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Physicochemical parameters of *Blighia sapida* (K.D. Koenig) oil extracted in Togo

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Oils extracted from *Blighia sapida* fruits are usually consumed without any information on its chemical composition. However the bad quality of oil can be a source of toxicity. Thus, the aim of this study is to investigate the physicochemical quality of the oil extracted from *B. sapida* from Togolese flora. To reach the goal of the study, mature and immature of *B. sapida* arils were used for oil extraction by the solvent method using hexane. The physicochemical parameters including density, acid value, saponification value, ester value, iodine value and impurity content were determined according to the French Association for Standardization (AFNOR) standards. The results of the extraction yields were 41.7% (immature arils) and 48.8% (mature arils). The mature arils oil had acid value of (7.013 mg of KOH/g), saponification (195.17 mg of KOH/g), iodine (87 g I_2/100 g) and ester (188.157 mg of KOH/g) values were different for those of the immature arils' which were 30.86 mg of KOH/g (acid value), 191.68 mg of KOH/g (saponification value), 85 g I_2/100 g (iodine value) and 160.82 mg of KOH/g (ester value). The densities were 0.916 g/cm^3 (mature) and 0.77 g/cm^3 (immature) while the impurity content was 3.4% (mature) and 16.1% (immature). The effect of heating the oils resulted in very high values of the physicochemical parameters. The results obtained deduce that this oil meets the Codex Alimentarius standard.

Key words: *Blighia sapida* oil, physicochemical parameters, extraction, frying, Togo.

INTRODUCTION

Malnutrition remains a real public health problem and the food security appears unattainable in several developing countries (FAO, 2020). Diets pattern and lifestyles were disrupted with increasing industrialization and rapid urbanization. This has had an impact on the health and nutritional status of populations, especially those in

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developing countries (Kennedy et al., 2004). Among the most sustainable solution approaches is the production of fruits and vegetables which contribute to the reduction of poverty and malnutrition in all its forms (CIRAD/FAO, 2021). Among the strategies adopted to overcome malnutrition and food insecurity, is the sanitary and nutritional quality control of oil, since it plays an essential role in the proper functioning of the body. Lipids provide the body essential fatty acids such as linoleic acid and alpha linolenic acid. It also contributes to the supply of fat-soluble vitamins (vitamins A, D, E and K) (Li et al., 2014). In addition, lipids contribute to the organoleptic quality of food, providing them with a smooth, creamy, melting texture, a shiny appearance and a specific flavor (Akintayo et al., 2002).

Vegetable oils are vulnerable to numerous reactions such as isomerization and oxidation of fatty acids due to their rich profile of mono and polyunsaturated fatty acids. These reactions lead to the production of trans-fatty acids. If consumed in excess, they can be associated with obesity, increased risk of cardiovascular disease, cancer and type 2 diabetes (Akintayo et al., 2002). Nevertheless, much research has been done on the chemical changes of fats during heating in relation to consumer health. The heating technique damages the integrity of lipids and proteins, thus favouring the appearance of neo-formed compounds (Prache et al., 2020).

Among the food plants of the Togolese flora, *Blighia sapida* fruits are usually consumed. This plant belongs to the Sapindaceae family and found in several regions of the world (Africa, Jamaica and Haiti). According to Dossou et al. (2014), this fruit tree has very interesting medicinal and nutritional values. Almost all of the plant's parts, such as its roots, leaves, bark, and seeds, are used in food and traditional medicine for the treatment of certain diseases (Dossou et al., 2014). Due to its high oil content (45.5%), special attention must be given to this plant species. However, despite the proven nutritional values of *B. sapida* arils, this plant can be a source of toxicity through the consumption of the fruit at an early stage of ripening (Ouattara et al., 2014). Indeed, improper consumption of *B. sapida* is reported to be toxic mainly due to the presence of hypoglycin A and B (Bowen-Forbes and Minott, 2011). The presence of these toxic compounds decreases in *B. sapida* upon its maturity (Bowen-Forbes and Minott, 2011).

