ORIGINAL PAPER

LIPID CHARACTERISTICS OF MANGO SEED KERNEL OIL AS AFFECTED BY DIFFERENT RIPENING STAGES OF FRUIT

ABIONA OLUSEYE OLADAPO[1], OLUWADAMILOLA OGUNSADE[1], ADEDAYO O. ADEBOYE[1], AGBAJE B. WASIU[2]

Manuscript received: 11.02.2021; Accepted paper: 14.03.2021; Published online: 30.03.2021.

Abstract. *In this study, the effect of different stages of ripening (i.e., unripe, semi-ripe and ripe) on quality parameters of oils extracted from the kernels of Mango (Magnifera indica) seeds was investigated. The kernels were oven-dried and oil extracted from them using soxhlet apparatus and n-hexane as solvent. The fatty acid profile, phospholipids, sterol contents and some chemical properties such as saponification value, peroxide value, iodine value and acid value of oils obtained from the seeds at different level of maturity were determined. The results show that the oils are rich in saturated fatty acid most especially stearic and palmitic acids varying from 34.36 - 37.86% and 8.84 -10.66 %, respectively. The predominant unsaturated fatty acid present in the oils is oleic acid ranging from 41.96 – 45.65 %. For the chemical parameters, the peroxide values (1.82 - 2.23 %) meq/kg, acid values (5.00 – 5.50) mg/KOH/g decreased with fruit maturity. For phospholipids, phosphatidyl choline (380 – 451 mg/100 g) and phosphatidyl ethanolamine (217.42 - 342.63 mg/100 g) having the highest quantities, they all increased with fruit maturity except sphingomyelin and phosphatidic acid. Stigmasterol, sitosterol and cholesterol contents of the oils decreased with fruit maturity while Δ-5-avenasterol, campesterol and the cholestanol contents increased with fruit maturity. Sitosterol and stigmasterol and had the highest values at 345.81 - 386.96 mg/100 g and 83.70 – 137.09 mg/100 g, respectively. Conclusively, the kernel oils have potential for use as domestic and industrially as a non-conventional source of vegetable oil in chocolate and confectionery products.*

Keywords: *mango seed kernel oil; ripening; fatty acids; sterols; phospholipids.*

1. INTRODUCTION

Mango (*Mangifera indica* L.) is widely produced and cultivated in more than 100 countries across the tropical and subtropical regions of the world at an annual growing rate of 2.7 % and ranking at fifth position among the majorly cultivated fruits [1]. Mango (*Mangifera indica*) fruit is processed into various products, viz. juice, nectar, jam, sauce, chutney, syrup and canned or sliced mango [2, 3]. During the processing of mango for pulp, the stone (contributing 15-20 % of total fruit weight) is generated as by-product. To obtain the mango kernel, mango stone is decorticated. Mango contains (on a dry weight average) 6.0% protein, 11% fat, 77% carbohydrate, 2.0% crude fiber and 2.0% ash [4]. On the other hand, it is a good source of polyphenols, phytosterols such as campesterol, β-sitosterol and tocopherols. Total

[1] Osun State University, Department of Food Science and Technology, 210001 Osogbo, Nigeria. E-mail: oluseye.abiona@uniosun.edu.ng; dammyogunsade2001@yahoo.com; adedayo.adeboye@uniosun.edu.ng.
[2] Osun State University, Department of Pure and Applied Chemistry, 210001 Osogbo, Nigeria. E-mail: wasiu.agbaje@uniosun.edu.ng.

lipids (11.6% of dry kernel) consisted of 96.1% neutral and 3.9% polar lipids, which comprised 2.9% glycolipids and 1.0% phospholipids [5].

Mango can be harvested at three different maturity stages: immature, half-mature and fully mature fruits [6, 7]. Mango fruits ripen rapidly after harvest and are susceptible to diseases [8]. They perish quickly due to ripening and softening which limit the storage, handling and transport potential of the fruits. In Nigeria, the postharvest handling of mango fruits is a major challenge [9]. Fats are chemically triesters of glycerols and fatty acids and can be referred to as fats, oils or lipids based on different characteristics especially physical state [10]. Triacylglycerols are the main component of most of the fats and oils while minor components consist of mono- and diacylglycerols, free fatty acids and fat-soluble vitamins such as vitamin A & D, sterols, etc. [11]. Saturated fatty acids are those without double bonds and when present in fats in higher proportion, such fats exist as solid at normal room temperatures. They have stable and good shelf life and do not readily turn rancid [12]. Unsaturated fatty acids contain one, two or more double bond and based on this, can either be categorized as mono-unsaturated or polyunsaturated fatty acids. Monounsaturated fatty acids are comparatively stable to oxidation and the development of rancidity while polyunsaturated fatty acids are least stable fatty acids and are highly prone to oxidation [13-23].

