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Physicochemical study of kernel oils from ten varieties of *Mangifera indica* (Anacardiaceae) cultivated in Cote d'Ivoire

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Mango consumers only use pulp and consider the kernel as wastes. This study aims to valorize the kernel of mango (*Mangifera indica*). In this study, the kernel of ten mango varieties (*Ruby*, *Kent*, *Retard*, *Key*, *Assabony*, *Smith tête de chat*, *Smith normal*, *Palmer*, *Governeur* and *Aravia*) collected at Yamoussoukro in the center of Cote d'Ivoire were used. The oils of these kernels were extracted by maceration method. Their physicochemical properties were determinate using standard methods. The yields of oils extracted are higher than 10%. The acid value of these oils varies from 2.50±0.25 to 27.06±0.35 mg of KOH/g, the saponification value ranges between 164.17±1.30 and 199.21±0.32 mg of KOH/g, iodine value varies from 36.38±0.96 to 54.46±0.54 g of iodine per 100 g of fat and the refractive index ranges between 1.458±0.001 and 1.480±0.002. The water and volatile matter content are varying between 1.08±0.19 and 12.30±0.46%. The study of the lipid composition of these fats showed a significant presence of fatty acid and unsaponifiables. The major fatty acids are palmitic acid (6.77-12.80%), stearic acid (36.36-45.76%), oleic acid (43.20-52.42%) and arachidic acid (0.85-1.65%). The major unsaponifiables are ergosterol (1.94%), sitosterol (78.65%), stigmasterol (10.67%), campesterol (5.33%) and 3-hydroxy-pregn-5-en-20-one (3.39%). The results of the study indicated that mango kernel oils could be used in cosmetics and also in human nutrition for prevention against arteriosclerosis and cardiovascular diseases.

Key words: *Mangifera indica*, Anacardiaceae, fatty acids.

INTRODUCTION

Mangifera indica, commonly known as mango is a plant in the family Anacardiaceae. It is cultivated for the sweet flavor of its fruit. The latter is an important alternative in agro-industry because of its physico-chemical composition and nutritional properties (Julio and Marie, 2005). In food processing industry after the extraction of

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mango pulp and kernel butter, a considerable quantity of kernel seed cake is discarded as waste (Ahmed et al., 2007a).

Mango seeds are used traditionally against gastric pathogens, especially in children treatment, or in anti-diarrhoeal cure (Sairam et al., 2003). Mango parts, such as stem bark, leaves, and pulp are known for various biomedical applications, including antioxidative and free radical scavenging (Gabino et al., 2008), and anticancer activities (Susan et al., 2006). Several studies carried out on the various organs (leaves, roots, barks, flowers and fruits) of *M. indica* have shown their wealth in secondary metabolites (Yango et al., 2004).

Studies on the kernel of *M. indica* fruit have shown the presence of fats (Ahmed et al., 2007b) and polyphenolic compounds (Riberio and Barbosa, 2008). Other studies have shown that the mango kernel has several biological activities such as anti-diarrhea (Sairam et al., 2003), antibacterial (Thoshihide et al., 2000) and antioxidant (Ahmed et al., 2007b).

Mango is one of the most popular tropical fruits. According to FAO data (FAO, 2002), the mango occupies sixth place in world fruit production, after orange, banana, grapes, apples and plantains. In Cote d'Ivoire, the annual production of mango is about 100,000 t (Sangare et al., 2009). The kernel of mango, after extraction of the pulp, is generally abandoned in nature. Thus, this agricultural waste constitute environnemental problems; however to our knowledge, very few studies have been done about the almonds of mango species from Cote d'Ivoire. This is what justifies the choice of the study of mango kernel to better value.

A previous study (Amian et al., 2014) on the seed kernel mango showed the presence of tannins and gallic acids. In this new study, it is about to extract and characterize the almond fat from the core of 10 varieties of mango.

