Chemical and physicochemical properties of the lipid extract of (*Ricinodendron heudelotii)* Baill. almonds (Euphorbiaceae) from Côte d'Ivoire

ABSTRACT

The study focused on the valorisation of the fat extracted from the kernels of *Ricinodendron heudelotii*, (Baill.) a plant of the Euphorbiaceae family cultivated in Côte d'Ivoire. The extraction was performed using Soxhlet with n-hexane, followed by the determination of fatty acids and physicochemical parameters such as acid, ester, peroxide, saponification, and iodine indices, as well as calorific value and unsaponifiable matter content. The oil obtained has a pale yellow colour and a fat content of 38.70 ± 0.45%. The physicochemical analysis yielded the following results: an iodine index of 109.51 ± 0.86 g iodine/100 g oil, indicating a high level of unsaturated fatty acids, primarily linoleic acid (45.21%); a peroxide index of 23.33 ± 2.35 meq O2/kg oil, revealing a high level of primary oxidation and low oxidative stability; a saponification index of 187.70 ± 11.19 mg KOH/g oil, reflecting a significant content of esterified and free fatty acids; an acid index of 4.20 ± 1.14 mg KOH/g oil, within the acceptable limits for edible oils; an ester index of 183.50 ± 10.05 mg KOH/g oil; a calorific value of 40414.44 ± 427.36 kJ/kg, suggesting its potential as an energy source; and an unsaponifiable matter content of 0.72 ± 0.08%.

GC-MS analysis revealed a low content of saturated fatty acids and a significant proportion of unsaturated fatty acids, primarily linoleic acid. These findings suggest that *Ricinodendron heudelotii* fat may have potential applications in food and as a source of energy. However, its high oxidative instability indicates that precautions must be taken when using it in food products.

Key words: physicochemical parameters, fatty acids, fatty matter, *Ricinodendron heudelotii*, Ivory Coast

INTRODUCTION

Ricinodendron heudelotii (Baill.), commonly known as "Akpi" in West Africa, is a fruit tree belonging to the Euphorbiaceae family. This tree is widely distributed in the tropical rainforests of West Africa [1]. It holds significant nutritional, economic, and medicinal value for local populations. Its almonds are highly prized for their distinctive flavor and are commonly used in traditional culinary preparations, such as sauces and stews, making them a valuable commodity in local markets [2]. The almonds of *Ricinodendron heudelotii* (Baill.) are notable for their high fat content, which ranges from 45% to 64%, according to various studies [3]. One of the key components of this fat is α-eleostearic acid (C18:3), a conjugated fatty acid that makes up more than half of the total fatty acids found in the oil [4]. This particular fatty acid endows the oil with interesting chemical properties, particularly in the food and cosmetics industries. Oils rich in unsaturated fatty acids, such as α-eleostearic acid, are highly sought after for their nutritional benefits and potential as active ingredients in cosmetic formulations due to their moisturizing and antioxidant properties [5, 6]. In addition to their use in food, various parts of *Ricinodendron heudelotii* (Baill.),are used in traditional medicine across many regions of Africa. The bark, leaves, sap, latex, and roots of this tree are traditionally employed to treat a wide range of ailments, including yellow fever, anemia, toothache, and malaria [7, 8]. Several ethnobotanical studies have documented the use of this plant in traditional medicinal practices due to its antimicrobial and anti-inflammatory properties [9]. Recent pharmacological research

has also confirmed that certain extracts of *Ricinodendron heudelotii* (Baill.) exhibit promising biological activities, including antioxidant and antimicrobial properties, further emphasizing the potential for greater valorization of this species [10, 11]. Despite its many traditional applications and industrial potential, there are still very few comprehensive scientific studies on the chemical composition and physicochemical properties of the oil extracted from its almonds, particularly in Côte d'Ivoire. Yet, the abundance of unsaturated fatty acids and the functional properties of this oil could offer new opportunities for its use in the food, cosmetic, and pharmaceutical industries. A deeper understanding of the chemical composition and physicochemical properties of the oil would not only optimize its use but also contribute to the economic valorization of this species.

The objective of this study is therefore to conduct a chemical and physicochemical analysis of *Ricinodendron heudelotii* almonds in order to highlight their characteristics and explore their potential for diverse applications.

