Analysis and Characterization of *Pericopsis mooniana* Seed Oil for Potential Applications in Cosmetics and Nutritional Supplements

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Abstract

Pericopsis mooniana is renowned for wood applications, while its bark and leaves find uses in ayurvedic medicine. The shifting of global cosmetic and nutritional supplement industries towards plant-based oils has led to explore novel sources. No prior studies were done on *P. mooniana* seed oil. Therefore, this study aims to characterize the seed oil of *P. mooniana* by determining Fatty Acids (FA) composition as their methyl esters, nonpolar constituents in unsaponifiable matter, and other physio-chemcial properties. The oil was extracted using the soxhlet extraction method. Ash and moisture contents of seeds, Acid Value (AV), Iodine Value (IV), smoke point and thermal stability of oil were also determined. Prepared fatty acid methyl esters and chemical constituents in unsaponifiable matter were identified and quantified using Gas Chromatography-Mass Spectrometry method. Results indicated a substantial oil yield of 36.71± 0.01% with moisture content of 5.60 ± 0.19%, ash content of 3.65 ± 0.38%, AV of 2.97 ± 0.40 mg KOH/g, IV of 112.13 ± 0.14 g I_2/100g, smoke point of 233.6 ± 8.57°C, decomposition temperature of 409.95 ± 1.74°C and yield of unsaponifiable matter of 1.35 ± 0.01%. The dominant FAs are oleic (41.02%) and linoleic (38.12%) acids. Major unsaponifiable matter constituents are squalene (4.01 mg/g), beta.-sitosterol (2.63 mg/g), stigmasterol (1.23 mg/g), phytol (1.45 mg/g), geranylgeraniol (1.03 mg/g) and (α,β)-amyrin (0.95 mg/g). Based on the findings of this study, it can be concluded that *P. mooniana* seed oil has the potential to be utilized in both cosmetic and nutritional supplement industries.

Keywords: Cosmetics and nutritional supplements, fatty acids, Pericopsis mooniana, seed oil, unsaponifiable matter

1. Introduction

Global demand for plant seed oils has acquired significant growth during recent decades, mainly driven by increased demand in the culinary, nutritional supplement, cosmetic, biofuel and lubricant industrial sectors. The growth trend of plant seed oils in cosmetic and nutritional supplement industries has grown even faster than other sectors because of the global demand trend towards natural resources (Łopaciuk and Łoboda, 2013). While certain fats and oils like canola, jojoba, sunflower, avocado, shear butter, kokum butter, cocoa butter, rice bran and olive dominate the global market in this sector, the room for new plant oils is always wide open (Aburjai and Natsheh, 2003). Sri Lanka being a tropical country with a very rich biodiversity is a land with a large number of unexplored oil seed plants. Though some seed oils are used in ayurvedic and indigenous medicine, most of these seed oils are poorly or uncharacterized for their chemical constituents (Kankanamalage et al., 2014). Furthermore, the increasing global population and scarcity of conventional fats and oils in the market have rendered them to be limited and expensive. Therefore to address this shortage, it is crucial to explore alternative sources of fats and oils, focusing on unconventional seeds (Łopaciuk and Łoboda, 2013).

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The global beauty market has experienced consistent growth, approximately 4.5% annually over the past two decades. Manufacturers are increasingly incorporating plant-based renewable feedstocks, such as fats and oils, into cosmetic formulations (Łopaciuk and Łoboda, 2013). Presently, the cosmetic industry employs seed oils like almond oil, apricot kernel oil, castor oil, sunflower oil, jojoba oil, and plant fats like shea butter, kokum butter, and mango kernel butter. Fatty acid (FA) composition and chemical constituents in unsaponifiable matter of seed oils are the main contributors to diverse health-enhancing and cosmetic properties in cosmetic formulations. (Rabasco Alvarez and González Rodríguez, 2000)

Fish oil, a rich source of polyunsaturated fatty acids (PUFA), is a highly demanded nutritional supplement, particularly for its proven properties against cardiovascular diseases. Concerns regarding overfishing and environmental impact prompt the exploration of alternative sources for fish oils (Lenihan-Geels et al., 2013). Plant oils such as soybean, olive and rapeseed oil, known for their richness in linoleic and oleic acid, emerge as promising alternatives to traditional fish oil sources (Nasopoulou and Zabetakis, 2012). However exploration of new alternative plant oil sources is continuing throughout the world due to the inability to satisfy the current demand for existing plant oil sources (Caligiani *et al*., 2010).

Lipids, particularly triglycerides primarily composing fats and oils are essential for living organisms. Plant fats and oils, encompassing saturated fatty acids (SFAs) and unsaturated fatty acids (UFAs), play vital roles (Rabasco Alvarez and González Rodríguez, 2000). The FA composition of plant oils varies depending on the species, influencing their use in cosmetics and nutritional supplements. Long-chain SFAs, such as myristic (C14:2), palmitic (C16:0), and stearic (C18:0) in plant oils, offer softening, soothing, and protective properties in cosmetic formulations. Plant seed oils with higher SFA than UFA are more favourable and in demand for cosmetic applications rather than as nutritional supplements (Johnson, 1978). Recognizing the SFA/UFA ratio is vital for the application in dietary considerations, as high SFA levels correlate with increased LDL cholesterol (Kostik *et al*., 2013). Specific oils like almond, canola, soybean, sunflower and sesame that are rich in UFAs such as oleic (18:1), linoleic (18:2) and linolenic (18:3) acids are proven to produce a vast array of health benefits (Rabasco Alvarez and González Rodríguez, 2000).

