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Influence of Drying Methods on the Chemical Characteristics of *Irvingia gabonensis* Kernel Oil and Oil Cakes

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Abstract

Optimizing the drying conditions prior to processing *Irvingia gabonensis* kernels into vegetable oil is a crucial step in preserving the quality of the final product. This study aimed to evaluate the influence of two drying methods (air-drying and oven-drying) on the quality parameters of the extracted oil and the resulting oil cakes. The results showed that oven-dried kernels exhibited a significantly lower moisture content (0.58 ± 0.01%) compared to air-dried kernels (2.44 ± 0.01%). The oil yields were 62.71 ± 7.65% for air-dried kernels and 74.68 ± 9.60% for oven-dried ones. The oils extracted from air-dried and oven-dried kernels presented similar values, with peroxide indices of 0.13 ± 0.03 and 0.14 ± 0.01 meq O_2/kg, acid values of 0.79 ± 0.08 and 0.98 ± 0.04 mg KOH/g, and saponification values of 179.55 ± 3.97 and 178.15 ± 9.92 mg KOH/g, respectively. The oil cakes obtained from air-dried and oven-dried kernels showed, respectively, protein contents of 19.06 ± 0.36% and 18.97 ± 0.62%, ash contents of 8.58 ± 0.41% and 7.68 ± 0.12%, potassium contents of 2.30 g/100 g and 1.95 g/100 g, calcium contents of 0.79 g/100 g and 0.82 g/100 g, sodium contents of 0.73 g/100 g and 0.64 g/100 g, phosphorus contents of 0.68 g/100 g and 0.62 g/100 g, magnesium contents of 0.40 ± 0.06 g/100 g and 0.33 ± 0.03 g/100 g, and identical iron contents of 0.01 ± 0.001 g/100 g. Statistical analysis revealed no significant differences between the two drying methods for most of the oil quality parameters and the chemical characteristics of the oil cakes. Nevertheless, air drying at 25˚C better preserves most of the chemical parameters of both the oil and the oil cake, whereas oven drying at 60˚C better preserves phosphorus.

Subject Areas

Food Science & Technology

Keywords

Irvingia gabonensis, Kernels, Oil, Oil Cakes, Drying, Chemicals Characteristics

1. Introduction

Irvingia gabonensis is an African plant commonly known as "wild mango" and belongs to the family Irvingiaceae [1]. It is distinguished by its exceptional nutritional properties. Widespread throughout tropical regions, this species is a non-timber forest product of great economic and nutritional importance. The kernels of *Irvingia gabonensis* are among the main sources of vegetable oil in West and Central Africa [2]. According to previous reports, the kernels are also rich in proteins and minerals (P, Ca, K, and Mg) [3]. Furthermore, the oil cakes obtained from the kernels are also rich in proteins, serving as an alternative source of plant proteins comparable to cereals and legumes [4] [5]. Additionally, it was reported that *Irvingia gabonensis* kernels contain a high amount of soluble fiber, which may slow gastric emptying and thus confer laxative properties [6]. Furthermore, it has been mentioned that extracts from *Irvingia gabonensis* kernels have been shown to improve blood glucose levels, increase High-Density Lipoprotein (HDL) cholesterol, and reduce total cholesterol, Low-Density Lipoprotein (LDL) cholesterol, and triglycerides, suggesting their potential use as antidiabetic and anti-obesity agents [1]. The high oil and protein yields of *Irvingia gabonensis* kernels offer promising opportunities for their valorization in both vegetable oil production and the development of nutritionally valuable oil cakes. The processing of these kernels typically begins with a critical drying step, which is essential for reducing the moisture content and optimizing oil yield. It was demonstrated that the maximum oil extraction yield is achieved when the kernels have a low moisture content, which can be attained through adequate drying [7]. However, this step remains delicate, as it can significantly influence the quality of the extracted oil. The effects of various drying methods on pistachio seed oil were investigated, revealing that these methods affect both the stability and quality of the oil [8]. Moreover, it was reported that the electric oven and sun drying methods result in a slight decrease in mineral content in all dried fruits and vegetables [9]. Despite the importance of this stage, very few studies have been conducted in the Republic of the Congo on the impact of drying on the chemical properties of *Irvingia gabonensis* oil and its byproducts, specifically the oil cakes. Therefore, the present study aims to evaluate the impact of oven and air drying on the chemical characteristics of the oil and the oil cakes.

2. Plant Material of the Study

Irvingia gabonenesis fruits were collected in June 2024 by random sampling in the village of "Tala Tala", located a few kilometers from the town of Ouesso, in the Republic of Congo.

3. Study Methods

3.1. Fruit Processing

The harvested fruits were transported to the laboratory, cleaned, and then left to ferment for five days to facilitate the detachment of the pulp adhering to the seed**,** and thus allow the isolation of the seed containing the kernel [10] [11]. The hard shells of the stones were then broken to extract the kernels, which were subsequently prepared for drying.

3.2. Drying Process of *Irvingia gabonensis* Kernels

Two drying methods were applied to *Irvingia gabonensis* kernels. The first method, carried out under ambient conditions at an average laboratory temperature of 25˚C, involved spreading the kernels on a clean tablecloth and exposing them to air drying for four consecutive days in June 2024. The second method was performed over the same period using a ventilated oven set at 60˚C in the laboratory. The air-dried and oven-dried kernels were designated as **AD*Ig*K** (air-dried *Irvingia gabonensis* kernels) and **OD*Ig*K** (oven-dried *Irvingia gabonensis* kernels), respectively. After drying, the kernels were ground using a porcelain mortar, and the resulting powder was used for subsequent analyses.