MATERIAL AND METHODS

Plant material

The plant material consists of kernels of 10 varieties of mango namely: *Ruby*, *Kent*, *Retard*, *Key*, *Assabony*, *Smith tête de chat*, *Smith normal*, *Palmer*, *Governeur* and *Aravia*. The most famous varieties in Cote d'Ivoire are *Kent*, *Key*, *Palmer*, *Ruby* and *Smith*. The fruits used for the study are those that have a natural ripening. The ripe fruits of these mangoes were harvested from an orchard in Yamoussoukro in central Cote d'Ivoire. The names of the species are those given by the owner of the orchard and confirmed by the vendors on the market. The fruits were then sent to the laboratory LAPISEN of INP-HB Yamoussoukro. After consumption of the pulp, the mango kernel are freed of their envelopes, and then dried for 5 days in the sun and 48 h in an oven (at 50°C). Dry almonds are crushed and stored in a refrigerator at 4°C for previous studies.

Extraction of fats

A mass of powder (1 kg) of the plant material is introduced into a flask, and then macerated with an amount of distilled hexane (1 L) with stirring for 1 h. Hexane is the solvent used for the extraction of vegetable oils (Frederic et al., 2013). The extract obtained is filtered on cotton and then on filter paper. The same operation is repeated twice on the same residue. The various filtrates are combined and concentrated on a rotary evaporator at 40°C. The crude residue obtained constitutes the fats.

Chemical characterization of the fats

Physicochemical characteristics of the fats

The physicochemical characteristics of the fats of mango kernel were determined according to the methods defined by the AFNOR standards (AFNOR, 1984):

1. Acid value (ISO 660)
2. Iodine value (ISO 3961)
3. Peroxide value (ISO 3960)
4. Refractive index (ISO 6320)
5. Saponification value (ISO 3657)
6. Moisture and volatile matter content (ISO 662)
7. Density or specific gravity (ISO 6883)
8. Unsaponifiables (ISO 3596)

Statistical analysis

Results were expressed as mean±standard deviation of three replicates. Data were evaluated by one-way analysis of variance (ANOVA) using statistica 7.1 (Stat Soft, Inc, USA) solfware. Newman-keuls test performed to determine significant.

Gas chromatography coupled to mass spectrometry (GC / MS)

The chromatographic analyzes were carried out according to the methods defined by the International Organization of Standardization: (ISO 12966-1,2). Before GC / MS analysis, the fatty acids are converted into methyl esters. GC / MS analyzes were performed with a Trace GC Thermo Finnigan gas chromatograph coupled to a Thermo Finnigan AUTOMASS mass spectrometer. The GC chromatograph is equipped with a split/splitless injector. The capillary column of BP-X5 type (5% phenyl and 95% methylpolysiloxane) is 30 m long, and has an inside diameter of 0.25 mm and a film thickness of 0.25 µm. The carrier gas is helium with a flow rate of 1 $mL.min^{-1}$. The injector and detector temperatures were set at 280 and 290°C, respectively.

The operating conditions of the electronic impact mass spectrometer are; ionization source temperature 200°C and electron energy 70 eV. The identification of the compounds was possible by comparing the spectral data obtained from the NIST libraries.

RESULTS AND DISCUSSION

Extraction of fats

The extraction yields and aspects of the 10 varieties of mangoes studied are shown in Table 1. The result of Table 1 shows that the oil yields of mango kernel ranges from 7.04±0.66 to 10.61±0.36. These yields are low compared to those of oleaginous seeds (OCDE/FAO, 2015). Knowing that maceration does not make it

Table 1. Extraction yields and aspects of the oil of different varieties of mangoes.

Variety of mango	Yield (%)	Aspects of oil at 25°C
Rubis	10.16±0.21[e.g]	Butter
Kent	7.04±0.66[a]	Oil
Retard	7.84±0.10[a.b.c]	Butter
Key	8.70±0.57[c.d]	Butter
Assabonie	9.88±0.29[e.g]	Butter
Smith tète de chat	9.19±0.97[d.e]	Butter
Smith normal	9.22±0.26[d.e]	Butter
Palmer	10.61±0.36[g]	Butter
Gouverneur	7.50±0.45[a.b]	Butter
Aravia	8.40±0.18[b.c.d]	Butter

In each column the averages not followed by the same lowercase letter are statistically different at a threshold of 5% ($P < 0.05$).

Table 2. Chemical characteristics of butters and oils of ten varieties of almond mangoes.