Unsaponifiable matter is another important set of chemical constituents in plant seed oil that mainly consists of phytosterols, carotenoids, triterpene alcohols, tocopherols, long-chain saturated and unsaturated hydrocarbons, fatty alcohols, and squalene. They are present at a minor level in seed oils in the range of 0.2% - 8 % compared to triglycerides. These compounds individually or synergistically provide health and cosmetic benefits like cholesterol-lowering effects, antioxidant, anticancer, anti-inflammatory, emollient, moisturizing, skin softening and soothing properties (Caligiani *et al*., 2010; Fontanel, 2013; Ogbe et al., 2015). These are nonpolar or low-polarity substances in fats and oils that do not undergo saponification reactions with alkali hydroxide treatments.

Pericopsis mooniana commonly known as "Nedun" in Sinhala and " Nandu wood" in English, belongs to the family Fabaceae (Leguminosae). This family is the third-largest family of flowering plants and holds high ecological and economic value. Compared to other Pericopsis species categorized as luxury wood, *P. mooniana* has a wider distribution spanning Sri Lanka and Southeast Asia. In Sri Lanka, it is mainly grown in moist wet low land regions. *P. mooniana* possesses valuable economic potential. Classified as a luxurious and expensive fancy wood, it holds significant economic value in the international market Its strong characteristics make it suitable for diverse applications, including household tools, veneers, and even heavy construction purposes such as bridges, railway sleepers and frame wood etc. However, this economic importance is threatened by over-exploitation due to the lack of a proper cultivation system (Kinho *et al*., 2023). The IUCN Red List categorizes *P. mooniana* as "vulnerable (A1cd)" due to this unsustainable harvesting of its high-quality furniture wood (Anoop *et al*., 2016).

P. mooniana seed oil was selected for this study mainly due to the lack of prior research on the chemical characterization of *P. mooniana* seed oil which offers an opportunity for novel discovery.

Furthermore, *P. mooniana* seeds possess significantly high oil content and the trees themselves produce a large yield during fruiting seasons. These factors suggest the potential for a substantial and sustainable resource. This study aims to determine and evaluate the physicochemical properties, FA composition, and unsaponifiable matter composition of *P. mooniana* seed oil to identify potential applications in cosmetics and nutritional supplements. Furthermore, this study will unveil more economic value of *P. mooniana* species leading to promoting sustainable utilization and conservation of this vulnerable species.

2. Materials and Method

2.1 Seed material

Seeds were collected from the Yagirala forest reserve in the Kalutara District in the month of September. For this study, well-ripened, dried pods of *P. mooniana* were selected, ensuring quality and free from fungi and pests. After removing the seed coat, kernels were ground and sieved to obtain a fine powder. This powder was oven-dried at 60°C for 2-3 hours before performing further tests.

2.2 Moisture content of seed kernel

Modified AOAC 934.06 method was employed to measure moisture content. The ground seed kernel sample of *P. mooniana* was dried at 103±2°C for 2 hours in an oven and repeated till a constant weight was obtained. The moisture content was calculated as a percentage of the initial seed sample weight (Zang *et al.*, 2017). The final moisture content was determined by averaging the results of three replicate measurements.

2.3 Ash content of seed kernel

Modified AOAC 942.05 method was followed using a muffle furnace. A known weight of dried ground seed kernel of *P. mooniana* was ignited at 550°C for 5 hours. The weight of the resulting ash was measured at room temperature, and ash content was calculated as a percentage of the initial seed sample (Yadav *et al.*, 2022). The final ash content was determined by averaging the results of three replicate measurements.

2.4 Extraction of seed oil and determination of oil content

Around 25 g of ground seed kernels of *P. mooniana* were used to extract the oil. Oil was extracted using the Soxhlet extraction method employing 150.0 cm^3 of HPLC-grade hexane for six hours. After refluxing, anhydrous sodium sulphate was added, and the solvent was removed using a rotary evaporator. The crude oil percentage (w/w) was expressed as the oil percentage in the dried ground seed kernel powder (Keneni *et al.*, 2021).

2.5 Physical analysis of crude oil

2.5.1 Smoke point

The smoke point was determined by heating 0.5 mL of *P. mooniana* seed oil on a hot plate, noting the temperature at which continuous smoke appeared. The temperature was measured using an IR thermometer (Falade *et al.*, 2008). The final smoke point value was determined by averaging the results of five replicate measurements.

2.5.2 Thermal analysis

Thermal analysis was conducted using the Discovery SDT 650 model, equipped with simultaneous Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) capabilities (Trios software). The analysis involved heating the *P. mooniana* seed oil sample starting from room temperature to 600.0°C at a rate of 10.0°C/min under a nitrogen atmosphere. The resulting mass changes were plotted using Origin software to generate TGA and Differential Thermogravimetry (DTG) curves (Solís-Fuentes et *al.*, 2010). The highest decomposition temperature was obtained from the average of 3 measurements.

