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EXTRACTION PROCESSES, PHYSICOCHEMICAL AND NUTRITIONAL CHARACTERISTICS OF THE OIL FROM THE ALMONDS OF ROASTED SEEDS OF *TAMARINDUS INDICA L.* FROM BENIN

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ABSTRACT

Vegetable oils are essential to the body and must be varied in the human diet for their nutritional virtues. From the fruit to the *Tamarindus indica* oil, various unit operations follow one another, ranging from the maceration of the fruit pulp to the solid-liquid extraction of the crude oil, which is characterized to meet the consumer's wishes and needs. Atomic Absorption Spectrophotometry evaluated the minerals' contents, and the quality indices (refractive, acid, saponification, peroxide, and iodine indices) were quantified according to NB ISO 660 2006, NB ISO 3657-2006 and NF T60220. The oil from roasted almonds of *Tamarindus indica L.*is rich in calcium (308.52mg/kg of oil), magnesium (285.73mg/kg) and iron (19.32mg/kg). It has a refractive index of 1.47 and a free acid of 5.67mg KOH/g of oil. Its peroxide index varies from 0.87 to 0.97, and its iodine index greater than zero reveals a functional character of this oil. It can be recommended for seasoning.

***Keywords*:** Tamarind, Seeds, Technology, Vegetable oils, Quality

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1. INTRODUCTION

From the dicotyledonous legume family (Samarou et al. 2022), *Tamarindus indica L. (T. indica L.) is a* fruit agroresource of African origin and widespread in the tropics (Hemalatha and Parameshwari 2021; Sheikh and Shivanna 2022; Aly et al. 2023; Ghaly et al. 2023; Mukherjee et al. 2024). It is a cash crop in Asia but remains undervalued in Africa. Industrially and traditionally used for its fruits, which contain about 30-55% pulp, 25-40% seeds, and 11-30% shells, it is called "Adjagbon" among the Yoruba and related people. Although the seeds of *T. indica L.* constitute a significant part of the fruit, they are a waste product for the tamarind industry and are discarded in nature (Mahajani 2021; Makinde et al. 2022). However, they have potential for use (Singh et al. 2021; Nasser and Masmali 2022; Ahmad et al. 2024; Kanfon et al. 2025). Several studies have shown that roasted almonds are a real potential source of nutrients. They contain 19.90% protein, 11.25% fat, and 3.32% crude ash (Hemalatha and Parameshwari, 2021). Current interest in almonds shows that they can lead to numerous applications in food, cosmetics, and medicine (Vitoekpon and Fandohan 2021; Kanfon et al. 2023a; Aguilar-Ávila et al. 2023). However, there is very little scientific data on the nutritional and functional properties of oil extracted from almonds, including quality indices and mineral and physicochemical composition. *T. indica L.* seeds are less rich in fat of important nutritional quality (Kanfonet al. 2023b). The latter contains a content of (0.06±0.01%) in water and matter for a density of 1.31kg/L at 25°C and (5.67±0.02mg KOH/g of oil) for the acid number. The values obtained for the saponification index (504.9±0.01mg KOH/g of oil) and the iodine index (106.099±0.01g I_2/100 g of oil) show that the oil from the roasted almonds of *T. indica L.* is rich in long-chain unsaturated fatty acids. The predominant fatty acids in the oil from roasted almonds of *T. indica L.* are linoleic acid (45.66%) and oleic acid (27.55%) followed by palmitic acid (20.55%). The ratio of unsaturated fatty acids to saturated fatty acids (UFA/SFA) is 2.837 and shows stability to auto-oxidation and significant nutritional value of the analyzed oil. It is a good source of phosphorus (1880.12mg/kg), potassium (366.09mg/kg), calcium

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(308.52mg/kg) and contains 19.32mg of iron/1kg of oil. The general objective of this study is to contribute to the valorization of *T. indica L.* Specifically, it was: More precisely, the objective was to: (1) Evaluate the extraction yield of the oil extracted from the roasted almonds of *T. indica L.*; (2) Determine the physicochemical characteristics and quality indices of the oil extracted from the roasted almonds of *T. indica L.*; (3) Determine the mineral composition of the oil extracted from the roasted almonds of *T. indica L.*; (4) Establish the fatty acid profile of the oil extracted from the roasted almonds of *T. indica L.*

2. MATERIALS AND METHODS

2.1. Plant Material

The *T. indica* seeds obtained from fruits collected in Bassilain April 2022constituted the plant.

