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Effect of Grinding Baobab Seeds (*Adansonia digitata* L.) on the Quality of Screw Pressed Oils

Alioune Sow[1,2,3*], Oumar Ibn Khatab Cissé[3,4], Edouard Mbarick Ndiaye[3,5], Médoune Gaye Sarr[3,6], Bou Ndiaye[3,7], Omar Touré[3], Khadim Niane[3,4], Pape Guédel Faye[3,5], Nicolas Ayessou[3,5], Mady Cissé[3,5]

[1]Laboratoire des Sciences Biologiques, Agronomiques, Alimentaires et de Modélisation des Systèmes Complexes (LaBAAM), Saint-Louis, Sénégal
[2]UFR des Sciences Agronomiques, de l'Aquaculture et des Technologies Alimentaires (S2ATA), Université Gaston Berger de Saint-Louis, Saint-Louis, Sénégal
[3]Laboratoire Eau, Energie, Environnement et Procédés Industriels (L3EPI), Ecole Supérieure Polytechnique, Université Cheikh Anta Diop, Dakar, Sénégal
[4]Ecole Nationale Supérieure d'Agriculture (ENSA), Thiès, Sénégal
[5]Centre d'études sur la sécurité alimentaire et les molécules fonctionnelles (CESAM)-ESP/UCAD, Dakar, Sénégal
[6]Polytechnic Diamniadio, Université Amadou Mahtar Mbow, Dakar, Sénégal
[7]UFR des Sciences Fondamentales de l'Ingénieur (SFI), Université du Sine Saloum El-Hâdj Ibrahima Niass, Kaolack, Sénégal
Email: *alioune.sow@ugb.edu.sn

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Abstract

Baobab oil (*Adansonia digitata* L.) is highly valued in the cosmetic and pharmaceutical sectors and holds significant global economic potential. However, various factors can influence its composition. Consequently, optimizing pressing conditions is essential to increase extraction yield and preserve oil quality. This study aims to evaluate how the particle size of ground baobab seeds affects extraction efficiency and the quality of oil obtained using a screw press. To this end, three types of ground seed samples were prepared from a batch originating in Bignona and used for cold-press extraction with a single-screw press. The results show oil contents in the filtrate of 62.72% ± 1.52% and 76.76% ± 0.60% for particle size ranges of 0 - 1000 µm and 1000 - 2500 µm, respectively. However, particles larger than 2500 µm did not allow for oil drainage and extrusion. Furthermore, the residual oil content in the press cake was higher for particles smaller than 1000 µm (29.17 ± 1.64%) than for those in the 1000 - 2500 µm range (7.50% ± 1.13%). The unsaponifiable matter content and the iodine, peroxide, saponification, and acid values for oils extracted from the fine and medium fractions were 1.687% and 1.751%, respectively; 90.49 and 89.53 mg $I_2 \cdot 100g^{-1}$; 5.48 and 5.69 $mEq \cdot kg^{-1}$; 210.07 and 212.63 mg $KOH \cdot g^{-1}$; 0.72 and 0.85. Overall, these results demonstrate the impact of the grinding process on the key characteristics of the extracted oil and provide

avenues for improving the extraction process.

Keywords

Adansonia digitata L., Pressing, Oil, Unsaponifiables, Physicochemical Characteristics

1. Introduction

The genus *Adansonia*, belonging to the subfamily Bombacoideae (family Malvaceae), comprises eight species of large trees [1] [2]. Six species are endemic to Madagascar, while the other two are found in mainland Africa and Australia [3]-[6]. Indeed, various parts of the baobab tree have long been used by local populations for food, medicinal, cultural, and economic purposes [6]-[11]. The pulp accounts for 20% of the baobab fruit, while the remaining 80% consists of the shell, the fibers surrounding the seeds, and the seeds themselves [12]. Baobab seeds make up more than half the mass of the shelled fruit and are underutilized compared to the pulp [3] [4]. They contain lipid levels of approximately 12.2% [13]. Baobab oil is rich in palmitic, stearic, oleic, and arachidic acids, as well as tyrosol, hydroxytyrosol, and caffeic acid [14]. Furthermore, the presence of polyphenols, phytosterols, and tocopherols contributes to the antioxidant and therapeutic properties of baobab oil [2] [9] [14] [15]. Additionally, the oil is known for its high permeability, skin-nourishing properties, emollient nature, and ability to soften the skin and scalp [16] [17]. In the industrial sector, cold-press extraction is the most widely used method for producing baobab oil [18] [19]. However, the extraction yield for cold-pressed baobab oil is very low-approximately 6.28% [19]. This low yield results in significant lost revenue for manufacturers. Indeed, this extraction method requires preliminary seed pretreatment steps, which are demanding in terms of physical effort, water and electricity consumption, and time. Consequently, there is a need to implement a new process to improve extraction yield, reduce production costs, and preserve the quality of the extracted oil. Against this backdrop, our study aims to evaluate how the particle size of ground baobab seeds influences extraction efficiency and the quality of oil extracted using a single-screw press.

2. Materials and Methods

2.1. Plant Material and Pre-Treatments

The fruits were collected in the locality of Bignona (12˚45'0" North, 16˚30'0" West) in southern Senegal. The depulped seeds were washed and then oven-dried at 65˚C ± 1˚C for 24 hours. A total mass of 25 kg was required for oil production. Washing the seeds involved using approximately 50 liters of water and a total of 2 hours of soaking and mixing. The seeds from the various batches were ground using a millet mill. This mill, featuring steel components 3 to 5 mm thick, was manufactured in Senegal and has a capacity of 300 - 350 kg/h. It is powered by a

7.5 CV electric motor operating at 2800 rpm. A 25 kg capacity hopper mounted on top feeds seeds into the grinding chamber via a manually adjustable flow mechanism. Inside the grinding chamber, the seeds are crushed against the walls of the screen (2 mm mesh) by five hammers rotating at 4800 rpm. The resulting ground material is collected in a basin and subsequently used in the oil extraction process via pressing.

