Original Research Article

Biochemical Characterization of Mango Kernel (*Mangifera indica*) Grown in Côte d'Ivoire and Formulation of Butter for Cosmetic Use

ABSTRACT:

Aims: The peel and the kernel, although presenting enormous nutritive and technological potentialities, are considered as waste and, as a result, rejected in nature causing environmental pollution. This study therefore set itself the general objective of contributing to the development of mango by-products (*Mangifera indica*) by incorporating them into formulations of products for cosmetic use.

Study design: Almond butter was obtained from the fresh and dried almonds of two varieties of mangoes (KENT and KEIT).

Place and Duration of Study: Fruits of mango (KENT and KEIT) varieties used in this study came from Banco fruit market (Abidjan, Côte d'Ivoire). The tests were carried out at the laboratory of food biochemistry of Nangui Abrogoua University, between May and July 2020.

Methodology: The mango kernels (*Mangifera indica*) were extracted and the biochemical characterization of both fresh kernels and almond powders was carried out on parameters such as lipids, ash, fibers, etc. Then, mango kernel powder of KENT with good potential was used for the formulation of butter. Following the control formulation, different formulations were made by reducing volume of extraction solvent (sunflower oil) and varying the amount of beeswax used at 10% and 35% of the mass of macerate used. Finally, physicochemical properties of butter were determined.

Results: The study showed that mango kernels produced in Côte d'Ivoire, specifically mango kernel powders, were rich in lipids (8-9%), proteins (2-7%), fiber (9-11%), carbohydrates (35-76%), ash (2.99-5.66%), vitamin C (35-104 mg/100g) and many other biomolecules, which made possible the production of butter. The physicochemical properties of butter gave results of acid numbers of 8.24 to 9.03 mg KOH/g oil and saponification of 189.45 to 212.09 mg KOH/g oil. These indices combined with pH (4.6 to 5.2), density (0.3 to 0.91) and color are indicators of the good quality of butter. Finally, the KE 1/3 formulation, with 35% beeswax added, gave the most satisfaction.

Conclusion: These physical and chemical properties obtained would suggest a finished product of quality and good conservation and good scent pleasant and would have various applications in the cosmetic field in particular in the nutrition of the skin and the hair.

Keywords: Almond, Indices, Formulation, Mango butter, Cosmetic products, Mango (Mangifera indica)

1. INTRODUCTION

The fruits constitute a carbohydrate supplement in the ration of the populations [1]. They contribute to the improvement of social well-being and the state of health of these by

providing them with nutrients such as sugars, fibers, minerals, vitamins, waters and antioxidants [2,3]. One such fruit is the mango. From its scientific name *Mangifera indica*, it is the fruit of the mango tree (*Mangifera indica* L.), a tree of the Anacardiaceae family, growing mainly in tropical and subtropical regions [4]. Côte d'Ivoire produced more than 100000 tons against 55.4 million tons worldwide. It is the fifth fruit production in the world behind bananas, apples, grapes and citrus fruits [5]. At the local level, it is the third export fruit behind bananas and pineapples and has generated more than seven (7) billion FCFA [6]. It is therefore a real source of income for the Ivorian populations. Mango is consumed freshly or after processing into jam, nectar, dried mango or dairy products, etc. [7]. Also, the waste consisting of peel and kernel could make it possible to obtain biogas by fermentation and the oil extracted from the almond of the kernel would be used in cosmetics. Unfortunately, in Côte d'Ivoire and as is the case almost everywhere else in Africa and even in the world, even less industrial eating habits are still free of pits and skins, systematically favoring the use of pulp: stone and peel being considered as waste. Indeed, according to Banerjee *et al.* [8] consumption and processing of mango fruit produces 25-40 % waste including peels and pits. Reduced to 2018 production, between 38,000 and 62,000 tons of waste would be generated and released into nature. This could represent a real risk of environmental pollution. In addition, the 30 to 40 % post-harvest losses reported by FIRCA [9], mainly due to the high water content of the mango and the resurgence of pathogens [10], would accentuate this observation insofar as the losses essentially relate to the depreciation linked to the pulp. Moreover, few studies have focused on the technological potential of mango kernels in Côte d'Ivoire, which constitutes a handicap to its development.
Still, mango kernels are substantially nutritional, including essential amino acids, vitamins, and antioxidant compounds [11, 12]. They are excellent sources of polysaccharides (74-75 %), fat (9-13 %) [13]. This fat is an excellent source of vitamin E and bioactive compounds including phenolic compounds, carotenoids, vitamin C and dietary fiber [14]. In view of all the above, we have therefore set ourselves the general objective during this study of contributing to the development of mango by-products (*Mangifera indica*) by incorporating them into product formulations for cosmetic use.