2.6 Chemical analysis

2.6.1 Acid value

The Acid Value (AV) was determined using a modified A.O.C.S official method, Cd 3a-63, 2006. A weight of 0.2g of *P. mooniana* seed oil was dissolved in a freshly prepared, pre-neutralized methanol-diethyl ether 1:1 (v:v) mixture. Then it was neutralized with 0.05 M KOH solution using phenolphthalein as the indicator (Abdullahi et al., 2021). AV was calculated using the following equation (1), where 56.1 was the molecular weight of KOH. The final AV was determined by averaging the results of three replicate measurements.

$$Acid\ Value = \frac{Volume\ of\ \ KOH\ solution\ \times\ 56.1\ \times\ KOH\ concentration}{Weight\ of\ Oil} \qquad (1)$$

2.6.2 Iodine value

Modified AOAC 920.159 was followed using Wij's solution to determine the Iodine Value (IV). A known weight of the *P. mooniana* seed oil was titrated against 0.1M $Na_2S_2O_3$ solution, and the IV was calculated using the given formula (2), where V_{blank} and V_{sample} represent the volumes of 0.1M $Na_2S_2O_3$ consumed by the blank and the sample during the titration reaction. (Pardeshi, 2020). The final IV was determined by averaging the results of three replicate measurements.

$$Iodine\ Value = \frac{(V_{blank}\ -\ V_{sample}) \times\ Na_2S_2O_3\ concentration\ \times 12.69}{Weight\ of\ Oil} \qquad (2)$$

2.7 Determination of FA composition by Gas Chromatography-Mass Spectrometry (GC-MS).

To identify and quantify the FAs present in the extracted *P. mooniana* oil was converted to Fatty Acid Methyl Esters (FAME) by using the method given below. A weight of about 0.05 g of oil was mixed with 5.00 cm3 of isooctane in a test tube which can be stoppered. For that solution, 200 µL of 2 M Methanolic KOH was added, stoppered, and vigorously shaken for 30 seconds resulting in the appearance of cloudiness. Finally, approximately 1g of sodium dihydrogen orthophosphate was added and shaken until cloudiness disappeared. The upper layer of the freshly prepared sample was subjected to GC-MS analysis after drying with anhydrous sodium sulphate and filtration. 1.0 µL of filtered sample was injected at a split ratio of 1:20 to an Agilent GC model-7890A and MS model-5975C with a non-polar ultra-inert capillary column that includes 5% phenyl methyl siloxane. (19091S-433HP-5MS with internal diameter 250 µm, 30.0 m column length and 0.25 µm film thickness). The temperature program included an initial temperature of 100.0°C held for 3.0 minutes, increased to 240.0°C at a rate of 3.00C/min and then held for 7.0 minutes. Compound identification is performed by comparing the total ionic current spectrum of each peak of P. mooniana oil extract with that from NIST mass spectral library and the retention time windows of the each matching FAME of the mass spectrum of the Supelco 37 component FAME reference mix standard (Sigma Aldrich). The quantification is carried out by the internal standard method by considering the response factors using heptadecanoic acid methyl ester (Sigma Aldrich) as the internal standard.

2.8 Unsaponifiable matter composition

2.8.1 Extraction of unsaponifiable matter

A modified AOAC 933.08 procedure was used to extract unsaponifiable matter from *P. mooniana* seed oil. Saponification was carried out using 5 g of oil boiled with 50.0 cm^3 of 1 M methanolic KOH in a reflux apparatus for 1 hour. 100 cm^3 of distilled water was added, transferred to a separatory funnel and extracted unsaponifiable matter three times using 100 cm^3 of HPLC grade hexane. The hexane extract was

pooled into a separatory funnel and washed with 100 cm^3 of distilled water until the wash gave a neutral reaction. The solvent was removed from rotary evaporation and acetone was added to eliminate volatile components. The obtained unsaponifiable matter's weight was measured to calculate the yield (w/w) as a percentage of the initial fat weight (Giacometti, 2001; Janporn *et al.*, 2015).

2.8.2 Identification and quantification of unsaponifiable matter using Gas Chromatography-Mass Spectrometry (GC-MS)

The yellow-coloured unsaponifiable matter was dissolved in HPLC-grade hexane, dried with anhydrous sodium sulphate, and subjected to GC-MS analysis using an Agilent GC model-7890A and MS model-5975C with the same column used for FAME analysis. The temperature program included an initial temperature of 70.0°C kept for 1.5 minutes, increased to 280.0°C at a rate of 10.00C/min and then held for 38.0 minutes at 280.0°C. The compound identification was carried out by the same method followed in FAME identification and the quantification was carried out by an external calibration method with reference standards (Sigma Aldrich).

2.9 Statistical analysis

As for the statistical analysis of titrations, average values were calculated for the triplicated readings to minimize the random errors and the standard deviation was calculated to analyze the precision. As per the other results, uncertainty analysis was performed. The chemical compositions obtained from GC-MS analysis were compared with other reference plant oils based on the numerical closeness of the values.

3. Results

Figure 1: Mature pods, seeds and kernels of *P. mooniana* used for the oil extraction in this study and the extracted yellow colour seed oil.

The physiochemical properties of *P. mooniana* seed kernel and extracted oil are given in Table 1.

Table 1: Table showing the physiochemical properties of *P. mooniana* seed kernel and extracted oil studied under this study

Physiochemical property	Average ± SD
Yield of Crude Oil (%)	36.71 ± 0.01
Moisture Content (%)	5.60 ± 0.19
Ash Content (%)	3.65 ± 0.38
Acid Value (mg KOH/g)	2.97 ± 0.40
Iodine Value (g I_2/100g)	112.13 ± 0.14
Yield of Unsaponifiable Matter (%)	1.35± 0.01
Smoke Point (°C)	233.6 ± 8.57
Decomposition Temperature (°C)	409.95 ± 1.74