3.3. Determination of the Residual Moisture Content of Dried Kernels

The determination of the residual moisture content of the dried *Irvingia gabonensis* kernels was carried out according to the oven-drying method described by the AOAC [12]**.** The powdered sample was placed in a ventilated oven at 105˚C for 24 hours. The moisture content was calculated using the following formula:

$$Moisture\,content\left(\%\right)=\frac{W_0-W_1}{W_0}\times 100$$

W_0: Weight of the sample before oven-drying (initial weight).
W_1: Weight of the sample after oven-drying (final weight).

3.4. Extraction of *Irvingia gabonensis* Kernel Oil

Extraction of *Irvingia gabonensis* kernel oil was performed using the Soxhlet method. A Whatman thimble was filled with 30 g of crushed kernel sample and placed in a Soxhlet-type extractor connected to a condenser. A previously weighed flask containing 200 mL of hexane was placed on the Soxhlet heating block. The extraction was carried out continuously for 3 hours. After extraction, the solvent was evaporated, and the oil was recovered in the same flask. The percentage of oil yield

determination was carried out in accordance with the AOAC method [13], using the following equation:

$$\textbf{Oil yield}(\%) = \frac{weight\ of\ oil\ extracted\,(g)}{weight\ of\ sample\,(g)} \times 100$$

3.5. Chemical Properties of the Extracted Oils

Saponification value

The Saponification value was determined according to the standard method described by [14]. This method is based on alkaline saponification of the oil sample followed by acid titration of the excess alkali. Two grams (2 g) of oil were weighed into a round-bottom flask, and 25 mL of a 0.5 mol/L alcoholic potassium hydroxide (KOH) solution was added. The mixture was refluxed for one hour, then cooled under running tap water. After cooling, 2 to 3 drops of phenolphthalein indicator were added, and the solution was titrated with 0.5 N Hydrochloric acid (HCl) until the pink color disappeared and the original color of the solution was restored. A blank test was prepared under the same conditions, replacing the oil with 2 mL of distilled water. The Saponification Value (SV) was calculated using the following formula:

$$SV = \frac{V_0 - V}{W} \times N \times 56.11$$

V_0 = volume of HCl used for the blank (mL)
V = volume of HCl used for the sample (mL)
N = normality of the HCl solution
W = weight of the oil sample (g)
56.1 = molecular weight of KOH

Acid value

The acid value was determined by titrating free fatty acids with an alcoholic solution of potassium hydroxide, following the method described by [14]. One gram (1 g) of oil was placed in an Erlenmeyer flask, and 25 mL of 95% ethanol, along with 3 drops of 0.2% Phenolphthalein (pp) indicator, were added. After vigorous shaking, the free fatty acids were titrated with a 0.1 mol/L ethanolic potassium hydroxide (KOH) solution until a persistent pink color appeared. The Acid Value (AV) was calculated using the following formula:

$$AV = \frac{56.11 \times V \times N}{m}$$

V = volume of KOH used for titration (mL)
N = normality of the KOH solution
m = mass of the oil sample (g)
56.1 = molecular weight of KOH

Peroxide value

The peroxide value was determined according to the standard iodometric method, which is based on the reaction of oil dissolved in acetic acid and chloroform with potassium iodide (KI), followed by titration of the liberated iodine with a stand-

ardized sodium thiosulfate ($Na_2S_2O_3$) solution. For this procedure, 1 g of oil was placed in an Erlenmeyer flask, and 15 mL of acetic acid and 10 mL of chloroform were added simultaneously. After homogenization, 1 mL of a saturated potassium iodide (KI) solution was added. The flask was vigorously shaken for one minute and kept in the dark for 5 minutes to allow the reaction to proceed. Subsequently, 75 mL of distilled water was added, and the liberated iodine was immediately titrated with a standardized sodium thiosulfate ($Na_2S_2O_3$) solution under continuous shaking. A few drops of freshly prepared starch indicator were used to detect the completion of the titration, as indicated by the disappearance of the blue coloration. A blank sample was prepared under the same conditions, replacing the oil sample with distilled water. The Peroxide Value (PV) was calculated using the following equation:

$$PV = \frac{(V - V_0) \times 1000}{m}$$

V = volume of sodium thiosulfate used for the sample (mL)

V_0 = volume used for the blank (mL)

N = normality of the sodium thiosulfate solution

m = mass of the oil sample (g)

3.6. Chemical Analysis of Oil Cake

3.6.1. Determination of Protein Content

Protein content was determined by measuring the total nitrogen content in the dry matter, using the Kjeldahl method AOAC [13]. Nitrogen was released from the dry matter after mineralization with sulfuric acid in the presence of a selenium-based catalyst. The resulting ammonia was distilled in the presence of excess sodium hydroxide and collected in boric acid, using bromocresol green and methyl red as indicators. The nitrogen content was then determined by titration with sulfuric acid until the indicator color changed from green to pink. The percentage of nitrogen obtained was converted to protein content by applying a conversion factor of 6.25.

3.6.2. Determination of Ash Content

Ash content was determined according to the AOAC procedure [13], which involves incinerating the dry matter in a muffle furnace at 550˚C for 6 hours. The ash content was expressed on a dry matter basis and reported as a percentage of the dry matter.

3.6.3. Determination of Mineral Content

After mineralization of the different samples in a muffle furnace at 450˚C, the ash was recovered, moistened with distilled water and concentrated hydrochloric acid, and then the mineral elements (P, Fe, Ca, K, Na, and Mg) were determined using the methods described by [13].