Variety of mango	Acid value (mg de KOH/g)	Iode value (g d'iode/100 g)	Peroxyde value (méq d'O_2/kg)	Saponification value (mg de KOH/g)	Moisture and volatile contents (%)	Unsaponifiable content (%)
Rubis	5.41±0.27[c]	46.40±0.21[c]	1.40±0.05[a]	199.21±0.32[e]	1.08±0.19[a]	1.90±0.09[b]
Kent	27.06±0.35[e]	54.46±0.54[d]	4.28±0.36[b]	190.29±1.48[d]	12.30±0.46[g]	0.94±0.09[a]
Retard	5.41±0.61[c]	46.86±0.80[c]	1.38±0.13[a]	187.56±1.49[c.d]	6.84±0.44[e]	2.83±0.62[d]
Key	7.09±0.77[c]	45.34±0.01[b.c]	2.23±0.31[a]	ND	6.52±0.12[e]	1.90±0.08[b]
Assabonie	10.00±0.46[d]	42.18±0.20[a.b.c]	5.71±0.55[c]	164.17±1.30[a]	3.22±0.49[d]	1.00±0.22[a]
Smith tète de chat	10.00±0.36[d]	36.38±0.96[a]	20.71±0.75[g]	ND	7.00±0.34[e.f]	2.00±0.32[b]
Smith normal	10.00±0.13[d]	37.87±0.82 [a.b]	30.71±0.31[h]	170.96±1.45[b]	1.64±0.17[b]	1.10±0.11[a]
Palmer	3.33±0.52[b]	37.88±0.73 [a.b]	17.50±0.86[f]	182.85±1.67[c]	7.50±0.14[f]	2.00±0.10[b]
Gouverneur	2.50±0.25[a]	42.63±0.62 [a.b.c]	12.43±0.81[e]	172.73±1.95[b]	1.95±0.13[c]	2.74±0.77[c]
Aravia	5.83±0.61[c]	42.18±0.28 [a.b.c]	7.14±0.13[d]	172.45±1.34[b]	6.32±0.24[e]	1.20±0.07[a.b]

In each column the averages not followed by the same lowercase letter are statistically different at a threshold of 5% ($P < 0.05$).
ND: not determined.

possible to extract all of the fats, these yields could be improved by other techniques such as soxhlet and the press. The fat extracted from these mango kernels is solid at room temperature with the exception of that of the *Kent* species which is liquid. The results showed that certain almonds of mango contain more oil than other. The oil yields of *Palmer* and *Rubis* species are higher while *Gouverneur* and *Kent* species are weaker.

Physico-chemical characteristics

The physicochemical characteristics (at room temperature) of the almond oils of ten (10) varieties of mango are shown in Tables 2 and 3.

Acid value

The acid value presents the free fatty acid content of the fats. These values are equivalent to an acidity rate expressed as a percentage. The acid value of the oils of mango kernels are between 2.50±0.25 and 10.00±0.13, except of the *Kent* species oil which has an acid value of 27.06±0.35. These acid value are less than or equal to that of virgin palm oil (10 mg KOH / g oil) except for *Kent* species. The acid value of *Kent* species is similar to that of seeds of *Duranta repens* (Emmanuel et al., 2017). At the exception of *Gouverneur* species (2.50±0.25 mg KOH / g oil) and *Palmer* species (3.33±052 mg KOH / g oil), the various acid value remain higher than those allowed for edible virgin oils (≤ 4 mg KOH / g oil) (AFNOR, 1981). These undesirable fatty acids could be removed by refining these butters and oils.

Peroxide value

The peroxide value is a very useful parameter for appreciating the first stages of oxidative deterioration.

Table 3. Physical characteristics of butters and oils of ten varieties of almond mangoes.

Variety of mango	Density index (28°C)	Réfraction index
Rubis	0.85±0.01[c]	1.463±0.001[b]
Kent	0.87±0.00[c]	1.480±0.002[c]
Retard	0.88±0.01[c]	1.461±0.001[a,b]
Key	0.87±0.01[c]	1.458±0.000[a]
Assabonie	0.95±0.00[d]	1.461±0.001[a,b]
Smith tète de chat	0.81±0.00[b]	1.458±0.001[a]
Smith normal	0.77±0.02[a]	1.460±0.003[a,b]
Palmer	0.85±0.03[c]	1.460±0.001[a,b]
Gouverneur	0.81±0.01[b]	1.459±0.001[a]
Aravia	0.81±0.01[b]	1.458±0.002[a]

In each column the averages not followed by the same lowercase letter are statistically different at a threshold of 5% (P <0.05).