2.2. Methods

2.2.1. Oil extraction from T. indica seeds: The technology of extracting vegetable oil from roasted almonds of *T. indica* (Fig. 1) involves several unit operations and can be described as follows.

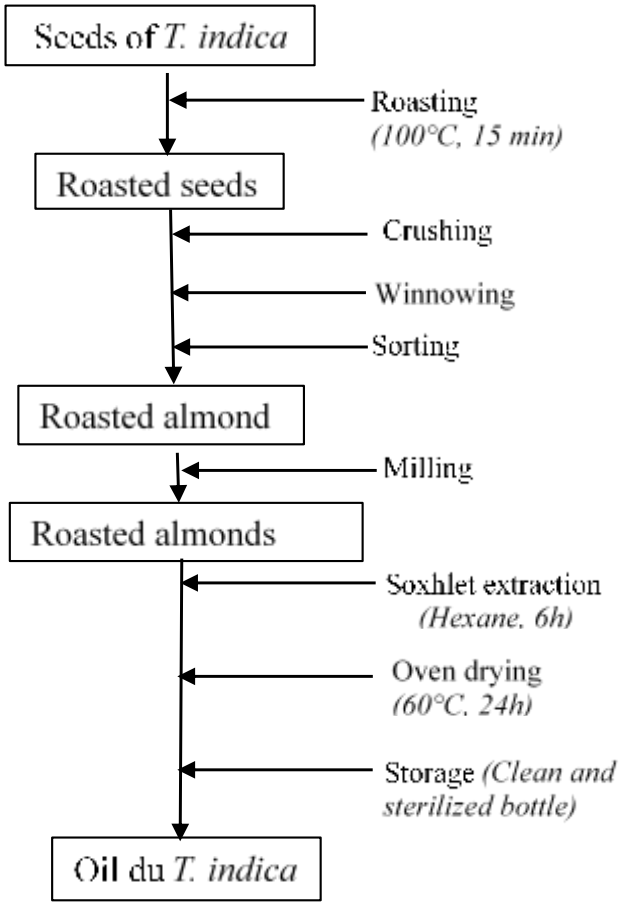

Fig. 1: Production diagram of vegetable oil from roasted almonds of *T. indica* L.

The fruits of *T. indica* (Fig. 2a) were soaked in water and after softening, the pulp was washed and the seeds (Fig. 2b) were separated from the fibers and fragments of husks. These were dried at 25°C in a dry place for 24 hours and then roasted in an open pan at 100°C for 15min. They were then mechanically shelled and the almonds (Fig. 2c) thus obtained were ground into fine flour (Fig. 2d). The flour obtained was stored in airtight jars under a hood for use. Vegetable oil from roasted almonds (Fig. 2e) was obtained by solid-liquid extraction in a Soxhlet using hexane. A rotary evaporation allowed for recycling of hexane and the crude vegetable oil was dried in an oven for 20min at 60°C, cooled in a desiccator for 30min and then weighed. The extracted oil was then packaged in bottles for further analysis.

2.2.2. Determination of extraction yield: The oil yield (R_H) was determined according to the NB ISO 659: 2006 standard. It expresses oil mass in relation to that of roasted seeds of *T. indica L.* flour by:

$$R_H(\%) = \frac{m_2 - m_1}{m_0} X\ 100$$

m_0: mass (g) of roasted seeds of *T. indica L.* flour; **m_1:** empty beaker mass (g); **m_2:** beaker containing the extracted oil mass (g).

2.2.3 Physicochemical characterization of kernels of T. indica seeds oil: It concerned the water and volatile matter content, density, refractive index and some quality indicators of the oil extracted from roasted almonds of *T. indica L.*

2.2.2.1. Determination of water and volatile matter content: It was determined by the water loss suffered by 5 g of oil from roasted almonds of *T. indica* after drying at 103±2°C in accordance with the international standard ISO 660.