I. MATERIAL AND METHODS

I.1. Material

I.1. Plant material

The *Ricinodendron heudelotii* (Baill.) almonds came from Zoukougbeu, a town in the centre-west of Côte d'Ivoire (Haut-Sassandra region). The kernel were finely pulverized using an electric grinder.

I.1. Technical equipment and chemicals

The technical equipment includes the usual laboratory glassware, an electronic balance, a Soxhlet, a spectrophotometer, a rotary evaporator, an oven, and a gas chromatograph coupled to a mass spectrometer (GC-MS).
The chemicals used were Na_2SO_4, hexane, N-O-bis(trimethylsilyl)-trifluoroacetamide (BSTFA), KOH, etc.

I.2. Methods

I.2.1. Method of fat extraction

Thirteen grams (13 g) of *Ricinodendron heudelotii* (Baill.) kernel powder were mixed with 3 g of Na_2SO_4. The resulting mixture was placed into a Wattman cartridge, covered with a cotton wool pad, and then placed in an extraction chamber connected to a flask. The 250 mL extraction flask, filled to three-quarters of its volume (approximately 190 mL) with hexane, was heated to reflux in a water bath for 2 hours. The extracted fat was then dried, weighed, and analyzed after vacuum distillation of the solvent using a rotary evaporator [9, 10]. The fat content percentage was calculated using the following formula:

$$\text{Fat content percentage} = \left(\frac{\textbf{Mass of fat extracted}}{\text{Initial sample mass}}\right) \times 100$$

I.2.2. Physico-chemical parameters of fat.

The physico-chemical parameters (saponification, acid, iodine, peroxide and ester indices, calorific value and unsaponifiable matter content) were determined using the procedures described in the literature.

I .2.2.1. Saponification value

Twenty-five (25) mL of 0.2 N KOH were placed in a flask containing 0.4 g of the extracted fat. The mixture, equipped with a reflux condenser, was brought to a boil while stirring. After one hour, the resulting mixture was titrated while hot using 0.2 N HCl in the presence of phenolphthalein as an indicator (2 drops). A blank titration without fat was carried out under the same conditions [11, 12]. The saponification value is obtained using the following equation:

$$SV = \frac{N_{HCl}(V_T - V_E)}{m} \times 56.1$$

Where:

- SV: Saponification value (in mg KOH/g of oil),
- V_T: Volume of HCl used for the blank titration,
- V_E: Volume of HCl used for the fat extract titration,
- N_{HCl}: Normality of the HCl solution,
- m: Mass of the fat in grams,
- 56.1: Molecular weight of KOH.

I .2.2.2. Acid value

Ten (10) mL of 0.2 N KOH were placed in a 250 mL Erlenmeyer flask containing 0.4 g of the extracted fat, then two drops of phenolphthalein were added. The resulting mixture was titrated with 0.2 N HCl until a stable discoloration was observed [11, 12]. A blank titration without fat was carried out under the same conditions. The acid value is given by the following formula:

$$AV = \frac{N_{HCl}(V_T - V_E)}{m} \times 56.1$$

Where:

- AV: Acid value (in mg KOH/g of oil),
- V_T: Volume of HCl used for the blank titration,
- V_E: Volume of HCl used for the fat extract titration,
- N_{HCl}: Normality of the HCl solution,
- m: Mass of the fat in grams,
- 56.1: Molecular weight of KOH.

I .2.2.3. iodine value

In a 250 mL Erlenmeyer flask, 0.3 g of fat were dissolved in 10 mL of $CHCl_3$. Two (2) mL of this solution were pipetted and transferred into another 250 mL Erlenmeyer flask, to which 5 mL of Wijs reagent were added. The mixture, after vigorous shaking, was left to stand for 1 hour, then 2 mL of 10% KI and 50 mL of distilled water were added. The excess iodine released was titrated with 0.1 N $Na_2S_2O_3$ in the presence of 2 mL of starch. The starch indicator was added near the end of the titration when a pale-yellow color appeared, and the titration was continued until decolorization [14]. The iodine value was calculated using the following formula:

$$IV = \frac{(V_T - V_E)}{m} \times 1.269$$

Where:

- V_T: Volume of $Na_2S_2O_3$ used for the blank titration,
- V_E_EVE: Volume of $Na_2S_2O_3$ used for the fat extract titration,

- m: Mass of the fat in grams,
- IV: Iodine value (in g of I_2 / 100 g of oil).