The peroxide value of the oils of mango kernels are between 1.38±0.13 and 30.71±0.31. The peroxide value of kernel mango oils and butters are lower than the allowed value for crude vegetable oils (≤15 mqq / kg oil) (FAO/OMS, 1999) except for *Smith normal* species (30.71±0.31), *Smith tète de chat* species (20.71±0.75) and *Palmer* species (17.50±0.86). These high values could be due to the oxidation of the unsaturated free fatty acids present in these oils and butters. However, to avoid this oxidation, antioxidants such as ButylHydroxyAnisol (BHA) or ButylHydroxytoluene (BHT) could be added to these fats.

Density

The density of the oils depends on its chemical composition. The densities of the oils of mango kernels are between 0.77±0.02 and 0.95±0.00. These values are comparable to those of butter and vegetable oils (FAO/OMS, 1999) such as shea butter (0.9), cocoa butter (0.88-0.90), palm oil (0.89- 0.90) and cotton oil (0.91-0.92).

Refractive index

The refractive index depends also on the chemical composition of the oil and the temperature. This index grows with the unsaturation or with the presence on the fatty chains of secondary functions. The refractive index values of oils and butters mango are between 1.458±0.001 and 1.480±0.002. This values are comparable to butter and vegetable oils (FAO/OMS, 1999) such as cocoa butter (1.455 to 1.458), palm oil (1.454 to 1.456), cotton seed oil (1.458 to 1.466) and shea butter (1.463 to 1.468). The refractive index of the oil of the *Kent* species (1.480±0.002) is higher. This species reflects a degree of insatuation higher than other varieties.

Iodine value

The iodine value is a chemical parameter that presents the degree of unsaturation of a fat. The iodine value of butters and oils of mango kernel are between 36.38±0.96 and 54.46±0.54. The oils and butters of mango kernels generally have a lower iodine value than shea butter (57-66) and cotton seed oil (100-105). The oil of the *Kent* species (54.46±0.54) has a value comparable to palm oil (50-55), while the other varieties have an iodine value comparable to cocoa butter (33-42) (FAO/OMS, 1999). These iodine value of butters and oils of mango are consistent with its (liquid) appearance.

Moisture and volatile matter

The moisture and volatile contents of butters and oils of mango kernels is between 1.08±0.19 and 12.30±0.46%. The values of *Rubis* species (1.08±0.19%) and *Gouverneur* species (1.95±0.13%) is comparable of shea butter (0.10-1.24%), cotton oil (0.80-1.50%) and palm oil (0.05-2%). However, the values of others species are higher than the maximum level recommended by the regulations for vegetable oils and butters (0.2%) (FAO/OMS, 1999). The high presence of water and volatile matter could promote enzymatic activity. This suggests that our butters and oil are more likely to suffer the hydrolytic or enzymatic alteration that leads to the formation of secondary products such as monoglycerides and diglycerides. These high values could also reflect the hygroscopic nature of these butters and oil in the presence of moisture in the air.

Saponification value

This index presents the richness of the oil in long chain fatty acids for a given mass of triglycerides. The different

