EVOLUTION OF PHYSICOCHEMICAL INDICES OF OILS EXTRACTED FROM PASTES OF THREE GROUNDNUT VARIETIES PRODUCED AND CONSUMED IN CÔTE D'IVOIRE ACCORDING TO TWO STORAGE METHODS

ABSTRACT:

In Côte d'Ivoire, peanut paste represents one of the main forms of peanut consumption, particularly in the northern part of the country. However, its storage raises significant concerns related to the deterioration of oil quality. This study aims to evaluate the impact of two storage conditions (ambient temperature and cold storage) on the physicochemical parameters of oils extracted from pastes produced from three local peanut varieties: large striped shell (Gcs), medium striped shell (Mcs), and small smooth shell (Pcl). After processing the kernels into paste and subsequently into oil, analyses were conducted to monitor changes in acid value, peroxide value, iodine value, saponification value, and refractive index over a twelve-month storage period. The results revealed a significant increase ($p < 0.05$) in acid value (from 0.08 ± 0.00 to 1.19 ± 0.01 mg KOH/g oil), peroxide value (from 0.15 ± 0.01 to 1.38 ± 0.01 meq O_2/kg), iodine value (from 87.68 ± 0.11 to 99.75 ± 0.01 g I_2/100 g oil), and saponification value (from 185.28 ± 0.30 to 200.19 ± 0.02 mg KOH/g) throughout the storage period, regardless of paste type. Conversely, the refractive index showed a significant decrease at the 5% significance level, with values ranging from 1.46 ± 0.02 to 0.70 ± 0.02 at 20 °C ± 1. These findings highlight the influence of storage conditions on the stability of oils derived from peanut pastes and provide insights for optimizing storage and processing conditions.

Keywords: Peanut paste; Peanut oil; Quality indices; Storage; Quality.

INTRODUCTION

Peanut (*Arachis hypogaea* L.), belonging to the legume family, represents the sixth most important oilseed crop worldwide (**FAO, 2013**). It is cultivated on approximately 26.4 million hectares, with steadily increasing production estimated at 37.1 million tonnes and an average yield of 1.4 tonnes per hectare (**Barraud-Didier *et al.*, 2014**). Globally, this legume is mainly processed into oil, flour, peanut paste, and various derived products used in the formulation of processed foods (**Revoredo and Fletcher, 2002**).

In Côte d'Ivoire, peanut is primarily grown in the northern and central regions (ANADER, 2009), with an estimated production of 88,000 tonnes (FAOSTAT, 2008). However, nearly all of this production is consumed locally, mainly in the form of peanut paste (**Boli *and al.,* 2013; Diakité *and al.,* 2017**). Peanut paste, also known as peanut butter, remains the most widely consumed peanut-based product. Highly nutritious, it is used both as a spread and as an ingredient in various food products such as porridges, biscuits, cakes, and ice creams (**Tonetto *and al.,* 2005**). It has gained popularity in developed countries due to its safety, microbial stability, long shelf life, and ease of consumption (**Matsiko *and al.,* 2014**).

Although peanut paste is widely consumed in Côte d'Ivoire, few studies have focused on the quality of oils extracted from these pastes, particularly their stability during storage. Oils derived from peanut paste are especially susceptible to oxidation due to their high content of unsaturated fatty acids. This degradation is reflected in variations of certain physicochemical indices, including acid value, peroxide value, iodine value, saponification value, and refractive index. It is therefore essential to understand how these parameters change over time, depending on the peanut varieties used and the storage conditions applied, in order to assess the impact of these factors on oil stability.

Such knowledge will help optimize storage conditions and ensure improved quality of the consumed products.

In this context, the present study aims to evaluate the evolution of quality indices of oils extracted from pastes obtained from three peanut varieties produced in Côte d'Ivoire during storage under two different conditions ambient temperature and cold storage over a twelve-month period.

I. MATERIAL AND METHODS

I. Material

The biological material used in this study consisted of pastes obtained from the processing of three forms of peanut belonging to the species *Arachis hypogaea* L. The peanuts were harvested at full maturity from different farms in the department of Korhogo, a city located in the Poro Region, approximately 569 km from Abidjan. After harvesting, the peanuts were sun-dried, packaged, and transported to the Laboratory of Biocatalysis and Bioprocesses for analyses and storage experiments.