In Togo, *B. sapida* stands are mostly present on fertile, deep, and well-drained soils but also on calcareous soils. Several studies have been conducted in Togo and elsewhere on the virtues of edible oils, but scientific work carried out in Togo and in the sub-region on *B. sapida* oils is almost non-existent. Nevertheless, some work has been carried out on *B. sapida,* notably on the physicochemical composition of the plant's arils in Ivory Coast (Ouattara et al., 2014). Due to its importance for the Togolese population and the harmful effects generated, especially by the immature arils of this plant; it is important to broaden and deepen the knowledge about its oil. It is necessary for the better use and subsequent management of *B. sapida* to investigate its oil composition. Thus, the main objective of this study was to evaluate the physicochemical quality of the *Blighia sapida* oil extracted in Togo.

MATERIALS AND METHODS

Sampling and samples collections

Three towns (Figure 1) were chosen, for the collection of *B. sapida* arils, based on the representativeness of the plant in relation to its geographical distribution as previously reported by Tourey et al. (2020) and recently confirmed by Nabede et al. (2022). In these three targeted towns (prefectures of Kozah, Haho and Tône) immature and mature arils of *B. sapida* (Figure 2) were collected during the months of March to October 2021.

Sample analysis

Oil extraction

Once collected, *B. sapida* arils were sun-dried for about two weeks and then pulped using a Retsch blender type SM 2000/1430/ Upm/Smfet for oil extraction. The lipid content of the pulped arils was determined according to the Association of Official Analytical Chemists (AOAC) method using hexane as solvent (AOAC, 2005). Briefly, 100 g of each dry pulped arils sample was mixed with 150 ml of hexane for about 7 h. After filtration, the solvent was evaporated (90°C for 24 h). The extract was then weighed and stored (4°C) in dark freezer for later analysis.

After extraction, the yield was determined by the ratio between the amount of oil obtained and the amount of the used plant material. This yield is given by the following formula:

$$Y\ (\%) = \frac{M1}{Mo} \times 100$$

where y represents the yield, M1=mass of the oil after evaporation, M0=mass of the starting plant material.

Determination of the extracted oil density

The density of extracted oil was determined using the French Association for Standardization (AFNOR) standards (AFNOR, 2000). A part of the *B. sapida* arils extracted oils, peanut oil was used to make comparison. Thus, the following formula was used for its determination:

$D = (P_3-P_1)/(P_2-P_1)$.

Where D: density, P_1: weight in gram of the empty pycnometer, P_2: weight in gram of the pycnometer filled with distilled water, P_3: weight in gram of the pycnometer filled with oil.

Determination of the melting point

The evaluation of the temperature at which extracted *B. sapida* arils oils changes from solid to liquid (melting point) is based on the linear variation of the temperature along the heating plate. For this