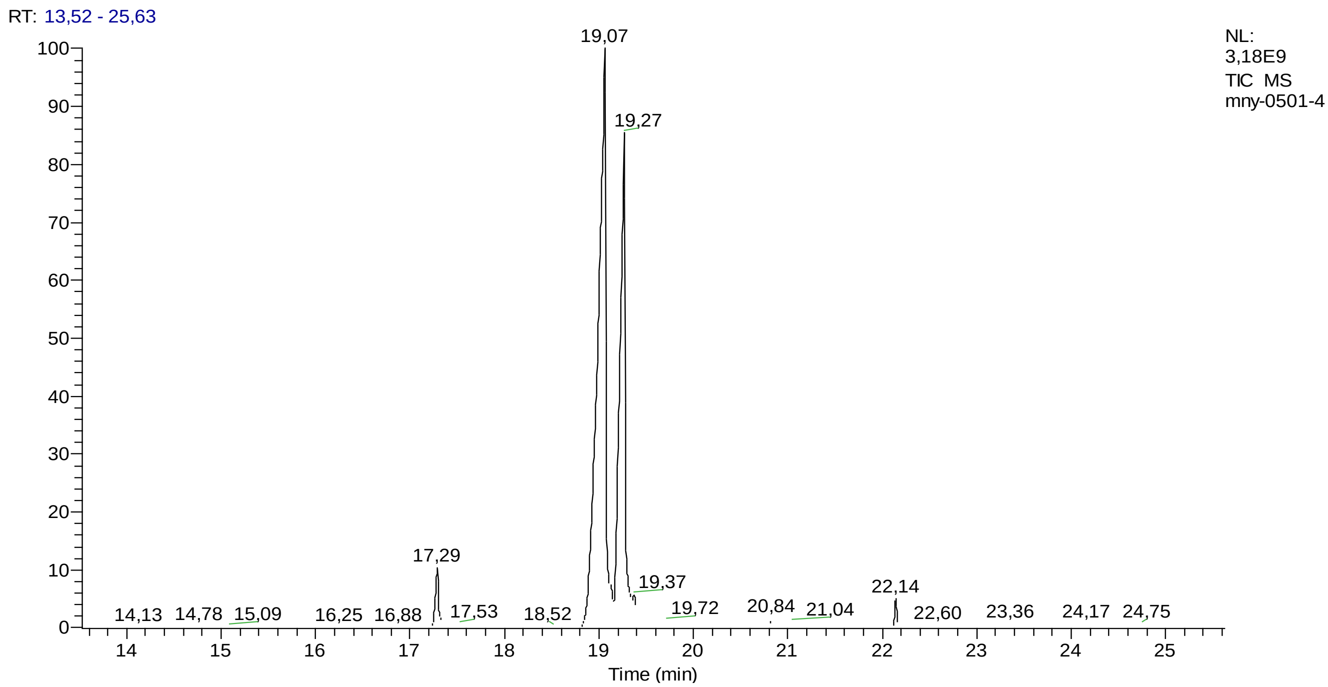


Figure 1. GC Chromatogram of Fatty Acids of *Mangifera Indica* almond.

Table 4. Major fatty acid composition of butters and mango almond oils.

Rt	Mass	Compound	Yield (%)
17.29	m/z 256.25	Palmitic acid (C16:0)	(6.77-12.80%)
19.07	m/z 282.27	Oleic acid (C18:1)	(46.60-58.24%)
19.27	m/z 284.28	Stearic acid (C18:0)	(31.06-45.76%)
20.84	m/z 312.32	Arachidic acid (C20:0)	(0.85-1.65%)

values of the saponification index obtained for butters and oils of mango kernels are between 164.17±1.30 and 199.21±0.32 mg of KOH / g of oil. These values are comparable to those of vegetable oils and butters (FAO/OMS, 1999) used in soapmaking such as shea butter (178-193), cocoa butter (188-200), peanut oil (187-196), cotton seed oil (189-198) and colza seed oil (168-181).

Unsaponifiable content

Unsaponifiables generally consist of several families of compounds such as paraffins, tocopherols, sterols, carotenoid pigments and fat-soluble vitamins. The results show that the various butters and oils of mango kernels contain 0.94±0.09 to 2.83±0.62% of unsaponifiables. Except *Kent* species (0.94±0.09), these values are higher than those of vegetable oils in general (≤ 1%) (FAO/OMS, 1999).

Composition in fatty acids

The analysis of the fatty acids is carried out using a gas chromatograph coupled to the mass (GC / MS). The molecules were identified on the basis of mass spectral analysis compared with the National Institute of Standards and Technology (NIST) mass spectral library (version 2.0 dated April 26, 2005).

Analysis of the chromatogram of Figure 1 coupled to the mass as shown in Table 4 shows that the butters and oils of the almonds mango are predominantly rich in oleic acid (45.82-58.24%) and stearic acid (31.06-45.76%). They are also composed of palmitic acid (6.77-12.80%) and arachidic acid (0.85-1.65%). The analysis of the different varieties as indicated in Table 4 shows that the fatty acid contents differ from one variety to another. The oils and butter of mango almonds have fatty acids comparable to butters and oils from oilseeds (Odile and Xavier, 2012; Davrieux et al., 2010) known for their various biological properties.