I .2.2.4. Peroxide value

Twenty (20) mL of the $CH_3COOH/CHCl_3$ mixture (3:2) were placed in a 250 mL Erlenmeyer flask containing 1 g of extracted fat. Then, 0.1 mL of a KI solution, prepared by dissolving 1 g of KI in 1 mL of distilled water, was added. The stoppered Erlenmeyer flask was shaken vigorously and kept in the dark for 5 minutes. After adding 50 mL of distilled water, the released iodine (I_2) was titrated with 0.1 N $Na_2S_2O_3$ in the presence of starch paste as an indicator. A blank titration without fat was carried out under the same conditions [15]. The peroxide value is given by the following formula:

$$PV = \frac{N \times (V_T - V_E)}{m} \times 1000$$

Where:

- V_T: Volume of $Na_2S_2O_3$ used for the blank titration,
- V_E: Volume of $Na_2S_2O_3$ used for the fat extract titration,
- N: Normality of the $Na_2S_2O_3$ solution,
- m: Mass of the fat in grams,
- PV: Peroxide value in meq O_2/kg of oil.

I .2.2.4. Unsaponifiable value

Five (5) g of extracted oil were mixed with 50 mL of an ethanolic KOH solution (2N). The mixture was refluxed for 1 hour on a hot plate. After cooling, 100 mL of distilled water were added. The entire mixture was transferred into a separatory funnel, and the organic phase was extracted with 4 × 50 mL of pentane, followed by washing with distilled water until a neutral pH was achieved. The organic extract was then dried over anhydrous Na_2SO_4, filtered, and evaporated to dryness under reduced pressure using a rotary evaporator. The residue obtained, representing the unsaponifiable fraction, was dried and weighed, yielding a mass of 66.25 mg [13].
The content of unsaponifiables was calculated using the following formula:

$$\text{Unsaponifiable content (\%)} = \left(\frac{m_1}{m_2}\right) \times 100$$

Where:

- Unsaponifiable content (%): Percentage of unsaponifiables,
- m_1: Mass of the unsaponifiables, in grams,
- m_2: Mass of the sample, in grams.

I .2.2.4. Ester value and Calorific value

Finally, the ester **value** (EV) [16] and calorific value (VC) [17] were determined according to the following equations: EV = SV - AV (mg KOH / g) and VC =47645-4.187 IV -38.31 SV (kJ/kg).

I.2.3. Determination of fatty acids by GC-MS

Identification of fatty acids by GC-MS of *Ricinodendron heudelotii* fat was carried out using the method described by Bamba and coll. [9].

Fatty acids in *R. heudelotii* oil are determined in two stages. In the first stage, the fatty acids are extracted using dichloromethane and then concentrated. The acids are then derivatized with N-O-bis(trimethylsilyl)-trifluoroacetamide (BSTFA) to obtain trimethylsilyl esters. In the second stage, the trimethylsilyl esters were analyzed by gas chromatography-mass spectrometry (GC-MS) in selective ion acquisition mode. The GC-MS instrument consisted of a DB-5.625 capillary column measuring 30 m x 0.25 mm ID x 0.25 µm. Helium was used as the carrier gas with a linear velocity of 1 mL/s. The oven temperature program was 130°C for 2 minutes, followed by three programming stages: the first programming stage (Rate: 10°C/min; Final: 180°C for 0 minutes); the second programming stage (Rate: 3°C/min; Final: 245°C for 5 minutes) and finally the third programming stage (Rate: 15°C/min; Final: 300°C for 5 minutes). The temperature of the injector and detector was set at 250°C. Injection was carried out in splitless mode. The mass spectrometer parameters for the electron impact mode were: ionization source temperature (230°C) and electron energy (70 eV). The concentration of fatty acids present in the sample is determined by comparing the chromatographic surfaces obtained at a given retention time with the surfaces of the standards used to establish the calibration curve under the same assay conditions.

II. RESULTS AND DISCUSSION

II.1. Fat content of *Ricinodendron heudelotii* kernels

The fat extracted from *Ricinodendron heudelotii* is pale yellow in color. It has a fat content of 38.70 ± 0.45%. This value is within the range of proven oilseed oils: cotton 35%-40% [18, 19]; rapeseed 37.3%-42%; palm kernel 33.3%-50% and sunflower 36.7%-47.7% [18, 20]. *Ricinodendron heudelotii* could therefore be classified as an oilseed.