Mango seed kernel oil is suitable for blending with other vegetable oils rich in unsaturated fatty acids since its more stable and it can also serve as cheap alternative source of vegetable oil that has similar chemical and physical properties to cocoa butter for use in confectionery industry [2]. Rukmini and Vijayaraghan [24] studied the nutritional and toxicological properties of the mango seed kernel and indicated that its fat is promising and a safe source of edible oil which was found to be nutritious and non-toxic and therefore could be substituted for any solid fat without adverse effects [25]. Lipids extracted from different mango varieties were free from toxic material such as hydrocyanic acid [26]. The oil quality depends on the quality of the raw material used for production [27]. The physiological change of the fruit, which is directly linked to the age of the fruit and maturity, occurs with a change in the oil quality [28].

Mango seed, a by-product after the consumption of the fleshy part of the fruit, is mostly discarded indiscriminately thereby contributing to environmental pollution. Also, the mango fruit is highly perishable postharvest thereby contributing to agro-waste and consequently pollution as mentioned above. Researchers have explored the possibilities of oil extraction, characterization and fatty acids profile of the oil extracted from the mango seed kernel amongst other studies, however, there is scarcity of information on how maturity affects the quality parameters of the oil. Hence, in this study, the effect of maturity stages on the quality of mango seed kernel oil including the composition of fatty acid was investigated.

2. MATERIALS AND METHODS

2.1 MATERIALS

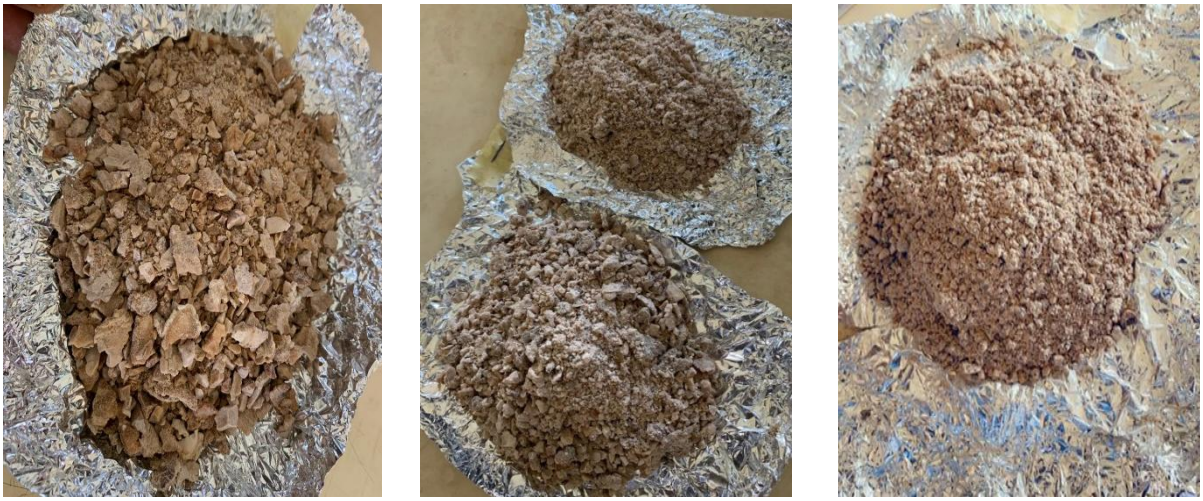
For the purpose of this study, Mango fruits at different stages of ripening (unripe, semi-ripe and ripe) were purchased from Ogbomoso Market, Oyo state, Nigeria.

Reagents for the chemical analyses used were of analytical grade as follow: n-hexane; 0.5M KOH; 14% boron triflouride; chloroform; chromo-genic solution; carbon tetrachloride; potassium iodide; sodium thiosulphate; ethanolic potassium hydroxide; acetic acid; ethanol; diethyl ether; sodium hydroxide.

2.2 METHODS

2.2.1. Sample extraction

The mango seeds were extracted from the mango fruit with the aid of a knife. The mango seeds were broken and the kernel samples were removed from it. The kernel samples were then transferred to an oven for it to be dried to a considerable moisture level. The samples were ground using a manual grinder (Fig. 1.). The samples were then transferred to an air-tight container to prevent moisture change.



Unripe **semi-ripe** **ripe**

Figure 1. Samples of ground mango seed kernels at different fruit maturity levels.

Fifty grams (50 g) of the ground mango seed kernels was weighed and transferred into a thimble and plugged with a wad of cotton wool, and then the Soxhlet apparatus (500 mL) was used to extract the oil from the mango seed kernels. The extraction was done with 250 mL of n-hexane (68 – 70°C) as solvent for 5 hours. The solvent was concentrated with a rotary vacuum evaporator. The extracted oil was bottled and refrigerated until needed for analysis.

