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Physicochemical Studies of Tiger Nut Oil Incorporation in Cosmetic Products Formulation (Face Cream, Body Lotion, and Soap)

Bou Ndiaye[1,2,3,*], El Hadj Moussa Diop[1,3], Mouhamed Ndoye[1], Oumar Ibn Khatab Cisse[1,2,4], Binta Fall[3], Seyni Ndiaye[1,2], Nicolas C. M. Ayessou[1,2]

[1]Laboratoire Eau, Energie, Environnement et Procédés Industriel (LE3PI), Ecole Supérieure Polytechnique / Université Cheikh Anta Diop, Dakar, Sénégal
[2]Center for Studies on Food Safety and Functional Molecules (CESAM-RESCIF) ESP-UCAD, Dakar, Senegal
[3]Ecole Supérieure de Génie Industriel et Biologique (ESGIB), Dakar, Senegal
[4]Ecole Nationale Superieure d'Agriculture (ENSA), UIDT, Thies, Senegal

Abstract Tiger nut (*Cyprus esculentus*) is an underused crop that has longtime been focused in the food field either by consuming the flour, milk, or tubers directly. Tiger nut has a very nutritional oil which is rich in unsaturated fatty acid and bioactive compounds. Thus, the use of tiger nut oil on the skin can be beneficial due to its antioxidant, healing, and regenerative properties. Its use in cosmetics should be consider. The aim of this present study is to develop cosmetic products based on this oil. The tiger oil is used in combination with *Balanites aegyptiaca* and *Moringa oleifera* seed oils. The analysis reveals that a specific gravity, acid value, peroxide value, and saponification value range respectively from 0.85 to 0.90; 2.24 to 23.79 meq O_2/kg; 5.40 to 7.10 mg KOH/g, and 192.84 to 202.66 mg KOH/g. The refractive index is 1.465 for all oils. Color analysis shows a significant difference between oils. The saponification value shows that the oils are good materials for soap processing. The analysis of the soaps shows a pH ranging between 9.92 and 10.29. The moisture content, free alkalinity, and foam heigh range respectively from 9.99 to 11.85%; 0.022 0.040%; 16.25 to 18.50 9.92 cm. They have a higher foaming power compared to the reference soap. The melting temperature is 150℃ for all soap samples. The soaps resulting from this preparation are hard and are resistant to the solubilizing action of water. Formulations made with more tiger nut oil (SF2 and SF3) are the most adapted. The analysis of creams and lotions shows densities within the standards. The monitoring of the pH of lotion and cream shows values ranging from 4.43 and 5.10. The sensory analysis shows that formulation LF2 for lotion and CF2 for creams are the most appreciated. The results obtained in this study show that all the oils are suitable for cosmetic production. Thus, the results of the analysis show that tiger nut oil is a good material for cosmetic products.

Keywords Vegetable oil, Tiger nut oil, Soap, Lotion, Cream

1. Introduction

Seeds such as peanut, soybean, rapeseed, sunflower and palm, coconut, olive and argan nuts are the main sources of vegetable oils most traded in the world [1], [2], [3]. Oil demand is constantly increasing, hence the use of non-conventional oil-producing plant species to find alternative sources of lipids with better nutritional value as well as to improve commercial application [4] [5] [6]. Beyond their inclusion in food preparation, the important presence of bioactive compounds could direct their use in cosmetics. Indeed, the use of natural products such as seed oils for skin application is known for a long time [7]. Plant oils have important pharmacological properties, which have gained ground in the pharmaceutical field [8]. The demand for natural or organic cosmetic products in the community has become a fundamental need, especially with the harmful consequences that chemical cosmetics have on human skin as well as on the environment. The current trend of replacing synthetic products in the cosmetic and pharmaceutical industry is becoming more and more important [9]. As a result, non-conventional vegetable oils from oilseeds have the potential to become the main raw materials for the production of cosmetics. Vegetable oils are

