

Valorisation of waste Ogbomoso mango (*Mangifera indica* L.) Kernel as Precursor for Vegetable Oil Extraction

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Abstract: Mango seed kernel oil was extracted using Soxhlet extraction with petroleum ether, ethanol and N-hexane. The mango oil yield from ethanol, N-hexane and petroleum ether was 20%, 13% and 8%, respectively. The physicochemical properties (acid value, iodine value, peroxide value and saponification value) of the mango seed kernel oil were examined. There was significant variation observed in Ash 1.05-2.95 %, protein value 3.985-6.17%, saponification value 163.76-176.66 mg KOH/g, iodine value 6.24-7.27 mg KOH/g, acid value 7.95-9.59%, peroxide value 0.46-2.28 meq/kg, and free fatty acid 1.47-2.24% of mango kernel oil produced. The results suggested that mango seed kernel oil can be economically useful.

Keywords—Ogbomoso Mango, Solvent Extraction, Vegetable Oil

1. INTRODUCTION

Mango (*Mangifera indica* L.) is one of the most important fruits for nutritional and economic aspects. In Nigeria (Ogbomoso), the fruit of *Mangifera indica* L. is popularly known as "sherri," followed by variety names such as "Ogbomoso mango," "Cherry," or "Sherry." Mango consists of an edible peel and seed. The seed consists of a tenacious coat enclosing the kernel. It is present in about 18% of the total fruit (Mas'ud *et al.*, 2018). The mango fruit is a drupe, or stone fruit, which embeds a shell within its hardened endocarp (Fang *et al.*, 2025). Mango (*Mangifera indica* L.) belongs to the Anacardiaceae family, a family of fruit-bearing trees.

Mangoes (*Mangifera Indica*) are one of the most popular fruits in the world and are cultivated in more than 100 countries at both tropical and subtropical latitudes (Ohale *et al.*, 2022). According to FAOSTAT (2016), Nigeria is the 10th largest producer of mango in the world (917,617 metric tons) and the second largest producer in Africa behind Egypt. Mango seed (MS) is a major by-product of mango fruit processing. It consists of a thick and rigid endocarp which enfolds the kernel (Ohale *et al.*, 2022). Currently, there are over 1000 known varieties of mango, whose nomenclature is sometimes complicated because of certain regionalisms. In the world, only a few varieties are grown on a commercial scale and traded (Solís-Fuentes and Durán-de-Bazúa, 2020).

Mango seed kernel (MSK) is an important source of nutrients and oil (Mas'ud *et al.*, 2018). Mango seed kernel is

being re-evaluated not only for its qualities as a natural food (edible, non-toxic, with a high quality protein and amino acid score) and for the biological activity of some of its constituents (lipid fractions and phenolic compounds identified as active antioxidants and modulators of lipid metabolism) that have shown positive impacts, directly or indirectly (Solís-fuentes and Durán-de-bazúa, 2020), on health and nutrition, but also because its fat in the natural state has shown significant functional and physicochemical characteristics that could lead to it replacing fats like cocoa butter or others that are widely used in industry and in food processing but are now facing serious objections because of their adverse effects on nutrition and human health (Choudhary *et al.*, 2022).

Mango kernel oil can be defined as the oil fraction extracted from the mango seed; it contains nearly 15% oil. Mango kernel is a potential source of a wide range of bioactive compounds and antioxidants (Gurjar and Raj, 2022). Mango kernel oil is favourable and a safe source of edible oil and was found to be nutritious and non-toxic, so that it could be substituted for any solid fat without adverse effects. Mango kernel oil can be used in butterscotch toffee given that mango kernel oil and cocoa butter are almost uniform in several of their triglycerides, fatty acids and effects on the taste, odour and texture of the toffee, mango seed kernel oil also has been used as an ingredient in soaps, shampoos and lotions as it is a good source of phenolic compounds (Singh Yadav and Paudel, 2022).

Mango seed kernel oil (MSKO) is a promising edible oil, a safe and natural source of edible fat; it does not contain trans FA. MSKO is a promising and safe source of edible oil and was found to be nutritious and non-toxic, so that it could be a substitute for any solid fat without adverse effects. Toxicity was not observed in rats fed diets containing 100g/kg crude MSKO. The lipids were extracted from several varieties of mangoes, free of toxic materials such as hydrocyanic acid (Mas'ud *et al.*, 2018). Mango kernel oil is rich in unsaturated fatty acids and phenolic compounds, making it used as a nutritious oil and in the cosmetics industry (Erwa *et al.*, 2019).

Variation in oil content in some reports is due to differences in plant variety, cultivation (soil, climate, etc.), ripening stage, harvesting time and the extraction method of oil used (Mas'ud *et al.*, 2018). This can be a result of differences in the climatic conditions of their geographical locations. Previous studies on the kernel of *Mangifera indica* varieties revealed high levels of saponification value ranging from 143.6 to 207 mg KOH/g oil. The major fatty acids detected in *Mangifera indica* are stearic acid, oleic acid, linoleic acid, and arachidonic acid (Erwa *et al.*, 2019). The oil produced from the mango seed kernel could be an efficient method of utilizing the waste seed kernels. The operating conditions, including the particle size, extraction time, and solvent type, solid-to-solvent ratio, temperature and moisture content, were proved to have an effect on the oil yield (Kemal *et al.*, 2018).

Soxhlet extraction, maceration, microwave-assisted extraction, ultrasound-assisted extraction, high hydrostatic pressure extraction and supercritical fluid extraction with CO₂ are among the different solvent extraction techniques used for extraction of phenolic compounds in plants (Anta *et al.*, 2020). Solvent extraction is the most common means of recovering phenolic compounds from plant materials due to the simplicity of the technique, efficiency, and a wide range of possible applications (Gurjar and Raj, 2022). Although it is a simple process, chemical extraction is driven by conditions such as time allotted for extraction, extraction temperature and sample-to-solvent ratio, which affect yield and extent of recovery (Singh Yadav and Paudel, 2022). Under the same conditions, the nature of the compounds to be recovered is an important factor to consider, as it helps in selecting the most suitable solvent for extraction. No single solvent can extract all of the bioactive compounds in a plant material, and it is with this premise that binary solvent systems, water and organic solvent, are favoured as opposed to their native counterparts (Lim *et al.*, 2019).