II.2. Chemical parameters of the fat content of *Ricinodendron heudelotii* kernels

The iodine, acid, peroxide, saponification, ester, calorific value and unsaponifiable content indices of *Ricinodendron heudelotii* kernel oil were determined and the results obtained are given in Table 1.

The iodine value of *Ricinodendron heudelotii* kernel oil obtained was 109.51 ± 0.86 g iodine/100 g oil. This physico-chemical parameter provides information on the degree of unsaturation of an oil. When the value of this index is high (Ii ≥ 90), it means that the fat studied is mainly made up of unsaturated fatty acids [18, 21]. In addition, the iodine value of *R. heudelotii* oil is higher than that of certain high-quality oils, such as olive oil (75-94) and rapeseed oil (97-107) [18, 22]. This high iodine value suggests that *R. heudelotii* fat is rich in unsaturated fatty acids and therefore recommended for use in food. In addition, this oil could be classified as a non-drying oil (Ii < 110) [18, 23].

The peroxide value of *R. heudelotii* oil is 23.33 ± 2.35 meq. O2 / kg of oil. This index is used to assess the level of primary oxidation of an oil by oxygen. According to the Codex Alimentarius, the oil studied has a fairly high level of oxidation (Ip > 10 meq of O_2 / kg of oil) [24]. It is also higher than that of shea butter (14.5-17.5) [16, 18] and desert dates (9.78±1.9) [18, 25]. This index is also higher than that of *Moringa oleifera* fat (0.74 ± 0.02) from Côte d'Ivoire [10, 26] and that of *Irvingia gabonensis* fat (20 ± 2.18) from Côte d'Ivoire [9], two plants commonly used in Côte d'Ivoire.

The saponification number obtained for *R. heudelotii* oil is 187.70 ± 11.19 mg KOH / g oil. This index generally gives the fatty acid content (esterified and free) of an oil. Its high value makes an oil a recommended raw material for soap making. The content of *R. heudelotii* oil in this study was lower than that of coconut (248-265) and palm kernel (230-254) oils [18, 24], which are oils commonly used in soap-making. In view of these findings, *R. heudelotii* fat is not recommended as an ingredient in soap manufacture [18, 27].

The acid value of *R. heudelotii* kernel oil obtained in this work is 4.20 ± 1.14 mg KOH /g oil. This quantity is very close to that of the food standard (Ia max = 4) [18, 24]. This value of the acid number thus reflects an acceptable quantity of free fatty acids in the oil in this study. Furthermore, the acid value of R. *heudelotii* oil is in the same range as those of edible oils such as coconut (4-7), palm kernel (4-7) and groundnut (0.08-6) [18, 25]. Additionally, the acid value of *R. heudelotii* oil is lower than that of soybean oil (7) [18, 25].

The ester number obtained for *R. heudelotii* oil was 183.50 ± 10.05 mg KOH / g oil. This value for the ester number of *R. heudelotii* kernel oil is slightly lower than that for the saponification number of the same oil (187.70 ± 11.19 mg KOH/g oil). This finding could mean that the fat of *R. heudelotii* contains a low quantity of fatty acid. However, this does not rule out the possibility that it may undergo treatment (pre-refining and conditioning) before use [9, 28].

The calorific value of *Ricinodendron heudelotii* kernel oil obtained was 40414.44 ± 427.36 kJ / kg of oil. This parameter provides information on the energy value of the fat for human consumption and its hypothetical use as a biofuel and engine lubricant. The calorific value of *R. heudelotii* kernel oil obtained in this study is greater than 35,000 kJ/kg, so it could be considered for use as a fuel and engine lubricant [16]. However, further research, particularly into the viscosity of this oil, could determine its potential as a biodiesel or engine lubricant. In this study, food use will be favored for ethical reasons on the one hand, and on the other hand to provide a response to undernourishment in most tropical countries where food supplements are used [16]. The calorific value of this oil could make it a nutritional source of energy [16, 18, 26, 28].

The unsaponifiable content of *Ricinodendron heudelotii* kernel oil is 0.72±0.08%. This value is within the range of values reported in the literature for plant species (of the order of 0.5 to 4%) [18, 29, 30, 31, 32, 33, 34].