* Corresponding author:
cheikbou20@yahoo.fr (Bou Ndiaye)
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good sources of bioactive compounds including unsaturated fatty acids and antioxidants (phenolic compounds, vitamins A and E…) [10] [11] [12] [13] [14]. Depending on the presence of numerous substances, vegetable oils can help fight several human pathologies [15], [16], [17], [18]. Thus, in order to follow the evolution of organic cosmetics, it would be interesting to exploit Senegalese vegetable oils as the main raw material. The Senegalese flora is known for its richness in plants providing oil seeds [19], [20], [21]. Among these seeds, the use of certain plants in cosmetics has been experimented notably moringa and balanites. Known as *Moringa oleifera*, the plant produces seeds that are a good source of fat with high levels of vitamin E [9], [12], [22]. Moringa oil has also been a part of folk medicine for thousands of years. In the past, it was used as a perfume and skin lotion by the Egyptians, Romans and Greeks [7]. *Moringa oleifera* seed oil possesses a skin protecting effect and was suggested to maintain the natural skin pigmentation as it possesses a mild sun protective activity [23]. *Balanites aegytiaca* is an abundant plant in the south of Saharan Africa. It is a source of fats used by some populations in agri-food and in the production of cosmetics [3], [24]. Tiger nut (*Cyperus esculentus*) present an oil rich in unsaturated fatty acids and fat-soluble vitamins [25], [26], [27], [14]. The use of tiger nut has long been focused in the food field either by consuming the flour, milk or tubers directly [27], [28]. The application of tiger nut oil on the skin could be beneficial due to the presence of numerous components which have antioxidant, healing, and regenerator effect. The objective of this work is to study tiger nut oil effect in cosmetic products.

2. Material and Methods

2.1. Material

For the conception of the products, we used as biological material: tiger nut oil, coconut oil, *Moringa olifera* seed oil and *Balanites aegyptiaca* seed oil, shea and mango butter. The production of cream required the use of tiger nut, moringa and *Balanites* oils and shea butter. The body lotion is made from tiger nut, balanites and moringa oils and mango butter. The soaps are made from tiger nut and coconut oils and shea butter. The oils are purchased from approved distributors.

2.2. Methods

2.2.1. Lotion and Cream and Production Method

Lotion and cream are obtained from an oil-in-water (O/W) emulsion using a stirrer and made according to precautions such as the respect of the temperature, operating mode and agitation. The oil and water phases are mixed at a temperature of 70℃ under a stirring of 600 rpm. After cooling, the production is stored in bottles. The composition of each formulation is established in Table 1.

Table 1. Body lotions and face creams formulation

Composition		Body lotion		Face Cream	
		LF1	LF2	CF1	CF2
Aquaous phase	Water (%)	77	77	68.894	68.894
	Glycérin (%)	2	2	1	1
	Aloé (%)	0	0	10	10
Oil phase	Tiger nut oil (%)	5	10	5	10
	Moringa oil (%)	3	0	3	0
	Balanites oil (%)	2	0	2	0
	Shea butter (%)	2	2	0	0
	Mango butter (%)	0	0	2	2
Active ingredients		0.2	0.2	0.006	0.006
Emulsifier (%)		5.8	5.8	5.8	5.8
Thickening (%)		0	0	0.3	0.3
Preservatives (%)		1	1	1	1
Perfume (%)		2	2	1	1

2.2.2. Soap Production Method

The oil phase is composed of tiger nuts, coconut oil, and shea butter. The caustic solution is prepared by calculating the mass of soda needed to saponify the oils and deducting the mass of water to dissolve the soda. The mass of sodium hydroxide pellets used is equal to the sum of the masses of the various fats to saponify multiplied by their saponification index. An overgreasing of 5% was made by multiplying the mass of sodium hydroxide pellets obtained by 95%. This gives the final mass of sodium hydroxide pellets. This mass of final NaOH was multiplied by 2.5 to obtain the mass of water necessary for its dissolution. The saponification was carried out cold. The composition of each formulation is shown in Table 2.

