2S_2O_3$) solution used for the sample,
N = normality of the sodium thiosulfate ($Na_2S_2O_3$) solution,
W= weight of the watermelon oil sample.

4) Determination of peroxide value (P.V.)

Approximately 2 g of oil sample was measured and placed into a clean, dry Erlenmeyer flask. To the flask was added 30 mL of a mixture of glacial acetic acid (CH_3COOH) and chloroform ($CHCl_3$) in a ratio of 3:2 v/v. Thereafter, drops of saturated potassium iodide (KI) solution were added to the flask and thoroughly mixed. The solution was left in the dark cupboard for 5 minutes. A standardized 0.1N iodine (I) solution was used to titrate the released iodine until a persistent yellow colour was achieved. Following that, 1 ml of the starch indicator solution was added, and the titration was carried out till the blue colour mixture disappeared. A blank titration was performed using the same procedure but without a watermelon oil sample. The peroxide value (meq/kg) was calculated using Equation (6),

$$\text{Peroxide value (meq/kg)} = \frac{(V \times N \times 1000)}{W} \quad (6)$$

where,
V=Volume of iodine solution used
N=Normality of iodine solution(0.1N)
W=Weight of oil sample(g)

5) Determination of refractive index (R.I.)

Abbe refractometer was employed to determine the refractive index (I.R). The lower prism of the instrument was coated with watermelon oil, and then the prism was sealed. The light was directed through the refractometer machine using an angled mirror, causing the reflected light to create a dark background. Refractometer's telescope tubes were adjusted until the absence of shadow, which was seen as centre dark region in the cross-wire indicator, was attained. The refractive index (RI) of oil was then read off from the refractometer's scale.

6) Specific Gravity (S.G.) determination

The 50 ml pycnometer bottle was carefully cleaned using soap and water; then rinsed with petroleum ether. Thereafter, the pycnometer bottle was weighed to determine its empty weight. The 50 ml bottle was subsequently filled with purified water, and its weight was once more measured. The 50 ml bottle was filled with the oil sample after being dried, and then weighed to determine its weight. Using the formula in Equation (7), the specific gravity (S.G.) of oil sample was determined.

$$\text{Specific gravity (S.G.)} = \frac{Weight\ of\ specific\ volume\ of\ oil\ sample}{Weight\ of\ an\ equal\ volume\ of\ distilled\ water} \quad (7)$$

7) pH determination

By first employing a buffer solution, the pH electrode was calibrated. After the calibration was finished, the pH electrode was put into the sample of watermelon oil to measure its pH level, and the readings were recorded.

8) Boiling point determination

The [13] method was employed to determine boiling point of the oil sample. The temperature at which sampled oil began to boil and transform into vapour was measured using a thermometer with an accuracy of ± 1°C. The boiling point of the oil sample is influenced by the level of unsaturation in its fatty acids.

9) Cloud point determination

The cloud point, which indicates the temperature at which the oil starts to become cloudy due to the presence of waxes or solid impurities, was determined following FSSAI 02.015:2021 method [14]. The oil samples were gradually cooled, and temperature at which a cloudiness or haze was observed was recorded.

10) Flash Point Determination

The flash point, represent lowest temperature at which vapours from the oil can ignite when exposed to an open flame or spark, was determined following FSSAI 02.004:2021 method (Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester) [14]. The oil sample was put into a container that was completely sealed, and then a source of fire or heat was introduced. The temperature at which a sudden burst of light or flame appeared was documented as the flash point.

11) Melting point determination

The melting point, which refers to temperature at which oil or fat starts to soften or become fluid enough to slip or flow, was determined using the open-tube capillary-slip method outlined in the FSSAI 02.006:2021 standard [14].

12) Flame- type determination

The type of flame produced by burning the oils was observed by igniting a small amount of oil on a heat-resistant surface. The colour, intensity, and characteristics of the flame were noted.

13) Solubility determination

The solubility of sampled oil in ether was evaluated by adding small quantity of sampled oil to an ether solvent and observing the degree of dissolution or separation. The solubility was noted as soluble, partially soluble, or insoluble.