Table 1. Chemical composition of *Ricinodendron heudelotii* fat

Characteristics studied	**Results obtained**
Iodine value (g iodine/100g oil)	109.51 ± 0.86
Peroxide value (meq O_2 /kg oil)	23.33 ± 2.35
Saponification value (mg KOH / g oil)	187.70 ± 11.19
Acid value (mg KOH / g oil)	4.20 ± 1.14
Ester value (mg KOH / g oil)	183.50 ± 10.05
Calorific power (kJ/kg)	40414.44 ± 427.36
Unsaponifiable matter content	0.72 ± 0.08

II.3. Fatty acid content of *Ricinodendron heudelotii* fatty matter

The fatty acids in *Ricinodendron heudelotii* fat were identified and the chromatographic profile of the fat from R. heudelotii kernels is shown in Figure 1. This profile highlights the fatty acids present in this oil.

The fatty acids identified and their various levels are shown in Table 2. In total, *Ricinodendron heudelotii* fat contains seven fatty acids, including three (3) polyunsaturated fatty acids (PUFA), one (1) monounsaturated fatty acid (MUFA) and three (3) saturated fatty acids (SFA). The ratio of polyunsaturated to saturated fatty acids (PUFA/SFA= 2.11> 1) and the value of the iodine index (Ii=109.51 ± 0.86 > 90) increase the potential nutritional properties of *R. heudelotii* fat [21, 35].

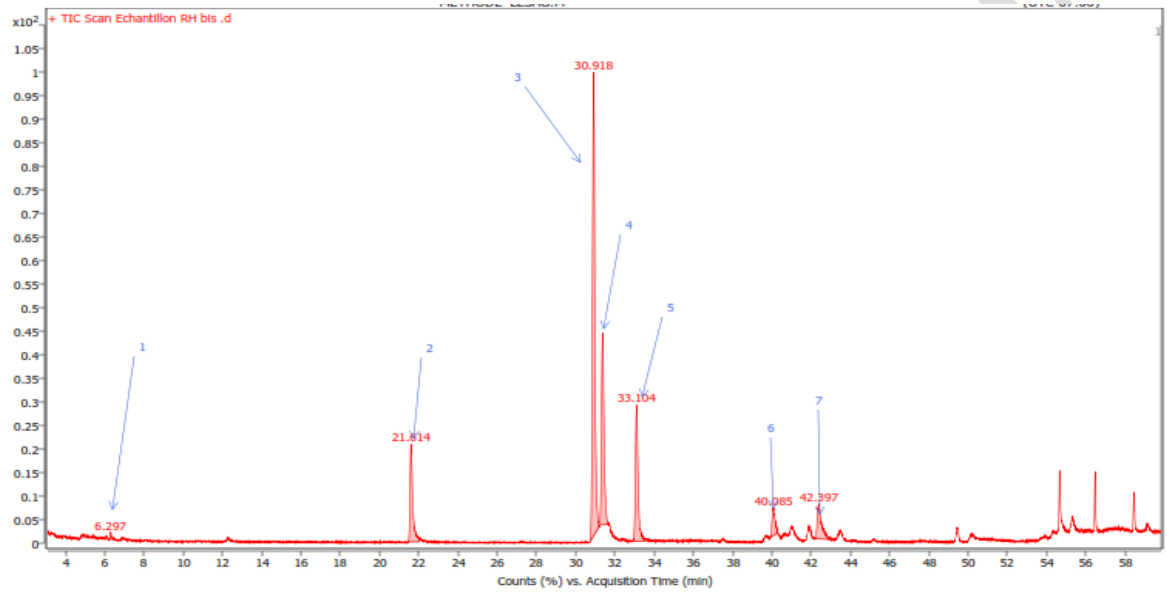

Figure 1 : Chromatographic profile of the fat content of *R. heudelotii*

Table 2. Fatty acids identified in the fatty matter of *Ricinodendron heudelotii*

Order number	Fatty acids identified	Fatty acid family	Rate (in %)
1	Lauric acid	Saturated	0.49
2	Palmitic acid	Saturated	10.74
3	Linoleic acid	Polyunsaturated (Omega-6)	45.21
4	Oleic acid	Monounsaturated (Omega-9)	19.35
5	Stearic acid	Saturé	14.69
6	Linoleic acid	Polyunsaturated (Omega-6)	3.39
7	Gamma-linolenic acid	Polyunsaturated (Omega-6)	6.13
Saturated fatty acids (SFA)			**25.92**
Polyunsaturated fatty acids (PUFA)			**54.73**
Monounsaturated fatty acids (MUFA)			**19.35**