II. Methods

1. Procedure for obtaining peanut paste and oil

Peanut pods were washed with tap water and sun-dried for 2 to 3 days at approximately 35 °C. They were then shelled to remove the kernels, which were sorted to eliminate spoiled seeds and foreign matter. The kernels were subsequently roasted and allowed to cool. After cooling, the kernels were manually de-skinned, winnowed, and ground to obtain peanut paste. The resulting paste was then kneaded and pressed to yield, on the one hand, defatted peanut paste and, on the other hand, peanut oil (Figure).

Peanuts in shells

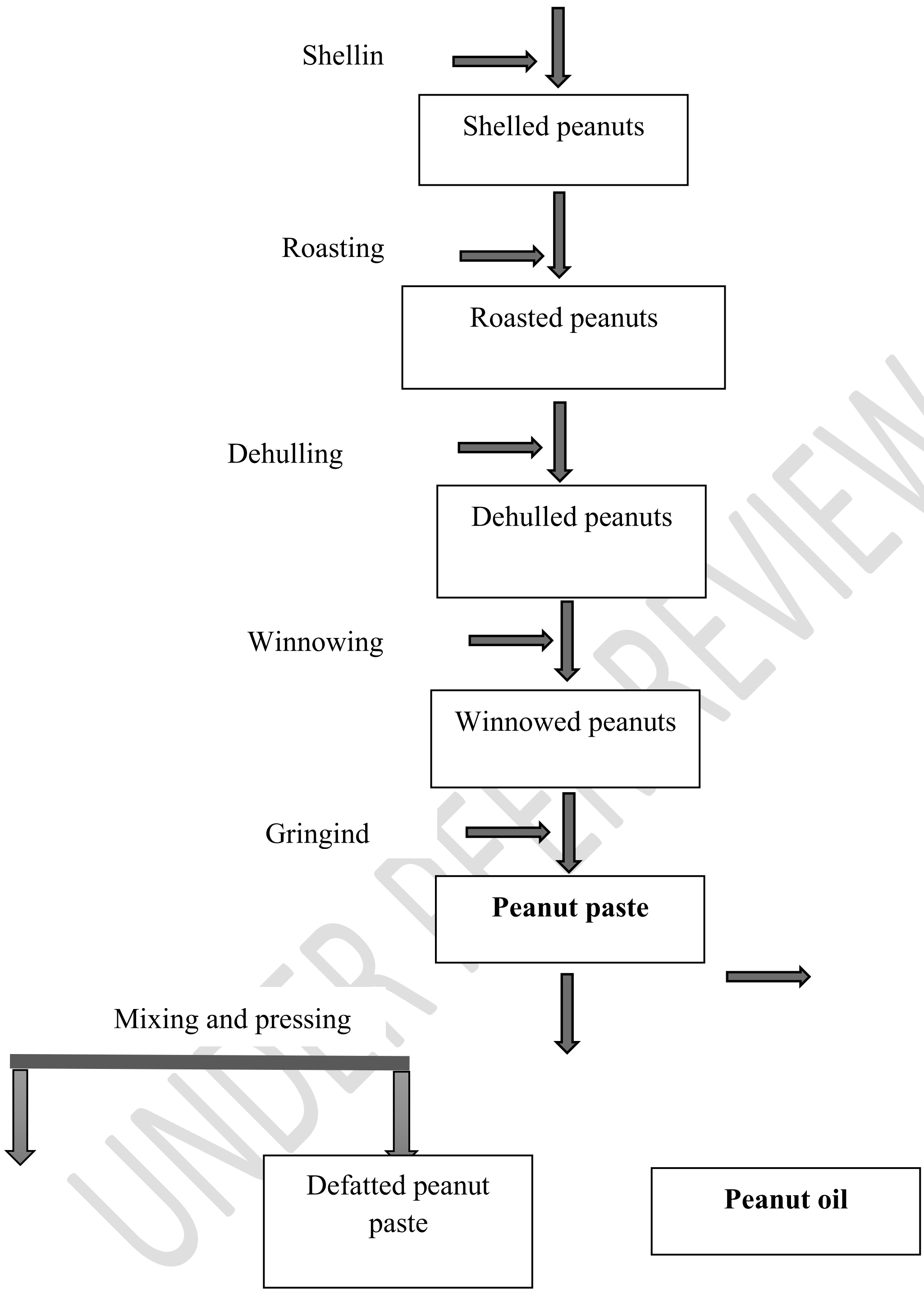

Figure: Diagram of traditional peanut paste and oil production

2. Analysis of the Physicochemical Parameters of Oils from the Three Peanut Paste Types

2.1. Peroxide Value (IP)

The peroxide value (IP) of a fat or oil is defined as the number of milliequivalents of active oxygen contained in one kilogram of product that oxidizes potassium iodide, releasing iodine, which is then titrated with sodium thiosulfate. It was determined following the procedure described in the NFT 60-220 standard (**AFNOR, 1984**). The principle involves dissolving the fat in a mixture of acetic acid and chloroform, treating it with a potassium iodide solution, and titrating the liberated iodine with sodium thiosulfate.