2.2.2.2. Determination of density: It is expressed in kilograms per liter (L) and was evaluated by determination at room temperature the mass of the same volume of distilled water and oil extracted using a pycnometer that had been previously calibrated at the same temperature by:

$$d\ (kg/L) = \frac{m_{3-m_1}}{m_{2-m_1}}$$

where **m_3 - m_1** : mass of oil (g) and m_2 **- m_1 :**mass of distilled water (g).

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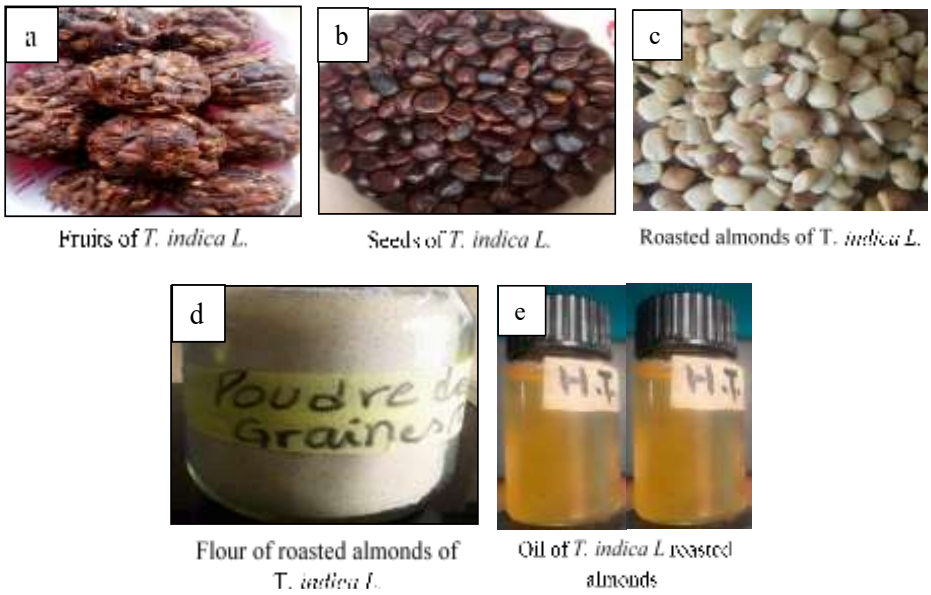

Fruits of *T. indica L.* Seeds of *T. indica L.* Roasted almonds of *T. indica L.*

Flour of roasted almonds of *T. indica L.* Oil of *T. indica L* roasted almonds

Fig. 2: Some products of *Tamarindus indica L.*

***2.2.2.3. Determination of the refractive index*:** The method followed was that standardized NB ISO 6320: 2006, which consists of measuring by direct reading at 20°C on the screen of an "OPTI Digital Handheld" type refractometer whose surface has been previously wiped with distilled water, then petroleum ether.

2.2.2.4. Determination of acid index: *The* acid index was determined by the ethanol method (NB ISO 660: 2006; NF T 60-204: 1995). 2g of the oil extracted were dissolved in 100mL of a mixture of equal volumes of ethanol and diethyl ether previously neutralized. Then, the mixture was titrated by stirring with a decinormal ethanolic solution of potassium hydroxide until the phenolphthalein turned pink.
The acid number was expressed in mg KOH/g of oil and determined by the relationship**:**

$$I_a = \frac{V\,M\,N}{m} \text{ or}$$

v: potassium hydroxide volume used (mL); **N:** potassium hydroxide solution normality; **m:** Oil analysed mass (g); M: potassium hydroxide molecular molar mass.

2.2.2.5. Saponification index determination: A mixture of 2g of analyzed oil and 25mL of alcoholic potash (0.5N) subjected to 60min of reflux heating was titrated with a standard solution of hydrochloric acid (0.5mol/L) until the disappearance of 1mL phenolphthalein violet color alongside a blank titration carried out under the same conditions. The saponification index was determined by**:**

$$I_S = \frac{((V_1 - V_2).N.M)}{m}$$

V_1**:** Hydrochloric acid solution used volume in the blank test; V_2: Hydrochloric acid solution volume used in oil titration; **N**: Hydrochloric acid solution used normality; **m**: mass of the test sample (g) and **M**: Molecular molar mass of KOH (g/mol).