Consistent with the concept of a circular bioeconomy, extraction supports resource recycling, waste minimization, and greenhouse gas reduction, contributing to the achievement of selected United Nations Sustainable Development Goals (SDGs) (Gabriele *et al.*, 2026). Addressing these systemic inefficiencies is essential to achieving the United Nations Sustainable Development Goals (SDGs); the valorisation of agricultural waste aligns with

several Sustainable Development Goals (SDGs), particularly (Acharya and Narula, 2025). SDG 2 ("Zero Hunger"), SDG 3 ("Good Health and Well-being"), SDG 12 ("Responsible Consumption and Production"), and SDG 13 ("Climate Action") (Franco, 2023). The transition toward sustainability requires not only technological innovation but also the restructuring of production and consumption systems, underpinned by circular bioeconomy principles that prioritize resource recirculation, waste minimization, and value retention throughout the food chain (Gabriele *et al.*, 2026).

This study focuses on sherri-mango cultivars due to their unique agronomic and taste requirements, widespread cultivation, and plant-based compounds. Sherri yields a high-unsaturated oil, suitable for industrial use. This study provides an expansive perspective on mango kernel oil, highlighting its applications in food, cosmetics, and industrial sectors, informed by the variety of mangoes utilized.

2. MATERIALS AND METHODS

2.1 Research materials

The Sherri mango varieties utilised in this study were procured from the fruits and vegetable market at Odo-oba, Ogo-Oluwa Local Government, Ogbomoso, Oyo State, Nigeria (8° 3' 23.9" N and 4° 8' 45.1" E). The taxonomist at the Department of Crop Production, LAUTECH, verified these mango varieties.

2.2 Chemicals and reagents

Necessary chemicals and reagents for mango kernel oil analysis are n-hexane, methanol, sulphuric acid (H_2SO_4), hydrochloric acid (HCl), potassium hydroxide (KOH), sodium hydroxide ($NaOH$), phenolphthalein indicator, Wijs reagent, sodium thiosulphate solution ($Na_2S_2O_3 \cdot 5H_2O$), starch indicator, potassium iodide (KI), acetic acid, perchloric acid, chloroform, distilled water, fatty acid methyl ester (FAME) standard mixture, anhydrous sodium sulphate (Na_2SO_4), and distilled water. All these chemicals and reagents were of analytical grade. They were purchased from Mich-Mikendenson Nigeria Limited in Ilorin, Kwara State, Nigeria.

2.3 Methods

2.3.1 Material processing

Five kilograms (5 kg) of sherri-mango were rinsed with tap water and subsequently peeled using a kitchen knife to obtain the seed. The seeds were sun-dried for a period of 7 days. The covering layer of the core was removed to obtain the maximum kernel portion; the kernels were removed from their tenacious leathery coat, and then they were milled using a Kenwood blender mill (BLP15.150WH, China) into a fine powder or flour to obtain a small particle size for better solvent penetration. Kernel flour was packaged and placed in the freezer to await the extraction process.

2.3.2 Technique for oil extraction

The solvent extraction technique described by Torsen *et al.* (2025) was used with slight adjustments. One thousand five hundred grams (1500 g) of mango kernel powder was wrapped in muslin fabric and placed into a 1500 mL conical flask. The flask held 500 mL of n-hexane solvent and was tightly sealed at its opening. The sample was allowed to sit for 12 hours for the extraction of oil. The experimental apparatus was then subjected to heating through a regulated water bath maintained at 70 °C. The solvent and oil underwent separation, followed by the retrieval of the solvent through distillation. The extracted oil was subjected to phytochemical screening (Yadav *et al.*, 2022).

The percentage oil yield was calculated as outlined by Torsen *et al.* (2025).

$$\text{Percentage Oil Yield (wt. \%)} = \frac{\text{Volume of the Oil (g)}}{\text{Weight of the sample (g)}} \times 100 \quad (1)$$

2.3.3 Determination of physicochemical properties of the extracted Mango kernel oils

The iodine value, peroxide value, saponification value, acid value, fatty acid profile, crude fibre, titratable acidity of the oil, protein content, specific gravity and density, fat content, viscosity and carbohydrate content were determined according to the method described.

2.3.3.1 Moisture content

The moisture content was evaluated by the hot-air oven method by drying the sample in a hot-air oven at 105° C to constant weight, as indicated by AOAC method number 930.15 (Ojha *et al.*, 2019).

2.3.3.3 Protein determination

Two grams of the sample and eight grams of the catalyst mixture were measured on filter paper and transferred to a digestion flask. 20 mL of concentrated H_2SO_4 solution was introduced into the flask, which was subsequently heated at an angle. Heating persisted with intermittent spinning until the solution became colourless; thereafter, the resultant solution was diluted to 100 mL in a volumetric flask using distilled water (Kayode *et al.*, 2020). The processed sample underwent distillation with a 10 mL solution of 50%, and the resulting distillate was placed in a beaker containing 10 mL of 1% boric acid, with screened methyl red as the indicator. This was subjected to titration using a 0.05 M solution (Torsen *et al.*, 2025). The outcome was expressed in Equation 2.

$$\% \text{ Nitrogen} = \frac{\text{sample titre} - \text{Blank titre} \times 0.0014 \times 100}{\text{sample weight}} \quad (2)$$

$$\text{Crude protien (\%)} = \% \text{ Nitrogen} \times 5.83 \quad (3)$$

where 0.0014 is the g of nitrogen in 0.05 M, and 10 mL is the dilution factor.

2.3.3.2 Determination of crude fibre

Three grams (3 g) of the defatted sample were placed in the round-bottom flask containing 200 mL of 0.13 M H_2SO_4 and were refluxed for 30 minutes. The solution was filtered through a linen cloth on a funnel and washed with boiling water. The residue was transferred to a beaker and boiled for 30 minutes with 200 mL of 0.313 M NaOH (Kayode *et al.*, 2020). The residue was mixed with 50 mL of acetone to remove any further traces of oil and placed in a crucible. This was then dried in the oven at 1050°C for one hour and then incinerated in the muffle furnace (Joyce *et al.*, 2014). The result is expressed in Equation 3.

$$\text{Crude fibre (\%)} = \frac{100 - (W_1 - W_2)}{W} \quad (3)$$

where W_1 = weight in gramme of porcelain and content before ashing, W_2 = weight in gramme of porcelain crucible containing ash and W = weight of sample in gramme

2.3.3.4 Fat content determination

Two hundred and fifty (250 ml) round-bottom flasks were washed and dried in an oven for one hour at 105°C. It was then cooled in the desiccator and weighed. The thimbles were washed with the solvent used for extraction, dried in the oven, and cooled in the desiccator. 2 g of moisture-free samples was weighed, wrapped with filter paper, and placed in the thimble, which was then plugged with defatted (soaked in ether) cotton wool with 200 ml of petroleum spirit in a round-bottom flask, and the extraction was carried out for six hours (Jin *et al.*, 2016). After extraction, the solvent was distilled off, and the weight of residual fat was noted; this was calculated as a percentage of the sample used for characterization of seed kernel oil of Bangladeshi mango and its evaluation as a cosmetic ingredient. Crude fat is calculated using Equation 4 (Kayode *et al.*, 2020).