2.2.2. Determination of fatty acid methyl ester

A gas chromatograph (HP 5890, Palo Alto, CA, USA) equipped with a flame ionization detector (FID) and a SGE BPX70 column (Cat No.CGO-5512, i.d. = 0.25 mm, length = 30 m, film thickness = 0.25 m) was employed for the qualitative and quantitative analyses of the fatty acid composition. The FAC was determined by the conversion of oil to fatty acid methyl esters (FAMEs) using the method of [29].

2.2.3. Determination of phospholipid

Modified method of [30] was employed in the analysis of the extracted lipids content determination.

2.2.4. Determination of phytosterol

The phytosterol extraction and analysis were carried out by following the method described by [31] and the extract subjected to gas chromatography. The samples were injected in a gas chromatograph equipped with a flame ionization detector, a split/split less injector

and capillary column. Detection was carried out at 325°C while the oven temperature was isothermal at 280°C for 40 min. The carrier gas was helium at a flow rate of 0.5 mL/min. Identification of sterols was done by determining the relative retention time which is the ratio of the retention time of each sterol to the retention time of β-sitosterol. The internal standard (cholesterol) method was used for the quantification.

2.2.5. Determination of chemical properties of the oil

Analyses of chemical properties were carried out using the method described in [32].

2.2.6. Statistical Analysis

The data obtained from the experimental measurements were subjected to a one-way analysis of variance (ANOVA) and the means were separated using Duncan multiple Range Test.

3. RESULTS AND DISCUSSION

3.1. FATTY ACID PROFILE

The fatty acid contents of the oil samples are as shown in Table 1. The samples had the Total Saturated Fatty Acids (TSFA) with the lowest in UR at 44.19±4.12 %, followed closely by SR at 45.70 ± 4.36 % and highest in R at 49.54±4.90 % in which stearic acid with a percentage composition of 34.36±3.001 % in UR, 35.21±3.12 % in SR, 37.86±3.46 % in R and was the most dominant fatty acid present in the three oil samples. Palmitic acid with a percentage composition of 8.84±0.11 % in UR, 9.52±0.12 % in SR, 10.66±0.21 % in R and was also present in appreciable amount. The results compare relatively with the study carried out by [18] where it was reported that the Iranian mango seed kernel oil has 37.73% stearic acid and 6.43% palmitic. It was also observed that the saturated fatty acids increased with fruit maturity. This trend is similar to the results reported by [33] for fruits of *Pistacia atlantica* with palmitic acid results of between 13.9 % and 21.9 % for the immature fruits, and between 22.1 % and 25.7 % for the mature fruits.

From the total unsaturated fatty acids (50.73 – 55.81 %) present in the three oil samples, the total monounsaturated fatty acids (TMUFA) was found to have the value of 46.02±4.87 % in UR, 44.85±4.16 % in SR and 42.34±4.05 % in R. Oleic acid with a percentage composition of 45.65±3.78 % in UR, 44.48±3.35 % in SR and 41.96±3.11 % in R was found to be most significant in the three oil samples while the other MUFA were present in little quantities as shown in Table 1. A caloric replacement of about 5% of energy from saturated fatty acids by oleic acid reduced coronary heart disease risk by 20–40%, mainly via low-density lipoprotein (LDL) cholesterol reduction was reported [34].

Also, total polyunsaturated fatty acids (TPUFA) present in the three oil samples were found to have the value of 9.78±0.83 in UR, 9.71±0.82 in SR and 8.39±0.65 in R. Linoleic acid was observed to have the highest percentage composition of 6.46±0.25 in UR, 6.27±0.23 in SR, 5.87±0.21 in R while Linolenic acid was present in fairly significant quantities in the three oil samples and Arachidonic acid in little quantities as shown in Table 1.

The fatty acid composition of the oil samples indicates they have potentials in the chocolate production industry. Mango kernel oil has been recognized as a possible alternative to cocoa butter in the production of chocolate. According to research by [35], the oil obtained from the mango seed kernels, blended at right proportion with palm oil, could be used as a cocoa butter alternative.

Table 1. Fatty acids profile of oil extracted from the seeds of unripe, semi-ripe and ripe mangos.

