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Physico-chemical and nutritional characteristics of kernels oil from two mangoes varieties (Amélie and Kent) harvested at Orodara in Burkina Faso

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Abstract

The mango tree (*Mangifera indica*) plays an important role for Burkina Faso people. This importance is due to its consumption, its pharmaceutical properties and its shade. However, all this importance is limited to the fleshy parts, leaves, bark and roots, whereas the mango tree's kernels are full of potential that can be exploited, but remain little known. Two mango varieties (Amélie and Kent) were sampled at the Bobo-Dioulasso fruit and vegetable market from Orodara. The fat content and physico-chemical parameters of the mangoes were determined using conventional methods. The results obtained show that the oil's biochemical composition gives it its full importance. This oil meets most of the standards set by the Codex Alimentarius for virgin oils. Mango kernels do indeed contain a fat content of between 3.039 and 6.486%. For moisture content, we found 56.095% and 56.070%, which already exceeds half the kernel's constitutional weight. In terms of chemical parameters, the highest acid value was 2.664 mg KOH/g, compared with 4.0 mg KOH/g as the maximum limit of the Codex Alimentarius standard. The peroxide value was equal to 9.523 $mEqO_2$/kg against 10 $mEqO_2$/kg as the maximum limit of the standard. We have a good concentration of saturated fatty acids at least 47% for the lowest concentration and 24% of unsaturated fatty acids for the lowest concentration. In view of these results, mango kernels should be valorized in order to add value to mango waste, with a view to use in cosmetics or medicine, as well as to depollute the environment.

Keywords: Oil; Mango Kernel; Physicochemical; Nutritional Characteristics

1. Introduction

The mango tree (*Mangifera indica*), now highly appreciated in West Africa for its fruit and shade, is a recent introduction to Africa. The mango tree was first reported in West Africa, more precisely in Senegal, in 1824, and it was at the end of the 19th century that mango trees began to spread significantly, especially in coastal areas. It returned to Mali around 1890 and was the source of numerous grafted plants that were widely distributed in neighboring countries (Rey et al 2004). A member of the Anacardiaceae family with the scientific name *Mangifera indica*, it is native to the forests of India, Pakistan and Burma, where it still grows wild in some 600 species in 70 genera (Watson and Dallwitz, 1992; Lizada, 1993). Burkina Faso accounts for between 11 and 18% of West African mango production. Mango accounts for around half of national fruit production by volume, and is a major socio-economic and climatic issue in Burkina. The mango value chain in Burkina Faso is a major employer. It employs 28,000 people in 21,000 entrepreneurial and related jobs (farmers, trackers, retailers, etc.), around 350 permanent jobs in processing and packaging companies for fresh export, and around 7,000 seasonal jobs throughout the chain. Seasonal sales of fresh mango on the local market also

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provide a livelihood for some 10,000 retailers. In fact, the mango sector generates over 15 billion euros in sales per year (apex Burkina, consulted 02/02/2024). Prized for its succulent, fleshy fruit, the mango has become an integral part of our diet. The mango tree is also used for its medicinal properties, contained in its roots, bark, leaves and pit. The mango pit is an important part of the fruit, representing around 20% by weight of the mango, but is little known to consumers. However, its valorization can make a major contribution to environmental protection, since the daily rate of waste will be reduced, and mangoes that are rotten at harvest will also be valorized. Deterioration of the fruit has no impact on the state of the kernel. Inside is a kernel which, after extraction, yields mango butter containing fatty acids, polyols and antioxidants. In view of the many virtues of mango kernel butter, we dare to believe that the oil from this kernel could strengthen the dietary arsenal (Dokalahy, 2017). And yet, very few people are interested in its kernels, which are discarded immediately after consumption or processing of the fleshy part of the fruit. Therefore, the present study attempted to estimate the physico-chemical and nutritional characteristics of kernels oil from two mangoes varieties (Amélie and Kent) harvested at Orodara in Burkina Faso.