$$\text{Crude fat (\%)} = \frac{WF - W}{S} \times \frac{100}{1} \quad (4)$$

where, WF = weight of the receiver flask and fat deposits, W = weight of empty receiver flask only and S = weight of sample used

2.3.3.5 Determination of iodine value

The iodine value was determined using AOAC (Ohale *et al.*, 2022). Method No. Cd 1–25. Oil extracted from the mango kernel was digested in the volumetric flask (with lid) using 5 mL of carbon tetrachloride (CCL_4) and 25 mL of Wijis solution. The flask was then distilled for an hour in the dark with 20 mL of a 15% potassium iodide solution and 25 mL of distilled water. The flask solution was then titrated against $Na_2S_2O_3$ and freshly prepared starch indicator. The reading was observed without executing the sample (Ojha *et al.*, 2019). The iodine value of the extracted oil was calculated as specified by Eq. 5.

$$\text{Iodine Value} \frac{g}{100g} = \frac{(B - S) \times 12.69 \times n}{\text{Weight of sample (g)}} \quad (5)$$

where S is the value of $Na_2S_2O_3$ used in the sample, and B is the volume of $Na_2S_2O_3$ used in the empty sample.

2.3.3.6 Determination of peroxide value

The peroxide value of the extracted oil was determined using the AOAC (Zahoor *et al.*, 2023) Method No. Cd 8b-90 procedures. Five grammes were mixed with 250 mL in an Erlenmeyer flask. These were then added to 30 mL of glacial acetic acid, a mixture in chloroform solution. Once covered, the flask was gently agitated for about a minute to dissolve the oil thoroughly in the solvent mixture. Then, 0.5 mL of freshly prepared potassium iodide (KI) solution was added to the beaker. A constant stream of stirring was applied to the solution while titrating it against a 0.1 N standard sodium thiosulphate ($Na_2S_2O_3$) solution until the yellowish hue disappeared completely. Then, 0.5 mL of starch solution was used as an indicator, and the titration was carried out with vigorous stirring until the dark blue colour disappeared. Individual measurements of empty readings were conducted without sample runs (Villanueva *et al.*, 2020). The concentration of peroxide is determined using the formula in Eq. 6.

$$\text{Peroxide Value} = \frac{(B-S) \times N \times 1000}{\text{Weight of sample (g)}} \times 100 \quad (6)$$

where N is the normality of $Na_2S_2O_3$ S is the volume of $Na_2S_2O_3$ used in the sample, and B is the volume of $Na_2S_2O_3$ used in the empty sample.

2.3.3.7 Determination of saponification value

The saponification value of the mango kernel oil was assessed according to AOAC Method No. CD 3a-94. Two (2 g) samples were placed in a conical flask and dissolved in 25 mL of 0.5 N alcoholic potassium hydroxide solution. Subsequently, the reaction mixture was circulated for 30 minutes through the water condenser in the water bath. The produced solution was subsequently cooled to ambient temperature and titrated using a 0.5 N HCl solution, incorporating 1 mL of phenolphthalein indicator. The endpoint reading was assessed autonomously utilising Equation 7. (Villanueva *et al.*, 2020).

$$\text{Saponification value} = \frac{(B-S) \times 0.02805 \times 1000}{\text{weight of sample (g)}} \quad (7)$$

2.3.3.8 Determination of acid value

The acid value, known as the neutralization number, acid number, or acidity, refers to the mass of potassium hydroxide (KOH) in milligrams necessary to neutralize one gram of a chemical compound. The acid number quantifies the concentration of carboxylic acid groups inside a chemical substance, like a fatty acid, or within a blend of various substances (Nwaokobia *et al.*, 2020). The acid value of mango kernel oil was assessed according to the methodology outlined by AOAC (Nwaokobia *et al.*, 2020). In a conical flask, one gram (1 g) of the oil sample was diluted in 50 mL of ethanol, followed by the addition of 2 to 3 drops of phenolphthalein indicator, and titrated with 0.1 N potassium hydroxide solution (KOH) until a pink endpoint was reached

(Diomande, Kh *et al.*, 2021). The acid value was ascertained utilizing the equation. 8.

$$\text{Acid value} = \frac{V \times C \times 56.1 \times 1000}{\text{weight of sample (g)}} \quad (8)$$

where V represent the volume of KOH solution consumed during titration, measured in mL; C denote the concentration of the KOH solution, expressed in mol/L; and 56.1 signifies the molar mass of potassium hydroxide, in g/mol.

2.3.3.9 Determination of fatty acid profile

Fatty acids in extracted oils were determined by High-Pressure Liquid Chromatography (HPLC) (Buck Scientific BLC 10/11 USA) according to the method described by AOAC (Jin *et al.*, 2016). Hexane was used as a solvent to extract the oil content of the samples using a Soxhlet extractor. They were converted to methyl esters via the ISO process (Jin *et al.*, 2016). Fatty acid methyl esters (FAMES) were isolated using petroleum ether and analysed using an HPLC system with a fixed-wavelength UV detector. The mobile phase comprises 59:41 acetonitrile and 2-propanol, and the column is a Prevail C-18 (5 μ m, 150 $\times$ 4.6 mm) with a 1 mL/min flow rate. The temperature of the oven was maintained at 210°C for 45 min. Peak identification was carried out by comparing the retention times of authentic fatty acid standards with those extracted from samples using the Peak Simple chromatography data system processor (Buck Sci. Chromatopac data processor). The fatty acid composition was expressed as a % of total fatty acids (Awolu and Manohar, 2019).

2.3.3.10 Determination of titratable acidity of the oil

In the study, the sample oil's titratable acidity (TA) was analysed according to the methodology described in AOAC. A total of 10 mL of oil extract was transferred to a beaker and titrated with 0.1 N sodium hydroxide ($NaOH$) solution, using phenolphthalein solution as an indicator. Titratable acidity was determined as a percentage of oleic acid, as expressed in Equation 9 (Awolu and Manohar, 2019).

$$\text{Titratable acidity (TA)} = \frac{V \times N \times \text{Titre value}}{\text{Volume of sample used}} \times 100 \quad (9)$$

where, V represents the volume of $NaOH$ in litres (L) and N denotes the normality of $NaOH$

2.3.3.11 Determination of specific gravity and density of the oil

The specific gravity of mango kernel oil was determined according to the procedure outlined by AOAC (Erwa *et al.*, 2019). The specific gravity bottle was cleansed with detergent, rinsed with distilled water, dried, and subsequently weighed (W_1). The bottle contained water and had a weight of (W_2). Subsequent to the dried bottle, it was filled with a sample of oil and weighed (W_3) as expressed in Equation 10 (Villanueva *et al.*, 2020).

$$\text{Spevific gravity} = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad (10)$$

where, W_1 = weight of the empty specific gravity bottle, W_2 = weight of the specific gravity bottle containing water, W_3 = weight of the bottle containing the oil sample.