2.2.2.6. Determination of the iodine index: The iodine index is iodine mass fixed per 100gof oil. It was quantified it was quantified as follows: 25mL of Wijs reagent measured with a measuring cylinder and 15mL of chloroform were added to 0.100g of oil weighed in a dry 250mL ground-glass flask. The flask containing the mixture was stoppered and incubated for at least 2 hours with stirring. After incubation and the addition of 20mL of potassium iodide solution (10%) and 150mL of distilled water, the resulting mixture was assayed with decinormal sodium thiosulfate ($Na_2S_2O_3$) solution in the presence of starch until discoloration occurred. A blank assay was performed in parallel under the same conditions but without the test sample. The iodine value was obtained using the formula (Wolf, 1968):

$$I/_i = \frac{(12,69 \times N \times (V1 - V2))}{m}: \text{ 0ù}$$

N: $Na_2S_2O_3$ solution used normality; V_1: Blank assay $Na_2S_2O_3$ solution used volume (mL); V_2: Determination $Na_2S_2O_3$ solution used volume (mL); **m**: sample test mass (g)

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2.2.2.7. Determination of peroxide index: The peroxide value was evaluated according to French standard NF T 60-220, 1968. 15mL of glacial acetic acid and 1mL of potassium iodide (KI) solution were added to 2g of the analyzed oil dissolved in 10mL of chloroform by stirring. The resulting mixture, sealed and allowed to stand for 2min away from light, was diluted with 75mL of distilled water. The resulting mixture was titrated with a centimolar solution of sodium thiosulfate ($Na_2S_2O_3$) in the presence of a few drops of starch paste, in parallel with a blank test performed under the same conditions. Peroxide index (Ip)was obtained by the formula:

$$I_p(\mathbf{mEqO2/kg}) = \frac{\mathbf{10\ X\ N\ X\ (V_0 - V_1)}}{m}$$

N: $Na_2S_2O_3$Solution used normality; $\mathbf{V_1}$: $Na_2S_2O_3$ volume used (mL); $\mathbf{V_0}$: blank test $Na_2S_2O_3$ volume used (mL); **m**: Mass of oil sampled (g).

2.2.2.8. Insoluble impurities determination: 10g of *T. indica L.* oil were dissolved in 200mL of hexane in a stoppered conical flask and stirred. After standing for 30minat room temperature, the resulting mixture was filtered in small amounts through filter paper pre-dried in an oven at 103±2°C for 10min, then cooled in a desiccator and weighed. The filter paper was then washed with hexane, dried in an oven for 1 hour at 103±2°C, cooled in a desiccator, and reweighed. Two replicates were performed, and the insoluble impurity content was determined by:

$$I/ins(\%) = \frac{m_2 - m_1}{m_0}$$

$\mathbf{m_0}$: mass of the test sample (g); $\mathbf{m_1}$: mass of the filter paper (g) and $\mathbf{m_2}$: mass of filter paper containing dry residue (g).

***2.2.3. Mineral composition of oil extracted*:** The nutritional potential of the analyzed oil was established by measuring some minerals (Ca, Fe, K, Na, P, Mg, Mn) using an atomic absorption spectrophotometer (AAS).

***2.2.4. Fatty acid profile of oil extracted*:** The fatty acid profile of roasted almond oil from *T. indica L.* was determined using gas chromatography coupled with mass spectrometry (GC/MS). This analysis precedes a trans esterification phase of the oil by methanol, which transforms glycerides and free fatty acids into methyl esters with lower boiling points, carried out according to the French standard NF T 60-233. The GC/MS analysis was then carried out at lower temperatures. The methyl ester peaks were identified by comparing retention times with the control methyl esters previously analyzed and saved in the NIST 11. L library. The calculation of the different percentages of fatty acids was possible thanks to an automatic integrator. All analyses were carried out in triplicate and the results are expressed as means and standard deviations.