Gas Chromatography-Mass Spectrometry (GC-MS) method was used to identify and quantify the FAs as their methyl esters. Figure 2 shows the Total Ion Chromatogram (TIC) of the GC-MS analysis of FAME. According to the FA profile in Table 2, the total composition of FAs is 96.79%. The total percentage of SFA is 16.94% with palmitic acid (C16:0) 11.70% and stearic acid (C18:0) 3.55% as the most abundant SFAs. Long chain SFAs with above 20 carbon atoms resulted in minor levels including arachidic acid (C20:0) 0.59%, behenic acid (C22:0) 0.90% and lignoceric acid (C24:0) 0.20%. The total percentage of UFAs is 79.85% with oleic acid (C18:1) at 41.02% and linoleic acid (C18:2) at 38.12% as the most abundant UFAs while gondoic acid (C20:1) is present in minor levels at 0.71% (Table 2). The SFA/UFA ratio is 0.21 (Table 2) supporting the physical state of the oil of *P. mooniana* seed. Due to the high amount of oleic and linoleic FAs present, *P. mooniana* oil can be named oleic-linoleic type oil.

Table 2. Table showing the FA composition of *P. mooniana* seed oil obtained through GC-MS analysis under this study

Fatty Acid		Percentage (%)
Saturated Fatty Acids		
C16:0	Palmitic acid	11.70
C18:0	Stearic acid	3.55
C20:0	Arachidic acid	0.59
C22:0	Behenic acid	0.90
C24:0	Lignoceric acid	0.20
Unsaturated Fatty Acids		
C18:1	Oleic acid	41.02
C18:2	Linoleic acid	38.12
C20:1	Gondoic acid	0.71
Total FAs (%)		96.79
Total % of Unsaponifiable Matter		1.35
Unidentified FAs (%)		1.86
SFA/ UFA Ratio		0.21

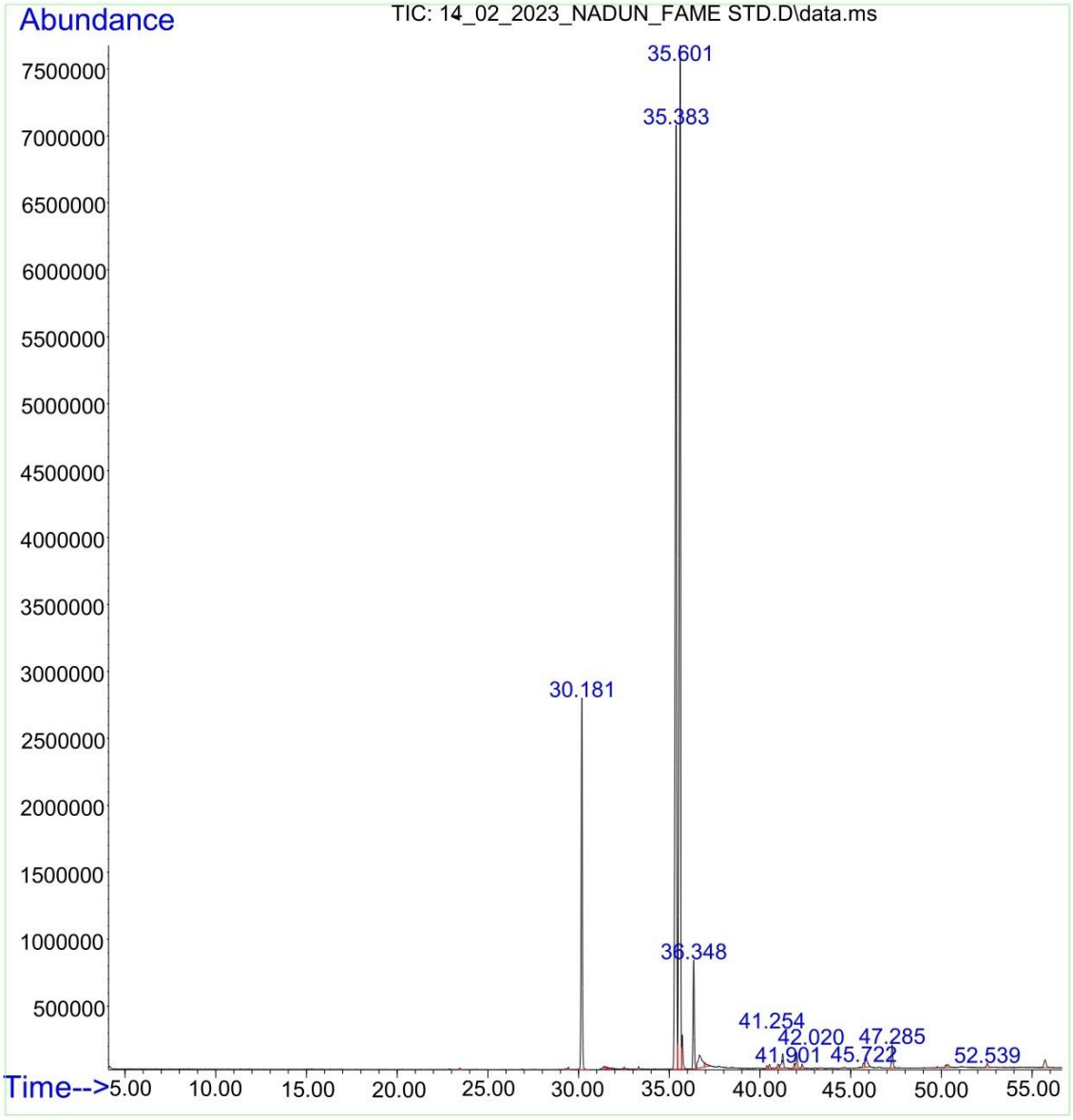

Figure 2. Total ion chromatogram of the FAME present in *P. mooniana* seed oil obtained from the GC-MS analysis in this study. The retention times of relevant FA are; 30.181 min (C16:0), 35.383 min (C18:2), 35.601 min (C18:1), 36.348 min (C18:0), 41.254 min (C20:1), 42.020 min (C20:0), 47.285 min (C22:0) and 52.539 min (C24:0).