Composition [%]				
	Chemical Name	**UR**	**SR**	**R**
C8:0	Caprylic Acid	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00[a]
C10:0	Capric Acid	0.00±0.00 [a]	0.00±0.00 [a]	0.00±0.00 [a]
C12:0	Lauric Acid	0.00±0.00 [a]	0.00±0.00[a]	0.00±0.00 [a]
C14:0	Myristic Acid	0.11±0.01 [a]	0.12±0.01 [a]	0.12±0.011 [a]
C16:0	Palmitic Acid	8.84±0.11 [a]	9.52±0.12[b]	10.66±0.21[c]
C16:1	Palmitoleic Acid	0.25±0.02 [a]	0.25±0.01[a]	0.26±0.02 [b]
C17:0	Margaric Acid	0.02±0.00 [a]	0.02±0.001 [a]	0.02±0.00 [a]
C18:0	Stearic Acid	34.36±3.00 [a]	35.20±3.12 [b]	37.86±3.46 [c]
C18:1	Oleic Acid	45.65±3.78 [c]	44.48±3.35 [b]	41.96±3.11 [a]
C18:2	Linoleic Acid	6.46±0.25 [a]	6.27±0.23 [a]	5.87±0.21 [a]
C18:3	Linolenic Acid	3.30±0.03 [b]	3.16±0.05 [b]	2.22±0.022 [a]
C20:0	Arachidic Acid	0.26±0.01[b]	0.24±0.01 [a]	0.25±0.01 [a]
C20:4	Arachidonic Acid	0.03±0.01 [a]	0.28±0.01[b]	0.30±0.01 [c]
C22:0	Behenic Acid	0.17±0.02 [a]	0.16±0.01 [a]	0.17±0.01 [b]
C22:1	Erucic Acid	0.12±0.01 [a]	0.12±0.011 [a]	0.12±0.02[b]
C24:0	Lignoceric Acid	0.44±0.01 [b]	0.44±0.015 [a]	0.46±0.02 [c]
TSFA		44.19±4.12 [a]	45.70±4.36 [b]	49.54±4.90 [c]
MUFA		46.02±4.87 [c]	44.85±4.16 [b]	42.34±4.05 [a]
PUFA		9.78±0.83 [c]	9.71±0.82[b]	8.39±0.65 [a]
TUFA		55.81±5.85 [c]	54.55±5.51 [b]	50.73±5.00 [a]

Each value in the table represents the mean of three replicates ± SD. Means within each row for each treatment with different superscripts are significantly (P<0.05) different; UR = Unripe seeds; SR = Semi ripe seeds; R = Ripe seeds; TSFA = Total saturated fatty acid; MUFA = Monounsaturated fatty acid; PUFA = Polyunsaturated fatty acid; TUFA = Total unsaturated fatty acid.

It was also reported that mango oil is highly suitable for preparing coco butter substitute (CBS) or coco butter equivalents (CBE) [36]. Overall, the quantities of all the unsaturated fatty acids showed a steady decrease with fruit maturity. This aligns with the submission of [37] that observed decrease in the unsaturated fatty acid content of Jatropha seed oil as fruit maturation advance and associated it to the chemical instability of unsaturated fatty acids (easily oxidized), therefore making the oil susceptible to oxidation and degradation. It was also observed that the difference in quantity of unsaturated fatty acids to saturated fatty acids was significantly higher in unripe fruit oil compared with the ripe one.

3.2. PHOSPHOLIPID PROFILE

The phospholipid profiles of the oil samples are as represented in Table 2.

Table 2. Phospholipids profile of oil extracted from the seeds of unripe, semi-ripe and ripe mangos.

Sample [mg/100g]			
Phospholipids	**UR**	**SR**	**R**
Phosphatidylethanolamine	217.42±18.01^{a}	221.13±18.02^{a}	324.63±22.03^{b}
Phosphatidylcholine	380.55±25.04^{a}	406.09±20.05^{b}	451.82±22.05^{b}
Phosphatidylserine	3.158±0.06^{a}	4.284±0.02^{b}	4.051±0.01^{b}
Lysophosphatidylcholine	0.59±0.02^{a}	0.65±0.01^{a}	0.35±0.01^{a}
Sphingomyelin	0.05±0.00^{a}	0.06±0.00^{a}	0.04±0.01^{a}
Phosphalidylin sitol	94.78±10.02^{a}	105.77±10.02^{b}	127.79±15.05^{c}
Phosphatidic acid	80.45±8.90^{c}	70.99±7.08^{b}	60.25±6.07^{a}

Each value in the table represents the mean of three replicates ± SD. Means within each row for each treatment with different superscripts are significantly (P<0.05) different; UR = Unripe seeds; SR = Semi ripe seeds; R = Ripe seeds.

Phosphatidylethanolamines values of 217.42±18.01 mg/100 g, 221.13±18.0.02 mg/100 g, 324.63±22.03 mg/100 g were obtained for UR, SR, and R respectively, with UR having lowest value while R had the highest. Phosphatidylcholine values of 380.55±25.04 mg/100 g, 406.09±20.05 mg/100 g, and 451.82±22.05 mg/100 g were obtained for samples UR, SR, and R, respectively with R having the highest value and SR the lowest values. For phosphatidylserine, 3.158±0.06 mg/100 g, 4.284±0.02 mg/100 g and 4.051±0.01 mg/100 g were the results obtained for samples UR, SR, and R, respectively with R having the highest value and UR having the lowest values. In the case of lysophosphatidylcholine, 0.59±0.02 mg/100 g, 0.65±0.01 mg/100 g, and 0.35±0.01 mg/100 g were the values obtained for samples UR, SR, and R, respectively. In addition, the obtained results of sphingomyelin were 0.05±0.01 mg/100 g, 0.06±0.01 mg/100 g, and 0.04±0.01 mg/100 g for samples UR, SR, and R, respectively and the SR sample having the highest value. For phosphatidylinositol, the obtained data were 94.78±10.02 mg/100 g, 105.77±10.02 mg/100 g, and 127.79±15.05 mg/100 g for sample UR, SR, and R, respectively with sample R having the highest value and UR the lowest. The results for phosphatidic acid were 60.25±6.07 mg/100 g, 70.99±7.08 mg/100 g, and 80.45±8.90 mg/100g for sample UR, SR and R, respectively, where R had the highest value and UR the lowest. On the other hand, phosphatidylcholine (380 - 451 mg/100 g) and phosphatidylethanolamine (217.42 - 342.63 mg/100 g) had the highest quantities while sphingomyelin had the lowest quantity (0.04 - 0.06 mg/100 g) as shown in Table 2.