3. RESULTS

3.1. Oil Physicochemical Characteristics

Table 1 summarizes the average extraction yield, investigated quality indices and physicochemical properties of *T. indica* oil extracted as well as the standards on these parameters. In the present study, the analyzed oil is yellow in color (Fig. 2) and has a low water content (0.06%) for an oil extraction yield of 11.64±2.45%. The quality index values obtained for this oil were 1.31kg/L at 25°C for density, 5.67±0.02mg KOH/g oil for acidity, 0.92±0.02meq O2/kg oil for peroxide value and 7.67±0.01% for insoluble impurities content. Physicochemical analysis revealed that the saponification value, iodine value and refractive index of oil analyses are 504.9 mg KOH/g oil; 106.099 g I_2/100g oil and 1.47, respectively.

Table 1: *T. indica L* oil *physicochemical parameters*

Physicochemical parameters	Extraction/ Soxhlet	
	Values obtained	Standard
Color	Yellow	-
yield of extracted oil(%)	11.64±2.45	-
Water content (%)	0.06±0.01	0.2%
Density at 25°C (kg/L)	1.31±0.03	0.2%
Acid value (mg KOH/g oil)	5.67±0.02	-
Peroxide value (meq O_2/kg oil)	0.92±0.02	≤10 meqof O_2/kg
Insoluble impurities content (%)	7.67±0.01	0.05%
Iodine index (g of I_2/100g of oil)	106.099±0.01	-
Saponification index (mg of KOH/g of oil)	504.9±0.01	-
Refractive index at 25°C	1.47±0.01	-

3.2. *T. indica L.* oil mineral Composition

Table 2 presents the mineral contents sought for the determination of the mineral composition of the *T. indica L.* oil. The nutritional analysis of this oil revealed that phosphorus, potassium, calcium, and magnesium

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are the major minerals of *T. indica L.* oil. At the same time, iron, sodium, and manganese are present in small quantities (Table 2).

Table 2: Mineral composition of *T. indica L.*oil

	T. indica L. oil
P (mg/kg)	1880.12±15.54
K (mg/kg)	366.09±2.95
Na (mg/kg)	16.36±1.30
Ca (mg/kg)	308.52±8.12
Mg (mg/kg)	285.73±7.23
Fe (mg/kg)	19.32±1.99
Mn (mg/kg)	2.13 0.46

3.3. Fatty Acid Profile of Oil from *T. indica L.*

It is proven that the fatty acid profile of an oil can have a great influence on its nutritional characteristics. Fig. 3 shows the chromatogram of the establishment of the fatty acid profile in the roasted almond oil of *T. indica*. It shows four peaks of respective retention times of 12.9, 13.36, 17.40, and 20.13min corresponding to four major fatty acids. Table 3 shows the proportions of fatty acids in the analyzed oil. It reveals that it contains 13 different fatty acids, the most dominant of which are: linoleic (45.66%), oleic (27.55%), palmitic (20.50%) and stearic (4.46%) acids.

Table 3: *T. indica L.*oil fatty acids

Fatty acids	Apex RT	Start RT	End RT	% Area HSSN A	% Area HSSN B	% Area HSSN C	Mean (%)
Saturated fatty acids (SFA)							25,99
Tridécanoate (C13:0)	7.20	7.14	7.29	0.22	0.18	0.23	0.21
Myristate (C14 : 0)	11.34	11.29	11.39	0.02	0.01	0.01	0.02
Palmitate (C16:0)	12.91	12.74	13.12	20.6	19.98	20.93	20.6
Stearate (C18:0)	17.90	17.75	18,17	4,44	4,53	4.51	4.49
Arachidate (C20:0)	25.08	24.95	25.27	0.41	0.44	0.39	0.41
Behenate (C22:0)	34.46	34.31	34.68	0.16	0.17	0.15	0.16
Lignocerate (C24:0)	45.20	45.09	45.34	0.1	0.11	0.09	0.1
Monounsaturated fatty acids (MUFA)							27,73
Palmitoleate (C16:1)	13.36	13.29	13.44	0.16	0.16	0.17	0.16
Oleate (C18:1)	18.57	18.33	18.76	27.41	27.94	27.31	27.55
Gondoate (C20:1)	25.79	25.55	25.91	0.05	0	0	0.02
Polyunsaturated fatty acids (PUFA)							46.28
Linoleate (C18:2)	20.13	19.83	20.25	45.72	45.73	45.51	45.66
Linolenate (C18:3)	22.07	21.95	22.18	0.61	0.64	0.6	0.62
Total				100	100	100	100