Determination of phosphorus content

Content Phosphorus was assayed by the cold colorimetric method using Mur-

phy and Riley's reagent [15]. Murphy and Riley's reagent was obtained by combining solution A and solution B. Solution A was prepared by mixing 50 mL of water with 10 mL of concentrated sulfuric acid in a 100 mL flask. After cooling, 0.6 g of ammonium molybdate and 0.014 g of potassium antimonyl tartrate were added, and the flask was then filled up to the mark. For solution B, 2 g of ascorbic acid, 50 mL of distilled water, and 5 mL of concentrated hydrochloric acid were mixed, and the mixture was brought to volume. In a 200 mL flask, solutions A and B were mixed to obtain Murphy and Riley's reagent. In a plastic vial, 0.5 mL of mineralized sample, 10 mL of distilled water, and 3 mL of Riley reagent were mixed. After 30 minutes of incubation, the absorbance of the mixture was read at the wavelength (λ) of 660 nm. The phosphorus content of the sample was obtained by calculation using a phosphorus calibration curve.

Determination of iron content

The iron content was determined using a colorimetric Spectro colorimeter [15]. Iron content was determined after mixing in a plastic pillbox, 5 mL of mineralized sample, 5 mL of hydroxylamine chloride, 2 mL of sodium citrate, 2 mL of sodium acetate buffer solution, pH 3.5, and 2 mL of orthophenantroline. Under the same conditions, an iron standard was prepared. After 30 minutes of incubation at room temperature, a red coloration developed. The absorbance of the reaction medium was measured using the spectrophotometer at 490 nm.

Determination of calcium and magnesium content

The calcium and magnesium content were determined using the complexometric titration method described by [15]. Calcium and magnesium form soluble Ca-EDTA and Mg-EDTA complexes with EDTA (Ethylene Diamine Tetraacetic Acid). A volume of 5 mL of mineralized sample was introduced into a 200 mL Erlenmeyer flask. Then, 45 mL of distilled water and 4 mL of buffer solution at pH 10 were added to the mixture. The titration was carried out with EDTA, using NET as color indicators, until the solution changed from pink to blue. At this stage, total calcium and magnesium (Ca + Mg) were determined simultaneously. For calcium determination, 5 mL of mineralized sample was placed in a 200 mL Erlenmeyer flask, to which 45 mL of distilled water, 1 mL of KCN, 5 mL of triethanolamine hydrochloride, and 5 mL of 2.5N NaOH were added. The pH of the solution was raised to 12 to precipitate the magnesium. Calcon was used as the color indicator during titration. The magnesium content was determined by subtracting the Ca concentration from the total (Ca + Mg) concentration.

Determination of potassium content

A volume of 0.5 mL of the mineralized sample was transferred into a 100 mL Erlenmeyer flask, and then a solution of lanthanum oxide was added, up to 25 mL. The dosage was performed using a flame spectrometer, using a range of standard solutions that enabled a calibration curve to be plotted. From this curve, the potassium concentration was determined.

Determination of sodium content

A 15 mL aliquot of the mineralized sample was transferred into a 100 mL volu-

metric flask. A lanthanum oxide solution was added to bring the volume up to the calibration mark. The resulting solution was analyzed using a flame photometer. A series of sodium standard solutions was used to establish a calibration curve, from which the sodium concentration in the sample was determined by interpolation.

3.7. Data Processing and Analysis

The data were processed using Microsoft Excel 2013 and analyzed with SPSS Statistics version 22.0. A two-sample t-test was performed to compare the means between groups.

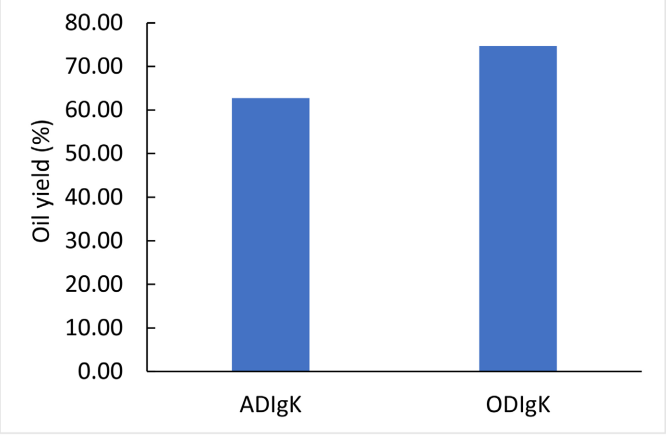
4. Results

4.1. Residual Moisture Content of Dried Kernels

The drying process, whether by air-drying or oven-drying, resulted in kernels with very low residual moisture content. The air-dried kernels exhibited a residual moisture content of 2.44 ± 0.01%, whereas the oven-dried kernels had a significantly lower value of 0.58 ± 0.01%.

4.2. Oil Yield of Kernels

Figure 1 illustrates the oil extraction yield from the dry matter of AD*Ig*K and OD*Ig*K. The results show that *Irvingia gabonensis* kernels air-dried and oven-dried have a high average oil yield. The oil yield of OD*Ig*K is higher than that of AD*Ig*K, with respective values of 74.68 ± 9.60% and 62.71 ± 7.65%. However, statistical analysis showed that this difference is not significant (P > 0.05).



AD*Ig*K: Air-Dried *Irvingia gabonensis* Kernels, OD*Ig*K: Oven-Dried *Irvingia gabonensis* Kernels.

Figure 1. Oil yield of two types of *Irvingia gabonensis* kernels.

4.3. Chemical Properties of the Oil

Table 1 presents the chemical properties of the oils extracted from AD*Ig*K and OD*Ig*K.