2.2. Iodine Value (IV)

The iodine value (IV) is defined as the number of grams of iodine absorbed by 100 g of fat. It was determined according to Wijs' method (**Wolff, 1968**). In the experimental protocol, the fat, dissolved in chloroform, is treated with an excess of iodine monochloride (Wijs' reagent). After allowing the reaction to proceed for several minutes, potassium iodide and distilled water are added. The liberated iodine is then titrated with a standardized 0.1 N sodium thiosulfate solution in the presence of starch as an indicator.

2.3. Acid Value (Ia)

The acid value of the peanut paste samples was determined according to **AOAC (1997)**. This method involves titrating the free acidity of fat, initially dissolved in an equal-part solvent mixture, with an alcoholic potassium hydroxide solution. Two grams (2 g) of peanut paste were dissolved in ten milliliters (10 mL) of a 1:1 (v/v) ethanol-diethyl ether mixture. The solution was then titrated in the presence of three drops of phenolphthalein using 0.5 N alcoholic KOH from a burette until a persistent pink endpoint was observed. A blank titration was performed under the same conditions. All measurements were conducted in triplicate for each peanut paste sample.

The acid value was calculated using the following formula:

$$Ia = \frac{56{,}1 \times N \times (V - V_0)}{m}$$

Ia: Acid value in mg KOH/g of oil;

N: Normality of the alcoholic potassium hydroxide solution;

V0: Volume in mL of alcoholic potassium hydroxide added at the equivalence point for the blank test;

V: Volume in mL of alcoholic potassium hydroxide added at the equivalence point for the test portion;

m: Mass in grams of the paste sample

2.4. Refractive Index (IR)

The refractive index is defined as the ratio between the sine of the angle of incidence and the sine of the angle of refraction of a light ray of a specific wavelength passing from air into oil maintained at a constant temperature. For this measurement, the wavelength used corresponds to the mean of the sodium D-lines (λ_1 = 588.995 nm and λ_2 = 589.592 nm). For liquids, the most commonly used instrument is the Abbe refractometer (**Mutanen *and al.*, 2007**). The refractive index of the oil in this study was determined according to the NF T60–212 standard (**AFNOR, 1984**). Measurements were performed using an Abbe-type "AZZOTA" refractometer equipped with a thermometer covering the 20–80 °C range. Naphthalene bromide was used as a calibration standard.

2.5. Saponification Value (IS)

The saponification value was determined according to the **AOAC method (1997**). This method consists of treating the fat with an excess of hot alcoholic potassium hydroxide solution and then titrating the excess alcoholic potassium hydroxide with hydrochloric acid solution. A mass of two (2) g of paste was dissolved in 25 mL of 0.5 N alcoholic potassium hydroxide. The mixture was heated to a boil in a boiling water bath for 1 hour under reflux. After cooling, the excess alcoholic potassium hydroxide was titrated with 0.5 N hydrochloric acid solution in a burette, in the presence of three (3) drops of phenolphthalein, until the solution turned colorless. A blank test was performed under the same conditions. The tests were carried out in triplicate for each oil sample. The saponification value will be calculated using the following formula:

$$Is = \frac{56{,}1 \times N \times (V0 - V)}{m}$$

Is: Saponification value in mg KOH/g of oil;

N: Normality of the hydrochloric acid solution;

V0: Volume in mL of hydrochloric acid added at the equivalence point for the blank test;

V: Volume in mL of hydrochloric acid added at the equivalence point for the test portio (8)

m: Mass in grams of the peanut paste sample (test portion).

3. Statistical Analyses

All measurements for the various analyses were performed in triplicate, and the results are expressed as the arithmetic mean ± standard deviation. A one-way analysis of variance (ANOVA) was conducted on the complete dataset to determine the existence of statistically significant differences among the mean values. Significant differences were further identified using Duncan's multiple range test at a 95% confidence level. All statistical analyses were performed using **Statistica 7.1** software.