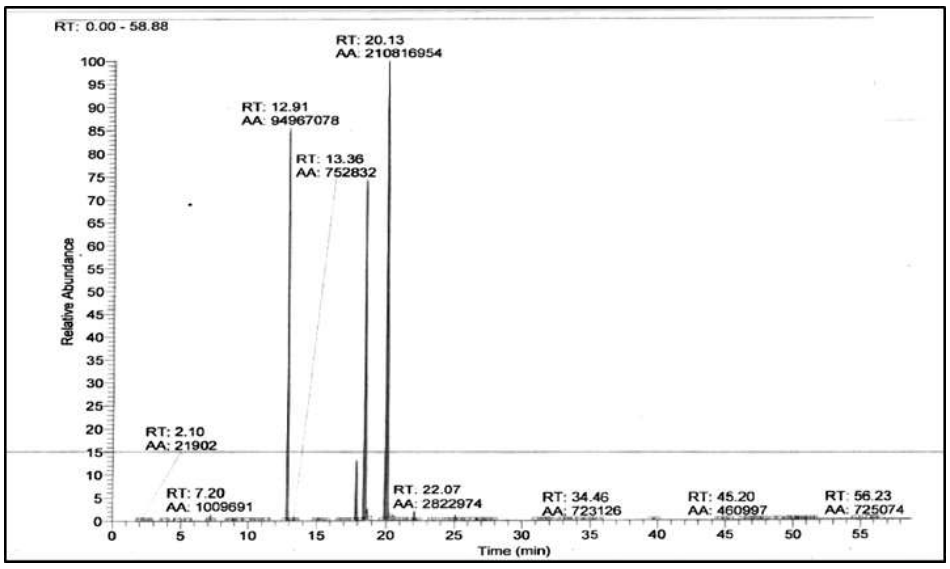

Fig. 3: T. indica L.oil fatty acid chromato-gram.

4. DISCUSSION

The Soxhlet extraction method using a solvent is the most widely used. The yield in oil from roasted almonds of *T. indica* is 11.64% oil (Table 1). Compared to previous work, this value is higher than those obtained on the same samples analyzed in Nigeria (8.9±0.96% (Yusuf et al. 2007) and 3.66±0.01% (Uzodinma et al. 2020). The oil content extracted from *T. indica L.* is similar to that of baobab seeds (12.2%) but lower than the value recommended for soybeans (20.6%) by the Codex Alimentarius.

The quality of the oil from roasted almonds of *T. indica L* was evaluated using various parameters, as presented

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in Table 1. The results show that the water and volatile matter content of the oil analyzed in this study is 0.06%. It is significantly lower than that recommended by the Codex Alimentarius (0.2%). This low water content is of capital importance in that it prevents alteration reactions of the prospected oil to the detriment of its stability.

Density is one of the purity criteria that indicates the presence of foreign bodies. The one found in the present study (1.31 kilograms per liter at 25°C) (Table 1) is higher than that found (0.887 kg/L) at the same temperature by Hounkpe (2018) but lower than that reported by Akabassi et al. (2016) for vegetable oil extracted (6kg/L) from *Hibiscus sabdariffa* seeds acclimatized in Benin.