2. Materials and methods

2.1 Sampling

Two varieties of mango from Orodara were sampled at the Bobo-Dioulasso fruit and vegetable market. These were the Amelie variety and the Kent variety shown in figure 1 below:

Figure 1 Mango varieties used: a (Amelie variety) and b (Kent variety)

2.2 Fat extraction by the Soxhlet method

Mangoes undergo a number of pre-treatments before the actual kernels are obtained.

2.2.1 Fruit pre-treatment

This operation consists of separating the kernel from the rest of the fruit. Fleshy mangoes are washed in plenty of water. After washing, the different parts of the fruit are separated: skin, flesh and stone. If the mango is very fresh, the flesh can be eaten directly, or processed into other products such as jam, mango juice, etc. The skin, which is very rich in pectin and tannin, can also be used.

2.2.2 Mango kernel preparation

Figure 2 Peeling (a) mango cores (b)

The purpose of this operation is to separate the shell from the kernel. The washed kernels are dried in an oven or just in the open air. This is done to facilitate the next operation, hulling. Once dried, the kernels undergo a hulling operation (Fig. 2). The kernels are separated from the shell by hand, using a stainless steel knife.

2.2.3 Mango kernels processing

Once separated from the shell, the almonds undergo a further treatment before extraction. First of all, the almonds were further dried to remove any remaining residual water that might distort the extraction result. The dried kernels were then ground using a mortar or ball mill. The lipids contained in the almonds are enclosed in droplets in the oil cells. This step is therefore essential, as reducing the granulometry of the kernels facilitates contact between the extraction solvent and the sample, and improves yield. In other words, the contact surface between the two solvent-sample phases must be increased by grinding the kernels to powder.

It should be pointed out that in this pre-treatment of fresh mangoes, only the kernels were exploited. However, the other parts, i.e. the pulp, the peel and even the shells, can all be used. In the case of rotten mangoes, only the kernels are recovered during the entire operation.

2.2.4 Soxhlet extraction of mango kernel oil

The Soxhlet extractor is an ingenious glass device for extracting a substance. Generally used for solid-liquid extractions, it extracts a chemical species from a solid and transfers it to a carefully chosen solvent. This type of extraction is performed using a reflux heating system.

Procedure

Place 15g of mango kernel powder in the cellulose cartridge, then in the Soxhlet tank. Fill the flask with a sufficient quantity of hexane as solvent (take into account the quantity that will be trapped in the tank during handling) and mount the extractor on a cooler. Using a heating mantle, bring the solvent to the boil. The solvent passes through pipe 1 and is condensed by the coolant. It then falls into the tank containing the cartridge and solubilizes the substance to be extracted. The tank fills up. As soon as the solvent level reaches elbow 2, the tank empties automatically. The solvent and the substance to be extracted are drawn into the flask. To extract a substance correctly, several cycles as described above are usually carried out, the process taking 6 hours.

Advantages and disadvantages of Soxhlet extraction

Soxhlet extraction uses small quantities of solvent, which is advantageous. Moreover, the solvent that condenses is always pure. Solubilization of the substance is therefore favored, thanks to better partition coefficients. There are, however, a few drawbacks: extractions take a long time (hence the need for multi-station equipment), and there is no possibility of working cold, which can be a problem with heat-sensitive substances. For your information, there are other types of extractor on the market: Randall, Fibertest. and SPE extraction is becoming increasingly popular.

The powdered kernels are then extracted to remove their constituent oils. The method used here is the Soxhlet-heated balloon system. Hexane is used as the extraction solvent because it is a highly volatile product, which facilitates separation of the two solvent-oil phases during evaporation; it is chemically inert with the oil; and it is stable at high temperatures.

Solvent evaporation

After the 6-hour extraction, the oil is mixed in a single phase with hexane. This is a liquid-liquid mixture, so we proceeded with evaporation to separate the solvent from the oil. This solution was then placed in an oven for a few minutes to ensure that all the hexane had evaporated.

2.3 Fresh fat extraction

The fat was extracted fresh using the following procedures:

- Weighing: the almond powder was weighed and placed in filter paper;
- Soaking: Place the pre-packaged mango kernel in a 500 ml Erlenmeyer flask, add hexane and heat for five minutes on a hot plate.
- Rest: Close tightly to prevent hexane evaporation, and leave to stand at room temperature, preferably protected from light, for 24 hours.