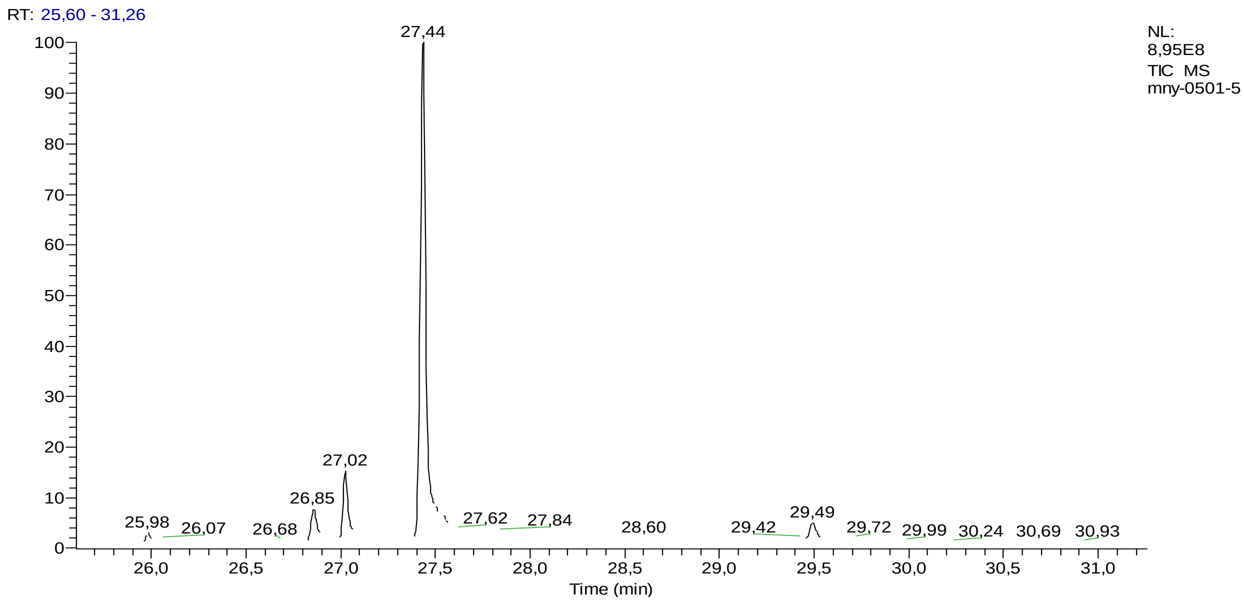


Figure 2. GC Chromatogram of unsaponifiables of butters and oils of mango kernels.

Table 5. Fatty acid content of butters and almond oils of eight varieties of mangoes compared to that of shea butter and cacoa.

Fatty acid	Kernels mango oils (GC MS analysis)								Reference (Odile and Xavier, 2012)	
	Assabonie	Ruby	Key	Retard	Kent	Smith cat head	Smith normal	Governor	Shea	Cacao
Palmitic acid (C16: 0)	6.77	12.80	10.56	8.33	9.7	8.33	9.09	8.84	3-5	24-30
Stearic acid (C18: 0)	45.76	38.20	39.83	41.66	31.06	45.00	36.36	37.16	28-45	30-37
Oleic acid (C18: 1)	46.60	48.00	47.96	4916	58.24	45.82	53.63	53.08	42-59	33-39
Linoleicacid (C18: 2)	0	0	0	0	0	0	0	0	3-9	2-5
Arachidic acid (C20: 0)	0.87	1.00	1.65	0.85	1.00	0.85	0.90	0.92	0	0
Saturated fatty acids	53.40	52.00	52.04	50.84	41.76	54.18	46.37	46.92	35	61
Unsaturated fatty acids	46.60	48.00	47.96	49.16	58.24	45.82	53.63	53.08	60	35

They have an oleic acid content (45.82-58.24%) comparable to shea butter (42-59%) and superior to cocoa butter (33-39%).They have a stearic acid content (31.06-45.76%), close to those of shea butter (28-45%) and cocoa (30-37%).