Table 2. Soap formulation

Composition	Formulations		
	SF1	SF2	SF3
Tiger nut oil (%)	70	80	75
Coconut oil (%)	10	0	0
Shea butter (%)	20	20	25
NaOH (g)	33.63	33.82	33.06
Water (g)	84.075	84.55	82.65
Parfum%	2	2	2

2.3. Analysis Method

2.3.1. Oil Caracteristics

The peroxide value was determined by titrimetric methods using NE 2658-91standard method. Acid value was evaluated with AFNOR NFT 60-204. According to the method NFT 60-206, saponification value here determined. The refractive index was measured with a refractometer (CONVEX N° 042952, CETI-BELGIUM). A colorimeter (CM-5, Konica Minolta, Japon) was used to determine color parameters (L*, a*, b*) of the different oils.

Specific Gravity : The specific gravity (SG) of the oil was determined according to the method described by Zand *et al* [3] with little modifications. The weight of 50 mL empty flask (w_o) was taken and recorded. The test tube was first filled with water (w_1), weighed and recorded. After drying, an equivalent quantity of oil was replaced with the water in the same test tube and weighed (w_2). The specific density of the oil was determined as follows:

$$SG = \frac{W_1 - W_2}{W_1 - W_0}$$

2.3.2. Soap Analysis

pH analysis: The pH of the sample was determined using pH-meter (FI24-2). 2g of the sample was weighed into a flask and then 50 mL of distilled water was added and agitated to dissolve the sample. The electrodes were placed in the sample solution then pH was recorded [29].

Free Caustic alcali : soap sample (5g) were digested in freshly boiled ethanol (30 mL) on steam bath until the soap sample was dissolved. This was followed by the addition of about 5 drops of phenolphthalein indicator and 5 mL of BaCl2 (20%). The resultant solution was titrated against H_2SO_4 (0.05 M), to the disappearance of pink [3] The total free alkali is calculated using the relationship weight (g) of:

$$\%NaOH = \frac{0{,}31xV_a}{m}$$

Va: acid volume and m: soap mass

Foam capacity: About 2.0g of the soap (shavings) was added to a 100 ml measuring cylinder containing 50 mL of distilled water. The mixture was shaken vigorously so as to generate foams. After shaking for about 2 minutes, the cylinder was allowed to stand for about 10 minutes. The height of the foam in the solution was measured and recorded [29].

Foam capacity test in HCl and in NaCl solutions: A soap solution is prepared by dissolving 3 g of soap in 100 ml of distilled water in a screw tube, adding dropwise 1 ml of a hydrochloric acid solution (1mmol/l) to 2 ml of the soap solution. The tube is tightly closed and shaken vigorously in a horizontal position for about 15 seconds. After 5 min at rest, the height of the foam is measured. In a screw tube, 1 ml of a saline solution of NaCl (30%) is added dropwise to 2 ml of soap solution. The tube is capped and shaken vigorously in a horizontal position for about 15 seconds. After 5 min of rest, the height of the foam is measured [30].

Moisture content: water content was determined by gravimetric method. 2.0 g of samples were taken in dried and tarred moisture dish and dried in an oven at 105℃ for 4 hours. It was cooled in a desiccator and weighed.

Solubility test: A volume of 100 cm^3 of distilled water was added to 5.0g of soap in a beaker. The solution was left for a moment and the time taken for complete dissolution was recorded.

2.3.3. Sensory Analysis of the Lotions and Creams

Body lotions and face creams produced were subjected to a sensory evaluation by a group of 20 randomly selected people, consisting of 6 men and 14 women. The products were evaluated on the following criteria: hydration, penetration, greasiness. These different criteria were chosen by preference for each tester. For each product, lotion (LF1 and LF2) and cream CF1 and CF2), the two formulations were applied at the same time by the testers who then gave their appreciation a few minutes later. These appreciations are noted according to the chosen criterion from "more pleasant" to "less pleasant".

2.3.4. Processing of Statistical Data

The analysis of variance (ANOVA) is performed using Statistica version 7.1 software. The level of significance of the results is taken at the probability $p<0.05$.