The following equation was employed to determine the density of oil.

$$\text{Density of oil} = \text{Specific gravity} * \rho_{\text{water}}$$

where ρ_{water} represents the density of water, which is 1000 kg/m³.

2.3.3.12 Determination of viscosity of oil

The oil's viscosity was evaluated following the Brookfield method from the ASTM (Singh Yadav and Paudel, 2022) guideline D2983. The viscosity was measured using a rotational viscometer (Model: Visco Elite-R, V4002). The oil is held in a glass tube for this test and placed in a temperature-controlled insulated block (40°C). The oil is subjected to a metal spindle that is rotated at a constant speed, allowing the torque required to maintain its rotation to be recorded. The absolute viscosity of the oil was calculated based on the rotation resistance under the induced shear stress of the oil. The absolute viscosity is given in centipoise (cP = mPa.s, SI units) (Nzikou *et al.*, 2020).

2.3.3.13 Carbohydrate content determination

Carbohydrate content in the food decomposition table is usually given as total carbohydrate by difference. That is, the percentage of water, protein, crude fibre, fat and ash subtracted from 100%, as expressed in Equation 11.

$$\text{Carbohydrate content} = 100\% - (\% \text{moisture} + \% \text{protein} + \% \text{ash} + \% \text{fat} + \% \text{fibre})$$

3.0 RESULTS AND DISCUSSION

3.1 Effect of Solvent Types on Mango Oil Yield from Selected Solvents

The mango oil yield from ethanol, n-hexane, and petroleum ether was 20%, 13% and 8%, respectively, as shown in Figure 1. Ethanol (20% yield) provides the highest value compared to petroleum ether (8% yield). The result of 20% ethanol yield is significantly higher than some traditional Soxhlet extraction benchmarks, which have reported yields as low as 8.2% by K. Nwaokobia *et al.* (2020), but lower than yields achieved through advanced methods like microwave-assisted hydrodistillation, which can reach between 40% and 50%, as reported by Rahmiyati *et al.* (2025). This suggests that the extraction yield is quite efficient compared to standard solvent extraction but could be further optimized with modern techniques.

The results of the 13% N-hexane yield align closely with existing literature. For instance, a study reported a Soxhlet N-hexane yield of 13.06% by K. Nwaokobia *et al.* (2020). N-Hexane is a standard industry choice due to its high selectivity for neutral lipids and fatty acids (de Jong and

Ferreira, 2017). The results of petroleum ether (~8% yield): The yield from petroleum ether is relatively low compared to that of hexane and ethanol, as reported by Juhaimi *et al.* (2019) and Awolu and Manohar (2019), due to petroleum ether's limited polarity, which led to reduced oil extraction compared to ethanol and N-hexane.

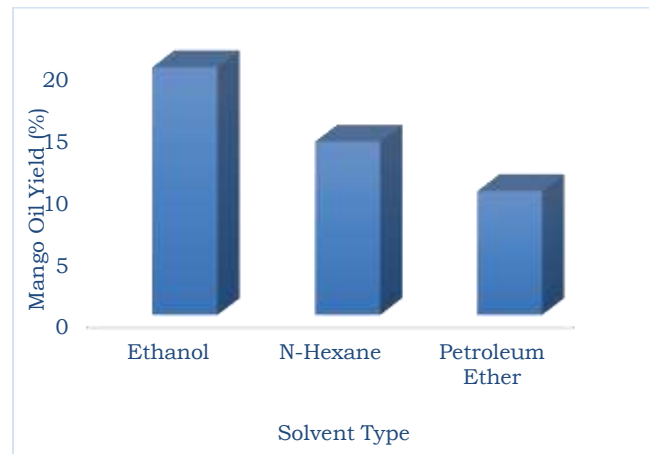


Figure 1: Mango Oil Yield from Selected Solvents

3.2 Proximate composition of Mango, *M. indica*, seed

3.2.1 Moisture content

The results of the moisture contents in raw mango seed flour and defatted mango seed cake studied are shown in Table 1. Ethanol-defatted mango seed cake had the highest moisture content (12.15%), while raw mango seed flour had the lowest (1.1%). Moisture content is substantially higher in defatted cakes (10.15% to 12.15%) compared to raw flour (1.1%). This trend is commonly observed due to changes in seed matrix and solvent interaction during defatting, which can retain more moisture.

The moisture content varied substantially across preparations, from 51.1% in the raw seed flour to 12% (N-hexane), 10.15% (petroleum ether), and 12.15% (ethanol) in the defatted cakes. The elevated moisture in the raw material reflects the hydrophilic nature of protein-fibre complexes and the presence of water-soluble compounds. The successful reduction of moisture in all defatted samples to approximately 10-12% suggests that the drying process following defatting was effective and achieved moisture levels suitable for shelf stability. These moisture levels align well with food safety standards, as demonstrated by complementary research on other seed cakes showing optimal moisture content below 10-11% for microbial stability and texture preservation. The moisture content obtained from petroleum ether defatted mango seed cake (10.5%) is likely lower than the moisture content reported by Falola *et al.* (2025), who obtained 11%. But slightly higher than the 9% reported by Maldonado-Celis *et al.* (2025).

3.2.2 Ash content considerations

The ash content ranged from 1.9% in the raw material to 1.05% (N-hexane), 2% (petroleum ether), and 2.95% (ethanol), as shown in Table 1. The ethanol-defatted sample exhibited notably higher ash content, suggesting potential extraction or concentration of mineral elements through the ethanol solvent interaction. The ash values are relatively moderate compared to other legume and seed materials. For context, African bush mango seeds have shown ash contents of 1.97-3.50% (Maldonado-Celis *et al.*, 2025), while watermelon seeds demonstrated 4.45% ash (Maldonado-Celis *et al.*, 2025). The ash content of mango seeds is therefore on the lower end of the range for seed-derived materials, suggesting moderate to low mineral density compared to other potential functional ingredients, though the specific micronutrient profile would require further mineral analysis. Ash content varies slightly, with ethanol defatted cake having the highest ash (2.95%) and raw flour the lowest (1.9%), suggesting mineral concentration increases post-defatting, consistent with other proximate analyses of defatted seed flours.

3.2.3 Crude protein contents

The proximate analysis of raw mango seed flour shows a higher crude protein content (13.45%) compared to the defatted mango seed cakes, which have protein contents ranging from 3.985% to 6.17% depending on the solvent used for defatting, as shown in Table 1. This decline in protein content after defatting is consistent with other studies where oil extraction reduces the overall protein percentage due to the removal of lipid fractions.