2. MATERIAL AND METHODS

2.1 Material

The plant material used in this study consists of mango kernel (*Mangifera indica*) of the KENT variety and the KEIT variety. In addition to these mango kernels, sunflower oil and beeswax were also used in this work.

2.2 Methods

2.2.1 Sampling

The fruits of the mango tree (*Mangifera indica* L.) of the KENT and KEIT varieties used in this study came from the Banco fruit market (Abidjan, Côte d'Ivoire). A total of 100 mangoes of the KENT variety and 100 mangoes of the KEIT variety were purchased and then sent to the Food Biochemistry and Tropical Products Technology Laboratory. Once in the laboratory, each variety of mango was split into two batches: the first batch was used to obtain fresh almonds while the second batch was used for the production of mango almond powder.

2.2.2 Processes for obtaining mango almond powders

Following each batch, the mangoes were cleared of debris and washed in soapy water then rinsed thoroughly with tap water. The mangoes were pitted manually using a stainless steel knife. The pits were opened and the kernels extracted. The latter are washed then weighed and stored in a refrigerator before use. Note that at this level, the operation stopped for batches whose purpose was to obtain fresh almonds. Then, a quantity of one (1) kg of mango kernels of each variety was crushed and spread individually on aluminum foil and then dried in a Biobase brand oven (Shandong, China) at 45 °C for 48h. After drying, the almonds were ground in a grinder. The ground material was sieved using a 500 µm mesh sieve and the powder obtained was packaged in previously dried glass bottles.

2.2.3 Analysis methods

2.2.3.1 Biochemical analysis

The biochemical characterization focused both on the fresh almonds and on the almond powders of the KENT and KEIT varieties of mangoes (*Mangifera indica*): either KEF, KES, KIF and KIS respectively for fresh almonds, almond powders of mangoes from the KENT variety and fresh almonds and ground mango almonds of the KEIT variety.

2.2.3.2 Determination of physicochemical parameters

Moisture was determined by drying in an oven at 105 ºC during 24 h to constant weight [15]. pH was determined using a pH meter (Consort P107, Belgique). Total ash was determined by incinerating in a furnace at 550 ºC [15]. Crude fat was determined by continuous extraction in a Soxhlet apparatus (Soxtec sostem HT 1043) for 7 h using hexane as solvent [15]. Crude protein was calculated from nitrogen (N x 6.25) obtained using the Kjeldahl method by AOAC [15]. The crude fibre contents were determined according to standard method [15]. The carbohydrates and vitamin C were determined by FAO [16] and Pongracz [17], respectively.

2.2.4 Formulation of mango butter

The formulation of the mango almond butter was carried out according to the modified FIRCA [9] method. The mango almond butter was obtained using mango almond powder of the KENT variety, sunflower oil which was used for the extraction of fat and photochemical compounds from the almonds; as well as beeswax for its cosmetic virtues but especially its thickening effect.

A quantity of twenty (20) g of mango almond powder was poured into 200 mL of sunflower oil in a glass jar. The jars containing the sunflower oil and the almond powder were then heated in a water bath at a low temperature (45-55 °C), for 3 hours, turning regularly. After 3 hours, the mixture was left to macerate for 24 hours in the cold. Then the oil was filtered. The filtrate obtained constituted the mango almond oil macerate. Then, 60 g of this macerate were weighed in new glass jars to which 15 g of beeswax were added. The whole was brought to a water bath (60 °C) until the beeswax was completely melted. Finally, the product was allowed to cool, stirring occasionally.

The operation was reproduced by varying the quantities of mango almond powder and vegetable oil in proportions 1/7, 1/5 and 1/3 (w/v). Furthermore, for each of these proportions, a second formulation was carried out by varying the amount of beeswax incorporated [25 % (control), 10 % and 35 % by mass of the amount of sunflower oil].