3. Results and Discussion

3.1. Oil Characteristics

The quality parameters of the oils used in this study are established in Table 3. They concern density, acid, peroxide, saponification and refraction indices.

Table 3. Oil physicochemical parameters

Samples	Parameters								
	Density	Acid value (mg KOH/g oil)	Peroxide index (meq O_2 /Kg oil)	Saponification value (mg KOH/g oil)	Refractive Index	Color index			
						L*	a*	b*	ΔE
Tiger nut oil	0.85	2.24 ±0.00[a]	7.10 ±0.10[a]	192.84 ±2.10[a]	1.465 ±0.01[a]	90.69 ±0.05[a]	-9.65 ±0.01[a]	83.28 ±0.05[a]	Référence
Moringa oleifera seed oil	0.90	5.04 ±0.00[b]	6.60 ±0.20[ab]	197.29 ±0.47[b]	1.465 ±0.01[a]	92.15 ±0.01[b]	-11.91 ±0.00[b]	59.65 ±0.01[b]	23.79
Balanites aegyptiaca seed oil	0.89	23.79 ±0.28[c]	5.40 ±0.4[b]	202.66 ±0.671[c]	1.465 ±0.01[a]	87.68 ±0.01[c]	-7.67 ±0.00[c]	81.32 ±0.03[c]	4.10

Means ± standard deviations followed by a different letter in the same column indicate that the differences are significant (p <0.05).

3.1.1. Specific Gravity

The densities of the different oil samples are respectively 0.85, 0.89 and 0.90 for tiger nut, *Balanites* and *Moringa* oils. This value found in tiger nut is lower than those found by Adel *et al.* (2015) [31], which range from 0.89 to 0.92. The specific gravity value in moringa is higher than the result of Hanna *et al.* [12], which is 0.82. The values are slightly higher than those obtained by Uzair *et al.* [32] in moringa oil which are 0.876 and 0.88 in different processing extraction. *Balanites* oil density is similar of the of Zang *et al.* (2018) [3] which are 0.90. A high value of 0.95 is obseved in *Balanites* oil [33].

3.1.2. Peroxide Value

Peroxide value is a very useful criterion to appreciate the first stages of oxidative deterioration of an oil [12]. The peroxide value determined for tiger nut, *Moringa* and *Balanites* oils are respectively 5.40, 6.60 and 7.10 meq O_2/Kg. Analysis of variance shows that the peroxide value of tiger nut and moringa oils are statistically different ($p<0.05$). The work of Adel *et al.* [31] reveals lower peroxide value ranging from 0.79 to 1.52 meq O_2/Kg on different types of tiger nut oils studied. However, the peroxide value of tiger nut oil is lower than the results of Awulu, et al. (2018) [34], which range from 7.63 to 9.95 meq O_2/Kg. The study of zang *et al.* [3] revealed a peroxide value 2.95 mEq/kg in *Balanites aegyptiaca* oil. The noticed peroxide value in moringa was is higher than the 0.01 meq O_2/kg oil reported by El Beky *et al.* [12]. Lower peroxide values were found in moringa oil, which range from 0.36 to 1.80 meq O_2/kg of oil obtained in different extraction method [14]. The peroxide indices from these analyses are lower than the maximum allowable value 10 meq O_2/Kg prescribed by the Codex Alimentarius Standards [35].

3.1.3. Acid Value

The oil acidity gives information on its free fatty acid content. It evolves according to the duration and the mode of conservation of the oil. The acid values are 2.24, 5.05 and 23.80 mg KOH/g respectively for tiger nut, moringa and *Balanites* oils. The analysis of variance shows that the acid indices are significantly different ($p<0.05$) for all samples. It was found that only tiger nut oil complies with the limits established by CODEX STAN 210-1999 [36] which are 0.6 and 4.0 mg KOH/g oil respectively for refined and cold pressed oils. The acid value of *Balanites aegyptiaca* oil is higher than the result of Zang *et al.*, [3] which was 2.14 ± 0.28 mg KOH/g and the result of Diedhiou et al. [22]. The acid value found by Hanna *et al.*, [12] was 0.02 mg KOH/g in moringa oil. The elevated acid value observed in *Balanites* oil could be due to the hydrolysis of triacylglycerides caused by the high water content. Lower value of 0.84 mg KOH/g oil is observed in moringa seed oil [37]. The study of Ogbunugafor *et al.* [38] shows an acid value of 3.8 mg KOH/g of moringa oil. In fact, the oxidation reaction is so rapid that the formation of secondary compounds takes precedence over the hydroperoxides. This could explain the low peroxide value observed while the acid value is very high.