The crude protein content of 13.45% in the raw mango seed flour represents a significant nutritional asset, and this finding aligns well with prior research on mango seed utilization. Research on mango seed kernels has reported protein contents ranging from 4.94 to 9.20% on a dry weight basis depending on the variety and processing method (Muchiri *et al.*, 2012). However, the slightly higher protein content observed in the present study may be attributed to the inclusion of the seed coat and other seed components, not just the kernel. When the seeds were defatted using different methods, the protein content varied considerably: N-hexane defatted cake showed 4.85%, petroleum ether defatted cake demonstrated 6.17%, and ethanol defatted cake exhibited 3.985%. This inverse relationship between protein concentration and defatting efficiency suggests that the extraction methods differentially affected the retention of protein-bound compounds. The N-hexane treatment, being highly non-polar, may have had greater affinity for lipid-protein complexes, potentially extracting some protein-associated lipids that were less affected by the more polar solvents (Falola *et al.*, 2025).

When compared with other seed flours valorised for food applications, the protein content of the raw mango seed flour falls within a reasonable range for seed-derived food ingredients. For instance, jackfruit seed flour has been reported with protein contents of approximately 12.22-12.79

g/100 g (Sreejaya *et al.*, 2024), while watermelon seed flour demonstrates protein contents around 22.89% (Sikdar *et al.*, 2017). The protein content of mango seeds is therefore intermediate, suggesting it could serve as a functional ingredient without requiring extensive fortification strategies, though potential co-processing with complementary plant proteins might enhance its food application potential.

3.2.4 Crude fibre

Crude fibre content increases in defatted cakes. The highest fibre was found in the petroleum ether defatted seed cake (14.05%) compared to raw flour (9.3%), as shown in Table 1. This increase aligns with findings in similar seed studies, indicating that defatting concentrates the fibrous fraction as lipids are removed.

The crude fibre content of 9.3% in the raw mango seed flour increased to 13.2% in the N-hexane defatted cake, 14.05% in the petroleum ether defatted cake, and 11.3% in the ethanol defatted cake. This substantial increase in fibre concentration following defatting is consistent with the principle that dietary fibre, being largely hydrophobic and lipid-insoluble, becomes proportionally enriched when fat is removed. The higher fibre content in petroleum ether- and N-hexane-defatted samples compared to ethanol-defatted samples suggests that ethanol extraction may have also removed some soluble fibre components or altered fibre structure through partial hydrolysis of fibre-associated compounds.

Comparative literature demonstrates that seed fibres vary considerably based on botanical source and processing method. African bush mango seed flour has shown crude fibre contents ranging from 13.00 to 16.75% depending on drying temperature (Maldonado-Celis *et al.*, 2025), while watermelon seeds exhibited a fibre content of 14.00% (Sreejaya *et al.*, 2024). The fibre profile observed in the mango seed samples is therefore competitive with these other potential functional ingredients. The significance of elevated fibre content extends beyond basic nutrition; it indicates potential prebiotic functionality and capacity for supporting gastrointestinal health. The effects of the different defatting methods on fibre content suggest that petroleum ether extraction may be the best way to retain as much fibre as possible. However, this benefit must be weighed against the fact that solvents can be toxic and that food applications must obtain regulatory approval.

3.2.5 Crude fat (ether extract)

The ether extract (crude fat) of 9.95% in the raw mango seed flour represents the lipid content before defatting. The N-hexane defatted cake retained 6.21% fat, indicating approximately 37.5% fat removal efficiency, while the petroleum ether defatted cake maintained 4.15% fat (58.3% removal efficiency), and the ethanol defatted cake showed 0.15% residual fat (98.5% removal efficiency), as shown in Table 1. In contrast, some mango varieties were reported to have higher fat contents. These findings were for 2 Costa

Rican varieties (10.70%–11.90%), 11 Indian varieties (9.90%–12.60%), and 3 Kenyan varieties (9.70%–10.40%) (Mokbul *et al.*, 2022). Besides geographical variations, the maturity of the fruit also affects the fat content, with ripe mangoes having a higher fat content than unripe mangoes (Mokbul *et al.*, 2022).

These results demonstrate that ethanol defatting was markedly more efficient than the non-polar solvents, likely

due to ethanol's amphipathic nature allowing better penetration into lipid-protein complexes and more complete extraction of both storage lipids and phospholipids. The superior defatting efficiency of ethanol aligns with research on oil-rich seeds, where polar solvents demonstrate enhanced extraction capability compared to non-polar alternatives for complete fat removal.

Table 1: Proximate composition of Mango (*M. indica*) seed

	Crude Protein	Crude Fibre	EE	Moisture Content (%)	Ash Content (%)	CHO
Raw Mango Seed Flour	13.45	9.3	9.95	1.1	1.9	65.4
N-Hexane Mango Seed Cake	4.85	13.2	6.2	12	1.05	74.7
Pet. Ether Defatted Mango Seed Cake	6.17	14.05	4.15	10.15	2	73.63
Ethanol Defatted Mango Seed Cake	3.985	11.3	10.15	12.15	2.95	71.615

3.3 Properties of mango seed oil

3.3.1 Iodine value (IV)

The iodine values obtained from the results are relatively similar across solvents, with ethanol (7.27 mg KOH/g) being slightly higher than n-hexane (7.15 mg KOH/g) and petroleum ether (6.24 mg KOH/g), as observed in Table 2. The iodine value is the amount of iodine necessary to saturate 100 g of oil and is a measure of the unsaturation in oil. It is used to determine the stability of oil in industrial applications (Mas'ud *et al.*, 2018).

The MSKO of petroleum ether (6.24 mg KOH/g) had the lowest iodine value, which reflected its characteristics, such as higher resistance to oxidation, longer shelf life, and higher quality. The iodine value is an index for assessing the ability of the oil to undergo rancidity. This suggests comparable degrees of unsaturation, consistent with reports by Sanz M *et al.* (2021), which indicate that the type of solvent minimally affects unsaturation levels. A high SFA level of oil is confirmed to be beneficial in terms of storage ability when compared to more unsaturated oil. Their work revealed that oil extracted with ethanol solvent has a high iodine value (27.55 mg/KOH/g), while oil extracted with hexane and petroleum ether has iodine values of 0.10 mg/KOH/g and 0.15 mg/KOH/g, respectively. The difference in iodine values between oil samples from different mango kernel varieties may be due to the different fatty acid compositions. The iodine value obtained from this study indicates that the oil contained an appreciable level of unsaturated fatty acids (FAs), especially oleic acid (Maldonado-Celis *et al.*, 2025).