Table 1. Different almond butter formulations

	Almond macerate		
Ratio (p/v)	Almond Qty (g)	Oil volume (mL)	Beeswax (%)
(1/10)	20	200	25
(1/10)	20	200	35

(1/7)	20	140	35
(1/5)	20	100	35
(1/3)	20	60	35

Source : (FIRCA, 2010) modified

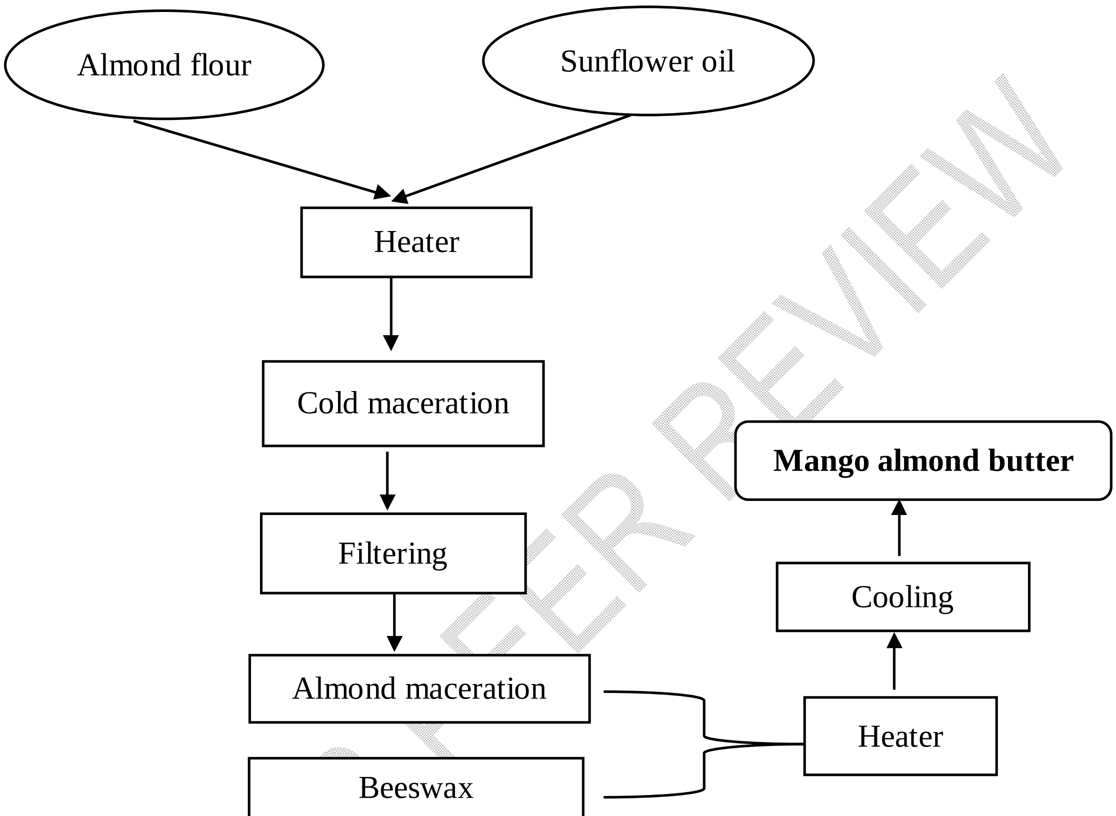

Fig. 1. Mango Almond Butter Production Chart

Source : (FIRCA, 2010) modified

2.2.4.1 Physical and chemical properties of mango almond butter

Color

The colorimetric indices L, a*, b* were determined using a chromameter. The results were recorded using the Hunter scale, which has L, a* and b* coordinates. The "L" scale measures light intensity (white-black and goes from no reflection L=0 to perfect diffuse reflection L=100), the "a*" scale goes from negative values (a< 0) for green to positive values (a> 0) for red, while the "b*" scale ranges from negative values (b<0) for blue to positive values (b>0) for yellow [18].