All of the phospholipids (phosphatidylethanolamine, phosphatidylcholine, phosphatidylserine, lysophosphatidylcholine, phosphalidylinsitol) of the oil samples increased with fruit maturity except sphingomyelin and phosphatidic acid that decreased with fruit maturity. Phosphatidylcholine is a vital component for all eukaryotic cells and the amplest class among all phospholipids. Besides being a crucial structural component of cellular membranes, phosphatidylcholine has been identified as an essential source for signaling molecules [38-42]. Phosphatidylethanolamines, one of the majorly occurring, often accounts for a high percentage of the total phospholipids present in animals and plants and as such are building blocks of membrane bilayer [42].

3.3. STEROL PROFILE

Phytosterols, also known as plant sterols are bioactive compounds present in over 200 types and related compounds in various plant materials [43]. Stanols are considered a subgroup and saturated form of phytosterols. It has been reported that phytostanols occur in high levels in a few cereals, while in many plants it is found in trace levels [44]. The sterol profiles of the oil samples are as represented in Table 3.

Table 3. Sterols Profile of Oil Extracted from the Seeds of Unripe, Semi-Ripe and Ripe Mangos.

	Sample [mg/100 g]		
Sterols	**UR**	**SR**	**R**
Cholesterol	$3.69\times10^{-4}\pm1.11\times10^{-4a}$	$2.09\times10^{-4}\pm1.10\times10^{-4a}$	$2.73\times10^{-4}\pm1.12\times10^{-4a}$
Cholestanol	$5.61\times10^{-5}\pm1.11\times10^{-5a}$	$6.73\times10^{-5}\pm1.11\times10^{-5a}$	$8.04\times10^{-5}\pm1.12\times10^{-5b}$
Ergosterol	$1.83\times10^{-3}\pm1.10\times10^{-3a}$	$1.83\times10^{-3}\pm1.0\times10^{-3a}$	$1.83\times10^{-3}\pm1.11\times10^{-3a}$
Campesterol	6.83 ± 0.5^{a}	6.49 ± 0.2^{a}	6.96 ± 0.2^{a}
Stig-masterol	137.09 ± 13.02^{b}	172.74 ± 17.02^{c}	83.70 ± 8.04^{a}
Δ-5-avenasterol	17.96 ± 1.50^{a}	28.23 ± 3.80^{b}	48.22 ± 5.14^{c}
Sitosterol	386.95 ± 10.02^{a}	363.49 ± 10.27^{a}	345.81 ± 10.30^{a}

Each value in the table represents the mean of three replicates ± SD. Means within each row for each treatment with different superscripts are significantly (P<0.05) different; UR = Unripe seeds; SR = Semi ripe seeds; R = Ripe seeds.

The values of cholesterol in the oil samples UR, SR and R were $3.69\times10^{-4}\pm1.11\times10^{-4}$ mg/100 g, $2.09\times10^{-4}\pm1.10\times10^{-4}$ mg/100 g and $2.73\times10^{-4}\pm1.12\times10^{-4}$ mg/100 g, respectively. Cholestanol obtained results in the oil samples ranged from $5.61\times10^{-5}\pm1.11\times10^{-5}$ mg/100 g to $8.04\times10^{-5}\pm1.12\times10^{-5}$ mg/100 g; R sample had the highest value and UR the lowest. The ergosterol results for the oil samples UR, SR, and R were $1.83\times10^{-3}\pm1.10\times10^{-3}$ mg/100 g, $1.83\times10^{-3}\pm1.0\times10^{-3}$ mg/100 g, and $1.83\times10^{-3}\pm1.11\times10^{-3}$ mg/100g respectively. There was no significant difference in the presence of ergosterol across the samples. The values of campesterol in the oil samples UR, SR, and R are 6.83±0.50 mg/100 g, 6.49±0.20 mg/100 g, and 6.96±0.20 mg/100g, respectively, while the results for stigmasterol in the oil samples UR, SR, and R were 137.09±13.02 mg/100 g, 172.74±17.02 mg/100 g, and 83.70±8.04 mg/100g, respectively. The Δ-5-avenasterol results in the oil samples UR, SR, and R were 17.96±1.50 mg/100 g, 28.23±3.80 mg/100 g, and 48.22±5.14 mg/100g, respectively, in which R had the highest value, while UR had the lowest. Sitosterol is also present in the oil samples UR, SR and R with values at 386.95±10.02 mg/100 g, 363.49±10.27 mg/100 g, and 345.81±10.30 mg/100g, respectively.