3.3.2 Peroxide value

A significant difference was observed in the results (Table 2), which showed that the ethanol extract had the lowest peroxide value of 0.46 meq/kg, indicating better oxidative stability compared to n-hexane at 2.73 meq/kg and petroleum ether at 2.28 meq/kg, making it a useful indicator of oil deterioration. MSKO had a high quality due to the low level of peroxide value; this value was lower than that expected of rancid oil, which ranges from 20.00 to 40.00 mg/g oil. The results suggested that the mango kernel oils could not be stored for a very long period to prevent deterioration (Ndokwe *et al.*, 2024). Generally, in fresh oil, the peroxide value should be less than 10 mg/g oil. The peroxide value is a good indicator of the stability of the oil and a useful indicator of the deterioration of oil. It is a measure of the concentration of peroxide and hydroperoxide formed in the initial stages of lipid oxidation. The peroxide value is a measure of the extent of oxidation or oxidative rancidity in oil. High peroxide values are associated with a higher rate of rancidity; this supports observations by Ohale *et al.* (2022), who emphasized ethanol's effectiveness in extracting oils with lower oxidation levels.

3.3.3 Saponification values (SV)

The results show an SV of 176.66 mg KOH/g for ethanol, which is higher than for hexane (168.92 mg KOH/g) and petroleum ether (163.76 mg KOH/g), as observed in Table 2. The saponification value is the milligrams of KOH necessary to saponify 1 g of oil and shows the capacity to form soaps from oil; it indicates the average mass of long-chain molecules or FFA (Diomande, Konan, *et al.*, 2021). Ethanol-

extracted oil exhibited the highest saponification value of 176.66 mg KOH/g and ester value of 169.39 mg KOH/g, indicating a shorter average fatty acid chain length and higher ester content, respectively. The saponification value was a useful tool for evaluating the chain length or molecular weight of FA occurring in the triacylglycerol in oil. Its value represents the average molecular weight, or chain length, of all the FA. Saponification value is inversely proportional to the molecular weight of the glycerides in the oil (Sanz M *et al.*, 2021). These values are in agreement with findings by K. Nwaokobia *et al.* (2020), who noted that ethanol's polarity facilitates extraction of more esterified lipids.

3.3.4 Acid value (AV)

The result of acid value (AV) obtained from Table 2 shows that ethanol produced the highest yield (9.59%) compared to N-hexane (8.33%) and petroleum ether (7.95%), indicating that the oils were edible because it falls within the recommended Codex range of 0.6 and 10 for virgin and non-virgin edible fats and oils, respectively. In general, the lower the acid value, the more its acceptability for edibility purposes. Acid value serves as an indicator for the edibility of oil. It is the mg of KOH required to neutralize the FFA in 1 g of oil. The acid value is used to measure the extent to which glycerides in oil are decomposed by lipases and other actions such as light and heat; its determination is often used as a general indication of the condition and edibility of oils (Mas'ud *et al.*, 2018). Kemal and Yimam (2015) observed the highest extraction values of ginger in water (16.62%), followed by ethanol (13.88%) and the lowest value for

acetone extract (10.14%). Different solvent extracts of the same plant contain different bioactive components, which may have varying medicinal and therapeutic benefits. `

The results are consistent with findings by Balacuit *et al.* (2021) and Jin *et al.* (2016), who reported that ethanol, being a polar solvent, often results in higher crude extraction yields because it extracts polar components and pigments in addition to neutral lipids. K. Nwaokobia *et al.* (2018) reported higher acid values in ethanol extracts due to ethanol's ability to extract more polar compounds, including free fatty acids.

3.3.5 Density and colour

The density of ethanol-extracted oil was higher (0.883 g/ml) and exhibited a brown colour, differing from the off-white appearance and lower densities of n-hexane and petroleum ether oils, as shown in Table 2. This difference may be attributed to co-extraction of pigments and other polar compounds by ethanol, as noted by Ndukwe *et al.* (2024). The results describe the Ethanol 0.883 g/ml extract as brown, while N-Hexane (0.783 g/ml) and Petroleum Ether (0.788 g/ml) produced off-white oil. This is a classic observation in solvent extraction studies. Ethanol's polarity allows it to co-extract phospholipids, proteins, and pigments (like carotenoids or phenolics), leading to a darker, brownish colour, whereas hexane selectively extracts neutral lipids, resulting in a cleaner, lighter-coloured oil.

Table 2: Characteristics of Ethanol Defatted Mango Seed Oil

Sample	Acid value	Iodine value	Saponification value	Ester value	Peroxide value	Moisture content	Density (g/ml)	Colour
N-Hexane Extracted Mango Kernel Oil	8.33	7.15	168.92	161.77	2.73	0.004	0.783	off-white
Pet. Ether Extracted Mango Kernel Oil	7.95	6.24	163.76	157.52	2.28	0.006	0.788	off-white
Ethanol-Extracted Mango Kernel Oil	9.59	7.27	176.66	169.39	0.46	0.006	0.883	Brown

4.0 CONCLUSION

Mango seed kernel oils were extracted using organic solvents (petroleum ether, ethanol and hexane) and evaluated for their characterization and quality analysis. According to the analysis of physicochemical properties, fatty acid profile and total phenols, the results showed that these oils are rich in oleic

acid and stearic acid, indicating that they are stable and tolerant to rancidity. A maximum oil yield of 20% was obtained for the seed kernel with ethanol as the solvent for the extraction time of 4 h. Due to the presence of a high percentage of unsaponifiable matter and phenolic content, the oil extracted from mango seed kernel guarantees its application in the food,

pharmaceuticals, cosmetics, and industrial sectors. The iodine value obtained from this study indicates that the oil contained an appreciable level of unsaturated fatty acids (FAs) and the result suggests that, the extraction yield is quite efficient compared to standard solvent extraction but could be further optimized with modern techniques. Furthermore, the results also verified that mango seed kernel oil contained high amounts of total phenolic, enabling their application as ingredients of functional or enriched foods/K.”