- Evaporation of solvent: The oil is mixed in a single phase with the hexane, and the mixture contained in the Erlenmeyer flask is placed in the rotary evaporator.

2.4 Analysis of physical parameters

2.4.1 Determination of water or volatile matter content

The water or volatile matter content was determined in accordance with ISO 662:2016. This involves heating the product in an oven at 103±2°C until complete elimination of water and volatile matter, and determining the mass loss. The moisture content of mango kernels was determined by weighing 209.052g of mango kernels in previously dried beakers incubated for 30 min in the oven (test weight). The whole set is heated at 105°C for 3h. After 3 h of incubation, the batch was removed from the oven and reweighed.

The water and volatile matter content (WVMC) is expressed as a percentage according to the formula below:

$$\boldsymbol{WVMC = \frac{M1 - M2}{TS} X\ 100}\ (\%) \quad \textbf{ou}\ \boldsymbol{WVMC = \frac{M1 - M2}{M1 - M2} X\ 100}\ (\%)$$

M0: Mass in g of crystallizer,
M1: Mass in g of crystallizer and test sample (PE),
M2: Mass in g of crystallizer and test sample after drying.
TS: Test sample

WVMC: Water and Volatile Matter Content

2.4.2 Extraction yield

The extraction yield (y) is calculated according to the formula:

$$\mathbf{y = \frac{m}{M} \times 100}$$

m : mass of extract
M : total mass of sample to be extracted

2.5 Analysis of chemical parameters

2.5.1 Determination of acid value

The acid value was determined in accordance with ISO 660 (2009). It is determined by neutralizing the free acids in mango kernel oil with potassium hydroxide (KOH) or caustic potash. In other words, it's the number of milligrams of KOH needed to neutralize the free acidity of 1g of the fat.

To determine the acid value, 2g of mango almond oil were weighed into an Erlenmeyer flask. In another empty Erlenmeyer flask, 10ml of diethyl ether was added, followed by approximately 3 drops of phenolphthalein and a few drops of potassium hydroxide (KOH 0.1N). After the addition of KOH, this solution turned pink. This mixture was then poured into 2g of mango almond oil, and the solution turned white.

This solution was titrated with KOH (0.1N) until the pink color reappeared. Finally, the volume of KOH consumed was read off. The acid value (av) is expressed in milligrams of KOH per gram of oil according to the formula below:

$$\boldsymbol{av = \frac{V \times T \times 56.1}{SS}}\ (\boldsymbol{mg\ de\ KOH/g\ huile})$$

V: volume of KOH solution
T: KOH solution titre
SS: sample size
56.1: molar mass of KOH

2.5.2 Determination of peroxide value

The peroxide value (pv) was determined in accordance with ISO 3961/2018. A test sample, dissolved in acetic acid and chloroform, is treated with a potassium iodide solution. The released iodine was then titrated with a sodium thiosulphate solution.

This determination was made by weighing 1g of almond oil into an Erlenmeyer flask. 5ml chloroform and 7.5ml acetic acid were added, followed by 0.5ml potassium iodide. Shake for about a minute and place in a dark place for 5 min. Then add about 37.5ml distilled water, followed by a few drops of starch. Finally, titrate with sodium thiosulfate (thiosulfate 0.01N) and read off the volume of thiosulfate consumed.

$$\boldsymbol{pv} = \frac{(\boldsymbol{V1} - \boldsymbol{V0})\boldsymbol{N}}{\boldsymbol{M}} \times \mathbf{10000}(\frac{\boldsymbol{mEqO}}{\boldsymbol{kg}}\boldsymbol{oil})$$

V1: Volume of sodium thiosulfate standard solution used for determination in ml
V0: Volume of titrated sodium thiosulfate solution used for the blank test in ml
N: normality of the sodium thiosulfate solution used
M: mass of test sample in grams

2.5.3 Determination of fatty acids

Preparation of reagents

To do this; 12.202 g of KOH crystals were weighed, then poured into a 50ml volumetric flask and methanol added up to the mark (add a little methanol to dissolve the KOH crystals first before filling up to Jose's mark). Homogenize well using a bar magnet and a plate.