GC-MS method was used to identify and quantify the unsaponifiable matter constituents extracted from the *P. mooniana* seed oil. Figure 3 displays the TIC of GC-MS analysis of these unsaponifiable matter compounds. Table 3 shows the concentrations of each constituent per 1g of the oil. Squalene (C30H50) is the most abundant with 4.01 mg/g (Table 3). It is a polyunsaturated hydrocarbon with various cosmetic and health-enhancing properties. The types of phytosterols present are beta-sitosterol (2.63 mg/g), stigmasterol (1.23 mg/g) and campesterol (0.05 mg/g) (Table 3). Furthermore, it contains phytol, geranylgeraniol and (α,β)-amyrin at 1.45 mg/g, 1.03 mg/g and 0.95 mg/g respectively (Table 3).

Table 3. Table showing the unsaponifiable matter constituents and their concentrations per 1g of *P. mooniana* seed oil

Name of the compound	mg/g
Phytol	1.45
Geranylgeraniol	1.03
Squalene	4.01
Campesterol	0.05
Stigmasterol	1.23
beta.-Sitosterol	2.63
(α,β)-Amyrin	0.95

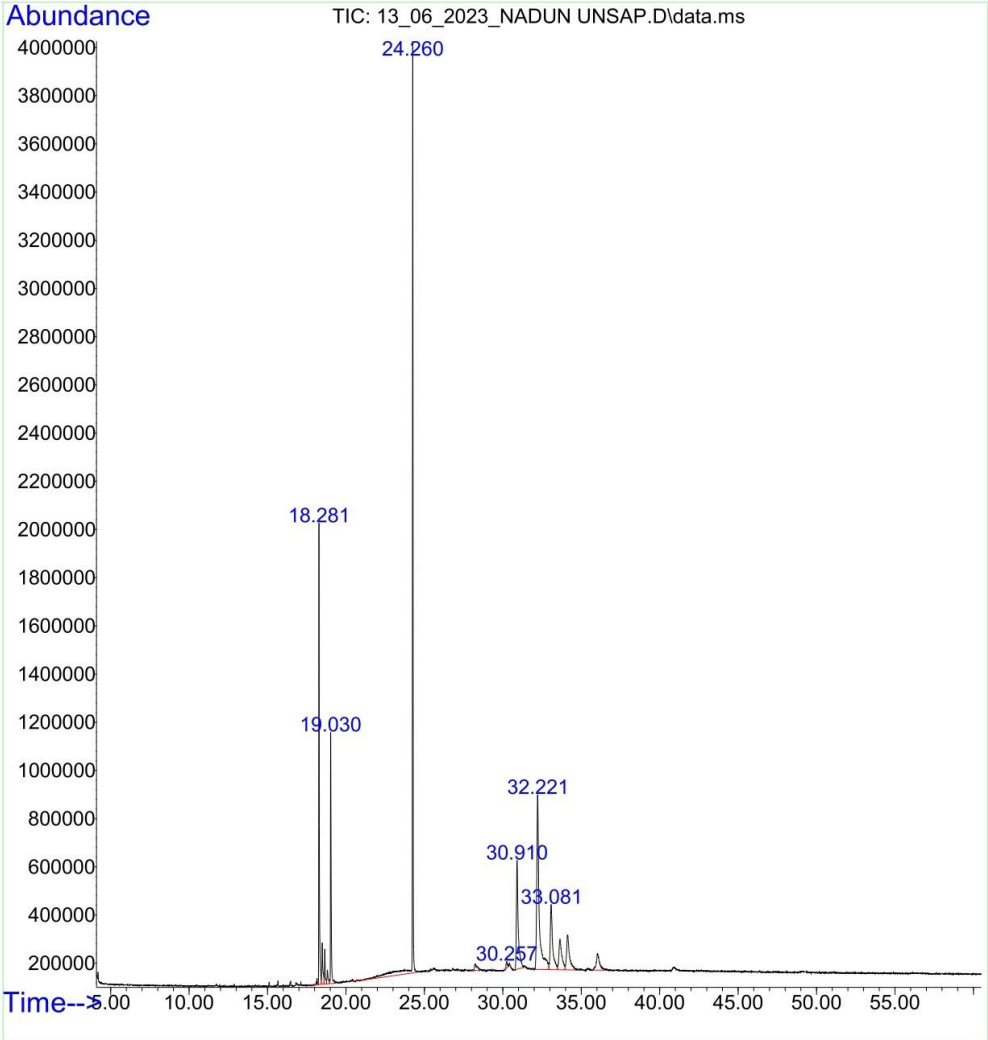

Figure 3. Total ion chromatogram of the unsaponifiable matter constituents present in *P. mooniana* seed oil obtained from the GC-MS analysis in this study. The retention times of relevant constituents are;

18.281min (Phytol), 19.030 min (Geranylgeraniol), 24.260 min (Squalene), 30.257 min (Campesterol), 30.910 min (Stigmasterol), 32.221 min (beta.-Sitosterol), 33.081 min (Amyrin)

Figure 4 displays the Thermogravimetric Analysis (TGA) and Derivative Thermogravimetry (DTG) curves for *P. mooniana* seed oil compared with peanut oil. Peanut oil is used as the standard for the thermal stability of plant seed fats and oils. The decomposition temperatures are 409.95 ± 1.74 °C (Table 1) and 423.08 ± 1.74°C respectively.