II- RESULTS AND DISCUSSION

II-1- Results

The table presents the different indices of the various oils in different types of peanut paste derived from three forms of peanut, according to the storage method. The acid, peroxide, iodine, and saponification indices showed a significant increase at the 5% threshold for all peanut pastes during the storage period. The values range from

0.08±0.00 mg KOH/g of oil to 1.19±0.01 mg KOH/g of oil for the acid value of peanut paste oils during storage, from 0.15±0.01 meq oxygen peroxide/kg of oil to 1.38±0.01 meq oxygen peroxide/kg of oil for the peroxide value, from 87.68±0.11 g I2/100 g of oil to 99.75±0.01 g I2/100 g of oil for the iodine value and from 185.28±0.30 mg KOH/g of oil to 200.19±0.02 mg KOH/g of oil for the saponification value.

However, the refractive index decreased significantly at the 5% threshold during the different storage methods for the various types of peanut butter oils. The refractive index values at 20 °C +/- 1 ranged from 1.46 ± 0.02 to 0.70 ± 0.02.

d'arachides.

Table: Oil indices of peanut paste during storage at room temperature and in cold conditions

Parameters	Forms	Conservation	Periods (Months)						
			Controls	Décember	February	April	June	August	October
Acid value (mg KOH/g)	Smooth	A	0,09±0,00a	1,04± 0,00b	1,05± 0,00b	1,07± 0,02c	1,08± 0,02d	1,14± 0,02f	1,16±0,01e
		F	0,09±0,01a	1,04± 0,00b	1,04± 0,03b	1,05± 0,02c	1,01± 0,02d	1,06± 0,02e	1,07±0,03e
	Medium	A	0,09±0,00a	1,01± 0,00b	1,04± 0,00b	1,08± 0,01b	1,13± 0,02b	1,17± 0,02c	1,19±0,02c
		F	0,09±0,00a	1,04± 0,00b	1,05± 0,02 b	1,09± 0,03c	1,05± 0,02d	1,03± 0,02e	1,03±0,01f
	Large	A	0,08±0,00a	1,04± 0,00b	1,06± 0,04c	1,07± 0,03b	1,08± 0,01d	1,12± 0,02e	1,18±0,01f
		F	0,08± 0,00b	1,03±0,02b	1,04± 0,00b	1,04± 0,00b	1,03± 0,02d	1,06±0,02f	1,03±0,01e
Peroxide value (méq peroxyde oxygène / kg d'huile)	Smooth	A	0,48±0,06a	1,05± 0,01b	1,06± 0,06b	1,07± 0,01a	1,08± 0,01b	1,11± 0,02c	0,19±0,02d
		F	0,48±0,06a	0,54± 0,04b	0,56± 0,03d	0,57± 0,00b	0,57± 0,00b	0,56± 0,01d	0,58±0,01
	Medium	A	0,37±0,02c	0,64± 0,09b	0,76± 0,00a	0,76± 0,00b	0,77±0,00c	0,86± 0,00a	1,16±0,01d
		F	0,37±0,02c	0,40± 0,07b	0,46± 0,05a	0,48± 0,00c	0,49± 0,00d	0,49± 0,00e	0,53±0,00
	Large	A	0,15±0,01a	0,34± 0,05b	0,09± 0,08d	0,05± 0,00b	0,06± 0,00c	1,04± 0,00b	1,38±0,01d
		F	0,15±0,01a	0,34± 0,03b	0,35± 0,01d	0,36± 0,00b	0,37± 0,00c	0,34± 0,00b	0,38±0,02d
Iodine value (g d'I2/100 g d'huile)	Smooth	A	87,68±0,11a	90,45±0,01b	90,96± 0,02b	93,62± 0,05c	94,34± 0,02d	95,10± 0,02e	99,75±0,01d
		F	87,68±0,11a	90,01±0,08b	94,75± 0,02e	91,13±0,02b	92,54± 0,02c	93,45± 0,01d	96,89±0,01f
	Medium	A	89,04±0,04a	92,82±0,03b	93,87± 0,01b	96,33± 0,02c	97,35± 0,01d	98,03± 0,03e	99,12±0,02d
		F	89,04±0,04a	94,05±0,05b	97,45± 0,02d	93,12±0,57b	93,47± 0,03b	95,34± 0,02c	97,78±0,01
	Large	A	88,49±0,14a	91,15±0,02b	92,96± 0,02b	94,86±0,01c	96,74± 0,03d	97,41±0,03ae	98,36±0,03
		F	88,49±0,14a	91,05±0,01b	91,65±0,16ab	97,14± 0,02c	98,15± 0,03e	98,89± 0,02f	97,56±0,01d
Saponification value (mg de KOH/g d'huile)	Smooth	A	189,30±0,19a	189,74±0,10b	190,34±0,13b	191,88±0,31b	192,36±0,02b	197,52±0,02d	194,45±0,05c
		F	189,30±0,19a	189,52±0,07b	189,71±0,28b	190,02±0,11b	190,15±0,01b	192,15±0,02c	195,67±0,01d
	Medium	A	186,59±0,2a	188,12±0,04b	190,21±0,11b	193,36±0,03b	195,02±0,01b	196,59±0,02c	197,66±0,01d
		F	186,59±0,2a	187,65±0,08b	189,18±0,07b	190,33±0,21b	191,45±0,01b	193,20±0,02c	194,88±0,04
	Large	A	185,28±0,3a	187,52±0,05b	190,48±0,14b	194,39±0,13b	196,74±0,15b	199,05±0,02c	200,19±0,02c
		F	185,28±0,3a	186,01±0,01b	192,19±0,38b	196,09±0,24b	199,35±0,01b	199,97±0,02c	198,65±0,01
Réfractive index	Smooth	A	1,46±0,02c	1,24±0,01b	1,19±0,02b	1,14±0,04b	1,13±0,01c	1,11±0,01a	1,10±0,01b
		F	1,46±0,01c	1,40±0,01b	1,39±0,04b	1,34±0,03b	1,36±0,00c	1,34±0,00b	1,31±0,02a
	Medium	A	1,46±0,02d	1,24±0,06b	1,10±0,05b	1,00±0,06b	0,88±0,01c	0,73±0,00a	0,70±0,02b
		F	1,46±0,02c	1,25±0,09b	1,21±0,01b	1,24±0,04b	1,22±0,01d	1,21±0,00a	1,20±0,03b
	Large	A	1,47±0,01d	1,11±0,01b	1,07±0,03b	1,04±0,03b	1,01±0,01c	0,91±0,00a	0,85±0,04b
		F	1,47±0,01d	1,04±0,08b	1,04±0,07b	1,04±0,03b	1,06± 0,02	1,00±0,01a	1,03±0,01b