Sample preparation

0.1 g of mango almond oil was weighed, to which 2ml of hexane was added. The mixture was vortexed and 4ml of KOH initially dissolved was added. The mixture is vortexed again, and the resulting solution is placed in a 60°c water bath for 45 minutes, with stirring every 8 minutes. The solution is then cooled to room temperature and 2ml of distilled water is added. In parallel with this solution, a blank was prepared, consisting solely of hexane, and a standard consisting of fatty acid and hexane. The blank and standard are decanted into separate vials, along with each sample.

2.5.4 Fatty acid determination

Determination is carried out using a separation technique known as gas chromatography coupled to an FID detector, based on separation, detection and quantification.

A sample solution was prepared at a concentration of 1 mg. mL-1, with hexane as solvent. An apolar column was used to inject 1 µL of ml solution into the injector. The default injector temperature is the highest temperature reached in the oven during analysis.

2.6 Statistical analysis of data

The various data obtained were recorded and processed in Microsoft Excel. They were then subjected to a single-factor analysis of variance (ANOVA) at the 5% threshold, using XLSTAT software version 2016.

3. Results and discussion

3.1 Physical analysis

3.1.1 Volatile matter

After analysis, the volatile matter content of our samples was 56.095% and 56.070% Te.mv. The lowest content was observed in sample A and the highest in sample K. It should also be noted that analyses of water and volatile matter content were carried out on fresh kernels. Similar results were reported by Hazzat et al. (2015); they also found values envious of our results, which are 48-63% of volatile compounds in green olives of the Moroccan Picholine variety. We can therefore conclude that, given the different percentages, volatile matter is worth more than half the total weight of the kernel.

3.1.2 Extraction yield

Fat extraction from the two varieties (Amélie, Kent) gave the results shown in Table 1

Table 1 Extraction yield of the two mango varieties

Sample	Kernels in g	Hexan in ml	Time	Yield %	Average yield
A	15.003	300	3h	3.039	**4.76**
K	15	300	3h	6.486	

Average yield : 4.76%

In view of these results, the mango kernel does not have a high fat concentration, as we have only 6.486% as the highest content and 3.039% as the lowest. We also note that the Kent variety is much more concentrated in fat than the Amélie variety. Our average yield is lower than the average yield found by Dokalahy (2017) on the hiesy variety in Madagascar, which was 7.68%.

3.2 Chemical analysis

3.2.1 Acid value

The results of our analysis of the acid index parameter are recorded in Table 2.

Table 2 Acid value results

Code	Test taking	Volum poured	Acid number
A1	2.000	0.95	2.664
A2	2.000	0.95	2.664
K1	2.000	0.95	2.664
K2	2.000	0.90	2.524
Kf 1	1.001	0.40	2.241
Kf 2	1.001	0.40	2.241

Table 3 Codex Alimentarius standards

Acidity	Maximum concentration
Acid number	
Refined Oils	0.6 mg KOH/g oil
Oils obtained by cold pressing and virgin oils	4.0 mg KOH/g oil

Source: Codex Alimentarius

The free acid content of fats increases with time, so the acid number is a good indicator of their state of deterioration. This index, unlike the saponification index, is determined cold. The results obtained after this analysis gave values ranging from 2.241 to 2.664mg KOH/g of oil. With regard to the standards established by the Codex Alimentarius (ISO 1996) (Table III) for crude oils or virgin oils with regard to the acid number, we can deduce that all of our samples are within the standards.

The results obtained by Dokalahy (2017) in Madagascar, ranging from 7.28 to 8.01mgKOH/g, are much higher than our results, which are 2.241 to 2.664mg KOH/g. Similar tests carried out in Mali by Diakité et al (2022) gave results ranging from 0.22 to 1.39 mg KOH/g on cottonseed oil, which are still lower than our results. As a result, our oils are much more stable and will be less exposed to possible deterioration. They will also be easier to preserve.