Omega-6 PUFAs are necessary for numerous physiological functions in the body, and their protective role against cardiovascular disease is well known. The American Heart Association recommends a dietary intake of Omega-6 PUFAs of around 5-10% of total energy intake [36, 37]. Omega-6 PUFAs are fatty acids (FAs) characterised by a carbon chain with two or more **cis** double bonds, the first of which is located between the 6th and 7th carbon atoms of the

methyl end (n-6 position). The PUFAs identified in *Ricinodendron heudelotii* almond oil include linoleic acid. This dietary acid is found in large quantities in vegetable oils from soya, maize, and rapeseed. It is an essential fatty acid that cannot be synthesised by mammals. Its only source is therefore the diet [38]. In addition to its role as a precursor of hormones (eicosanoids), linoleic acid is involved in the formation of cell membranes and helps maintain skin hydration by limiting water loss. Linoleic acid, the main PUFA in this oil, acts as a source of energy. In summary, this high omega-6 content in the fat of *R. heudelotii* (54.73%) is thought to help reduce levels of bad cholesterol in the blood [37, 39]. However, too much omega-6 compared with omega-3 tends to encourage the development of various diseases such as cardiovascular disease, cancer, and various inflammatory and autoimmune diseases [40]. Furthermore, the presence of oleic acid (Omega-9) in the fat of *R. heudelotii* almonds (19.35%) could contribute to good control of hypertriglyceridemia in diabetic rats [41]. This acid potentiates the effect of weight loss, which reduces cardiovascular risk in obese and diabetic patients [42].

CONCLUSION

This study focused on determining the physicochemical parameters and identifying fatty acids by GC-MS of the fat extracted from the kernels of *Ricinodendron heudelotii* grown in Côte d'Ivoire. Soxhlet extraction of the oil yielded an extraction rate of 38.70 ± 0.45%, classifying this plant as an oilseed. The physicochemical parameters and the fatty acids identified suggest that the oil could be useful in food and pharmaceutical applications. Further analysis could reveal whether the oil is suitable for use as a biofuel and/or engine lubricant.

The importance of this manuscript for the scientific community

This study holds particular significance for the scientific community, as it makes a valuable contribution to the valorization of an underutilized plant resource in West Africa, *Ricinodendron heudelotii*. By highlighting the chemical and physicochemical properties of this plant, it paves the way for its potential use in sectors such as the agri-food and pharmaceutical industries. Furthermore, the identification and analysis of the fat content from these kernels could offer new insights into the study of unsaturated vegetable oils, which are known for their nutritional benefits. This work serves as a promising foundation for further exploration of this species and contributes to the search for sustainable sources of plant-based lipids.

DISCLAIMER(ARTIFICIALINTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCE

1. **Fotso T.N. D., Duclaire M., Ndoumou Denis O. (2004). Propagation of *Ricinodendron heudelotii* by in vitro cuttings, Fruits. 59, p. 351–358.**

2. **Saki S. J., Mosso K., Sea T. B., Diopoh K. J. (2005). Determination of some essential components of akpi (*Ricinodendron heudelotii*) almonds in Côte D'Ivoire, African Agronomy. 17 (2): 137–142.**

3. **Tchiégang C., Aboubakar D. A. K., Kapseu C., Parmentier M. (2005). Optimization of oil extraction by pressing of *Ricinodendron heudelotii* almonds Pierre ex Pax, Journal of Food Engineering 68:79–87.**

4. **Tchiégang C., Kapseu C., Ndjouenkeu R., Ngassoum M. B. (1997). *Ricinodendron heudelotii* (Bail.) almonds: potential raw material for tropical food industries, J. Food Eng., 32, 1–10.**

5. **Agyare C., Asase A., Lechtenberg M., Niehues M., Deters A., Hensl A. (2009). An Ethnopharmacological survey and in vitro confirmation of ethnopharmacological use of medicinal plants used for wound healing in Gosomtwi-Atwima-Kwanwoma area, Ghana, Journal of Ethnopharmacology, 125, pp. 393- 403.**

6. **Ambé G. A. (2001). Edible wild fruits of the Guinean savannahs of Côte d'Ivoire: state of knowledge by a local population, the Malinké. Biotechnol, Agron. Soc. Environ. 5 (1), 43–58.**