Stigmasterol, sitosterol and cholesterol contents of the oils decreased with fruit maturity while Δ-5-avenasterol, campesterol and the cholestanol contents increased with fruit maturity. Sitosterol and stigmasterol had the highest values at 345.81 - 386.96 mg/100 g and 83.70 – 137.09 mg/100 g respectively. Sitosterol is a phytosterol with steroidal molecule similar to cholesterol. It is present in many oils from plants and vegetables sources because of its steroidal lipophilic nature [45]. It had also been reported [46] that the content of Sitosterol in Tunisian Safflower decreased significantly until full maturity while Δ-5-avenasterol, which was low at the immature stage, increased extensively at complete maturity. On the other hand, another study [47] reported that the level of sterols present in oil can be influenced by biosynthesis of sterols that occurs at the early stage of fruit ripening while [48] also,

submitted that decline in sterol accumulation towards the end of ripening can be as a result of the down regulation of enzymatic synthesis as well as the conversion of existing sterols to steroidal hormones, and vitamins, which are responsible for the regulation of growth and development of immature tissues. In addition, other authors [49] reported that as oil content of the fruit increases with ripening, the sterols can become more diluted.

3.4. CHEMICAL PROPERTIES PROFILE

Table 4 represents the results obtained for the chemical properties of the oil samples with iodine values of 114.25±11.10, 109.78±10.20, and 205.15±20.20 g/100 g for sample UR, SR, and R respectively, where sample R had the highest value and sample SR had the lowest value. The higher the iodine value, the rapid the oil tend to oxidize [47].

Table 4. Chemical properties of oil extracted from the seeds of unripe, semi-ripe and ripe mangos.

Samples	Saponification value [mg/KOH/g of oil]	Peroxide value [Meq/kg]	Iodine value [g/100 g]	Acid value [mg/KOH/g of oil]
UR	217.10±20.20^{a}	2.23±0.30^{a}	114.25±11.10^{b}	5.50±0.30^{a}
SR	208.20±20.10^{a}	1.93±0.10^{b}	109.78±10.20^{b}	5.14±0.30^{a}
R	197.05±9.20^{b}	1.82±0.10^{b}	205.15±20.20^{a}	5.00±0.20^{a}

Each value in the table represents the mean of three replicates ± SD. Means within each row for each treatment with different superscripts are significantly (P<0.05) different; UR = Unripe seeds; SR = Semi ripe seeds; R = Ripe seeds.

The presence of peroxide shows that there are some oxidative activities going on in the oil. Samples UR, SR and R had peroxide value of 2.23±0.30, 1.93±0.10 and 1.82±0.10 meq/kg, respectively, which showed steady decline with fruit maturity. The values were low when compared to high peroxide values of 77.5, 95.0, 150.0, 135.0 meq/kg obtained for *B. parkii, L. lanceolata, D. microcarpum* and *B. sapida* as reported by Kyari [50] and 57.74 ± 2.77 meq/kg obtained for African star apple as reported by Omeje et al. [51]. Reduction in the peroxide values as the fruit matures agrees with the findings of Baccouri et al. [52] that attributed this trend in olives to a decrease in the activity of lipoxygenase at full maturity. Saponification value, which is also known as the Koettstorfer number, is the measure of amount of potassium hydroxide (mg) needed to neutralize the acids in an oil sample and saponify the esters in 1 g of a lipid [52]. Samples UR, SR and R had saponification value of 217.10±20.20, 208.20±20.10, and 197.05±9.20 mg/KOH/g respectively, and the saponification values declined with fruit maturity. The results obtained were higher than the values (189 – 195 mg/KOH/g fat) reported by [47] for soya beans oil and 193 mg/KOH/g fat of soya beans oil as reported by Olaniyan and Oje [53], while within the range of saponification values of manually extracted boiled sheanuts shea butter (197.14 mg/KOH/g) and native shea butter (199 mg/KOH/g fat) as reported by [54]. Acid value indicates the proportion of free fatty acid present in an oil as well as the level of rancidity. It is also a factor for determining oil freshness [54]. Acid values of sample UR, SR and R were 5.50±0.30, 5.14±0.30, and 5.00±0.20 mg/KOH/g, respectively and the values declined with fruit maturity. The reverse of this trend was observed in olive oils as reported by El Qarnifa et al. [55] that there was an increase in acidity of olive oils during maturation and this was attributed to the increase in lipolytic activity, and also in the advanced stage of maturation, the olives become more sensitive to pathogenic infections and mechanical damage.