3.2.2 Peroxide value

The results of the peroxide value are shown in Table 4.

Table 4 Peroxide value results

Sample	Test taking	Volum poured	Peroxyde value
A1	0.500	0.35	7
A2	0.315	0.30	9.523
K1	1.001	0.35	3.496
K2	1.000	0.40	4
Kf 1	0.500	0.30	6
Kf 2	0.500	0.35	7

Analysis of our six (06) samples gave us results ranging from 3 to 9.523 mEq O_2/kg oil. However, all of our samples gave indices of less than ten (10). 100% of our samples had satisfactory results in relation to the Codex Alimentarius standard which stipulates that the best quality almond butters should have a peroxide value ≤10. Megnanou and Diopoh (2008) in their experiments at the Biotechnology Laboratory in Côte d'Ivoire obtained results ranging from 17.92 to 30.88 mEq O_2/kg for yellow shea butters, which is an oilseed. These results remain significantly higher than our results, which range from 3 to 9.523 mEq O_2/kg of oil. Also in Mali, the results obtained by Diakité et al (2022) gave peroxide values ranging from 0.19 to 13.71 mEq O2/Kg for cottonseed oils. These low values for our oils could give them interesting qualities, in particular the fact that they are not exposed to the effects of oxidation and rancidity.

3.2.3 Fatty acids

The fatty acid content of the two mango varieties is shown in Table 5 below:

Table 5 Fatty acid content of the two mango varieties and the cold extract

Variety A		**Variety K**		**Variety Kf**	
Fatty acids	Formula	Fatty acids	Formula	Fatty acids	Formula
Saturated fatty acids		Saturated fatty acids		Saturated fatty acids	
Tridecanoic acid	C13 : 0	Lauric acid	C12 : 0	Tridecanoic acid	C13 : 0
Pentadecanoic acid	C15 : 0	Tridecanoic acid	C13 : 0	Pentadecanoic acid	C15 : 0
Heptadecenoic acid	C17 : 0	Pentadecanoic acid	C15 : 0	Palmitic acid	C16 : 0
Palmitic acid	C16 : 0	Palmitic acid	C16 : 0	Heptadecenoic acid	C17 : 0
Stearic acid	C18 : 0	Heptadecenoic acid	C17 : 0	Stearic acid	C18 : 0
Arachidic acid	C20 : 0	Stearic acid	C18 : 0	Arachidic acid	C20 : 0
Heneicosanoic acid	C21 : 0	Heneicosanoic acid	C21 : 0	Lignoceric acid	C24 : 0
Tricosanoic acid	C23 : 0	Lignoceric acid	C24 : 0		
Lignoceric acid	C24 : 0				
Monounsaturated fatty acid		Monounsaturated fatty acid		Monounsaturated fatty acid	

Myristoleic acid	C14 : 1	Myristoleic acid	C14 : 1	Myristoleic acid	C14 : 1
Pentadecanoic acid	C15 : 1	Pentadecanoic acid	C15 : 1	Pentadecanoic acid	C15 : 1
Palmitoleic acid	C16 : 1	Elaidic acid	C18 : 1 trans (n9)	Palmitoleic acid	C16 : 1
Heptadecanoic acid	C17 : 1	Oleic acid	C18 : 1 cis (n9)	Gadoleic acid	C20 : 1
Elaidic acid	C18 : 1 trans (n9)	Gadoleic acid	C20 : 1	Erucic acid	C22 : 1
Oleic acid	C18 : 1 cis (n9)	Erucic acid	C22 : 1	Selacholeic acid	C24 : 1
Gadoleic acid	C20 : 1				
Selacholeic acid	C24 : 1				
Polyunsaturated fatty acid		Polyunsaturated fatty acid		Polyunsaturated fatty acid	
Linoleic acid	C18 : 2 trans (n6)	Linolelaic acid	C18 : 2 trans (n6)	Linolelaic acid	C18 : 2 trans (n6)
Linolenic acid	C18 : 2 cis (n6)	α-linolenic acid	C18 : 3n6	α-linolenic acid	C18 : 3n6
α-linolenic acid	C18 : 3n6	Eicosatetraenoic acid	C20 : 3 cis11	Alpha-linolenic acid	C18 : 3n3
Alpha-linolenic acid	C18 : 3n3	Arachidonic acid	C20 : 4		C20 : 2
	C20 : 2	Eicosapentaenoic acid	C20 : 5 EPA	Arachidonic acid	C20 : 4
Eicosatetraenoic acid	C20 : 3-cis8			Eicosapentaenoic acid	C20 : 5 EPA
Eicosatetraenoic acid	C20 : 3-cis11				C22 : 2n6
Arachidonic acid	C20 : 4				
Eicosapentaenoic acid	C20 : 5 EPA				
Decosahexaenoic acid	C22 : 6 (n3) GHA				