7. **N'guessan F. H., Tra Bi., Koné M. W. (2009). Ethnopharmacological study of antimalarial plants used in traditional medicine among the Abbey and Krobou of Agboville (Côte d'Ivoire). Bulletin of the French Society of Ethnopharmacology and the European Society of Ethnopharmacology, Ethnopharmacologia, No. 44.**

8. **Idu M., Ndukwu B. C. (2006). Studies of Plants Used in Ethnomedicine in Ethiope Concil Area of Delta State, Nigeria, Research Journal of Botany. 1 (1): 30-43.**

9. **Bamba S., Ouattara L. H., Tigori M. A ., Traoré L., Katou Y. S., Gué L. A., Kabran G. R. M. (2024). Chemical and physicochemical parameters of the lipid fraction of *Irvingia gabonensis* (Irvingiaceae) from Côte d'Ivoire, Journal of Chemical, Biological and Physical Sciences. Vol. 14, No. 1; 094-100.**

10. **Gué L. A., Bamba S., Kabran G. R., Kré N. R., Boa D., Touré A. K., Mamyrbékova-Békro J. A., Békro Y.-A. (2017). Determination of the chemical composition and physicochemical parameters of *Moringa oleifera* Lam. seed oil. (Moringaceae) of Ivory Coast, J. Soc. Ouest-Afr. Chim. 043: 17 -25.**

11. **AFNOR (1978). Collection of French standards for fatty substances, oilseeds, and derived products. Paris, 223.**

12. **Gnao K., Kademier M. (2004). Valorization of African hazelnut (Coula edulis): Study of some physicochemical characteristics, 21.**

13. **Bamba S., Mamyrbekova-Bekro, JA., Virieux D., Kabran GRM., Pirat JL., Bekro YA. (2015) Analysis of a Rutaceae fat matter from Côte d'Ivoire, Der Chemica Sinica, 6(4):47-50.**

14. **AOAC. (1980). Official methods of analysis 30th edn, Arlington.**

15. **AOCS. (1997). Peroxide value using chloroform official method Cd-8-53. In official methods and recommended practices of the American oil chemist society. 4th edition,**

16. **Dahouenon A. E., Djenontin T. S., Codjia D. R. M., Alitonou A. G., Dangou J. (2012). Morphology of fruits and some physical and chemical characteristics of oil and cakes of *Irvingia gabonensis* (Irvingiaceae), Int J Biol Chem, 6: 22-65.**

17. **Batel W., Graef M., Meyer GJ., Moller R., Schoedder F. (1980). Plant oils for fuel and energy supply, Basic Science of Land Technology, 30(2): 40-51.**

18. **Bamba S. (2016). Contribution to the valorization of extracted fat almonds of *Afraegle paniculata* (Rutaceae) from Ivory Coast. Doctoral thesis, Nangui Abrogoua University, Ivory Coast: 153 p.**

19. **Noumi G. B., Njouokam Y. M., Njiné C. B., Ngamenni E., Kapseu C. (2011). Effects of drying on the yield and quality of oil extracted from safou pulp, Tropicultura, 29(3), 138-142.**

20. **Hirsch R. (2002). West African oilseed sectors: what prospects in the face of integration and globalization? Oilseeds and fats, Crops and Lipids,9(6), 426.**

21. **Sanders T. A. (1983). Nutritional Signicance of Rancidity. In J. C. Allen and R. J. Hamilton (eds). Rancidity in Foods, Applied Science Publishers, London, UK: 59.**

22. **Lapierre J., St-Gelais K. (2013). The iodine value of five oils at different temperatures.expojournal.cegepstfe.ca/wp -content/uploads/Articles scientifique. pdf : 11 p.**

23. **Marcusson J. (1929). Laboratory Manual for the Oil and Fat Industry: Research on Fatty Substances. Laboratory Manuals for the Chemical and Allied Industries No. 14, France: 168 p.**

24. **Codex alimentarius. (2005). Standard for vegetable oils Named, Codex-stan 210- 1999. p 17.**

25. **M'baye B. K., Alouemine S. A., LÔ B. B., Bassene E. (2011). Physicochemical study of oils consumed in Mauritania, ScienceLib Editions Mersenne, 4(120101), 2111 -4706.**