4. CONCLUSION

From the obtained result, it is concluded that the level of maturity has quantifiable influence on the quality of mango seed kernel oil. Higher quantity of unsaturated fatty acid, low cholesterol level, high levels of phytosterols and phospholipids makes the oil samples potentially good for consumption. The seed kernel oil has potential for both domestic and industrial use and this can be explored to eradicate wastes, reduce environmental pollution and improve its utilization to achieve financial benefits. Even more, oil from ripe seed kernels of mango was found to be high in unsaturated fatty acid, phospholipids, and had the lowest peroxide and acid values thus making it the most suitable oil for consumption and industrial uses, e.g. for use as a non-conventional source of vegetable oil in chocolate and confectionery products, amongst the three maturity stages explored.

REFERENCES

[1] Fowomola, M.A., *Afr. J. Food Sci.*, **4**(8), 472, 2010.
[2] Dhingra, S., Kapoor, A.C., *J. Sci. Food Agric.*, **6**, 752, 1985.
[3] Kittiphoom, S., *Int. Food Res. J.*, **19**(4), 1325, 2012.
[4] Garg, N., Bajpai, J., Ashfaque, M., Yadav, P., *Extraction and characterization of oil from unripe mango kernel*, National Conference on conservation Horticulture, Uttarakhand, March 2010 Dehradun, 276, 21-23.
[5] Hemavathy J, Prabhakar JV, Sen DP. 1988. Drying and storage behavior of mango (*Mangifera indica*) and composition of kernel fat. ASEAN Food J. 4(2), 59–63.
[6] Majeed, M., Jeffery, K.B., *Sci. Hortic*., **95**, 297, 2002.
[7] Mitra, S.K., Baldwin, E.A., Mango. In: Mitra, S.K. (Ed.), *Postharvest physiology and storage of tropical and subtropical fruits*, CAB International, New York, 85-122, 1997.
[8] Onyeani, C.A., Osunlaja, O., Owuru, O.O., Sosanya, O., *Int. J. Sci. Tech.*, **1**, 30, 2012.
[9] Amarakoon, R., Illeperuma, D.C.K., Sarananda, K.H., *Trop. Agric. Res.*, **11**, 54, 1999.
[10] Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., Walter, P., *Molecular Biology of the Cell*, Garland Science, New York, 2002.
[11] Strayer, D., *Food Fats and Oil*, 9th Edn., *Institute of Shortening and Edible Oils*, Washington D.C., 2006.
[12] Amri, I.N., The lauric (coconut and palm kernel) oils. In: Gunstone, F. (ed.), *Vegetable Oils in Food Technology: Composition, Properties and Uses*, 2nd Edn., Wiley-Blackwell, West Sussex, 169-197, 2013.
[13] Bockisch, M., Composition, structure, physical data, and chemical reactions of fats and oils and their associates. In: *Fats and Oils Handbook*, AOCS Press, Champaign, 53-120, 1998.
[14] Dubois, V., Breton, S., Linder, M., Fanni, J., Parmentier, M., *Eur. J. Lipid Sci. Tech.*, **109**, 710, 2007.
[15] Firestone, D., *Physical and chemical characteristics of oils, fats and waxes*, AOCS Press, Champaign, 2006.
[16] Karkeskind, A., Sources of the main fats and relevant monographs. In: Karkeskind, A. (Ed.), *Oils and Fats Manual*, Lavoisier Publishing, Paris, 117-323, 1996.
[17] Radulescu C., Buruleanu L.C., Nicolecu C.M., Olteanu R.L., Bumbac M., Holban G.C., Simal-Gandara J., *Plants*, **9**(11), 1470, 2020.
[18] David M., Serban A., Radulescu C., Danet A.F., Florescu M., *Bioelectrochemistry*, **129**, 124, 2019.
[19] Radulescu C., Hossu A.M., *Rev. Chim (Bucharest)*, **56**(7), 742, 2005.
[20] Radulescu C., Tarabasanu-Mihaila C., *Rev. Chim. (Bucharest)*, **55**(1), 25, 2004.