3. ACKNOWLEDGMENT

This research is supported by the TetFund Institutional-Based Research for Ladoke Akintola University of Technology 2024/25 Batch. The authors appreciate the use of space and facilities of the Bioenvironmental, Water and Engineering Research Groups (BWERG) Laboratories, Chemical Engineering Department, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

4. REFERENCES

- Acharya, S., and Narula, R. (2025). Valorization of Agricultural Waste into High-Value Chemical Products. *DeepScience*, 3(4), 90–98. https://doi.org/10.70593/978-93-7185-662-1_10
- Anta, J. F. E. A., Biloa, D. M., and Raghavarao, K. S. M. S. (2020). Optimization of Extraction Parameters of Polyphenols from Mango Seed Kernel through Response Surface Methodology. *EJERS, European Journal of Engineering Research and Science*, 5(8), 877–883. <https://doi.org/10.24018/ejers.2020.5.8.2069>
- Awolu, O. O., and Manohar, B. (2019). Quantitative and qualitative characterization of mango kernel seed oil extracted using supercritical CO₂ and solvent extraction techniques. *Heliyon*, 5(03068), 1–6. <https://doi.org/10.1016/j.heliyon.2019.e03068>
- Balacuit, J. N. G., Guillermo, J. D. A., Buenafe, R. J. Q., and Soriano, A. N. (2021). Comparison of Microwave-Assisted Extraction to Soxhlet Extraction of Mango Seed Kernel Oil using Ethanol and n-Hexane as Solvents. *ASEAN Journal of Chemical Engineering*, 21(2), 158–169. <https://doi.org/10.22146/ajche.63533>
- Choudhary, P., Bidyalakshmi Devi, T., Tushir, S., Kasana, R. C., Popatrao, D. S., and K, N. (2022). Mango Seed Kernel : A Bountiful Source of Nutritional and Bioactive Compounds. *Food and Bioprocess Technology*, 4(10), 1–24. <https://doi.org/10.1007/s11947-022-02889-y>
- de Jong, C., and Ferreira, L. M. M. (2017). Mangifera indica Mango Seed Kernel Oil. *Engineering and Applied Science*, 2(3), 227–232. <https://doi.org/10.1016/B978-0-12-809435-8.00034-2>
- Diomande, M., Konan, K., Koffi, T., Gbotognon, J., Kanga, K., Kouadio, E., and Lucien, K. (2021). Physicochemical characteristics and fatty acid composition of kernel oil from four mango varieties (*Mangifera indica*) (Kent, Brooks, Keitt and Amelie) harvested and processed in North of Cote d'Ivoire.pdf. *World Journal of Advanced Research and Reviews (WJARR)*, 11(3), 102–108. <https://doi.org/10.30574/wjarr.2021.11.3.0334>
- Erwa, I. Y., Matenje, F. S., Mwachumu, Y. M., Omer Ishag, O. A., and Ahmed, H. M. (2019). Extraction, Physicochemical Characteristics and Fatty Acid Profile of Kernel Oil from *Mangifera indica* L. Cultivated in Sudan. *Chemical Science International Journal*, 28(4), 1–7. <https://doi.org/10.9734/CSJI/2019/v28i430147>
- Falola, O. O., Fasuan, T. O., and Adedeji, O. Y. (2025). Effect of Processing Techniques on Nutrient and Anti-Nutrient Contents of Mango Seed Kernel. *Research Journal of Botany (RJB)*, 20(1), 14–17. <https://doi.org/10.3923/rjb.2025.14.17>
- Fang, G., Liu, B., Guo, J., Goksen, G., Tosif, M. M., Jafarzade, S., Ezati, P., and Pandi, A. (2025). Valorization of mango byproducts for sustainable active packaging : Advances in functionalized biopolymer films. *Food Chemistry*, 30(102961), 1–15. <https://doi.org/10.1016/j.fochx.2025.102961>
- Franco, L. (2023). The role of fermentation technology in sustainable agriculture. *Journal of Plant Biotechnology and Microbiology*, 6(2), 1–2. <https://doi.org/10.35841/aapbm-6.2.142>
- Gabriele, M., Fabbri, L. P., Ventimiglia, M., and Lepecka, A. (2026). From Waste to Worth : The Role of Fermentation in a Sustainable Future. *Foods*, 15(664), 1–32. <https://doi.org/10.3390/foods15040664>
- Gurjar, H. R., and Raj, J. D. (2022). Extraction of Mango Kernel (*Mangifera indica*) Oil. *Asian Journal of Dairy and Food Research*, 41(3), 361–364. <https://doi.org/10.18805/ajdfr.DR-1855>
- Jin, J., Warda, P., Mu, H., Zhang, Y., Jie, L., Mao, J., Huang, J., Jin, Q., Wang, X., Xie, D., Huang, J., Jin, Q., and Wang, X. (2016). Characteristics of Mango Kernel Fats Extracted from 11 China - Specific Varieties and Their Typically Fractionated Fractions. *Journal of the American Oil Chemists' Society (J Am Oil Chem Soc)*, 4(10), 1–11. <https://doi.org/10.1007/s11746-016-2853-2>
- Joyce, O. O., Latayo, B. M., and Onyinye, A. C. (2014). Chemical composition and phytochemical properties of mango (*Mangifera indica*) seed kernel. *International Journal of Advanced Chemistry*, 2(2), 185–187. <https://doi.org/10.14419/ijac.v2i2.3549>
- Juhaimi, F. Al, Uslu, N., Babiker, E., Ghafoor, K., Ahmed, I. A. M., and Özcan, M. M. (2019). The Effect of Different Solvent Types and Extraction Methods on Oil Yields and Fatty Acid Composition of Safflower Seed. *Journal of Oleo Science*, 68(11), 1099–1104. <https://doi.org/10.5650/jos.ess19131>

Kayode, R. M., Sani, A., Oladoye, C., Annongu, A. A., Arekemase, M. O., Obalowu, M., and Abdulsalam, K. (2020). Physico-chemical and anti-nutritional characterization of the kernels of some mango (*Mangifera indica*) cultivars grown in Western parts of Nigeria. *Food Science and Quality Management*, 22(2013), 1–9. www.iiste.org

Kemal, M., Jabasingh, A. S., and Yimam, A. (2018). Ethiopian Mangoes: The Resourceful Raw Material for Mango Seed Kernel Oil Production. *Journal of the European Economic Association (JEEA)*, 36(25), 1–12.

Kemal, M., and Yimam, A. (2015). Optimization of Process Parameters for the Extraction of Oil from Mango Seed Kernel (*Mangifera indica*) for Cosmetics Application. In *Addis Ababa University*. Addis Ababa University Addis Ababa Institute of Technology (AAIT).