The acidity index (I_a) provides information on the free fatty acids present in an oil. It characterizes purity, alteration state, and stability of oils at room temperature (Louni, 2009), thus defining the quality of the oil. It depends on the oil's fatty acid profile and allows for an assessment of the value of the technological processes used to produce it. The acidity index obtained (5.67±0.02mg KOH/g of oil) is slightly higher than the standard recommended by the Codex Alimentarius (4mg KOH/g of oil) for vegetable oils. This could be explained by the maturity of the fruits, their harvesting, storage, and processing conditions, which would lead to an increase in the free fatty acid content under the action of lipases (El Antari et al., 2000). Its determination often has significant commercial importance because it allows checking the quality of a vegetable oil regarding its degradation over time during storage. It is a function of the fatty acid composition of the oil and allows for the appreciation of the value of the technological operations that led to its obtaining. The acid index value obtained 5.67±0.02mg KOH/g of oil is slightly higher than the recommended value (4mg KOH/g of oil) by Codex Alimentarius on vegetable oils. It could be explained by the maturity, harvest conditions, and those of storage and treatment of the seeds of *T. indica L.* from Benin, which would lead to the increase in the content of free fatty acids under the action of lipases (El Antari et al. 2000). Nevertheless, it could confer to the oil of roasted almonds of *T. indica* L. purity and stability at room temperature. Furthermore, the nutritional importance of an oil also depends on its acidity index. In the tropics, where vegetable oils are commonly used as food lipids, Onyeike & Acheru (2002) reported that an oil with an acidity percentage between 0.0 and 3.0% is of culinary quality. The low acidity index obtained for *T. indica L.* oil of indicates that it can be a good edible oil. Also, it reveals a prolonged shelf life of the oil without it becoming rancid.

The peroxide value indicates the oxidative stability of *T. indica L.* oil and allows estimating the amount of fatty acids oxidized by rancidity in a vegetable oil. The results presented in Table 1 showed that the peroxide value obtained in the present study 0.92±0.02meq O_2 /kg of oil is low and much lower than that of the Codex Alimentarius standard, which recommends a peroxide value of less than 10meq O_2/kg of oil. This low peroxide value could be explained by the fact that the *T. indica L.* oil studied would be free from any attack by light and oxygen in the air. The values obtained corroborate those of the acidity value and water content for the stability and purity of the roasted almond oil of *T. indica L.* studied.

Table 1 shows that the content of insoluble impurities is 7.67±0.01%. This value is nevertheless higher than that recommended by the Codex standard, which is 0.05%. This could be due to the extraction and storage conditions of the oil analyzed.

The saponification index is used to estimate the relative lengths of the fatty acids constituting a vegetable oil. The one obtained for *T. indica L.* oil in this study is high and was 504.9±0.01mg KOH/g of oil (Table 1). It is higher than the results of Ajayi et al. (2006) reported by De Caluwé et al. (2010) in their critical review on *T. indica* L. seed oils, which were 221 mg KOH/g of oil. Also, it is higher than the saponification index of some vegetable oils such as sunflower (188-194), palm (190-209), cottonseed (189-198), palm olein (194-202) reported by Aïssi et al. (2009), soybean (190-210) mg KOH/g oil reported by Hounkpe (2018), and the oil from the seeds of *Hibiscus sabdarifa* from Benin (145.76mg KOH/g oil) reported by Akabassi et al. (2016). This difference in indices depends on the vegetable oils' fatty acid profiles, and *T. indica L.*oil could present a fatty acid profile different from those investigated in previous studies. Furthermore, since the saponification index is an indirect measure of the average size of the fatty acids contained in a fat, the one obtained for the roasted almond oil of T. indica from Benin demonstrates its richness in fatty acids with high molecular masses. Indeed, the quantity of potash KOH used in the measurement of the IS varies with the molar mass of the fatty acids. The higher the molar mass, the lower the saponification index. The seeds studied could be recommended for the manufacture of soap and in the manufacture of shaving creams of foam because of their relatively higher saponification values **(**Wolf, 1968).

The iodine index highlights the degree of unsaturation of the oil. It is used to assess the unsaturated character of a fatty substance and reflects the oil drying properties. The more unsaturated an oil is, the higher its iodine index. The value of the iodine index found in this study (106.099±0.01g I2/100 g of oil) (Table 1) is higher than that obtained (less than 100mg/100g) by Ajayi et al. (2006) cited in De Caluwé et al. (2010), which classified *T. indica L.* oil in the non-drying oils group. It is also higher than the values recommended by the Codex Alimentarius for palm kernel oil (18.30g I_2/100g of oil) and crude palm oil (46.9g I_2/100g of oil). This indicates that *T. indica L.*oil is rich in ethylenic fatty acids, a source of its functional character. These results corroborate the fatty acid profile established for *T. indica L.* oil. The acidic composition shows that the predominant fatty acid in *T. indica L.*oil is