14) Solidification temperature determination

The solidification temperature, which indicates the point at which the oil changes from a liquid to a solid, was determined by slowly lowering the temperature of the oil sample. The temperature at which the transformation into a solid state occurred was documented as the solidification temperature.

15) Retention factor determination

The retention factor (Rf) was determined using thin-layer chromatography (TLC) analysis. A stationary phase was applied to a particular plate, and a small patch of oil was added to the plate. After that, the plate was developed in the proper solvent system. The distances that the oil spot and the solvent front covered were recorded. The ratio of oil spots and the solvent front's respective travel distances was used to get retention factor value.

16) FTIR-Fourier -Transform -Infrared -Spectroscopy Procedure

A small amount of sample oil was placed on a clean, transparent infrared sample holder. A blank sample container was employed as a reference to capture the background spectrum during measurement. The sample holder with oil sample was then inserted into the FTIR instrument, and the desired settings for spectral range and resolution were adjusted. The infrared spectrum of watermelon oil was captured using the Buck Scientific M530 FTIR instrument. An interferogram was generated and converted into a spectrum using Fourier transformation. The obtained spectrum was analyzed to identify characteristic absorption peaks present in sampled oil. Comparisons were made to reference spectra or databases to determine composition of watermelon oil.

3. RESULTS AND DISCUSSIONS

3.1 Results of Physical and Chemical Properties of Watermelon Seed Oil

Table 1 presents comprehensive physicochemical analysis of watermelon oil, including oil yield, pH, refractive index, specific gravity, boiling point, cloud-point, flashpoint, melting point, viscosity, flame nature, solubility, free fatty acid

(FFA) content, acid value (A.V.), saponification value (S.V.), iodine value (I.V.), peroxide value (P.V.), congealing temperature, and retention factor (R.F).

Table 1: Physical and chemical properties of watermelon oil

S/N	Parameters	Value
1.	Oil yield (%)	43
2.	pH	4.02
3.	Refractive index @ 25^{o}C	1.452
4.	Specific gravity @ 15^{o}C	0.934
5.	Boiling point, BP (^{o}C)	326
6.	Cloud point, CP (^{o}C)	7.3
7.	Flashpoint, FP (^{o}C)	289
8.	Melting point, MP (^{o}C)	2
9.	Viscosity (Pa.s)	0.04072
10.	Flame nature	Non-sooty
11.	Solvent	Soluble in ether
12.	Free fatty acid (FFA)	3.339
13.	Acid value (mgKOH/g)	6.678
14.	Saponification Value, SV (mg/KOH/g.)	147.6315
15.	Iodine Value, IV (mg Iodine/g)	88.526
16.	Peroxide value, PV (meq peroxide/g)	16.40
17.	Congealing temperature (^{o}C)	-14 to 22
18.	Retention factor (cm)	1.6