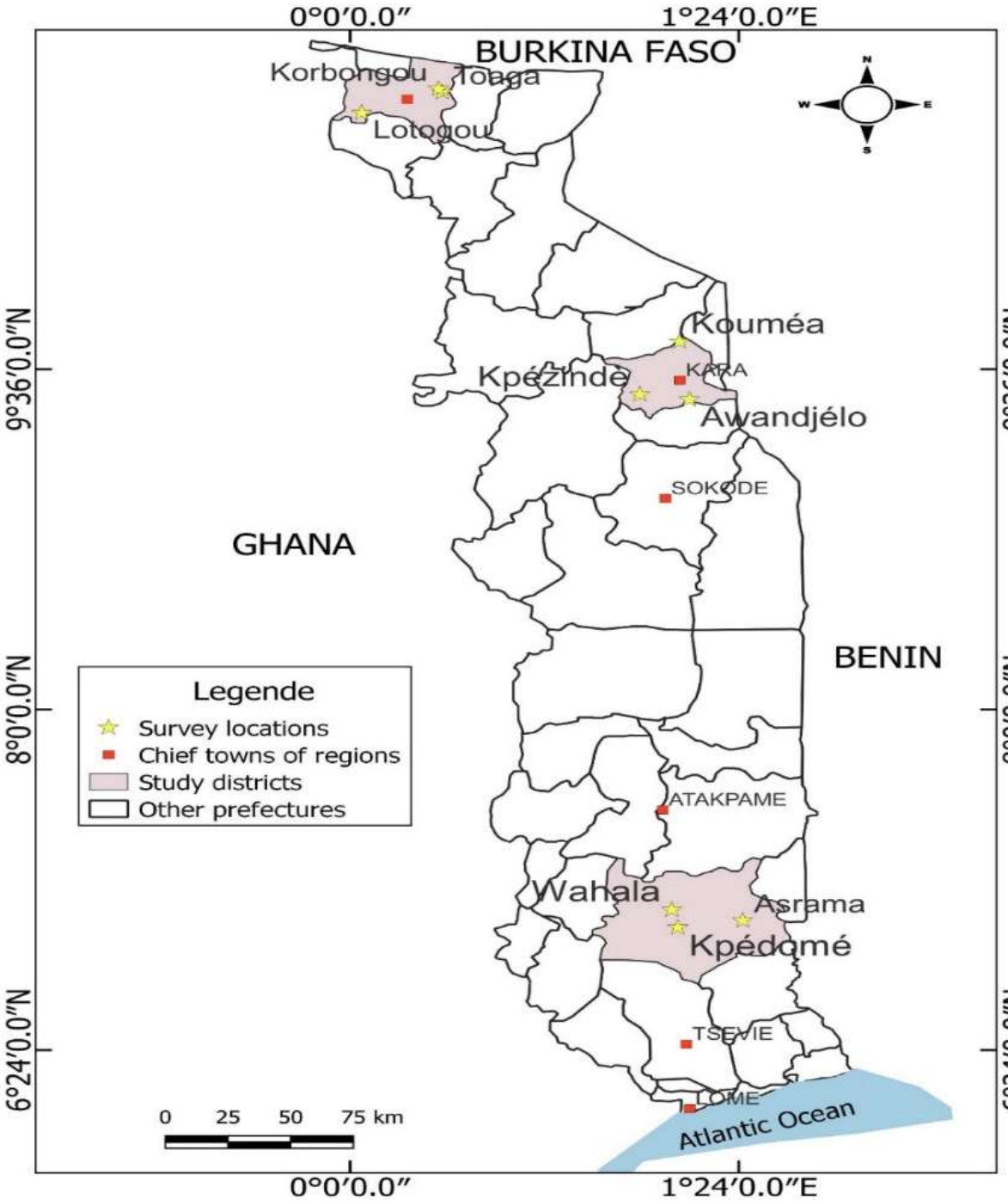

Figure 1. Map of the study area showing the samples collections places.
Source: Authors

purpose, the method described by the French Association for Standardization standard was used (AFNOR, 2000). Solid oil was deposited on the hot part of the plate after setting the plate to an initial temperature between 5 and 10°C below the expected melting point. Then, the oil paste was gently moved from the cooler region to the warmer region until the first lipid drop appeared. Finally, the index of the apparatus was adjusted to read the expected melting temperature. As it is difficult to define a single melting point for a substance, our measurements were made in triplicate and averaged.

Determination of the hydrogen potential (pH)

The pH was determined using a pH meter. To measure it, after calibrating the pH meter with the ambient environment, 50 ml of oil to be analyzed is taken in a beaker, then the probe is immersed in the

a. *B. sapida* immature fruit

b. *B. sapida* mature fruit

Figure 2. Picture of the immature and mature fruit of *B. sapida* collected for oil extraction.
Source: Authors

oil and the pH is read. In addition, between two measurements carried out in different solutions, the probe is immersed in a beaker containing distilled water and then wiped very lightly with absorbent paper. “Fried *B. sapida* oil”, are mature *B. sapida* oil that was used for 15 min frying during eight cycles. Apart from the *B. sapida* arils extracted oils, peanut oil was used to make comparison.