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linoleic acid (45.66%). It is followed by oleic acid (27.55%), palmitic acid (20.550%), and finally stearic acid (4.49%). The minor fatty acids whose percentages obtained are less than 4% consist of linolenic acid (0.62%), arachidic acid (0.40%), tridecanoic acid (0.21%) while the fatty acids present in trace form (percentage less than 0.2%) are among others palmitoleic acid (0.16%), behenic acid (0.16%), etc. The high abundance of diunsaturated fatty acid (linoleic acid) in the oil of roasted almonds of *T. indica* compared to other unsaturated fatty acids may be due to the transformation of oleic acid into linoleic acid under the effect of oleate desaturase, which is an enzyme present in foods (Schmeda-Hirschmann et al. 1999). These high percentages of linoleic, oleic, and palmitic acids in oil from roasted almonds of *T. indica* studied are similar to the values found by Ajayi et al. (2006). However, they are slightly higher than the values reported by Siddhuraja et al. (1995) in Kanfon et al. 2023a). From Table 3, it is clear that there is a predominance of monounsaturated fatty acids in the oil from roasted almonds of *T. indica.* It is therefore rich in essential fatty acids. For this reason, it must be used as a seasoning oil in order to avoid polymerization of unsaturated fatty acids during heating, resulting in thermo-oxidative and carcinogenic alteration products. The ratio of the percentages of unsaturated fatty acids to that of saturated fatty acids (AGI/SFA) is 2.837. This relatively high ratio gives the oil from roasted almonds of *T. indica L.* stability to auto-oxidation and a significant nutritional value. It could also be used to ensure the proper functioning thanks to its unsaturated character.

The refractive index informs us about the purity of the oil, which varies according to its unsaturations. In the present study, it was evaluated at 25°C and revealed a value of 1.47±0.01. This value is comparable to that found by Cissé et al. (2009) on the oil extracted from the seeds of *Hibiscus sabdarifa* from Senegal and that of the modified linseed oil of the NB ISO 6320 2006 standard. It indicates the need to purify the oil from the roasted almonds of *T. indica* before its use.

*T. indica L.*oil appears to be a good source of different elements such as phosphorus, potassium, calcium, and magnesium. All the minerals studied, phosphorus (1880.12mg/kg) is the element in the highest concentration, followed by potassium (366.09mg/kg) and calcium (308.52mg/kg), with trace values of Mn (2.13mg/kg). The iron and sodium contents are 19.32 and 16.36mg/kg, respectively. One of the important nutritional properties of the studied oil is revealed through its high potassium content, which plays a major role in neuromuscular function (Ajayi et al., 2006).

5. CONCLUSION

In this study, the quality indices and the physicochemical and nutritional properties of the oil extracted from *Tamarindus indica L.* seeds were evaluated. From the various investigations carried out, it appears that the *T. indica L.* almonds of seeds contain very little yellow oil, which is beneficial and has appreciable nutritional and functional properties. The evaluation of the quality of the oil extracted from the seeds indicated that this oil has a low degree of alteration due to its low water content, free acidity, and peroxides, which are in agreement with the recommended values. The density at 25°C and insoluble impurities were out of standard. From saponification and iodine indices, it appears that the oil is rich in long molecular chains and unsaturated fatty acids, which testifies to its functional character. Its mineral content can contribute to covering the daily needs of calcium, magnesium, potassium, iron, manganese, and especially phosphorus. It can therefore be integrated into the human diet mainly in developing countries to prevent or treat certain nutritional deficiencies or incorporated into cosmetic products to combat certain skin conditions. In addition, the valorization of *T. indica L.* for food and cosmetic purposes can contribute to its conservation.

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Author's Contribution: REK collected the plant material, performed the various analyses in the laboratory and prepared the preliminary version of the manuscript. TO contributed to the collection of the plant material and to the performance of the various analyses in the laboratory. CPAD provided the chemical reagents and supervised and coordinated the experiments. FJC and PA contributed to the collection of the plant material and to the writing of the manuscript. All authors critically revised the manuscript and approved the final version.

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