Table 1. Chemical properties of the oil extracted from two categories of kernels.

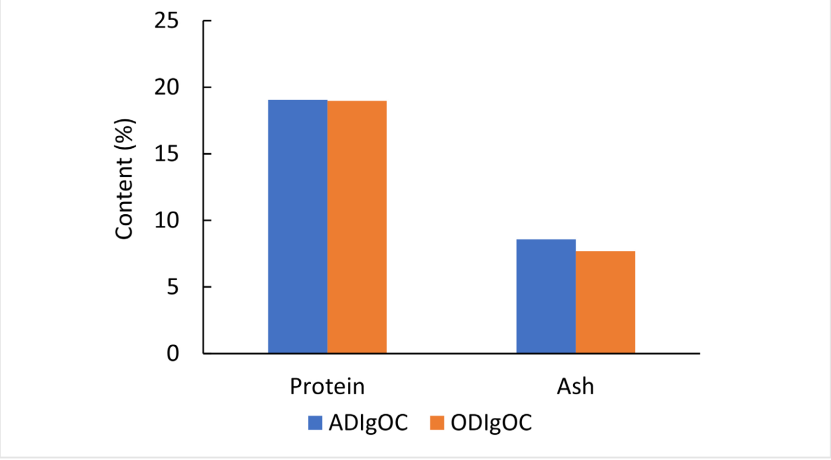
Oil category	SV (mg de KOH/g oil)	AV (mg KOH/g oil)	PV (meq O_2 /kg)
O. AD*Ig*K	179.55 ± 3.97[a]	0.79 ± 0.08[a]	0.13 ± 0.03[a]
O. OD*Ig*K	178.15 ± 9.92[a]	0.98 ± 0.04[a]	0.14 ± 0.01[a]

O. AD*IgK*: Oil extracted from air-dried *Irvingia gabonensis* kernels; **O. OD*IgK***: Oil extracted from oven-dried *Irvingia gabonensis* kernels. **SV**: Saponification Value; **AV:** Acid Value; **PV**: Peroxide Value. Means followed by the same superscript letter within a line are not significantly different at the 5% probability level ($p > 0.05$).

This table shows a saponification value of 179.55 mg KOH/g oil for AD*Ig*K oil and 178.15 mg KOH/g oil for OD*Ig*K oil. Regarding the acid value, the results were 0.79 mg KOH/g oil for AD*Ig*K oil and 0.98 mg KOH/g oil for OD*Ig*K oil. Finally, the peroxide value was 0.13 ± 0.03 meq O_2/kg for AD*Ig*K oil and 0.14 ± 0.01 meq O_2/kg for OD*Ig*K oil.

4.4. Protein and Ash Content

Figure 2 presents the protein and ash contents of oil cakes from air-AD*Ig*OC) and oven-dried (OD*Ig*OC) *Irvingia gabonensis* kernels.



AD*Ig*OC: Air-Dried *Irvingia gabonensis* Oil Cakes; OD*Ig*OC: Oven-Dried *Irvingia gabonensis* Oil Cakes.

Figure 2. Protein and ash contents of two types of *Irvingia gabonensis* oil cakes.

The results show that *Irvingia gabonensis* oil cakes have relatively high average protein content, with values of 19.06 ± 0.36% for AD*Ig*OC and 18.97 ± 0.62% for OD*Ig*OC. However, the difference between the two values is only 0.1%. Regarding ash content, Figure 2 shows values of 8.58 ± 0.41% for AD*Ig*OC and 7.68 ± 0.12% for OD*Ig*OC.

4.5. Minerals Content

The results presented in Table 2 indicate that potassium is the predominant

macro-element in both types of oil cake, with values of 2.30 ± 0.18 g/100 g for AD*Ig*OC and 1.95 ± 0.15 g/100 g for OD*Ig*OC. It is followed by calcium (0.79 ± 0.05 g/100 g and 0.82 ± 0.03 g/100 g), sodium (0.73 ± 0.18 g/100 g and 0.64 ± 0.17 g/100 g), and phosphorus (0.68 ± 0.02 g/100 g and 0.62 ± 0.01 g/100 g). Magnesium was the macro-element present in the lowest amounts in both types of oil cake, with values of 0.40 ± 0.06 g/100 g for OD*Ig*OC and 0.33 ± 0.03 g/100g for AD*Ig*OC. Both types of oil cake also showed identical iron contents of 10 ± 1 mg/100 g.

Table 2. Minerals content of both types of oil cakes.

Minerals	AD*Ig*OC (g/100g)	OD*Ig*OC (g/100g)
Potassium	2.30 ± 0.18[a]	1.95 ± 0.15[a]
Calcium	0.79 ± 0.05[a]	0.82 ± 0.03[a]
Magnesium	0.40 ± 0.06[a]	0.33 ± 0.03[a]
Iron	0.01 ± 0.001[a]	0.01 ± 0.001[a]
Sodium	0.73 ± 0.18[a]	0.64 ± 0.17[a]
Phosphorus	0.68 ± 0.02[a]	0.62 ± 0.01[b]

AD*Ig*OC: Air-Dried *Irvingia gabonensis* Oil Cake; **OD*Ig*OC**: Oven-Dried *Irvingia gabonensis* Oil Cakes. Means followed by the same superscript letter within a line are not significantly different at the 5% probability level ($p > 0.05$); means followed by different letters differ significantly at this level ($p < 0.05$).