Determination of the iodine index

For this purpose, a solution of iodine monochloride with chloroform was added to a test sample. After reaction, the excess iodine monochloride was reduced by the addition of 10% potassium iodide solution and finally the liberated iodine was titrated with a 0.1 N sodium thiosulphate solution (AFNOR, 2000). The iodine index was sought using the Wijus reagent (iodine monochloride) method. Thus, after weighing 2 g of extracted oil, 5 ml of chloroform was added. After dissolving, 25 ml of Wijus reagent was added and the resulting mixture was stoppered and shaken gently and incubated at room temperature for 1 h. Then 5 ml of the instantaneously prepared 10% potassium iodide were added. The titration was carried out with the 0.1 N sodium thiosulphate solution until the yellow color due to iodine had almost disappeared. In addition, a few drops of starch (color indicator) were added and the titration was continued until the blue-violet color disappeared. A blank test was carried out under the same conditions. Finally, the iodine index was calculated by the following formula:

$Ii = (Vo-V) \times 126.9 \times N/P$

Where Ii: iodine index, V0: volume (ml) of $Na_2 S_2 O_3$ (0.1 N) required to titrate the blank, V: volume (ml) of $Na_2S_2O_3$ (0.1 N) required to titrate the sample, P: test weight (g) of the sample, N: normality of the $Na_2 S_2 O_3$ (0.1 N) solution (AFNOR, 2000).

Determination of the acid index

The acid index of the *B. sapida* arils oils and peanut oil was determined according to the AFNOR NFT-60-2000 standard (AFNOR, 2000). 75 ml of 95% ethanol was added to 2 g of oil, a few drops of 1% phenolphthalein were added to neutralize the mixture, swirled vigorously and titrated with the potassium hydroxide solution (the titrated ethanolic solution is 0.1N) until a persistent pink color is obtained. This index was calculated by the following formula:

$Ai = (56.11 \times V \times N)/P$

Where Ai: acid index, P: mass (g) of the test sample; 56.11: molar mass expressed in g/mol of potassium hydroxide; V: volume in ml of KOH (0.1 N) required for the titration; N: normality of the potassium solution (0.1 N).

Determination of the saponification index

The saponification index of the *B. sapida* arils oils and peanut oils was determined using the AFNOR standard (AFNOR, 2000). 2 g of oil were mixed with 25 ml of 0.5 N KOH in a flask. After boiling for 1 h, the flask was cooled under tap water. Then 2 to 3 drops of phenolphthalein were added and titration with a 0.5 N HCl solution was performed until the pink color disappeared and the initial color of the mixture reappeared. A control was used according to the same procedure with a test sample of 2 ml distilled water. The saponification value was calculated using the formula:

$Si = (Vo-V) \times N \times 56.11/P$

Where Si: saponification index, V0: volume in ml of HCl used for the blank test; V: volume in ml of HCl used for the test sample; P: test sample in grams.

Determination of the ester index

The ester index (Ei) of the *B. sapida* arils oils and peanut oils was determined using the following formula (AFNOR, 2000):

$Ei = Si – Ai$

Determination of the impurity levels

The dockage rate of the *B. sapida* arils oils and peanut oils, which refers to the spoilage of fats, was calculated by the following formula:

$\% \text{ impurity} = Ai \times 100 / Si$

This proportion was combined with the effect of thermos-oxidation of this oil that was determined by frying the yam pieces (AOAC, 2005).

Determination of organoleptic characteristics

In order to deepen the study on *B. sapida* arils oils, some organoleptic characteristics were compared with the Codex Stan (33-1981) standard (CODEX 2001). This sensory analysis will allow the quality of this oil to be assessed.

Data analysis and processing

The data obtained were coded and inserted into the MS Excel 2016 spreadsheets and then analyzed using Minitab 17 software. The analysis of variance (ANOVA) test was used to verify the normality of the variables. Considering the effect of thermos-oxidation, both oils were subjected to analysis of variance of a two-factor mixed model (with 2 replicates): "*B. sapida* oil" and "Fried *B. sapida* oil". Results are considered significant at $P<0.05$, highly significant at $P<0.01$ and very highly significant at $P<0.001$.

RESULTS

Oil extraction yield

The yields of the different extractions were 41.7±0.66 and 48.8± 0.5% for immature and mature arils, respectively.

Physicochemical characteristics of extracted oils

The melting point results are 15.97±0.3 and 16.01±0°C for immature and mature *B. sapida*, respectively. These values show that there is no significant difference between these two oils (p>5%). The physicochemical characteristic of the extracted oils is summarized in Table 1. The results of this study recorded values of: 87±0.7, 85±1.1, 89±1.7 (g of I_2/100 g oil), respectively for oil extracted from mature arils, oil extracted from immature arils and peanut oil.