Essais : n=3; les moyennes ± écart type, affectées de lettres minuscules différentes dans la même ligne pour chaque forme sont significativement différentes à p< 0,05 selon le test de Duncan.

III. DISCUSSION

The oils from pastes made from the Smooth, Medium, and Coarse forms of peanut (Arachis hypogae L.) seeds under the two preservation methods show iodine values that increase significantly at the 5% threshold and range from 87.68 ± 0.11 g I2/100 g of oil to 99.75 ± 0.01 g I2/100 g of oil. These values are higher than those reported by De Melo et al. (2000) for Washingtonia filifera seed oils (67.33 g I2/100 g of oil) and palm seed oils (values between 50-60 g I2/100 g of oil) (**Nehdi, 2011**). However, the iodine values obtained are close to those of the oils from the seeds of Terminalia catappa fruit (83.92 g of I2/100 g of oil) (**Dos Santos *et al.,* 2008**), maize (103 g of I2/100 g of oil – 128 g of I2/100 g of oil), cotton (99 g of I2/100 g of oil – 119 g of I2/100 g of oil) (Gunstone et al., 1994), soybeans (120 g of I2/100 g of oil – 143 g of I2/100 g of oil) (**Hasibuan, 2012**), and the seeds of Nigella sativa cultivars from Iran and Tunisia (101 g of I2/100 g of oil and 119 g of I2/100 g of oil) (**Dos Santos *et al.,* 2008**). These results show that these oils from peanut paste are highly unsaturated. Consequently, the oils from peanut paste are of good quality.

Regarding peroxide values, the **Codex Alimentarius Commission (1993)** recommends that for edible vegetable oils, the peroxide value should be less than 10 meq oxygen per kilograms per kg of oil. The peroxide values of oils from various peanut pastes stored at room temperature and under refrigeration increase significantly at the 5% threshold. The values range from 0.15 ± 0.01 meq oxygen per kilograms per kg of oil to 1.38 ± 0.01 meq oxygen per kilograms per kg of oil. These results are well below the threshold value recommended by the **Codex Alimentarius Commission (1993)**.