Firmness

The firmness of mango almond butter was determined according to the method described by Dadzie and Orchard [19] using a hand-held penetrometer (WHF-600/Kg. N-1). This made it possible to measure the resistance of butter to a constant force.

Density
The method used to determine the density of butters was that described by IUPAC [20]. It consisted of measuring the mass, at a given temperature, of a volume of fat contained in a pycnometer previously calibrated at the same temperature.

pH
The pH of the butter samples was determined by pH-metry at 25 °C according to Afane et al. [21]

Acid and saponification indices
The acid and saponification indices of the butter samples were determined respectively according to standard NFV 03-906 and NF T 60-206 [22]. The method consists respectively in titrating with an alcoholic potash solution, the acidity of fat initially dissolved in a mixture of solvents in equal parts and in treating the fat with an excess of hot alcoholic potash solution then in titrating the excess of alcoholic potash with a solution of hydrochloric acid.

2.2.4 Statistical analyzes

Statistical analysis of the data was done using STATISTICA software (version 7.1). The results obtained were expressed as mean ± standard deviation. Significant differences were highlighted by one-way analysis of variance (ANOVA) followed by Duncan's test. These differences were considered significant at the 5% level.

3. RESULTS

3.1 Biochemical composition

Table 2 presents the biochemical composition of fresh kernels and dried kernels of KENT and KEIT variety mangoes. The values obtained showed a significant difference between the parameters of the samples studied (Table 2). Also the values are clearly high with the powdered almonds of the KENT variety.

Table 2. Biochemical composition of fresh almonds and mango almond powders (KENT and KEIT)

Parameters	Designation			
	KEF	KES	KIF	KIS
Humidity (%)	52.18 ± 1.01^{a}	9.45 ± 2.03^{b}	45.04 ± 4.82^{c}	5.30 ± 1.02^{d}
Dry matter (%)	47.82 ± 1.01^{a}	90.55 ± 2.03^{b}	54.96 ± 4.82^{c}	94.70 ± 1.02^{d}
PH	5.00 ± 0.01^{a}	5.32 ± 0.01^{b}	4.64 ± 0.00^{c}	5.27 ± 0.01^{d}

Titratable acidity (meq/g)	48.35 ± 0.31^{a}	21.46 ± 0.12^{b}	52.89 ± 0.10^{c}	11.44 ± 0.04^{d}
Fiber (%)	5.53 ± 0.38^{a}	10.49 ± 0.83^{a}	5.70 ± 0.25^{a}	9.83 ± 0.04^{a}
Proteins (%)	3.05 ± 0.01^{a}	5.77 ± 0.20^{b}	1.8 ± 0.08^{c}	2.74 ± 0.00^{d}
Lipids (%)	4.64 ± 0.12^{a}	8.78 ± 0.56^{c}	5.36 ± 0.03^{b}	9.25 ± 0.30^{c}
Ash (%)	2.99 ± 0.14^{a}	5.66 ± 0.06^{c}	3.24 ± 0.06^{a}	5.58±0.04^{c}
Carbohydrates (%)	34.75 ± 0.16^{a}	70.34 ± 0.22^{b}	43.88 ± 0.1^{c}	76.55±0.1^{d}
Vitamin C (mg/100g)	35±7.07^{a}	22.00 ± 0.71^{a}	103.75 ± 8.84^{b}	41±2.12^{a}

Trials : n=3 ; the means ± standard deviations, assigned different letters in the same line are significantly different at $p < 0.05$ according to Duncan's test.

3.2 Mango butter formulation

The control preparation (20 g of mango kernel powder (KENT) in 200 mL of sunflower oil) shows a slight phase separation in the butter obtained, over time, when going to 25% wax. bee (15 g of beeswax in 60 g of almond oil macerate). Also, the formulation of 35% wax with the control preparation gave satisfactory results as regards the texture of the butter (gel), color and its unique phase (Figure 2).