After our samples were assayed by gas chromatography coupled with FID, the results are arranged by type of fatty acid in Figures 3, 4 and 5.

From the statistics of the data collected for sample A, we can see that saturated fatty acids have a concentration of 47%, while unsaturated fatty acids have a concentration of 53%. Consequently, the unsaturated fatty acids in sample A have a much higher content than the saturated fatty acids. This is an advantage; as unsaturated fatty acids are much more recommended for food use. We can therefore use the A sample to strengthen our dietary arsenal, because our unsaturated fatty acids include essential fatty acids such as Omega 3 and 6.

This same sample can also be used in cosmetics, as the majority of its saturated fatty acids are prioritized in cosmetics, and this should not be overlooked.

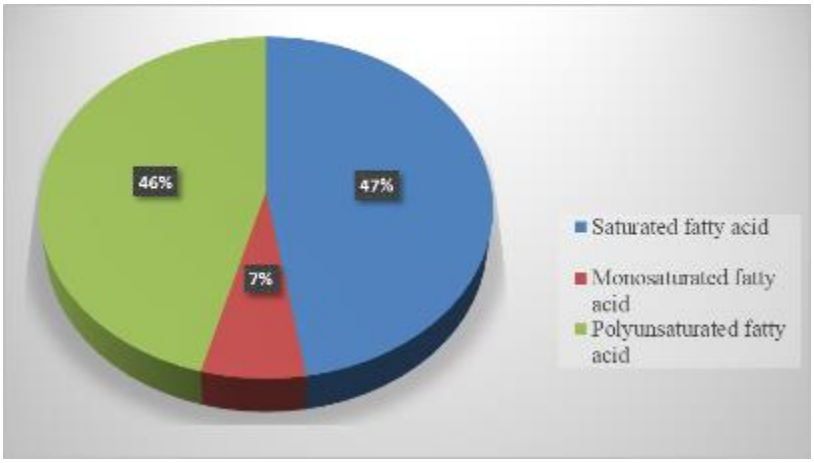

Figure 3 Fatty acid concentration, Sample A

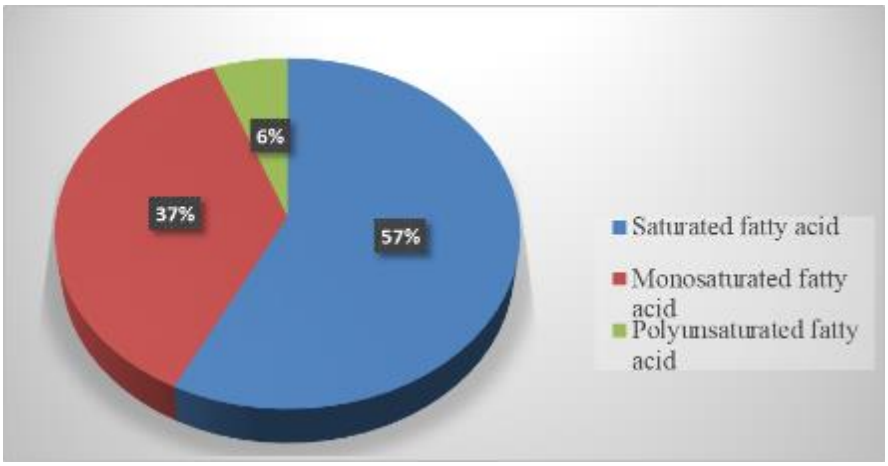

Figure 4 Fatty acid concentration, Sample K

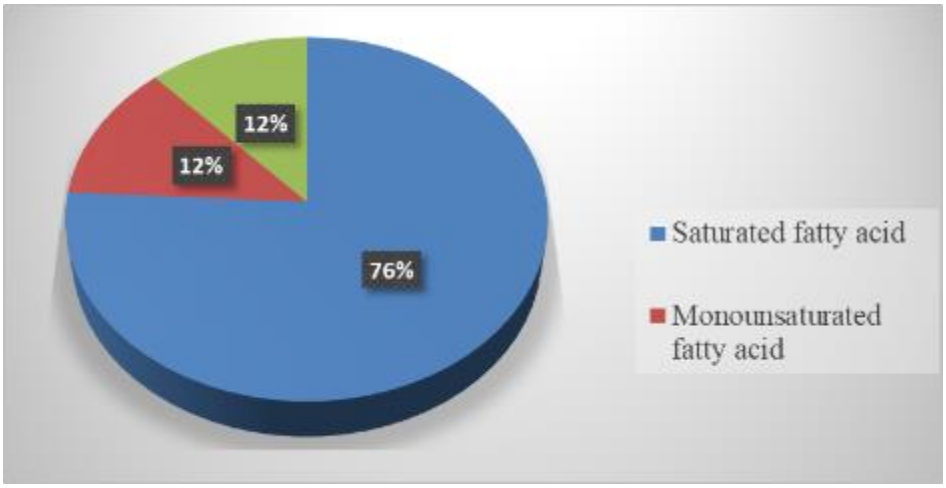

Figure 5 Fatty acid concentration Sample Kf

For sample K, saturated fatty acids have a concentration of 57% and unsaturated fatty acids are 43%. The concentration of saturated fatty acids far exceeds that of unsaturated fatty acids. We can therefore deduce that the K sample can be prioritized for cosmetics.

The Kf sample, which is one of our cold-extracted samples, has a concentration of 76% saturated fatty acids and 24% unsaturated fatty acids, confirming that this sample is highly recommended for cosmetic use.

We note that two of our samples, notably sample K (Kent) and sample Kf (Kent cold) are much more concentrated in saturated fatty acids, while only sample A (Amélie) has a high concentration of unsaturated fatty acids. We note that there is not much difference between the cold extraction of the Kf sample and the Soxhlet extraction of the K sample, as both samples have a high concentration of saturated fatty acids. However, it can be said that cold extraction increases the quantity of unsaturated fatty acids even more.