Lim, K. J. A., Cabajar, A. A., Lobarbio, C. F. Y., Taboada, E. B., and Lacks, D. J. (2019). Extraction of bioactive compounds from mango (*Mangifera indica* L. var. Carabao) seed kernel with ethanol – water binary solvent systems. *Journal of Food Science and Technology*, 4(5), 2536–2544. <https://doi.org/10.1007/s13197-019-03732-7>

Maldonado-Celis, M. E., Yahia, E. M., Bedoya, R., Landázur, P., Loango, N., Aguillón, J., Restrepo, B., and Ospina, Guerrero, J. C. (2025). Evaluation of the proximate composition, antioxidant potential, and antimicrobial activity of mango seed kernel extracts. *Frontiers in Plant Science*, 10(2025), 1–9. <https://doi.org/10.3389/fpls.2019.01073>

Mas'ud, F., Mahendradatta, M., Laga, A., and Zainal, Z. (2018). Physicochemical Properties and Fatty Acid Composition of Mango Seed Kernel Oil. *International Journal of Engineering Sciences and Research Technology*, 7(1), 361–369. <https://doi.org/10.5281/zenodo.1147523>

Mokbul, M., Cheow, Y. L., and Siow, L. C. (2022). Characterization of the physicochemical properties of mango (*Mangifera indica* L., Dragon variety) kernel fat extracted via supercritical carbon dioxide and Soxhlet techniques. *Journal of Food Processing and Preservation*, 46(16799), 1–10. <https://doi.org/10.1111/jfpp.16799>

Muchiri, D. R., Mahungu, S. M., and Gituanja, S. N. (2012). Studies on Mango (*Mangifera indica* L.) Kernel Fat of Some Kenyan Varieties in Meru. *Journal of American Oil Chemists' Society*, 89(110), 1567–1575. <https://doi.org/10.1007/s11746-012-2054-6>

Ndukwe, J., Okechi, R. N., Josephat, C. O., and Ebem, E. C. (2024). Evaluation of Proximate Composition and Characterization of Oil in Kernel Seeds of Selected Nigerian Mangoes. *Scope*, 14(04), 654–680. www.scopelibrary.com

Nwaokobia, K., Idibie, C. A., Ogboru, R.R., and Okolie, P. L. (2018). Effects of Extraction Solvents on the Yield and Physicochemical Properties of *Mangifera indica* L. seed oil. *The Pharmaceutical and Chemical Journal*, 5(2), 205–212. www.tpcj.org

Nwaokobia, K., Idibie, C., Ogboru, R., and Okolie, P. (2020). Effects of Extraction Solvents on the Yield and Physicochemical Properties of *Mangifera indica* L. Seed Oil. *The Pharmaceutical and Chemical Journal*, 5(2), 205–212. www.tpcj.org

Nzikou, J. M., Kimbonguila, A., Matos, L., Loumouamou, B., Pambou-Tobi, N. P., P. G., Ndangui, C., B., Abena, A. A., Silou, T., Scher, J., and Desobry, S. (2020). Extraction and Characteristics of Seed Kernel Oil from Mango (*Mangifera indica*). *Research Journal of Environmental and Earth Sciences*, 2(1), 31–35.

Ohale, P. E., Nwajiobi, O. Oachin, Onu, C. E., Madiebo, E. M., and Ohale, N. J. (2022). Solvent extraction of oil from three cultivars of Nigerian mango seed kernel: Process modelling, GA optimization, nonlinear kinetics and comparative characterization. *Applied Food Research*, 2(100227), 1–18. <https://doi.org/10.1016/j.afres.2022.100227>

Ojha, P., Raut, S., Subedi, U., and Upadhaya, N. (2019). Study of Nutritional, Phytochemical, and Functional Properties of Mango Kernel Powder. *Journal of Food Science and Technology Nepal*, 11(36), 32–38.

Rahmiyati, L., Saputri, D. R., Alhanif, M., Shifa, N. B., Akbar, D. A., Auriyani, W. A., Damayanti, D., Fahni, Y., Sanjaya, A., Safitra, E. R., Adiwibowo, M. T., and Wicaksono, R. M. (2025). Microwave-assisted Hydrodistillation Extraction of Crude Oil from Arumanis Mango Kernel (*Mangifera Indica* L.). *Jurnal Integrasi Proses (JIP)*, 14(1), 172–179. <http://jurnal.untirta.ac.id/index.php/jip>

Sanz M, E. C., Dix S, D. I. D., Robayo R, A. E., Bernal L, O. J., and Carrillo V, E. (2021). Use of mango seed almonds to obtain pastry oil. *Chemical Industry and Chemical Engineering Quarterly*, 38(2), 404–420. [https://doi.org/10.47280/RevFacAgron\(LUZ\).v38.n2.10](https://doi.org/10.47280/RevFacAgron(LUZ).v38.n2.10)

Sikdar, D. C., Hegde, S., Swamynathan, V., Varsha, S., and Rakesh, R. (2017). Solvent Extraction of Mango (*Mangifera Indica* L.) Seed Kernel Oil and Its Characterization. *International Journal of Technical Research and Applications*, 5(4), 43–47. www.ijtra.com

Singh Yadav, S. P., and Paudel, P. (2022). The Process Standardizing of Mango (*Mangifera Indica*) Seed Kernel for Its Value Addition: A Review. *Reviews In Food And Agriculture (RFNA)*, 3(1), 6–12. <https://doi.org/10.26480/rfna.01.2022.06.12>

Solís-fuentes, J. A., and Durán-de-bazúa, M. del C. (2020). Mango Seed : Mango (*Mangifera indica* L.) Seed and Its Fats. *Engineering and Applied Science*, 8(3), 79–90. <https://doi.org/10.1016/B978-0-12-818553-7.00008-5>

Solís-Fuentes, J. A., and Durán-de-Bazúa, M. del C. (2020). Mango (*Mangifera indica* L.) Seed and Its Fats. *Chemical Sciences and Engineering*, 4(6), 741–748. <https://doi.org/10.1016/B978-0-12-375688-6.10088-X>

Sreejaya, U., Krishnaja, U., Divakar, S., and Gopinath, P. P. (2024). Comparative Analysis of the Influence of Various Processing Techniques on Quality Attributes of Jackfruit Seed Flour (JSF) from Different Cultivars.pdf. *European Journal of Nutrition and Food Safety*, 16(9), 178–185. <https://doi.org/10.9734/ejnfs/2024/v16i91537>

Torsen, D. S., Hussein, J. B., Dan Allison, S., and Workneh, T. S. (2025). Characterization of oil solvent extracted from four Mango (*Mangifera indica* L.) kernels. *European Food Research and Technology*, 251(2025), 3633–3648. <https://doi.org/10.1007/s00217-025-04850-7>

Villanueva, P. X., Ávila, Y. C., Dávila, L. R., Méndez, J. J., and Arango, W. M. (2020). Characterization and Use of *Mangifera indica* L. Seeds from Four Varieties.

BioResources, 15(3), 5264–5280.

Yadav, K. K., Garg, N., Verma, A., Kumar, S., and Trivedi, M. (2022). Optimization and extraction of oil from mango seed kernel (*Mangifera indica*).pdf. *Indian Journal of Agricultural Sciences*, 87(7), 943–946. <https://doi.org/10.56093/ijas.v87i7.71925>

Zahoor, S., Anwar, F., Qadir, R., Soufan, W., and Sakran, M. (2023). Physicochemical Attributes and Antioxidant Potential of Kernel Oils from Selected Mango Varieties.pdf. *American Chemical Society Omega (ACS Omega)*, 8(10), 22613–22622. <https://doi.org/10.102/acsomega.3c01155>