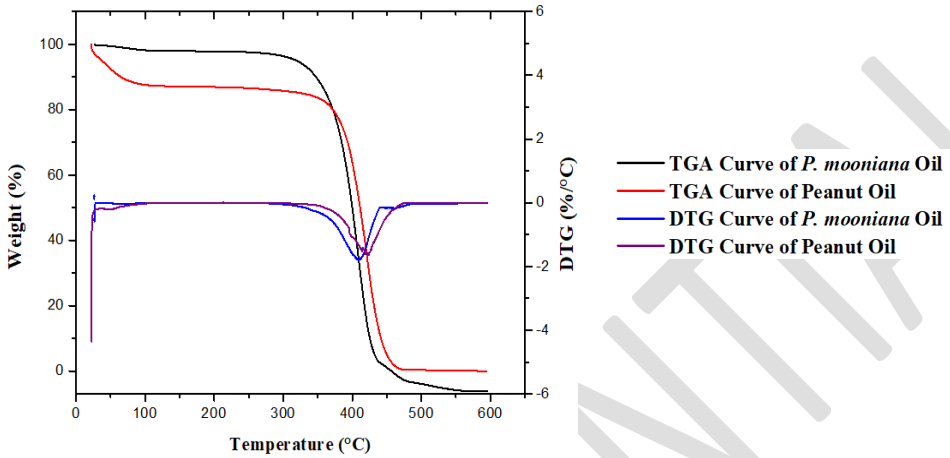

Figure 4: TGA and DTG curves of *P. mooniana* seed oil compared with peanut oil obtained from thermogravimetric analysis. Peanut oil was used as the standard for the thermal stability of plant seed fats and

4. Discussion

4.1 Evaluation and comparison of physical characteristics

Figure 1 depicts the mature pods, seeds and kernels of *P. moonia* distinctive yellow color, and the oil extracted from these kernels ma temperature, as illustrated in Figure 1. The determination of the perce significance in evaluating the economic feasibility and industrial potential of *P. mooniana* seeds as an oil-bearing source. The *P. mooniana* resulted in a crude oil yield (w/w) of 36.71 ± 0.01% (Table 1) which is higher than soybean (18%), cottonseed (14%) and groundnut (32%). Other oils like rapeseed and sunflower oil show average oil yields of 39% and 41% respectively. These are the United States Department of Agriculture (USDA) figures of world average yields obtained for 2008/09 (Gunstone, 2003). This suggests that the relatively high percentage of oil yield of *P. mooniana* oil makes it more advantageous and cost-effective in industrial applications.

TGA Curve of *P. mooniana* Oil
TGA Curve of Peanut Oil
DTG Curve of *P. mooniana* Oil
DTG Curve of Peanut Oil

To assess the quality of the extracted oils, the moisture content of the seed kernel was analyzed. It is found to be 5.60 ± 0.19% (Table 1). The observed low moisture content in the kernel is a positive indicator, suggesting extended storage stability with a lower risk of spoilage, aligning with findings from prior research (Onyeike and Acheru, 2002). The determined ash content of *P. mooniana* is 3.65 ± 0.38% (Table 1) and it is notably higher than the values of groundnut coconut, dikanut, melon, and palm kernel (Onyeike and Acheru, 2002). This finding provides an initial insight into the mineral content and nutritional value of *P. mooniana*, as the ash content is a quantification of the total minerals present in the seed kernel. Essentially, it represents the inorganic residue remaining after the removal of water and organic matter. This observation implies a substantial mineral richness in *P. mooniana* seeds, suggesting potential nutritional benefits and making it a noteworthy candidate for dietary inclusion (Zang *et al.*, 2017).

The acid value (AV) of the *P. mooniana* seed oil was determined as 2.97 ± 0.40 mg KOH/g (Table 1) which is a relatively lower value compared to other commodity oils such as sesame, soybean, sunflower and rapeseed oils. AV reflects the free FA content of oil. Edible oils intended for consumption as well as dermal application must have an AV below 4 mg KOH/g (Zang *et al.*, 2017) AV also serves as an important indicator of the potential rancidity of fats and oils over storage conditions. Having a notably low value for *P. mooniana* seed oil confirms the suitability for potential in dietary supplements, cosmetic applications and also commercial value due to the potential for longer self-life (Nyam *et al.*, 2009). The iodine value (IV) is determined to measure the degree of unsaturation of the extracted oil. Having a high IV of 112.13 ± 0.14 g I2/100g in Table 1 indicates a substantial amount of UFAs. This is also clearly reflected in its FA profile which has more than 80 % UFA content. A study done by Kyari, 2008 suggested that exposure to light gradually reduces the IV. That study further says that the observed decrease in IV implies a significant loss of unsaturation in the oil due to photo-catalyzed reactions. Higher levels of unsaturation may lead to the quick rancidity of the oil over storage conditions and in formulations. Therefore, the inclusion of stabilizers and other additives may be required to maintain the longer self-life of cosmetic and dietary supplement formulations (Kyari, 2008).

Smoke point is another important parameter when assessing the stability of fats and oils, especially in high-temperature applications. It is determined as the temperature at which a continuous wisp of smoke is produced upon heating. According to Canadian Government specifications, frying oil should have a smoke point exceeding 200 ˚C and the value resulting in this study for *P. mooniana* seed oil is 233.6 ± 8.57 °C (Table 1) indicating the suitability of the oil in high-temperature applications (Przybylski *et al.*, 2020).