5. Discussion

5.1. Effect of the Drying Method on the Residual Moisture Content

The results show that the residual moisture content of *Irvingia gabonensis* kernel varies significantly depending on the drying method used. Air-dried kernels have a higher residual moisture content than oven-dried kernels. This difference can be explained by the fact that, during oven drying, the temperature and ventilation are carefully controlled to accelerate the evaporation of water. This allows for a rapid achievement of low water content, thereby reducing the residual moisture in the kernels. Conversely, open-air drying relies on prolonged exposure to ambient air and is generally slower, resulting in higher water retention due to slower and less uniform evaporation. Similar results were reported in a study comparing oven and solar drying of mangoes [16].

These results confirm that the two drying methods used have a significant influence on the residual moisture content of *Irvingia gabonensis* kernels. Although oven drying results in a lower residual moisture content than air drying, both methods produce moisture levels low enough to effectively store *Irvingia gabonensis* kernels at room temperature. Moisture content is a crucial factor in maintaining the stability of oil cake over extended periods [17]. A level below 12% is considered safe for storage, as it prevents the rapid growth of mould [18].

5.2. Effect of Drying Methods on Oil Yield

The oil yield of the *Irvingia gabonensis* kernels is very high and varies slightly depending on the drying methods used. The high oil yield obtained from both types of kernels can be attributed to their low moisture content. These results were similar to those reported by an earlier study, which showed that an increase in the moisture content of dehulled sunflower seeds resulted in a progressive decrease in oil yield, from 91.01% at 6.2% moisture content to 85.45% at 8%, and further to 83.53% at 9.5% [19]. They also confirm the findings of a previous study which demonstrated that a low water content in dried *Dacryodes edulis* pulp yields higher oil [7].

The results show that oven-dried kernels have a slightly higher oil yield than those dried in the open air. This difference can be attributed to the lower residual moisture content of the oven-dried kernels. However, statistical analysis indicates that although oven drying results in a slightly higher oil yield, the difference observed between the two drying methods is not significant.

5.3. Effect of Drying Methods on the Chemical Properties of Oil Extracted from Kernels

The saponification value provides an indication of the molecular weight and chain length of the fatty acids [20]. It also serves as a crucial parameter for evaluating the purity and overall quality of edible oils [21]. It has been reported that the shorter the fatty acid chain length, the higher the saponification value and the lower the molecular weight of the fatty acids [22]. Similarly, it was reported that a high saponification value indicates triacylglycerols with shorter fatty acyl chains [23]. Consequently, the Saponification Value (SV) provides a simple and reliable approach to assessing the average chain length of fatty acids in specific fats or oils [23]. The oil extracted from air-dried kernels had a slightly higher saponification index (179.55 mg KOH/g oil) than that obtained from oven-dried almonds (178.15 mg KOH/g oil). However, this difference was not statistically significant ($p > 0.05$). These values obtained this study remain lower than those reported for coconut oil (248.5 mg KOH/g) and palm oil (236.5 mg KOH/g), whose composition is rich in short-chain fatty acids, particularly lauric acid (C12:0), myristic acid (C14:0) and myristoleic acid (C14:1). Furthermore, these saponification values are also lower than the recommended range of 188-198 mg KOH/g for edible oils (FAO/WHO) [24]. Therefore, these results suggest that the oil extracted from the dried kernels of *Irvingia gabonensis,* regardless of the drying method used, is predominantly composed of long-chain fatty acids.

The acid value of oils extracted from oven-dried and air-dried kernels is very low, with no significant difference between the two drying methods. The acid value reflects the amount of free fatty acids present in the oil and serves as an indicator of its quality and of changes resulting from oxidation processes [25]. An increase in free fatty acid content indicates triglyceride hydrolysis and a greater susceptibility of the oil to oxidation [26]. This study demonstrates that both drying meth-

ods yield a very low acid value, below the recommended limit of 2.5% free fatty acids for virgin oils [27]. The low acid value suggests that both types of oil contain low amounts of free fatty acids. This result can be attributed to the low water content of the kernels used for oil extraction. Indeed, it has been reported that dehydration has a reducing effect on the acid value by limiting the availability of water required for lipase hydrolysis or by causing denaturation of the enzyme responsible for this reaction [20].

As regards the peroxide value, the results show that the oils extracted from oven-dried and air-dried kernels exhibit very low values, with no significant difference. This indicates that the drying method has no significant influence on this parameter. The peroxide value is an indicator of oil deterioration that leads to rancidity [28]. It reflects the early stages of oxidative deterioration in oils and is a parameter used to assess the quality of edible oils [7] [29]. A high peroxide value is attributed to the formation of hydroperoxides and serves as an indicator of the initial stage of oxidation [30]. Therefore, the low peroxide value obtained in this study indicates a low level of oxidative rancidity in the oil and also suggests the presence of high levels of antioxidants [31]. The values obtained are below the limit of 10 meq O_2/kg, which is characteristic of good quality refined edible oils such as soybean, corn, and sunflower oils, according to the Codex Alimentarius, as well as the limit of 20 meq O_2/kg set by the International Olive Conseil Oléicole International for olive oil [32] [33]. These results are also within the range of 0.50 to 2.67 meq O_2/kg reported for oils extracted from the same kernels [34]. Consequently, the oils extracted from *Irvingia gabonensis* kernels, dried using both methods, can be considered of good quality and are likely to exhibit better stability during storage.

5.4. Effect of Drying Methods on the Protein and Ash Contents of Oil Cakes

The results obtained show that the protein and ash contents of the oil cakes from air-dried kernels are slightly higher than those of the oil cake from oven-dried kernels. However, statistical analysis revealed no significant difference between these values, suggesting that the drying method does not significantly affect the protein or ash content of the kernels. Oven drying, which involves the use of heat, did not lead to any significant protein loss, which can be attributed to the use of moderate temperatures during the drying process. Indeed, it has been shown that high temperatures can cause protein denaturation by breaking internal molecular bonds, and that the rate of denaturation increases with temperature [35] [36].