The mature *B. sapida* arils oil meets the Codex Alimentarius standard (2.2-7.26 mg KOH/g), concerning the acid value. In addition, the acid value recorded for mature *B. sapida* arils oil is not statistically different ($p > 0.05$) from that of peanut oil 6.73± 0.00 mg KOH/g. However, the analysis of the results of the oil of immature arils allows us to realize that this acid value is different from the Codex Alimentarius standard. The ester number deduced from the saponification number and the acid number is approximately close to international standard (186 -187.94). Peanut oil showed a significantly different effect from that set by the Codex Alimentarius standard. The pH values of the different oils are summarized in Table 2

Table 3 indicates the organoleptic characteristics of the different *B. sapida* oils used in the study. For given oil, the recorded data varies according to the organoleptic parameter. Thus, the mature *B. sapida* oil is yellow and clear with good smelling, taste and flavor. The immature oils are light yellow and viscous with fairly good smelling, bad taste and flavor. The fried oils are black and dark with good smelling, less good taste and pungent flavor (Table 3).

DISCUSSION

Different extractions yields were observed between immature (41.7±0.66%) and mature arils (48.8± 0.5%). This difference would be due to the state of maturity of the arils because in oil seeds the percentage of oil increases with the maturity of the fruits. The recorded values in this study are close to the 44.86±0.66% obtained by Akintayo et al. (2002) in the same plant species. Moreover, this proportion of oil in mature arils is also comparable to that contained in peanut which is 45.50% (FAO, 2011). This oil richness makes this plant an important potential in the oil industries.

The density, which provides information on the purity, fatty acid profile and oxidation state of an oil, was evaluated in this study. The results in Table 1 show values of 0.916±0.3 g/cm^3 and 0.93±0.022 for mature arils and peanut oil, respectively. Indeed, these values comply with the Codex Alimentarius standard and therefore confirm a better chemical composition of these two oils. These results corroborate those of Morin and Pagès-Xatart-Parès (2012) who found similar values (0.915 and 0.964 g/cm^3). On the other hand, the results revealed by the immature arils do not belong to the Codex Alimentarius standard; this therefore testifies to the importance of maturity for the quality of this vegetable oil because in the immature state water accelerates oxidation. Indeed, the melting point gives information on the structure of the fat; the lower the melting point, the

Table 1. Physicochemical characteristics of fresh *Blighia sapida* and peanut oils.

Parameter	Mature aril oil	Immature aril oil	Peanut oil	Codex standard
d^{20}_{20}	0.916±0.3	0.77±0.01	0.93±0.022	**0.913-0.932**
Ai	7.01±0.00	30.86±0.00	6.73± 0.00	2.2-7.26
Ii	87±0.7	85±1.1	89±1.7	92-102
Si	195.17±0.04	191.6±0.04	156.83±0.04	189-195.2
Ei	188.16±0.02	160.82±0.00	150.1±0.22	186-187.94
% impurity	3.4%	16.1%	4.29%	1.16-3.71%

d^{20}_{20}: Density in g/cm^3, Ai: Acid index in mg KOH/g, Ii: Iodine index in g of I_2/100g oil, Si: Saponification index in mg KOH/g, Ei: Ester index in mg KOH/g.
Source: Authors

Table 2. Table showing the pH values of the different oils.

Oil sample	pH
Mature *B. sapida* oil	7.03
Immature *B. sapida* oil	5.50
Fried *B. sapida* oil	5.71
Peanut oil	6.92

Source: Authors

Table 3. Organoleptic characteristics of the different oils used.

Organoleptic features	Types of *B. sapida* oil			Standard Codex Stan 33-1981
	Mature oil	Immature oil	Fried oil	
Color	Yellow	Light yellow	Black	Yellow to green
Smell	Good	Fairly good	Good	Good
Taste	Good	Bad	Less good	Good
Flavor	Good	Less good	Pungent	Good
Aspect	Clear	Viscous	Dark	Clear

BM: *B. sapida* mature oil; HBI: *B. sapida* oil immature; HBF: *B. sapida* oil fried.
Source: Authors

richer the fat in unsaturated fatty acids and should be recommended for consumption. Moreover, this characteristic parameter is proportional to the length of the carbon chain. Furthermore, the melting point results obtained in this study are lower than the melting point of lauric acid (44.2°C) and myristic acid (54.4°C). This difference would be due to the fact that lauric and myristic acids are saturated fatty acids whereas *B. sapida* oil would contain unsaturated fats. Nevertheless, the melting point of both oils (mature and immature *B. sapida*) is higher than that of olive oil. In addition, it should be noted that the crystalline forms significantly influence the melting point and consequently on the organoleptic properties of the lipids (Terescenco, 2018).