[21] Dumitrescu, C., Olteanu, R.L., Bumbac, M., Gorghiu, L.M., *Rev. Chim (Bucharest)*, **60**(4), 329, 2009.
[22] Nicolescu, C.M., Olteanu, R.L., Bumbac, M., *Analytical Letters*, **50**(17), 2802, 2017.
[23] Georgescu, A.A., Eliescu, A., et al, *Analytical Letters*, **52**(13), 2007, 2019.
[24] Rukmini, C., Vijayaraghavan, M., *J. Am. Oil Chem. Soc.*, **61**(4), 780, 1984.
[25] Fahimdanesh, M., Bahrami, E.M., *Int. Proc. Chem. Biol. Environ. Eng.*, **53**(9), 44, 2013.
[26] Rashwan, M.R.A., *Assiut. J. Agric. Sci.*, **21**(1), 105, 1990.
[27] Matthäus, B., Guillaume, D., Gharby, S., Haddad, A., Harhar, H., Charrouf, Z., *Food Chem.*, **120**(2), 426, 2010.
[28] Gharby, S., Harhar, H., et al, *LWT Food Sci. Technol*., **44**(1), 1, 2011.
[29] Timms, R.E., *Aust. J. Dairy Technol.*, **33**, 4, 1978.
[30] Raheja, R.K., Kaur, C., Singh, A., Bhatia, I.S., *J. Lipid Res*., **14**, 695, 1973.
[31] Ilyasoglu, H., Ozcelik, B., Van Hoed, V., Verhe, R., *J. Am. Oil Chem. Soc*., **87**(6), 627, 2010.
[32] ***** AOAC, International Official Methods of Analysis of the AOAC (W. Horwitiz, Editor), 18th Edn., AOAC International, Washington D.C., 2006.
[33] Guenane, H. et al., *Nat. Prod. Comm.*, **10**(10), 1723, 2015.
[34] Kris-Etherton, P.M., Pearson, T.A., Wan, Y., Hargrove, R.L., Moriarty, K., Fishell, V., Etherton, T.D., *Am. J. Clin. Nutr.*, **70**(6), 1009, 1999.
[35] Kaphueakngam, P., Flood, A., Sonwai, S., *As. J. Food Ag-Ind.*, **2**(4), 441, 2009.
[36] Dhara, R., Bhattacharyya, D.K., Ghosh, M., *J. Oleo Sci.*, **59**(4), 169, 2010.
[37] Jonas, M., Ketlogetswe, C., Gandure, J., *Heliyon*, **6**(1), e03285, 2020.
[38] Exton, J.H., *Biochim. Biophys. Acta.* **1212**(1), 26, 1994.
[39] Billah, M.M., Anthes, J.C., *Biochem. J.*, **269**, 281, 1990.
[40] Kiss, Z., *Prog. Lipid Res*., **29**, 141, 1990.
[41] Kester, M., Simonson, M.S., Mené, P., Sedor, J.R., *J. Clin. Invest.*, **83**(2), 718, 1989.
[42] Wirtz, K., *Ann. Rev. Biochem.*, **60**(13), 73, 1991.
[43] Lagarda, M.J., Gracia-Llatas, G., Farre, R., *J. Pharmaceut. Biommed. Anal.*, **41**, 1486, 2006.
[44] Shahzad, N., Khan, W., Shadab, M.D., Ali, A., Saluja, S.S., Sharma, S., Al-Allaf, F.A., Abdujaleel, Z., Ibrahim, I.A.A., Abdel-Wahab, A.F., Afify, M.A., Al-Ghamdi, S.S., *Biomed. Pharmacother.*, **88**, 786, 2017.
[45] Zhao, H.L., Houweling, A.H., Vanstone, C.A., Jew, S., Trautwein, E.A., Duchateau, G.S., Jones, P.J., *J. Am. Coll. Nutr.*, **30**(2), 155, 2011.
[46] Hamrouni-Sellami, I., Salah, H.B., Kchouk, M.E., Marzouk, B., *Pakistan J. Biol. Sci.*, **10**(21), 3829, 2007.
[47] Casas, J.S., Bueno, E.O., Montano Garcia, A.M., Cano, M.M., *Food Chem.*, **87**, 225, 2004.
[48] Sakouhi, F., Absalon, C., Harrabi, S., Vitry, C., Sebei, K., Boukchina, S., Kallel, H., *Food Chem*., **112**, 897, 2009.
[49] Gutierrez, F., Jimenez, B., Ruiz, A., Albi, M.A., *J. Agric. Food Chem.*, **47**(1), 121, 1999.
[50] Kyari, M.Z., *Int. Agrophys.*, **22**(2), 139, 2008.
[51] Omeje, K.O., Iroha, O.K., Edeke, A.A., Omeje, H.C., Apeh, V.O., *Oilseeds & fats Crops and Lipids*, **26**, 10 2019.
[52] Baccouri, O, Guerfel, M, Baccouri, B, Cerretani, L, Bendini, A, Lercker, G, Zarrouk, M, Daoud Ben Miled, D., *Food Chem.*, **109**(4), 743, 2008.
[53] Olaniyan, A.M., Oje, K., *J. Food Sci Technol*., **44**, 404, 2007.
[54] Ononogbu, I.C., *Lipids in human existence*, AP Express Publishers, Nsukka, 2002.
[55] El Qarnifa, S., El Antari, A., Hafidi, A., *J. Food Qual.*, **2019**, 1, 2019.