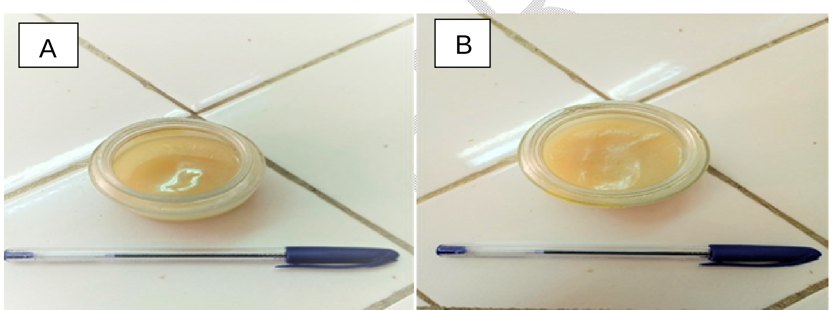

Fig. 2. Formation of almond butter from mango (*Mangifera indica*)

(A) : Control formulation (1/10 ; 25 %)
(B) : Formulation (1/3 ; 35 %)

3.3 Physical and chemical properties of mango butter

The specific gravity of different mango almond butter formulations ranges from 0.83 ± 0.01 to 0.91 ± 0.00. The control formulation recorded the lowest density (0.83 ± 0.01). This density increases when the amount of beeswax incorporated is increased (Table 3).

Table 3. Density of different formulations of mango almond butter (*Mangifera indica*)

Coded	Density
KE 1/10, 25 %	0.83 ± 0.02^{a}

KE 1/10, 35 %	0.87 ± 0.01^{b}
KE 1/5, 35 %	0.89 ±0.04^{c}
KE 1/3, 35 %	0.91 ± 0.08^{d}

Trials : n=3 ; the means ± standard deviations, assigned different letters in the same column are significantly different at $p < 0.05$ according to Duncan's test.

KE 1/10, 25 % : Formulation 1/10 (w/v) with 25% added beeswax (control)
KE 1/10, 35 % : Formulation 1/10 (w/v) with 35% added beeswax
KE 1/5, 35 % : Formulation 1/5 (w/v) with 35% added beeswax
KE 1/3, 35 % : Formulation 1/3 (w/v) with 35% added beeswax

The colorings of the different butter formulations show very small variations from one sample to another. A decrease in the indicator parameters "a*", "b*" and "c*" is observed with the decrease in the volume of sunflower oil used for maceration. On the other hand, the "L" and "h*" parameters evolve in sawtooth fashion (Table 4).

Table 4. Evaluation of the color of mango almond butters (*Mangifera indica*)

Coded	L	a*	b*	c*	h*
KE 1/10 ; 25%	22.7 ± 0.14^{a}	5.64 ± 0.0^{d}	5.4 ± 0.01^{d}	7.22 ± 0.0^{d}	38.59 ± 0.0^{a}
KE 1/10 ; 35%	42.66 ± 0.1^{c}	0.47 ± 0.0^{a}	4.95 ± 0.0^{c}	4.97 ± 0.0^{b}	84.54 ± 0.0^{c}
KE 1/3 ; 35%	46.48 ± 0.1^{d}	0.52 ± 0.0^{b}	4. 74 ± 0.0^{a}	5.01 ± 0.0^{c}	84.89 ± 0.0^{d}
KE 1/5 ; 35%	41.92 ± 0.0 ^{b}	0.7 ± 0.0^{c}	4.89 ± 0.0^{b}	4.91 ± 0.0^{a}	81.49 ± 0.01^{b}

Trials : n=3 ; the means ± standard deviations, assigned different letters in the same column are significantly different at $p < 0.05$ according to Duncan's test.

KE 1/10, 25 % : Formulation 1/10 (w/v) with 25% added beeswax (control)
KE 1/10, 35 % : Formulation 1/10 (w/v) with 35% added beeswax
KE 1/5, 35 % : Formulation 1/5 (w/v) with 35% added beeswax
KE 1/3, 35 % : Formulation 1/3 (w/v) with 35% added beeswax

The results of the firmness test of the various formulations are presented in Table 5. The highest value is recorded in the formulation KE 1/3, 35% (0.35±0.08 N) ; when formulation KE 1/10, 25% (control) shows the lowest value 0.1±0.00 N.