According to Table 1, 43% of sampled watermelon seeds oil was extracted. This indicates that about 43% of the 523.15 g of watermelon seed can be recovered as oil. Using supercritical extraction to get watermelon oil, [15] achieved an oil yield of 52.37 ± 0.7%. Using solvent extraction technique, [16] obtained a yield of 50 ±0.2%, and [3] recorded a yield of 40.0% using Soxhlet extractor. In addition, [17] reported yields of 30.55%, 32.61%, and 29.98% for n-hexane, benzene, and mixed solvent using Soxhlet extraction technique, respectively. [11] reported yield of 33±1.8% and 36.3±1.9%, respectively, for two different watermelon cultivars using Soxhlet extraction method. This study's findings are consistent with previous studies. The extraction technique, sample size, and watermelon variety all affect yield variability. pH of watermelon oil was 4.02, indicating acidic. The result obtained agrees with the 3.89 reported by [3]. At 25 °C, watermelon oil's refractive index was 1.452. The refractive index (RI) is a vital characteristic that determines the purity and makeup of the oil. This result agrees with 1.471, 1.4712±0.001, and 1.46 reported by [15, 16] and [3] respectively. Also, a refractive index (RI) value of 1.4735, 1.4752, and 1.4514 was reported by [17] for n-hexane, benzene, and mixed for watermelon oil extract, respectively. The specific gravity (SG) of watermelon oil at 15 °C is 0.93364. Specific gravity is measure of density and mass of oil compared to water. This result corresponds to 0.916 [15] and 0.90 [3]. However, [10] report specific gravity (SG) of 0.69. This result of specific gravity (SG) is lower than the result reported in this current study. The boiling point (BP) of sampled watermelon oil was 326 °C. This boiling point suggests that watermelon oil can withstand high temperatures without significant degradation. Cloud point (CP) which represent the temperature oil becomes cloudy was 7.3 °C. This property is important for understanding oil stability and its behaviour under different temperature conditions. The flash point (FP) of watermelon oil in the current study was 289 °C. This result agrees with the 287.2 °C reported by [15] was reported. [3] recorded flash point of 153°C, which was lower than that found in this current study. The melting point of watermelon oil was 20 °C. This value indicates temperature sampled oil changes from solid to liquid state. The viscosity of watermelon oil was 0.04072 Pa.s. This result is well below the 4.12 Pa.s reported by [10]. Viscosity measure oil resistance to its flow and this has provided information about its use in various industrial processes. Watermelon oil has been observed to have no sooty flame characteristics, indicating that it produces minimal or no soot formation when burned. Watermelon oil is soluble in ether, indicating its compatibility with this particular solvent. The free fatty acid (FFA) content of watermelon oil was 3.339%. [18] reported free fatty acid (FFA) for sun-dried and oven-dried watermelon samples was 3.3 mg KOH/g and 2.2 mg KOH/g, respectively. But [10] determined 15.4 mg KOH/g as FFA in his work. The FFA level is a crucial factor in determining oil quality since it indicates how resistant watermelon oil is to its rancidity. The acid value (A.V) of watermelon oil was measured at 6.678 mg KOH/g. This value represents mg of KOH requires neutralizing FFA present in 1 g of sampled oil. The acid value determined in this current study is in agreement with 5.61-10.10 mg KOH/g reported by [19], but higher than 2.88, 5.44 and 3.45 mg KOH/g reported by [15] for n-hexane, benzene and mixed solvent extract of watermelon oil. Also [15] reported acid-value of 2.97 mg KOH/g was less than 6.678 mg KOH/g obtained in this current research.

The saponification value (S.V) of watermelon oil in our current study was found to be 147.6315 mg/KOH/g. This value is lower than previously reported in studies by [19], where they observed a range of 196.35-325.38 mg/KOH/g and a specific value of 181.40 mg/KOH/g [20]. Conversely, the saponification value (S.V) reported in this present study is

greater than 116.54 mg /KOH/g reported by [3]. The saponification result provides vital insights into the composition of fatty acid in the oil. A particular degree of saponification results when fatty acid concentration is higher than what is advised for cooking oil. When fatty acid decreased to a level that is above what is advised for cooking oil, it results in a degree of saponification, which suggests that watermelon oil is suitable for soap manufacturing. The iodine value(I.V) of the watermelon sampled oil was 88.526 g iodine/g. Although the observed result was lower than 156±0.2 g iodine/g claimed by [16] and 149 g iodine/g reported by [15]. To evaluate the oil's oxidative stability, the iodine number, which expresses the oil's unsaturation level, is employed. The peroxide value (P.V) of sampled oil was measured at 16.40 meq peroxide/g. The observed value was far higher than 3.24±0.1 meq peroxide/g by [16], 2.9 meq peroxide/g reported by [15] but within 2-16 meq peroxide/g reported in the work of [19]. Peroxide value (PV) reflects level of oxidation and existence of peroxides in the sampled oil. The congealing temperature range for the watermelon oil samples fell between -14 °C to 22 °C, as depicted in Table 1. This property indicates the temperature range at which the oil sample solidifies. The retention factor of watermelon oil was 1.6 cm. The retention factor is employed in chromatography for assessing the movement characteristics of various constituents present in oils.

3.2 Discussion of FTIR Analysis of Watermelon (*Citrillus Lanatus)* Seed Oil

Figure 1 depicts watermelon seed oil's FTIR spectrum. FTIR results for watermelon **(***Citrillus Lanatus***)** seed oil are summarized in Table 2.