4.2 Fatty acid composition P. mooniana seed oil

The GC-MS method was used to identify and quantify the FAs as their methyl esters. Figure 2 shows the TIC of GC-MS analysis of FAME. When analyzing the FA profile in Table 2 it was evident that around 80% of the total FAs are UFAs, contributing to the liquid nature of extracted oil. Additionally, SFAs like stearic and palmitic and UFAs like oleic are known for their ability to enhance skin permeation. (Vermaak *et al*., 2011) Oleic acid is also known for its effect in reducing LDL cholesterol levels. Previous research has indicated that FAs, specifically linolenic, linoleic, and oleic acids, play a significant role in the wound healing process and are essential components of lipid barrier structures. (Poljšak *et al*., 2020) Furthermore, linoleic acid is recognized for its moisturizing and skin-healing effects on sunburns (Vermaak *et al*., 2011). The significant presence of 38.12% linoleic acid (Table 2) in *P. mooniana* seed oil positions it as a potential source of essential FAs. Moreover, the FA profile, rich in oleic and linoleic acids, suggests the suitability of *P. mooniana* seed oil for edible oil and margarine manufacturing, making it nutritionally advantageous. Also the presence of high levels of UFAs places *P. mooniana* seed oil into the industrial application of producing hydrogenated oils which are widely used in the cosmetic industry as moisturizing oils. Very long-chain FAs, constituting a minor proportion with a total of 2.40% (Table 2), offer advantageous properties in the cosmetic industry, particularly for moisturizing and emollient effects. The drawback of a relatively high degree of unsaturation lies in the increased susceptibility of oils to oxidation, especially during deep-fat frying. Linoleic acid, for instance, oxidizes approximately 50 times faster than oleic acid (Nyam *et al*., 2009). Recognizing this challenge, the edible oil industry has shifted its focus to high-oleic plant oils. Varieties such as high oleic corn, sunflower, and canola oils exhibit enhanced oxidative stability, making them suitable for demanding applications like frying (Nyam *et al*., 2009).

4.3 Comparison of FA composition of P. mooniana seed oil with commonly used seed oils for possible use in cosmetics and dietary supplements.

One main objective of this study is to investigate the potential integration of *P. mooniana* seed oil into cosmetics and nutritional supplements by considering and comparing its FA composition with plant

oils and fats that are already used in these industries. This enables us to evaluate the feasibility of substituting *P. mooniana* seed oil for high-end fats and oils that are currently in use. We compared the FA composition of *P. mooniana* (Table 2 and Figure 2) with that of various currently used plant oils in the cosmetic and dietary supplement industries and found that the FA profile of *P. mooniana* closely resembles sunflower, sesame, and peanut oils as outlined in Table 4. These oils are characterized by a significant proportion of UFAs, particularly oleic and/or linoleic, along with minor levels of SFAs, such as palmitic and stearic acids (Table 4). These oils are widely integrated into these industries for being non-toxic and non-irritating renewable natural sources.

Table 4: Table showing the comparison of FA profiles of *P. mooniana* seed oil with other currently used plant oils in the cosmetic and dietary supplement industries (Rabasco Alvarez and González Rodríguez, 2000)

	SFA (%)		UFA (%)	
Species	C16:0	C18:0	C18:1	C18:2
	Palmitic	Stearic	Oleic	Linoleic
Sunflower	3.5-8	3-7	15-85	50-72
Sesame	7-12	3.5-6	35-50	35-50
Peanut	8-13	3-5	38-63	18-42
P. mooniana oil	11.86	3.55	41.02	38.12

P. mooniana oil falls into the category of an 'oleic-linoleic '-type plant oil. Notably, its oleic content is comparable to that found in olive oil (55-83%) which is a conventional edible oil with high oleic acid content (Gunstone, 2003). Sunflower oil is one of the four dominant plant oils in the world that are produced globally on a large scale. Its FA composition is being modified to obtain favourable properties from the oil. Sunflower oil is incorporated in skin care products due to the moisturizing and skin barrier-maintaining properties provided by linoleic acids (Aburjai and Natsheh, 2003). In terms of health benefits, it is used in diets due to its higher amount of UFAs that contribute to the reduction of LDL cholesterol levels. Similarly, sesame and peanut oils find extensive use in cosmetics and nutritional supplements. These oils showcase antioxidant and anti-inflammatory properties, making them valuable additions to skincare and health products (Gunstone, 2003). Therefore, this suggests the potential applications of *P. mooniana* oil in the cosmetic and dietary supplement industries and as a potential substitute for sunflower, sesame and peanut oils based on the FA composition.

4.4 Unsaponifiable matter of P. mooniana seed oil

The unsaponifiable yield of *P. mooniana* seed oil is found to be 1.35% (Table 1), comparable to the range of 1-1.5% found in soybean, olive, and sesame oils (Gunstone, 2003). GC-MS method was used to identify and quantify the unsaponifiable matter constituents extracted from the *P. mooniana* seed oil. Figure 3 displays the TIC of GC-MS analysis of these unsaponifiable matter compounds. In the unsaponifiable fraction, phytosterols emerge as the most abundant constituent after squalene (Table 3). The types of phytosterols present are beta-sitosterol (2.63 mg/g), stigmasterol (1.23 mg/g) and campesterol (0.05 mg/g) (Table 3). Phytosterol levels in plant oils serve for oil identification, derivatives, and quality determination. Some well-established health-enhancing properties of phytosterols are inhibiting cholesterol absorption and reducing LDL levels. It was scientifically proven that phytosterols

available in the market lowers blood LDL cholesterol by 10–15% as part of a healthy diet. It underscores their significant role in the nutraceutical context (Caligiani *et al*., 2010). Similarly to sunflower oil, beta-sitosterol dominates the phytosterol composition in the unsaponifiable yield of *P. mooniana* seed oil (Gunstone, 2003).