Table 5. Evaluation of firmness (N) of mango almond butter formulations (*Mangifera indica*)

Coded	Firmness (N)
KE 1/10 ; 25 %	0.1± 0.00^{a}
KE 1/10 ; 35 %	0.2 ± 0.08^{b}
KE 1/3 ; 35 %	0.35 ± 0.08^{d}
KE 1/5 ; 35 %	0.28 ± 0.01^{c}

Trials : n=3 ; the means ± standard deviations, assigned different letters in the same column are significantly different at $p < 0.05$ according to Duncan's test.

KE 1/10, 25 % : Formulation 1/10 (w/v) with 25% added beeswax (control)
KE 1/10, 35 % : Formulation 1/10 (w/v) with 35% added beeswax
KE 1/5, 35 % : Formulation 1/5 (w/v) with 35% added beeswax
KE 1/3, 35 % : Formulation 1/3 (w/v) with 35% added beeswax

The pH data is shown in Table 6. The KE 1/3, 35 % formulation had the lowest pH (4.60). The highest pH is observed at the control formulation KE 1/10, 25 %. As for the KE 1/10 formulation, 25 % shows a pH value of 4.66.

Table 6. pH of different formulations of mango almond butter (*Mangifera indica*)

Coded	pH
KE 1/10, 25 %	5.2 ± 0.00^{d}
KE 1/10, 35 %	4.66 ± 0.08^{c}
KE 1/5, 35 %	4.61 ± 0.08^{b}
KE 1/3, 35 %	4.60 ± 0.02^{a}

Trials : n=3 ; the means ± standard deviations, assigned different letters in the same column are significantly different at $p < 0.05$ according to Duncan's test.

KE 1/10, 25% : Formulation 1/10 (w/v) with 25% added beeswax (control)
KE 1/10, 35% : Formulation 1/10 (w/v) with 35% added beeswax
KE 1/5, 35% : Formulation 1/5 (w/v) with 35% added beeswax
KE 1/3, 35% : Formulation 1/3 (w/v) with 35% added beeswax

Table 7 presents the results of the assay of the indices (acid and saponification) of the various formulated butters. The latter shows slight variations in the samples assayed as well as high values of acidity (9.03 mg KOH/g oil) and saponification (212.12 mg KOH/g oil).

Table 7. Dosage of indices (acid and saponification) of mango almond butters (*Mangifera indica*) formulated

Coded	*Ia (mg KOH/g oil)*	*Is (mg KOH/g oil)*
KE 1/10 ; 25 %	8.89 ± 0.14^{c}	201.98 ± 1.05^{c}
KE 1/10 ; 35 %	9.03 ± 0.1^{c}	212.12 ± 0.3^{d}
KE 1/5 ; 35 %	8.47 ± 0.13^{b}	189.45 ± 0.35^{a}
KE 1/3 ; 35 %	8.24 ± 0.13^{a}	194.45 ± 0.35^{b}

Trials : n=3 ; the means ± standard deviations, assigned different letters in the same column are significantly different at $p < 0.05$ according to Duncan's test.

KE 1/10, 25 % : Formulation 1/10 (w/v) with 25 % added beeswax (control)
KE 1/10, 35 % : Formulation 1/10 (w/v) with 35 % added beeswax
KE 1/5, 35 % : Formulation 1/5 (w/v) with 35 % added beeswax
KE 1/3, 35 % : Formulation 1/3 (w/v) with 35 % added beeswax