3.1.4. Saponification Value

The analytical results reveal a saponification value of 192.84 mg KOH/g oil in tiger nut. This result is identical to the one observed in the work of El-Naggar [25], which is 192.88 mg KOH/g oil. The values observed for the physicochemical properties were significantly in favor of using the tiger oil for soap production. Saponification value of *Moringa oleifera* seed oil in this study is higher than those found by Hanaa et al., (2013) [12] and SURYADEVARA *et al*. [37] which is 179 and 152.14 mg KOH/g of oil respectively. Saponification value of *Balanites aegyptiaca* seed oil is 202.66. The study of Kaoke *et al.* [40] shows a saponification values of the *B. aegyptiaca* kernel oil ranging between 123.6 and 139.5 mg KOH/g. A saponification value of 182.2 mg KOH/g is observed in the study of Diedhiou *et al.* [22].

3.1.5. Refraction Index

The analyses reveal equal refractive indices, the value found is 1.465. This value is similar to those observed in tiger nut oil samples obtained under different conditions 1.464-1.465 [31]. In the study of Ahmed and Eid (2015) [33], results reveal that *Balanites* oil had a refractive index of 1.4699. *Balanites aegyptiaca* seed oil refraction index value is lower than the results of the refractive index of the sampling of *Balanites aegyptiaca* kernel seed oil in North Cameroon, wich vary between 1.471 and 1.476 [40]. Refraction index value is higher than the observed refraction values in moringa oil seed obtained in different extraction method which range from 1.4549 to 1.4591 [14]. The study of Ogbunugafor *et al.* (2011) [38] shows a refractive index of 1.4713 in moringa oil.

3.1.6. Color Parameters

The color parameters of the vegetable oils are presented in the table 3. A highly significant difference ($p \leq 0.05$) was observed in the color characteristics of the three types of oils. Thus, the luminosity (L*) value of moringa oil followed by tiger nut and *Balanites* oil respectively. This indicates that *Moringa* oil is whiter than the other oils. The results of color measurement showed that color index (L* and b*) were positive values. On the other hand, the yellow index (b*) is higher in tiger nut oil. It is deduced that tiger nut oil is more yellow than the other oils. *Balanites* oil, given its a* values, proves the nature of its dark yellow color. This difference in color between the three types of oils could be due to the extraction method but also to the presence of colored compounds in the oils such as carotenoids. The ΔE Cosmetics less than 1.0 indicated an unnoticeable difference of two colors [23]. This result suggests that tiger nut oil has a consistent yellow color. The evaluation of the color difference shows a significant difference which confirms the previous results.

3.2. Soap Analysis

After drying, the soaps formulation (SF1, SF2 and SF3) obtained from different formulations are shown in Figure 1. The results of physicochemical analysis are reported in Table 4.

Figure 1. Soap samples

The analysis of the color parameters of the soaps shows that there is a significant difference ($p<0.05$) between the color indices (Table 4). Compared to the reference taken in the market, the color difference is very remarkable. This difference would be due to the composition of the soaps.