Furthermore, during the twelve months of storage at room temperature and under refrigeration, the peroxide values of the oils are lower than those of Terminalia catappa fruit seed oils (8.59 meq oxygen peroxide/kg of oil) (**Omeje *et al.,* 2008**), Allium tuberosum seed oils (17.8 meq oxygen peroxide/kg of oil) (**Hu *et al.,* 2006**), Capsicum annuum (Paprika) seed oils (3.2 meq oxygen peroxide/kg of oil) (**El-Adawi and Taha,**

2001), Cucurbita sp. (Pumkrin) seed oils (3.6 meq oxygen peroxide/kg of oil) (**El-Adawi and Taha, 2001**), and Citrullis sp. (Watermelon) seed oils (3.4 meq oxygen peroxide/kg of oil) (**El-Adawi and Taha, 2001**). The low peroxide value values of peanut paste oils mean that they do not generate enough primary (hydroperoxides) and secondary oxidation products during storage.

The refractive index is an important criterion in oil identification. It provides information about the purity and classification of the oil. Based on the results, the refractive index values of the three peanut varieties stored for twelve months at room temperature and under refrigeration decreased significantly at the 5% threshold. The values dropped from 1.47 ± 0.02 to 0.70 ± 0.02. These results are very close to the standard established by the **Codex Alimentarius (1993)**, which is between 1.46 and 1.47. The refractive indices determined in this study are similar to those reported by **Oluba *et al.* (2008)** for olive oil. These authors found a refractive index of 1.45.

The acid value allows us to assess the degree of oil deterioration. During twelve months of storage at room temperature and under refrigeration, the peanut pastes showed acid values that increased significantly at the 5% threshold. The values ranged from 0.08 ± 0.00 mg KOH/g of oil to 1.18 ± 0.00 mg KOH/g of oil. These acid value values are lower than the **Codex Alimentarius standard (1992)**, which is 4. These values indicate that these oils generate a negligible amount of free fatty acids during storage. Consequently, they are very unlikely to become rancid. The oils in the peanut pastes are safe for consumption. The low acidity level gives these oils good stability during storage.

The low acidity level gives these oils good stability during storage. This characteristic was supported by the observations of **Monnet *et al.* (2012)**, who obtained low acid values.

The saponification values of the peanut paste oils under both storage methods increase significantly at the 5% threshold. These values range from 185.28 ± 0.3 mg KOH/g of oil to 200.19 ± 0.02 mg KOH/g of oil. These values are higher than those of grape seed oils (170-175 mg of KOH/g of oil) (**Karlesind, 1992**), Opuntia stricta seed oils (174.0

mg of KOH/g of oil) (**Ennouri *et al.,* 2005**), Allium tuberosum seed oils (176 mg of KOH/g of oil) (**Hu *et al.,* 2006**) and Capsicum anmum (Paprika) seed oils (168 mg of KOH/g of oil) (**El-Adawi and Taha, 2001**).

These saponification values are lower than those of Cucumis melo seed oils (210.6 mg KOH/g oil) (**Nehdi *et al.,* 2011**), Cucurbita sp. (Pumkrin) seed oils (206 mg KOH/g oil) (**El-Adawi & Taha, 2001**), Citrullis sp. (Watermelon) seed oils (201 mg KOH/g oil) (**El-Adawi & Taha, 2001**), and Nigella sativa seed oils from Tunisian and Iranian cultivars (211 and 218 mg KOH/g oil) (**Cheikh-Rouhou *et al.,* 2007**). The low saponification values indicate the presence of a significant amount of saturated fatty acids in these oils. These oils also contain a high amount of low molecular weight triglycerides. As a reminder, the saponification value measures the average molecular weight of the fatty acid chains present in the oil. This value tells us about the length of the carbon chains of the fatty acids that make up the oil. Indeed, the shorter the carbon chain of the fatty acids, the higher the saponification value of an oil (**Lion, 1955**).

CONCLUSION

The study of the evolution of the physicochemical parameters of oils extracted from the pastes of three peanut varieties (Gcs, Mcs, and Pcl) in Côte d'Ivoire confirms that storage time and conditions significantly influence product quality. At the end of the twelve-month monitoring period, the combined increase in acid, peroxide, iodine, and saponification values reveals an activation of lipid hydrolysis and oxidation processes, regardless of the storage method used (room temperature or refrigeration).

Ultimately, although the oils from these pastes maintain relative chemical stability over one year, the progressive degradation observed suggests that refrigeration alone is insufficient to completely halt the deterioration. For producers and consumers in northern Ivory Coast, these results recommend limiting the storage time of the pastes or improving packaging techniques (protection against oxygen and light) in order to best preserve the nutritional and organoleptic properties of the peanut.

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