4. DISCUSSION

The low moisture content in the dried almonds is due to their drying in an oven (45 °C) leading to evaporation of their water content. This relatively low moisture content of the mango kernel powder is very important for prolonging its shelf life.
Protein levels are higher in mango almond powders compared to fresh almonds. This could be explained according to Brou et al. [23], by the drying which would lead to a concentration of nutrients and would make it possible to obtain more appreciable protein contents. The relatively high protein levels in mango kernel powders are close to those of Elegbede *et al.* [24] and Mutua *et al*. [13]. These authors respectively recorded protein contents of (6-9 %) in the mango kernel powders and 5.25 % on the wet basis. And as a result, mango almond powders could be an important argument in cosmetics. Indeed, food proteins, including those of almonds, can be used in cosmetics for their emulsifying or even anti-inflammatory or even antioxidant qualities [25].
Lipids are important macronutrients that facilitate the availability of fat-soluble vitamins (A D E K) in the body ([26, 27]. Lipid levels are high in mango kernel powders with values of 8.78% and 9.25% respectively for the KENT and KEIT varieties. These results corroborate those of Muchiri *et al.* [28] and Mutua *et al*. [13] who found lipid levels of mango powder kernels of (8.15-13.16%) and (9-13%) respectively. The high lipid content in mango kernel powders could be explained by the concentration of lipids during drying. In addition, almonds belong to the family of oilseeds characterized by an abundance of fat. Indeed, according to Kittiphoom and Sutasinee [14], mango kernel is a good source of lipids, particularly polyunsaturated fatty acids such as oleic and linoleic acids which have health and cosmetic benefits. Furthermore, according to Solís-Fuentes and Durán-de-Bazúa [14], the lipids of mango kernels contain vitamin E involved in cell protection. Thus, vegetable oils such as mango kernel oil, could be used in the cosmetics industry, where they would limit the absorption of water and therefore prevent the swelling of the hair by their penetration, inducing the reduction of hygral tiredness ; one of the factors of hair breakage. Hygral tiredness corresponds to the repeated process between the swelling of the hair by water and drying [29]. Finally, such a proportion of oil observed in mango kernels could fulfill the function of barrier of damaged skin through occlusive agents which would create a hydrophobic film on the surface of the latter thus forming a barrier to the evaporation of water limiting skin dehydration [30, 31].
The increase in the ash content in the mango kernel powders, particularly in that of the KENT variety (5.66 %) would be due to the elimination of moisture during drying, resulting in a bioconcentration of nutrients, including the ashes facilitating their dosage in flours [32].
The results obtained in this work are superior to those of Omotubga *et al*. [33] and Mutua *et al*. [13] who found values of 2-3 % and 2.58 % respectively in mango kernel powders. The high ash content in mango kernel powders would be beneficial in butter formulation [34]. Indeed, it is an indicator of its mineral content the minerals which contribute to the balance of the skin by contributing to the regeneration and protection of the epidermis, to ensure its water content and promote microcirculation [35]. They are also essential in the solidification of teeth and certain biological functions such as the activity of enzymes [36]. Thus, these almond powders would be useful in animal feed and cosmetics.

Vitamin C is necessary for the formation of collagen, the main protein of connective tissue. It helps prevent anemia by enhancing the absorption of iron necessary for the formation of red blood cells [37]. The vitamin C contents in mango almond powders are lower than that of fresh almonds. These relatively low levels in the mango almond powders could be explained by the drying of the flours. According to Muhamad [38], temperature is a factor that strongly contributes to the degradation of the vitamin in fruits and vegetables. Vitamin C, due to its beneficial antioxidant power in the fight against oxidative stress responsible for aging, would be useful in the formulation of cosmetic products.

The carbohydrate contents in the different samples are relatively high at the level of the mango almond powders and are around 70.35 % for the KENT variety against 76.55 % for the KEIT variety. These carbohydrate contents are very close to those recorded by Mutua *et al*. [13] who noted a carbohydrate rate of between 72.86 to 75.92 % in mango kernels on a dry basis. The abundance of carbohydrates in mango almond powders would be due not only to the departure of water but also to the ripening of the fruit. This is all the more true since during ripening, the glucose and fructose levels remain constant, while the sucrose level increases by a factor of 3 to 4, leading to an increase in the total sugar level [2]. Thus, the good carbohydrate content would be a good source for recovery not only in animal feed but even more so in cosmetics. Indeed, according to Nzeza [39], sugars (complexes in particular) extracted from plants then transformed into active ingredients, would make it possible to obtain moisturizing, soothing or anti-inflammatory and tensor effects so much sought after in cosmetics.

Fiber is an important fraction in a foodstuff due to its crucial role in the proper functioning of intestinal transit. They facilitate digestion, reduce the risk of cardiovascular disease and help regulate blood sugar [40]. The fiber levels in the mango kernel powders are very close to those obtained by Omotubga *et al.* [33]. The high fiber content would be an asset for the use of almonds in formulations for animal feed and cosmetics (complex carbohydrates).