The values obtained in this study are higher than those reported for kernel *Irvingia gabonensis* oil cake collected in Libreville, which had a protein content of 13.0 ± 0.2% and an ash content of 2.3 ± 0.0% [37].

The high protein and ash contents of *Irvingia gabonensis* kernel oil cake obtained in this study, regardless of the drying method used, indicate that it is an undeniable source of proteins and minerals (K, P, Mg, and Ca). Therefore, this oil

cake can be utilized in human nutrition and in the formulation of functional foods, given the well-documented health benefits of plant proteins and minerals. It has been reported that a diet rich in plant proteins is associated with numerous health benefits, including reductions in body weight, blood cholesterol, and blood pressure [38]. This is the main reason why plant-based proteins are generally preferred over animal-based proteins [39].

5.5. Effect of Drying Methods on the Mineral Content of Oil Cakes

The mineral content in food refers to the amount of specific inorganic components present in that food. Minerals act as cofactors in enzymatic reactions [40].

The results of this study also indicate that, although the oil cakes have high macro-element contents, no significant difference ($p > 0.05$) was found between the two drying methods for most of these elements (Ca, K, Na, and Mg), except for phosphorus ($p < 0.05$). Regarding the only microelement analyzed, iron, both types of oil cake had similar contents.

Although the differences in mineral content in the oil cake obtained by the two methods used are not statistically significant, this study showed that the oil cake obtained from air-dried kernels had a slightly higher mineral content. This suggests that air drying promotes better preservation of most of the macro elements studied, particularly potassium, calcium, magnesium, and sodium, compared to oven drying. Furthermore, the results also show that, regardless of the drying method used, potassium is the predominant macro element in the oil cake obtained from dried kernels, followed by calcium. Magnesium, on the other hand, is the least abundant macro element. The other macro elements are also present in appreciable amounts.

The high macro-element content obtained in this study is indicative of the good quality of the oil cakes derived from *Irvingia gabonensis*. Therefore, they are considered a source of minerals necessary for the normal functioning of the body system. Potassium, the predominant macronutrient, is the main cation of the intracellular compartment. It plays a key role in maintaining acid-base balance, regulating osmotic pressure, transmitting nerve impulses, enabling muscle contraction, ensuring proper cell membrane function, and supporting the activity of the Na^+/K^+-ATPase [41]. Moreover, calcium, which is also present in significant amounts in the cakes, is an essential macro-element. It plays a crucial role in regulating nerve and muscle functions [41].

The results of this study suggest that air drying, which better preserves most chemical parameters, is the best option for pre-treating *Irvingia gabonensis* kernels for oil processing in rural areas, as it requires no energy expenditure and is therefore economically accessible. However, although oven drying at 60˚C involves higher energy costs, the results showed that it produces a slightly higher oil yield and better preserves phosphorus in the oil cake. Therefore, processors must strike a balance between energy costs and the quality of the final products, as both pretreatments offer distinct advantages.

6. Conclusion

The study on the influence of the drying method used as a pretreatment during the processing of *Irvingia gabonensis* kernels into vegetable oil reveals that kernels dried in an oven at 60˚C have a lower residual moisture content than those that were air-dried at 25˚C. Furthermore, the two drying methods (oven-dried and air-dried) showed no significant differences in oil yield and in the oil quality parameters studied (saponification, acid, and peroxide values). Regarding the oil cake obtained after oil extraction, the results also indicate no significant differences between samples from oven-dried kernels and those that were air-dried for most of the chemical parameters analyzed, particularly proteins and minerals (calcium, magnesium, sodium, and iron), which are concentrated in the ashes. Although the statistical analysis revealed no significant differences between the two methods, this study found that air drying at 25˚C better preserves most of the chemical parameters of both the oil and the oil cake. In contrast, oven drying at 60˚C better preserves phosphorus.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Hassan, Y.R., El-Shiekh, R.A., El Hefnawy, H.M. and Michael, C.G. (2024) *Irvingia gabonensis* Baill. (African Mango): A Comprehensive Review of Its Ethnopharmacological Significance, Unveiling Its Long-Standing History and Therapeutic Potential. *Journal of Ethnopharmacology*, **326**, Article ID: 117942. https://doi.org/10.1016/j.jep.2024.117942

[2] Ingram, V., Ewane, M., Ndumbe, L.N. and Awono, A. (2017) Challenges to Governing Sustainable Forest Food: *Irvingia* spp. from Southern Cameroon. *Forest Policy and Economics*, **84**, 29-37. https://doi.org/10.1016/j.forpol.2016.12.014

[3] Coulibaly, M., Kouamé, C., N'dri, D., Kouassi, N., Pereko, K. and Amani, G. (2018) Effect of Post-Harvest Traditional Technologies on the Nutrient Content and Antioxidant Compounds of Defatted Flours from *Ricinodendron heudelotti* (Baill. Pierre Ex Pax) Seed Kernels. *Technologies*, **6**, Article 37. https://doi.org/10.3390/technologies6020037

[4] Dahouenon-Ahoussi, E., Djenontin, T., Codjia, D., Tchobo, F., Alitonou, A., Dangou, J., *et al.* (2013) Morphologie des fruits et quelques caractéristiques physique et chimique de l'huile et des tourteaux de *Irvingia gabonensis* (*Irvingia*ceae). *International Journal of Biological and Chemical Sciences*, **6**, 2263-2273. https://doi.org/10.4314/ijbcs.v6i5.32