Table 4. Soap physicochemical caracteristics

Parameters		Samples			
		SF1	SF2	SF3	Standard
Moisture		11.18 ±0.78^{a}	9.99 ±0.13^{a}	11.85 ±0.49^{a}	11.40 ±0.07^{a}
pH		10.29 ±0.01^{a}	9.95 ±0.01^{a}	9.92 ±0.01^{a}	10.59 ±0.01^{b}
Color Index	L*	82.49 ±0.01^{a}	78.43 ±00^{b}	79.06 ±0.01^{c}	72.27 ± 0.13
	a*	3.09 ±00^{a}	3.67 ±00^{b}	3.70 ±0.01^{c}	1.82 ±0.01
	b*	23 ±0.02^{a}	25.88 ±0.01^{b}	25.23 ±00^{c}	31.54 ±0.07
	ΔE	13.27	8.57	14.08	Reference
Free alcali caustic (%)		0.028 ±0.003^{a}	0.022 ± 0.003^{a}	0.04 ±0.01^{a}	0
Height of Foam (cm)		16,25 ±0.25^{a}	18.50 ±0.50^{a}	17.25 ±0.75^{a}	13.75 ±0.125^{b}
Height of foam in acid medium (cm)		4.05 ±0.05^{a}	4.40 ±0.10^{ac}	4.55 ±0.05^{c}	3.35 ±0.05^{d}
Height of foam in alkaline environment(cm)		0	0	0	0
Solubility index (H)		6H50mn^{a}	7H15mn^{b}	6H20mn^{c}	4h05mnn^{d}
Melting temperature		150°C	150°C	150°C	>165°C

Means ± standard deviations followed by a different letter in the same column indicate that the differences are significant (p <0.05).

The moisture content is 9.99, 11, 18 to 11.85% respectively for the soap formulation SF2, SF1 and SF3 (Table 4). Variance analysis reveals that there is no significant difference ($p>0,05$) between samples for water content. These values are approximately equal to that of the market soap taken as standard but are lower than those observed by Vivian et al. [41]. The moisture content in the laundry soap samples studied by Ashafiri et al. [42] range between 14.75 to 21.06%. The moisture content in olive and palm soap ranges from 2.45 to 10.94% in the study of Antonić et al [43]. However, these water contents are within the standard limit values [44] [45]. The observed differences could be due to the difference in soap preparation methods.

The pH analyses of the soaps reveal the values of 10.29, 9.95 and 9.92 respectively for the SF1, SF2 and SF3 formulations. These values are therefore lower than that of the market soap which is 10.58. The analysis of variance shows that the pH values are statistically identical ($p>0.05$) between the formula soaps. However, they are statistically different ($p<0.05$) to the reference sample. The pH of the soaps is consistent with the normal range of pH for a soap which is 9 to 11 [46]. These pH values are in the same range of variation of shea butter and neem soap whose pH varied between 9.11 and 9.99 [29]. This low value could be due to partial alkaline hydrolysis resulting from the saponification process. The reaction can be supplemented by the addition of excess oil or butter or any other superfatting agent to reduce the harsh nature of the reaction [29]. Also, the alkalinity promotes detergency [47]. An excess of alkaline substances could neutralize the body's protective acid mantle that acts as a natural barrier against bacteria and viruses [48].

Free caustic alkali is the amount of free alkali to prevent the soap from becoming oily [49]. It determines the abrasiveness of the soap [48]. The lower this value is, the better is the quality of the soap. The results for the total alkali content show low values of 0,028, 0,022 and 0,043% for SF1, SF2, SF3 respectively. The analysis of variance shows that no significant difference ($p>0.05$). These values are higher than the reference sample which is 0%. However, these values are lower than those found by Mak Mensah (2011) [50] which shows a content of 0.06%. The work of Ashrafy et al. (2016) [48] on commercial toilet soaps show free alkali amounts between 0.00% and 1.45%. The detected free caustic alkali content of shea butter soap is 0.0% in Baodu *et al.*, [44]. These soaps can be classified in the 2nd range of household soaps (their caustic free alkali content being less than or equal to 0.3% according to ISO 684-1974 standards). From these low values of caustic free alkali, it could be predicted that they are in the incapacity to produce irritations on a standard skin.