The biochemical characterization made it possible to highlight high levels in the mango almond powders of nutrients such as lipids, fibers, carbohydrates or ashes. In general, the highest levels were observed in powdered mango kernels of the KENT variety. Hence the use of these KENT variety mango almond powders in the formulation of butter for cosmetic use. Thus, in the rest of the work, the physical and chemical properties of butter made from dried almonds will be discussed.

Density is a parameter that depends on temperature. This parameter was measured at a temperature of 20°C. The relative density of mango almond butters produced is between 0.8 and 0.9. The highest density is observed in the KE 1/3 formulation, with 35 % beeswax. These density values are very close to those observed by Codex Alimentarius [41], which recorded densities in the range of 0.91 to 0.98 at 20 °C for shea butter.

The analysis of the color of the formulated butters gives a light yellow coloring. This light yellow color could be explained on the one hand by the presence of antioxidant pigments which would be present in almonds similar to those reported by Megnanou and Diopoh [42] on shea butter sold on Ivorian markets. And on the other hand by the incorporation of yellow coloring beeswax. These results are close to those of Kitiphoom *et al*. [43] who state that mango oils are very light yellow in color. Indeed, this light yellow color is important insofar as it is a quality indicator that influences the choice of a product.

The acid number is a measure of the total acidity of lipids, involving the contributions of all of the constituent fatty acids that make up the glyceride molecule [44]. The indices obtained in this study are higher than those observed by Nzikou et al. [45] in mango kernel oils (5.35 mg KOH/g oil) but lower than those observed by Megnanou and Diopoh [42] on shea butter sold on Ivorian markets. The relatively average acidity would be due to the time and temperature of extraction of the butter as well as the drying of the almonds. Indeed, these two parameters according to Womeni *et al*. [46], are responsible for the release of fatty acids responsible for acidity. Temperatures below 50 °C and an extraction or drying time below 50 minutes lead to butter with a high acid value. The results of this work are therefore good omens and reflect better conservation of mango almond butter. In the sense that this characteristic accounts for the state of degradation of the butter insofar as the free fatty acids are products of degradation and more particularly of hydrolysis of triglycerides, the main constituents of the oil [47]. The saponification index measures the average molecular weight of the fatty acid chains present in an oil. This parameter is inversely proportional to the molecular weight of the fatty acids. The values of the saponification indices obtained are higher than those of soybean oil (13.47 mg of KOH/g of oil), palm kernel oil (28.04 mg of KOH/g of oil) [48]. They are below the range of 160 to 195 KOH/g fat defined for unrefined shea butter [41]. These high saponification indices would be due to a relatively low molecular weight of fatty acids in mango almond butter. Indeed, according to Kumar and Krishna [49], the saponification index is directly proportional to the number of short and medium chain fatty acids attached to the glycerol. Such saponification indices would be of great use in the cosmetics industry where it would find a job in the manufacture of soap with beneficial effects on the skin and hair.

5. CONCLUSION

Mango kernel powders of the KENT and KEIT varieties grown in Côte d'Ivoire are abundant in nutrients such as proteins (2.74-5.77 %), fiber (9.83-10.49 %), carbohydrates (70-76 %) or ashes (5.58-5.66 %) against values in fresh almonds of 1.8-3.05 % in proteins, 34.75-43.88 % in carbohydrates and 2.99-3.24 % ash. Overall, the highest levels were recorded in ground almonds of the KENT variety with a low moisture content (9.45 %) favoring its preservation. In addition, they are rich in lipids (8.78-9.25 %), which gives them a high energy value and good potential for use in cosmetics. The analysis of the physical and chemical properties of the different formulations of the product for cosmetic use showed densities between 0.83-0.91; a firmness of 0.1-0.35 N; pH of 4.6-5.2 and finally acid and saponification indices varying respectively between 8.24 to 9.03 mg KOH/g oil and 194.45 to 212.98 mg KOH/g oil. The most satisfactory values were recorded for the KE 1/3 formulation with 35 % added beeswax, by reducing the volumes of sunflower oil to a third of that recommended in the control formulation. These physical and chemical properties obtained would suggest a finished product of quality and good conservation with regard to the indices of weak acids and high saponifications as well as its density, firmness, coloring and good scent (characteristics of mango and beeswax) pleasant and would have various applications in the cosmetic field in particular in the nutrition of the skin and the hair.

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