These values of the iodine index are slightly higher than those obtained by Ouattara et al. (2014) (56.6 ± 2.55 g of I_2 / 100 g of oil) and Akintayo et al. (2002) (65.4 g of I_2 / 100 g of oil) but closer to the values set by the Codex Alimentarius standard. This difference would be due to the extraction conditions of the different oils and the ecological conditions in the different localities. The high-water content in the immature state would be at the origin of this result (Surmaitis and Hamilton, 2022). This result suggests that the immature oil of *B. sapida* is acidic and unfit for human consumption and that the oil from the mature arils should be preferred. Furthermore, the results for mature arils are similar to those reported by Akintayo (2001) and Ouattara et al. (2014), who found acid values of 4.91 and 2.31 mg KOH/g, respectively with *B. sapida*. Thus, the acid percentages are 2.52% (mature *B. sapida*

oil), 15.51% (immature *B. sapida* oil) and 2.82% (peanut oil) for immature *B. sapida* oil and peanut oil, respectively. These percentages are slightly higher than the Codex Alimentarius (2021) standards, whose maximum value for a refined vegetable oil is 0.6 mg KOH/g oil. Indeed, the lower the acidity, the better the oil. Furthermore, it has been shown that oil from arils harvested three days before fruit dehiscence is more acidic than oil from arils that have reached maturity on the tree (Falloon et al., 2013). This increase observed in our study would be due to the nature of the plants used and the ecological conditions. The high acidity of the immature *B. sapida* arils oil shows that a treatment of the crude oil is necessary before consumption. The refining technique could be one of the appropriate treatments.

The saponification value showed very interesting values with the two vegetable oils of *B. sapida* as they were well within the range set by the Codex Alimentarius standard (2021). Moreover, this oil with a saponification index in accordance with the official Codex Alimentarius standard (189 - 195.2 mg KOH/g oil) would be a potential source of soap manufacturing; thus, strengthening the Togolese soap industry. In addition, the saponification indices of mature and immature oils are not significantly different (P>5%) because the maturation of the arils does not influence the saponification indices of their oils. Therefore, both *B. sapida* oils can be classified as low molecular weight oils (Tsado et al., 2018). This new data reinforces the nutrition of Togolese infants because low molecular weight oils are easily digested throughout the digestive tract and are recommended for children. The present results on saponification indices are comparable to those reported by Ouattara et al. (2014).

Considering the impurity rate, this parameter was found to be interesting (3.4%) for mature aril oil within the margin set by the Codex Alimentarius standard (1.16 - 3.71%). In food industry control, an oil is only consumable if the percentage of impurities is close to 1% (FAO, 2020). In the light of these results (ester index and impurity rate), it can be deduced that *B. sapida* oils in its mature state complies with the standard and therefore can be promoted for it use as food, cosmetics and pharmaceutical potential.

These data obtained reveal approximately neutral pH values for mature *B. sapida* oil and peanut oil. On the other hand, the pH results for *B. sapida* oil from immature arils and fried oil of the said plant species revealed a high acidity. In fact, this increase in acidity would be due to the fact that in the fresh state or during frying, the water contained in the food accelerates the oxidation process (Karel, 1980), making the medium acidic by increasing the polar compounds.

Conclusion

This study showed that the density values obtained with mature arils and peanut oil are in conformity with the food standard and confirm a better chemical composition of these two oils. At the end of this study, the acid value indicates the acidic and unsuitable state of the immature *B. sapida* oils and allows preferring the mature arils oil for our diet. In addition, the oil of this plant species, which presented a saponification index in accordance with the official Codex Alimentarius standard, would be a potential source of soap making, thus strengthening Togolese soap making.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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