The height of the foam is used to determine the foaming power of soaps. The different values of the foam height of the soaps were range from 16.25, 18.50 and 17.25 cm respectively for SF1, SF2, SF3. The soap made with tiger nut oil and shea butter (SF2 and SF3) has the high heighest. These values are higher than that of the market soap which is 13.75 cm. Analysis of variance shows no significant differences were found ($p>0.05$) between soap formula. But these values are significatively different ($p<0.05$) to the foam height of market soap. The results found are superior to those found by Ameh A.O. et al. (2013) [29], whose foam heights range from 13.44 to 15.98 cm and those of Latif et al. [51] which range between 9.3 to 14.4 cm. These heights are within the recommended range of values. The soaps obtained are well foaming and therefore they are well detergent. The detergent action of a soap in water is related to its foaming power.

In saline medium, the lathering height of the 3 formulated soaps as well as that of the control soap is null. This shows that in alkaline medium, the soaps are deprived of their foaming properties and consequently the detergent ones too. On the other hand, the height of foam in acid medium of soaps SF1, SF2 and SF3 is respectively 4.05, 4.4 and 4.55 cm and is higher than that of the control soap which is 3.35 cm. The analysis of variance shows that the foaming powers of SF1 and SF3 formulations are statistically different ($p<0.05$). However, they are statistically identical to the SF2 formulation ($p>0.05$). From these results, it can be deduced that the formulated soaps react better in acidic medium than the control soap. The soap made with tiger nut oil and shea butter (SF2 and SF3) has the highest height.

The soaps solubility is an indication of the ability of the soaps to last longer when used due to its ability to slowly dissolve in water [47]. The dissolution time in distilled water of SF1, SF2 and SF3 soaps is respectively 6H45mn, 7H15mn and 6H4520mn compared to the market soap which is 4H05mn. The analysis of variance shows that the solubility index are statistically different ($p<0.05$). These results show that the soaps obtained are more resistant to water and therefore harder than the control soap. Moreover, it was found that the SF2 soap has the longest time and is therefore the hardest soap. This can be explained by the fact that it has the lowest humidity. Almost as a rule, the solubility of soap in water increased in the size of the monovalent cation.

Fusion temperature is 150℃ in all samples. This value is lower than the reference soap. The results are the same as those of Zerbani [45] observed in cold pressing soap. Accordind to Zerbani [45], the nature of the base used in saponification has a significant influence on the melting point of the synthesized soap, approximately 150℃ with a mineral base and 200℃ with a synthetic base.

3.3. Lotions and Creams Analysis

The parameters studied for lotions and creams are specific gravity, pH and color parameters (L*, a*, b*) are stablished in table 5.

The specific gravity values of body lotions are 1.07 and 1.03 in LF1 and LF2 respectively and those of face creams are 1.04 and 1.19 respectively in CF1 and CF2. These values are in accordance with those recommended by the standard (NB 09.01.001, 2006) which are in the range [0.8-1.2].

Table 5. Physical characteristics of body lotions and face creams

Samples	Specific gravity	pH	L*	a*	b*
Body lotions formulation					
Body lotion (LF1)	1.07	4.90 ±0.01[a]	79.59 ±0.02[a]	-2.44 ±0.00[a]	5.54 ±0.01[a]
Body lotion (LF2)	1.03	4.53 ±0.01[b]	72.64 ±0.01[b]	-2.51 ±0.01b	4.28 ±0.01[b]
Face creams formulation					
Face cream (CF1)	1.04	5.10 ±0.01[a]	81.10 ±0.01[a]	-2.30 ±0.01[a]	5.48 ±0.01[a]
Face cream (CF2)	1.19	4.99 ±0.01[b]	83.73 ±0.00[b]	-2,71 ±0.01[b]	7.38 ±0.01[b]

Means ± standard deviations followed by a different letter in the same column indicate that the differences are significant ($p <0.05$).