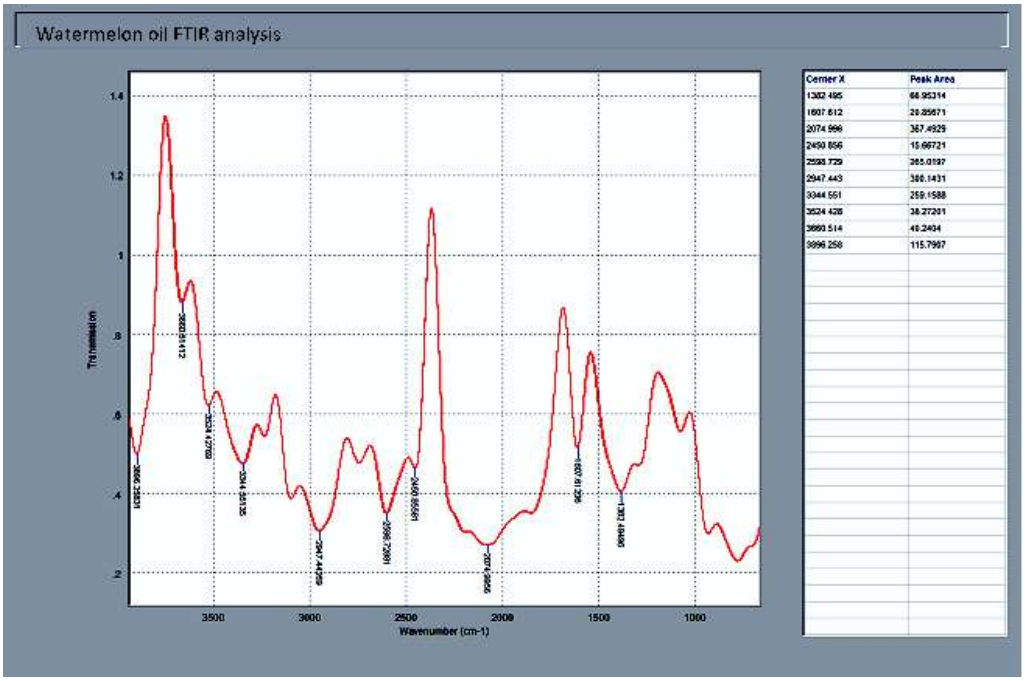

Figure 1: Watermelon (*Citrillus lanatus*) oil FTIR spectra

Table 2: Summary of watermelon oil FTIR analysis

S/No.	Wavelength (cm^{-1})	Assignment	Functional Group	Compound present
1.	3896.258	OH Stretch	Hydroxyl group (OH)	Alcohols or phenols
2.	3660.514	OH Stretch	Hydroxyl group (OH)	Alcohols or phenols
3.	3524.428	OH Stretch	Hydroxyl group (OH)	Alcohols or phenols
4.	3344.551	N-H stretch	Amine group(N-H)	Amines or amino acids
5.	2947.443	C-H stretch	Aliphatic hydrocarbon(C-H)	Alkanes or alkyl groups
6.	2598.729	C=O stretch	Carbonyl group(C=O)	Ketones or aldehydes.
7.	2450.856	C=O stretch	Carbonyl group(C=O)	Ketones or aldehydes.
8.	2074.996	C-N stretch	Carbon-nitrogen bond(C-N)	Amines or amides
9.	1607.612	N-H bend	Amine group(N-H)	Amines or amino acids
10.	1382.495	S=O stretch	Sulfoxide group(S=O)	Sulfoxide groups

The FTIR analysis of watermelon oil sample revealed presence of several functional groups. The identified functional groups include hydroxyl groups (OH), amine groups (N-H), aliphatic hydrocarbon groups (C-H), carbonyl groups (C=O), carbon-nitrogen bonds (C-N), and a sulfoxide group (S=O). These findings are consistent with previous studies [21], [22], [23], confirming the reliability of FTIR analysis. The observed peaks at specific frequencies provided valuable insights into