[5] Day, L. (2013) Proteins from Land Plants—Potential Resources for Human Nutrition and Food Security. *Trends in Food Science & Technology*, **32**, 25-42. https://doi.org/10.1016/j.tifs.2013.05.005

[6] Mateus-Reguengo, L., Barbosa-Pereira, L., Rembangouet, W., Bertolino, M., Giordano, M., Rojo-Poveda, O., *et al.* (2019) Food Applications of *Irvingia gabonensis* (Aubry-Lecomte Ex. O'rorke) Baill., the 'Bush Mango': A Review. *Critical Reviews in Food Science and Nutrition*, **60**, 2446-2459. https://doi.org/10.1080/10408398.2019.1646704

[7] Noumi, G.B., Njouokam, M., Njiné, C.B., Ngameni, E. and Kapseu, C. (2011) Effet du séchage sur le rendement et la qualité de l'huile extraite de la pulpe de safou. *Tropicultura*, **29**, 138-142.

[8] Sena-Moreno, E., Pardo, J.E., Catalán, L., Gómez, R., Pardo-Giménez, A. and Alvarez-Ortí, M. (2015) Drying Temperature and Extraction Method Influence Physicochemical and Sensory Characteristics of Pistachio Oils. *European Journal of Lipid Science and Technology*, **117**, 684-691. https://doi.org/10.1002/ejlt.201400366

[9] Elghazali, M.N., Osman, A.A., Abdullah, E.A. and Abdrabu, E.A. (2025) The Impact of Sun and Electric Oven Drying Methods on the Chemical Composition of Some Fruits and Vegetables. *Aswan University Journal of Sciences and Technology*, **5**, 113-128. https://doi.org/10.21608/aujst.2025.348150.1159

[10] Gnahoua, G.M., Konan, A. and Louppe, D. (2003) Boborou: *Irvingia gabonensis*. CIRAD-Forêt.

[11] Ekpe, O.O., Umoh, I.B. and Eka, O.U. (2007) L'effet d'une Méthode de Traitement Typiquement Rurale sur la Composition Rapprochée et le Profil de l'Acide Aminé du Noyau de la Mangue Sauvage (*Irvingia gabonensis*). *African Journal of Food Agriculture Nutrition and Development*, **7**, 12.

[12] AOAC (1995) Official Methods of Analysis. 16th Edition, Association of Official Analytical Chemists.

[13] AOAC (2005) Association of Official Analytical Chemists. 18th Edition, AOAC Official Methods of Analysis.

[14] Wolf, J.P. (1968) Manuel d'analyse des corps gras. Azoulay, 517 p

[15] Martin-Prével, P., Gagnard, J. and Gautier, P. (1984) L'Analyse Végétale dans le Contrôle de l'Alimentation des Plantes tempérées et tropicales. Lavoisier, 810 p.

[16] Mwamba, I., *et al.* (2017) Comparison of Two Drying Methods of Mango (Oven and Solar Drying). *MOJ Food Processing & Technology*, **5**, 240-243. https://doi.org/10.15406/mojfpt.2017.05.00118

[17] Rani, R. and Badwaik, L.S. (2021) Functional Properties of Oilseed Cakes and Defatted Meals of Mustard, Soybean and Flaxseed. *Waste and Biomass Valorization*, **12**, 5639-5647. https://doi.org/10.1007/s12649-021-01407-z

[18] Abdullah, M.H.R.O., Ch'ng, P.E. and Lim, T.H. (2011) Some Physical Properties of Parkia Speciosa Seeds. *International Conference on Food Engineering and Biotechnology*, **9**, 43-47.

[19] D, M., Saha, D., Gupta, R., Bhadwal, S., Arora, S., Kumar, P., *et al.* (2020) Oil Expelling from Whole and Dehulled Sunflower Seeds: Optimization of Screw Pressing Parameters and Physico-Chemical Quality. *International Journal of Chemical Studies*, **8**, 4002-4009. https://doi.org/10.22271/chemi.2020.v8.i4ay.10274

[20] Tiencheu, B., Claudia Egbe, A., Achidi, A.U., Ngongang, E.F.T., Tenyang, N., Tonfack Djikeng, F., *et al.* (2021) Effect of Oven and Sun Drying on the Chemical Properties, Lipid Profile of Soursop (*Annona muricata*) Seed Oil, and the Functional Properties of the Defatted Flour. *Food Science & Nutrition*, **9**, 4156-4168. https://doi.org/10.1002/fsn3.2380

[21] Xu, X., Wang, Y., Zhou, Y., Xu, Y., Zhang, M., Zhang, C., *et al.* (2024) Effects of Natural and Mechanical Drying Processes on Unsaturated Fatty Acids, Vitamin E, Estradiol, and Physicochemical Properties of *Rana chensinensis* Ovum. *Food Production, Processing and Nutrition*, **6**, Article No. 62. https://doi.org/10.1186/s43014-023-00217-1

[22] Candra Dewi, D., Mahdi, C., Sulistyarti, H. and Aulanniam, A. (2024) Alternative

Techniques for Animal Fat Authentication Based on Microscopic Crystal Pattern and Fatty Acid Composition Using Gas Chromatography-Mass Spectrometry (GC-MS). *The Journal of Pure and Applied Chemistry Research*, **13**, 102-116. https://doi.org/10.21776/ub.jpacr.2024.013.02.3351