The pH of lotion or creams is a very important parameter because any change in its value can provide information on the instability or contamination of the product that has occurred directly or indirectly during the preparation of the product. Variations in pH values also indicate that a possible chemical reaction could occur between the raw materials used in the product formulation. The pH values of the body lotions formulation are 4.90 and 4.53 for LF1 and LF2 respectively. The analysis of variance shows a significant difference ($p<0.05$). These values are lower than those in the study of Zang et al. [3] which value are between 5.09 to 5.26 in lotion formulated with *Balanites* oil. For creams formulation, the pH values are 5.10 and 4.99 respectively in formulation CF1 and CF2. Variance analysis shows a significant difference ($p<0.05$). The pH of the creams produced using moringa oil was found to be in the range of 5.6–7.4 [37]. Moreover, these pH values respect the range (4.5-6.5) skin pH [52].

Color is an important parameter in cosmetic products. Color changes can be caused by chemical interactions between the raw materials in the formulation such as oxidation or the clustering effects of the used ingredients. Analysis result show that the luminescence index (L) values of lotions are 79.59 and 72.64 respectively in LF1 and LF2. The creams of the formulations CF1 and CF2 show luminosity (L*) values of 81.10 and 83.73. respectively. The b* index values are positive in all samples. Statistical analysis indicates that a significant difference ($p<0.05$) between color parameters. These can do to initial oils colors and the presence some pigments.

The results of the sensorial analyses were presented in the form of graphs for each criterion except for the criteria of softening effect, penetrating effect and grassy state (Figure 2). These parameters were assessed in the same way for the different formulations. For the rest of the criteria, a preference is noted for the LF2 formulations made up of only 10% of tiger nut oil. They are considered more softening, more penetrating and less greasy than the LF1 formulations with less tiger nut, *Balanites* and moringa oils.

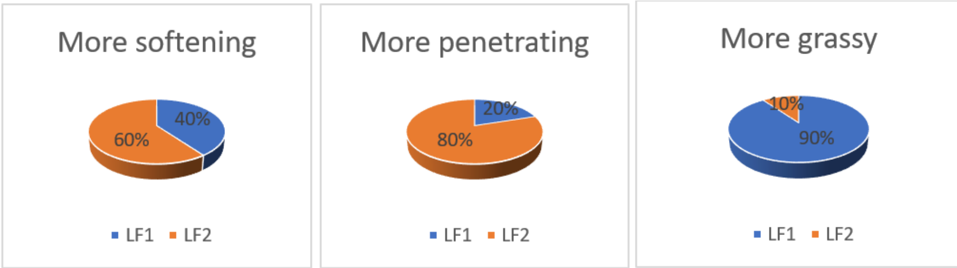

Figure 2. Sensory criteria curve of body lotions (LF1 and LF2)

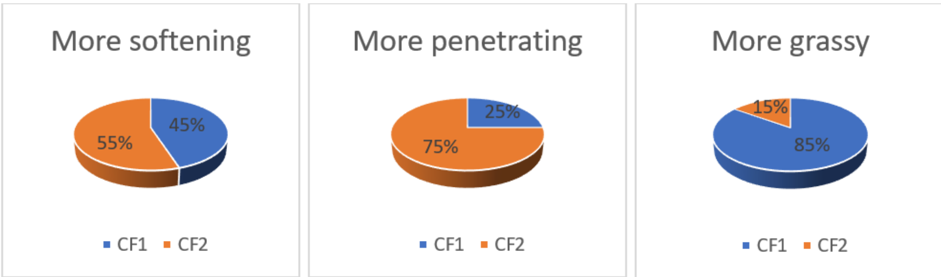

Figure 3. Sensory criteria curve of face creams (CF1 and CF2)

4. Conclusions

The objective of this work was to study the effect of tiger nut oil incorporation in cosmetic products. The physicochemical tests carried out on the oils show that they are suitable for cosmetic production. Soap made with high proportion of tiger oil show the best physicochemical proprieties. It can be noted a preference for the formulation SF2 which contains more tiger nut oil. The physical analyses carried out on and lotions and creams show that they respect the cosmetological standards and can be applied to the skin. Sensory tests carried on lotions and cream show a preference for the formulation LF2 and CF2 for lotion and creams respectively. Considering the results obtained it can be deduced that tiger nut is good material for cosmetic products. Further analysis is required in order to study the oxidative stability of lotions and creams.

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