chemical compounds present in watermelon sampled oil. Peaks at frequencies corresponding to OH stretch (3896.258 cm^{-1}, 3660.514 cm^{-1}, and 3524.428 cm^{-1}) indicated presence of hydroxyl (OH) groups, suggesting the existence of compounds containing hydroxyl groups, such as alcohols or phenols. The occurrence of a peak at 3344.551 cm^{-1} suggested vibration in the N-H bonds, signifying presence of compounds containing amine groups, such as amines or amino acids. This observation was further supported by a peak at 1607.612 cm^{-1}, which represents a bending vibration of N-H bonds. Aliphatic hydrocarbon groups (C-H) presence was confirmed by the observed peak at 2947.443 cm^{-1}, corresponding to the stretching vibration of C-H bonds typically found in hydrocarbon chains. The peaks observed at frequencies ranging from 2598.729 cm^{-1} to 2450.856 cm^{-1} indicated stretching vibrations of C=O bonds, suggesting presence of carbonyl groups such as ketones or aldehydes in oil sample. A peak at 2074.996 cm^{-1} suggested presence of carbon-nitrogen bonds (C-N), signifying the existence of compounds like amines or amides. Furthermore, the 1382.495 cm^{-1} peak indicated a stretching vibration of S=O bonds, suggesting presence of compounds containing sulfoxide groups.

3.3 Some Applications of Watermelon Oil

1) **Antioxidant properties:** According to a study conducted by [24], it was observed that watermelon oil exhibits more potent antioxidant properties compared to other seed oils. Watermelon oil exhibits significant antioxidant activity [25, 26, 27]. Antioxidants play a crucial role in combating oxidative stress, shielding cells from harm caused by free radicals. Antioxidants also help to lower chances of developing chronic ailments including cardiovascular disease, cancer etc.
2) **Anti-inflammatory effects:** Studies have put forward that watermelon oil possesses anti-inflammatory properties [26]. These effects may perhaps ascribe to specific bioactive complexes in the oil, which help alleviate inflammation and associated conditions.
3) **Antimicrobial activity:** Watermelon oil has demonstrated antimicrobial properties against various pathogens, including bacteria and fungi [27].
4) **Application in Cosmetics/Personal Care Products:** Watermelon oil has found used in cosmetic and skincare formulations as it's possesses moisturizing and skin-softening properties. It nourishes and moisturizes the skin, contributing to a healthy complexion. It's used ranges from different products which includes moisturizers, body lotions, hair care formulations and lip balms, contributes to healthier skin and hair [10, 28].
5) **Culinary Applications:** Watermelon seed (*Citrullus lanatus*) oil offers culinary benefits and provides a unique flavour and aroma. Watermelon oil has been utilized as suitable and edible cooking oil [29, 30]. Additionally, watermelon oil is added to salads, marinades, and sauces to boost flavour and nutritional content.
6) **Pharmaceutical and Nutraceutical Applications:** Watermelon oil contains bioactive compounds such as phytosterols, tocopherols, and carotenoids. These compounds possess antioxidant, anti-inflammatory, and anti-cancer properties, making *Citrullus lanatus* oil a promising ingredient in pharmaceutical and nutraceutical formulations [29]. Watermelon oil extracts contains secondary metabolites which allowed traditional healers to use it as an indigenous ethnomedicine [31]. Numerous phytochemicals like phenolic acids, flavonoids, alkaloids, and saponins can be located within watermelon seeds oil. Consequently, watermelon seeds oil has variety of therapeutic uses which includes antibacterial, anti-inflammatory, hypoglycemic, antihypertensive, antilipidemic, antineoplastic, and cardioprotective [32].
7) **Industrial application:** Emulsions and nano-emulsion paints have been formulated from watermelon seeds oil extract [24]. The utilization of watermelon oil has been employed as a key component in the synthesis of biodiesel [33].

4. CONCLUSION AND RECOMMENDATIONS

This study successfully extracted and characterized watermelon (*Citrullus lanatus*) oil, revealing its favourable physicochemical properties and the presence of functional groups. The high yield and valuable properties of watermelon oil make it a promising candidate for applications in various industries. The oil's ether solubility and soot-free flame quality enhance its utility in various formulations. The present of hydroxyl, amine, aliphatic hydrocarbon, carbonyl, carbon-nitrogen bonding, and sulfoxide groups in watermelon oil expands its potential applications. Further research study is needed to fully explore the antioxidant, antimicrobial, and nutritional values.

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