4. Conclusion

The results showed that our analyzed samples were of good quality according to the Codex Alimentarius standard. First of all, it should be noted that the almonds in our samples have a high water concentration. After extraction, we found that our analyses of the chemical parameters, in particular the peroxide value and acid value, complied perfectly with the standards set by the Codex Alimentarius. Mango kernels have a low fat content, and the Kent variety should be preferred for extraction, as it contains twice as much fat as the Amélie variety. However, the results show that the oil from our mango kernels has a high concentration of fatty acids, both saturated and unsaturated, as well as the presence of certain essential fatty acids such as alpha-linolenic acid and EPA fatty acids (a molecule in the omega 3 family, which contributes to the proper functioning of the cardiovascular system by preventing primary and secondary pathologies). Saturated fatty acids and their dominants found in our samples, in particular C18:0, C16:0, C12:0, Omega 3, Omega 6 and Omega 9, are generally used in cosmetics, providing an excellent protective barrier against wind, cold, sun and dryness.

Given the scientifically low fat content and the composition of our oils, it is preferable to use them for cosmetic rather than nutritional purposes. This study could enable researchers to focus their research on the value of mango kernels, particularly in terms of their therapeutic properties, as this oil could have useful medical constituents. This sector could also strengthen the food and cosmetics arsenal and provide jobs.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have declared that no competing interests exist.

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