[23] Ivanova, M., Hanganu, A., Dumitriu, R., Tociu, M., Ivanov, G., Stavarache, C., *et al.* (2022) Saponification Value of Fats and Oils as Determined from 1H-NMR Data: The Case of Dairy Fats. *Foods*, **11**, Article 1466. https://doi.org/10.3390/foods11101466

[24] FAO/WHO (2001) Fats and Oil and Related Products, Food Standard Program. Codex Alimentarius Commission. Food and Agriculture Organization of United Nations. 33-35. https://www.fao.org/4/y2774e/y2774e00.htm

[25] Shen, Y., Lu, T., Liu, X., Zhao, M., Yin, F., Rakariyatham, K., *et al.* (2020) Improving the Oxidative Stability and Lengthening the Shelf Life of DHA Algae Oil with Composite Antioxidants. *Food Chemistry*, **313**, Article ID: 126139. https://doi.org/10.1016/j.foodchem.2019.126139

[26] Mihaylova, D., Gandova, V., Deseva, I., Tschuikowa, S., Schalow, S. and Westphal, G. (2020) Arrhenius Equation Modeling for the Oxidative Stability Evaluation of Echium Oil Enriched with a Natural Preservative. *European Journal of Lipid Science and Technology*, **122**, Article ID: 2000118. https://doi.org/10.1002/ejlt.202000118

[27] FAO and WHO (2009) Report of the 21st Session of the Codex Alimentarius Committee on Fats and Oils.

[28] Omosuli, S.V., Oloye, D.A. and Ibrahim, T.A. (2017) Effect of Drying Methods on the Physicochemical Properties and Fatty Acid Composition of Moringa Seeds Oil. *Archives of Food and Nutritional Science*, **1**, 27-32. https://doi.org/10.29328/journal.afns.1001005

[29] Novidzro, K.M., Wokpor, K., Fagla, B.A., Koudouvo, K., Dotse, K., Osseyi, E., *et al.* (2019) Etude de quelques paramètres physicochimiques et analyse des éléments minéraux, des pigments chlorophylliens et caroténoïdes de l'huile de graines de *Griffonia simplicifolia*. *International Journal of Biological and Chemical Sciences*, **13**, 2360-2373. https://doi.org/10.4314/ijbcs.v13i4.38

[30] Umeda, W.M. and Jorge, N. (2021) Oxidative Stability of Soybean Oil Added of Purple Onion (*Allium cepa* L.) Peel Extract during Accelerated Storage Conditions. *Food Control*, **127**, Article ID: 108130. https://doi.org/10.1016/j.foodcont.2021.108130

[31] Etong, D.I., Mustapha, A.O. and Taleat, A.A. (2014) Physicochemical Properties and Fatty Acid Composition of Dikanut (*Irvingia gabonensis*) Seed Oil. *Research Journal of Chemical Sciences*, **4**, 70-74.

[32] Codex Alimentarius (2009) Normes alimentaires Internationales pour les huiles végétales portant un nom spécifiques CODEX STAN 210-1999.

[33] Conseil Oléicole International (2011) Norme commerciale applicable aux huiles d'olive et aux huiles de grignons d'olive. T. 15/NC nº 3/Rév. 6. 17p. Conversion and Management, 40, 657-667. https://www.internationaloliveoil.org/wp-content/uploads/2022/05/COI-T15-NC3-Rev.-6-Novembre-2011-Fr.pdf

[34] Saheed, A., Michael, A., Abiodum, A. and Adekunle, A. (2017) Chemical Composition and Industrial Benefits of Dikanut (*Irvingia gabonensis*) Kernel Oil: A Review. *Nutrition & Food Sciences*, **47**, 741-751.

[35] Schuck, P. (2011) Modifications des propriétés fonctionnelles des poudres de protéines laitières: Impact de la concentration et du séchage. *Innovations Agronomiques*, **13**, 71-99.

[36] Cuq, L. (2006) Technologie des protéines. Université de Montpellier, 289 p.

[37] Koumba Ibinga, S.K., Cerny, M., Lacroux, E., Fabre, J., Valentin, R., Merah, O., *et al.* (2022) Extraction and Physicochemical Composition of *Irvingiagabonensis* Almond Oil: A Potential Healthy Source of Lauric-Myristic Oil. *Separations*, **9**, Article 207. https://doi.org/10.3390/separations9080207

[38] Singh, R., Langyan, S., Sangwan, S., Rohtagi, B., Khandelwal, A. and Shrivastava, M. (2022) Protein for Human Consumption from Oilseed Cakes: A Review. *Frontiers in Sustainable Food Systems*, **6**, Article 856401. https://doi.org/10.3389/fsufs.2022.856401

[39] Langyan, S., Yadava, P., Khan, F.N., Dar, Z.A., Singh, R. and Kumar, A. (2022) Sustaining Protein Nutrition through Plant-Based Foods. *Frontiers in Nutrition*, **8**, Article 772573. https://doi.org/10.3389/fnut.2021.772573

[40] Mgbemena, N.M., Ilechukwu, I., Okwunodolu, F.U., Chukwurah, J.O. and Lucky, I.B. (2019) Chemical Composition, Proximate and Phytochemical Analysis of *Irvingia gabonensis* and *Irvingia wombolu* Peels, Seed Coat, Leaves and Seeds. *Ovidius University Annals of Chemistry*, **30**, 65-69. https://doi.org/10.2478/auoc-2019-0012

[41] Ewere, E., Etim, O. and Usunobun, U. (2016) Proximate Composition, Mineral Content and Amino Acid Profile of *Irvingia gabonensis* O'Rorke Baill Leaf. *International Journal of Scientific World*, **5**, 23-27. https://doi.org/10.14419/ijsw.v5i1.6969