The significant presence of squalene in *P. mooniana* seed oil at 4.01 mg/g is noteworthy (Table 3), compared to its amounts present in the unsaponifiable matter of peanut (0.28 mg/g) olive (5.64 mg/g) and amaranth (59.42 mg/g) oils (Lozano-Grande *et al*., 2018). Squalene is a highly unsaturated aliphatic hydrocarbon ($C_{30}H_{50}$), known for its superior cholesterol-lowering, antitumor, antioxidant, and emollient properties that hold potential in diverse applications like cosmetic and nutritional supplements. The reported plant sources of squalene include soybean oil, olive oil, peanut, wheat germ, corn, grape seed oil, and amaranth oil (Lozano-Grande *et al*., 2018). Despite its promising bioactivities, the intake of squalene remains low in humans due to limited natural sources and extraction methods (Kim and Karadeniz, 2012). Additionally, squalene plays a crucial role in preventing the oxidation of body lipids, particularly PUFAs (Nyam *et al*., 2009). Therefore, this study reveals that *P. mooniana* could be a good source of squalene for cosmetic and dietary supplement formulations.

Geranylgeraniol (1.03 mg/g) and phytol (1.45 mg/g) (Table 3) are isoprenoid alcohols found in *P. mooniana* seed oil which show similar structures that are derived from isoprenoid moiety. So the difference lies in the number of double bonds in structures with phytol having one and geranylgeraniol having four double bonds (Romer, 2020). Phytol, known for its antioxidant properties, adds to the cosmetic and health benefits of plant oils. Additionally, (α,β)-amyrin, a pentacyclic triterpene present in *P. mooniana* seed oil at 0.95 mg/g (Table 3), is recognized for its anti-inflammatory properties (Honfo *et al*., 2014). These constituents suggest that incorporating *P. mooniana* seed oil into cosmetic and health industries can provide beneficial properties for skincare and overall well-being.

4.5 Evaluation of thermal stability of P. mooniana seed oil

Figure 4 presents the TGA and DTG curves for *P. mooniana* seed oil compared with peanut oil. TGA curve illustrates the mass loss of the sample that occurred with the increasing temperature in an inert nitrogen atmosphere. The DTG curve's maximum peak corresponds to the temperature at which the highest fat mass loss occurs in the nitrogen atmosphere, providing a key indicator of the fat's thermal stability (Jayadas and Nair, 2006). The decomposition temperature mentioned in Table 01 was obtained from the DTG curve. The value, 409.95 ± 1.74 °C obtained indicates that it decomposes at a higher temperature, hence the higher thermal stability. To compare TGA was performed to peanut oil (Figure 4) as a standard and the decomposition temperature obtained was 423.08 ± 1.74 °C. The value of *P. mooniana* seed oil shows closer thermal stability to that of peanut oil (Figure 4). The heating rate of 10°C/min was adopted in this study because it was proven to give better information regarding the thermal behaviour of oils in previous studies (Jayadas and Nair, 2006). The onset temperature in TGA analysis refers to the temperature at which the TGA curve first deviates from the baseline before the occurrence of the thermal event. The onset temperature was determined at a 2% loss of mass allowing the weight loss that can occur from moisture and volatile compounds (Jayadas and Nair, 2006). The onset temperature of thermal decomposition of *P. mooniana* seed oil was compared in Table 5 with values of sunflower, sesame and coconut oils. The onset temperature is lesser than the other 3 oils (Jayadas and Nair, 2006).

Table 5: Table showing the onset temperatures of thermal degradation of *P. mooniana* seed oil compared with values of sunflower, sesame and coconut oils (Jayadas and Nair, 2006)

Name of the oil	**Onset temperature in °C**
Sunflower oil	345

Sesame oil	282
Coconut oil	257
P. mooniana seed oil	124

5. Conclusion

P. mooniana is a tree widely utilized for wood applications. In conclusion, the results of this study revealed that the ripened seeds of this plant are a significant source of oil due to its high oil yield of 36.71± 0.01% which is a favourable attribute for industrial-scale production. It further exhibited attributes such as low moisture content (5.60 ± 0.19%), acid value (2.97 ± 0.40mg KOH/g) and promising FA profile. The most abundant UFAs are oleic and linoleic which play an important role in the prevention of cardiovascular diseases and enhancing skin permeability. This FA composition adds more nutritional value to the oil. *P. mooniana* seed oil also shows closer thermal stability to that of peanut oil. Furthermore, the unsaponifiable matter in the oil offers enhanced cosmetic properties, including moisturizing, anti-inflammatory, and antioxidant effects. The presence of major constituents like squalene and phytosterols suggests potential applications as dietary supplements, adding nutritional value to the oil. While these initial findings are promising, additional confirmation studies are needed to explore the full potential of *P. mooniana*. It can further suggest the potential of *P. mooniana* to be developed into a low-cost renewable source of squalene. Future investigations can be done for shelf-life determination, toxicity assessments, microbial analysis and phase behaviour studies using Differential Scanning Calorimetry. Additionally, refining processes can be employed to remove unnecessary compounds, providing a more in-depth understanding of the industrial, cosmetic and nutritional applications of *P. mooniana* seed oil.

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