26. **Gué L. A., (2020). Contribution to the valorization of *Moringa oleifera Lam*. cultivated in Ivory Coast: studies chemical, physical and nutritional. Doctoral thesis, Nangui Abrogoua University, Ivory Coast: 76 p.**

27. **Mamyrbekova-bekro J. A., Bamba S., Akaffou S., Bekro Y.-A. (2009). Characteristic of Fat extracted from the almonds of *Afzelia Africana* (Fabaceaecaesalpinioideae) from Ivory Coast, Revue. Ivoirienne des sciences and Technologies, 13, 191 -198.**

28. **Novidzro K. M., Wokpor K., Amoussou F. B., Koudouvo K., Dotse K., Osseyi E., Koumaglo K. H. (2019). Study of some physicochemical parameters and analysis of mineral elements, chlorophyll pigments and carotenoids of *Griffonia simplicifolia* seed oil, International Journal of Biological and Chemical Sciences. Vol. 13, No. 4; 2360-2373.**

29. **Bereau D. (2001). Oils and unsaponifiable fractions of eight species of Amazonian palms. Thesis. National Polytechnic Institute, Toulouse, France: 152 p.**

30. **Serruya H., Bentes M. H. S., Simoes J. C., Lobato J. E., Muller A. H., Rocha Filho G. N., Luna M. S., Arruda A. C. (1979). Proprietades físico-quimicas e composição de ácidos graxos dos frutos de 3 nativas palmaceas nativas da Região amazônica, Anais da associação brazileira de química, 31: 93-96.**

31. **Serruya H., Da S., Bentes M. H., Muccini M. (1988). Análise do óleo extraido do Açaí branco (EUTERPE OLERACEA Mart.) – Resumo da 40° Annual Meeting of SBPC: p.610.**

32. **[32] Pesce C. (1985). Oil palms and other oilseeds of the Amazon - Reference publications, INC, Michigan: 28-90.**

33. **Lubrano C., Robin J. R., Khaiat A. (1994). Fatty acid, sterol and tocopherol composition of fruit pulp oils of six species of palm trees in Guyana, Oléagineux, 49(2) : 59-65.**

34. **Mambrim M. J. T., Barrera-Arellano D. (1997). Characterization of palm fruit oils from the Amazon region of Brazil, Fats and Oils, 48(3) : 154-158.**

35. **Mananga V., Kinkela T., Elenga M., Loumouamou B.W., Kobawila S.C., Makosso V.G., Silou T. (2012). Content and fatty acid composition of the lipids of the blue *cephalophus* (Cephalophus monticola), Bulletin of the Royal Society of Sciences of Liège, Vol 80, 2015, p 4-13.**
36. **Harris W. S., Mozaffarian D., Rimm E. (2009). Omega-6 fatty acids and risk for cardiovascular disease : a science advisory from the American heart association nutrition subcommittee of the Council on nutrition, physical activity, and metabolism, Council on cardiovascular nursing and Council on epidemiology and prevention, Circulation ; 119 : 902-907.**
37. **Czernichow S., Thomas D., Bruckert E. (2011). Omega-6 fatty acids and cardiovascular disease Recommendations on dietary intake, medicine/science; 27 : 614-8.**
38. **Astorg P., Bertrais S., Laporte F. (2008). Plasma n-6 and n-3 polyunsaturated fatty acids as biomarkers of their dietary intakes : a cross-sectional study within a cohort of middle-aged French men and women, Eur J Clin Nutr ; 62 : 1155-116.**
39. **Guesnet P., Alessandri J.M., Astorg P., Pifferi F., Lavialle M. (2005). The major physiological roles played by polyunsaturated fatty acids (PUFAs), OCL VOL. 12 No. 5-6. : 333-343.**
40. **Artemis P.S. (2002). The importance of the ratio of omega-6/omega-3 essential fatty acids », Biomedicine & Pharmacotherapy, vol. 56, no. 8, p. 365-379.**
41. **Giron MD., Sanchez F., Hortelano P., Periago J.L., Suarez M.D. (1999). Effects of dietary fatty acids on lipid metabolism in streptozotocin-induced diabetic rats, Metabolism ,48 : 455-60.**
42. **Gumbiner B., Low C.C., Reaven P.D. (1998). Effects of a monounsaturated fatty acid-enriched hypocaloric diet on cardiovascular risk factors in obese patients with type 2 diabetes, Diabetes Care, 21 : 9-15.**