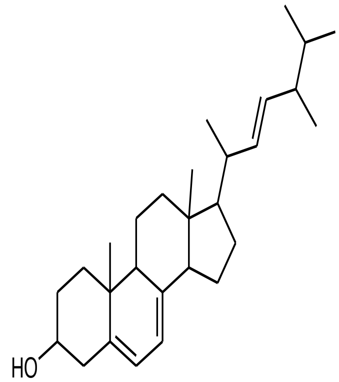
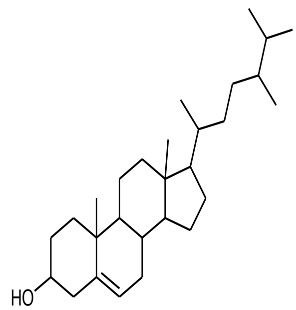
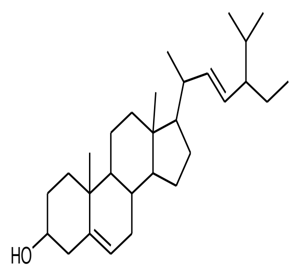
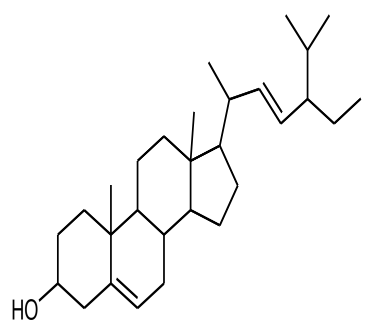
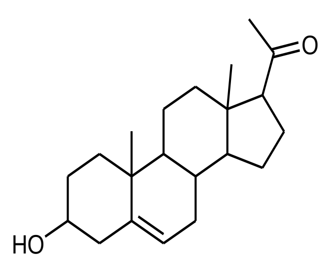
They are generally richer in palmitic acid (6.77-12.80%) than Shea butters (3-5%) but poorer than cocoa butter (24-30%). The *Kent* species has the highest unsaturated fatty acid content (58.24%), which explains its liquid appearance at room temperature (Table 5).

Chemical composition of unsaponifiables

Unsaponifiables are analyzed by Gas Chromatography coupled to GC/MS Mass Spectrometry. Figure 2 shows the GC chromatogram of the unsaponifiable fraction. Molecule structures were also identified based on mass spectral analysis compared with the National Institute of Standards and Technology (NIST) mass spectral library (version 2.0 dated April 26, 2005). Spectral analysis as shown in Table 6 reveals that the unsaponifiables of mango kernel oil consist of sterols, the majority of which are: Ergosterol (A: 1.94%), campesterol (B: 5.33%), stigmasterol (C: 10.67%), sitosterol (D: 78.65%) and 3-hydroxy-pregn-5-en-20-one (E: 3.39%). In the unsaponifiable, the sitosterol is the compound higher while the ergosterol is the compound weaker. The sitosterol is being studied for its potential to reduce benign prostatic hyperplasia (Kim et al., 2012) and blood cholesterol levels (Rudkowska et al., 2008).

The unsaponifiable constituents of the oil of mango kernels are comparable to those of cotton seed oil (campesterol 6.4-14.5%, stigmasterol 2.1-6.8%, sitosterol 76.00-87.1%) and palm kernel oil (campesterol 8.4-12.7%, stigmasterol 12.0-16.6%, sitosterol 62.6-73.1%)

Table 6. Composition of major unsaponifiables of butters and oils of mango kernels.

Rt	Mass	Compound	Strucure	Yield (%)
25.98	m/z 396.39	Ergostérol		(1.94%)
26.85	m/z 400.39	Campestérol		(5.33%)
27.02	m/z 412.43	Stigmastérol		(10.67%)
27.44	m/z 414.40	Sitostérol		(78.65%)
29.49	m/z 316.66	3-hydroxy pregn-5-en-20-one		(3.39%)

(FAO/OMS,1999).

Conclusion

We undertook the study of the almonds of 10 varieties of *M. indica* (Anacardiaceae) in order to contribute to its valuation. The study of the mango kernel has revealed the presence of about 10% fat whose physicochemical characteristics show some similarities with shea butter, cocoa, cotton oils and palm. The study of its lipid composition revealed a significant presence of oleic and stearic fatty acids, hence its potential use in dietetics and pharmacology. The butters and oils of the almonds of mango kernels can also be used in soapmaking, given their high saponification indices. The properties of oil extracted revealed that the seed of mangoes is a good source of oil which could be employed for industrial purposes

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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