2.2. Oil Extraction by Pressing

Baobab oil extraction was carried out using a mechanical press (DD85G, IBG Monforts Oekotec GmbH, Mönchengladbach, Germany). A 10 mm die was used throughout the extraction process, and a rotation speed of 25 rpm was maintained. The discharge head temperature was also kept at 105˚C throughout the operation. Prior to extraction, the discharge head was heated to this temperature for approximately 25 minutes. At the end of the process, the resulting crude baobab oil was a mixture of oil and gummy impurities. The crude oil was immediately bottled and stored for 2 days. With each particle size class, the pressing operation was carried out between three and six times.

2.3. Methods

2.3.1. Particle Size Analysis

The particle size distribution of the seeds ground using the millet mill was determined by sieving. A sieve shaker (RETSCH AS 200 Digit, Germany) was used for this purpose; this device allows for the adjustment of vibration frequency and duration. The sieves selected for this study had diameters of 2500, 2000, 1600, 1250, 1000, 630, 500, 315, and 160 µm. A 500 g sample was used for each run of the analysis. The vibration frequency for the stacked sieves was set to 50 Hz, and the duration was set to eight (8) minutes. Following sieving, the resulting fractions were weighed sequentially using a balance with a precision of 10^{-5} g. Analyses were performed in triplicate for each sample.

2.3.2. Determination of the Sludge and Oil Content of the Filtrate

The sludge content of the crude oils obtained by pressing was determined gravimetrically. Specifically, the oil obtained after extraction, initially held in a plastic bottle, was allowed to stand for several days to permit sedimentation. Following decantation, the oil was transferred to new bottles and centrifuged (Hettich Zentrifugen, Germany) at 4500 rpm for 10 minutes. The resulting oil was stored at 4˚C prior to analysis. The clarified oil and the solid fractions separated by decantation were weighed. Thus, the sludge content of the filtrate ($\boldsymbol{T_{sc}}$) is expressed by Equation (1):

$$T_{sc}(\%) = \frac{m_s}{m_{co}} \times 100 \quad (1)$$

where $\boldsymbol{m_s}$ is the mass of solid residues (g) and $\boldsymbol{m_{co}}$ is the mass of crude oil (g).

However, the oil content of the filtrate ($\boldsymbol{T_{fc}}$) corresponds to the ratio of the

mass of clarified oil to that of the crude oil extracted by pressing. It is expressed by Equation (2):

$$T_{fc}(\%) = \frac{m_{clo}}{m_{co}} \times 100 \quad (2)$$

where m_{clo} the mass of clarified oil (g) and m_{co} is the mass of crude oil (g).

Therefore, the efficiency of pressing corresponds to the ratio between the oil yield and the oil content of the filtrate.

2.3.3. Physicochemical Analyses

The physicochemical characteristics (extraction yield, density, acidity, peroxide value, acid value, refractive index, iodine value, saponification value, and color index) of the extracted oils were determined to gather information for promoting their use in pharmaceutical and/or industrial applications. The saponification value was determined according to the French norm NF T60-206; the acid value according to norm NF T60-204; the iodine value according to the French norm NF T60-203; the peroxide value according to the French norm NF T60-220; and the extraction yield of baobab seeds according to the Soxhlet extraction method (NF V03-905). The refractive index was measured using a refractometer (EXACTA-OPTECH, Mod-RMT, Munich, Germany). A colorimeter (CM-5, Konica Minolta Sensing Americas Inc., USA) was used to determine the color parameters L*, a*, b*, Y1, c*, and h for the various oils. The L* component, indicating lightness or luminance, ranges from black to white; the a* component corresponds to the green-red opponent pair; the b* component corresponds to the blue-yellow opponent pair; and Y1, c*, and h correspond to the yellowness index, chromaticity, and hue, respectively. Acidity, expressed as a percentage of oleic acid, was calculated from the acid value. The unsaponifiable matter content was determined according to the French norm NF T60-205.

2.4. Statistical Analysis

To compare the means, variance analyses with the Fisher LSD test at the 5% significance level were also performed. Thus, all analyses were carried out with R software (version 4.4.3, 2025). Furthermore, the reported values represent standard deviations or standard errors.

3. Results and Discussion

3.1. Particle Size Distribution

The ground baobab seed sample used for extraction exhibits a similar particle size distribution. This distribution is bimodal, with mean particle sizes of 630 µm and 2500 µm. Furthermore, the grinding process yielded a large quantity of particles larger than 2000 µm. Across the various samples used, particles ranging from 1000 to 2500 µm in size account for 39.2% to 45.1% of the weighed mass. Additionally, particles larger than 2500 µm represent 22.8% to 27.3% of the ground material. Conversely, the finest particles, those ranging from 0 to 1000 µm, make up a

smaller proportion (27.8% to 38.0%) of the various ground seed samples.

3.2. Effect of Particle Size on Oil Extraction

To evaluate the impact of grinding baobab seeds on pressing efficiency, three particle size classes were established. The parameters (oil content, fines content, residual oil content, yield, and pressing efficiency) determined for these three particle sizes are listed in Table 1.

Table 1. Effect of particle size on baobab oil extraction.

Parameters (%)	0 < Pd < 1000 µm	1000 ≤ Pd < 2500 µm	Pd ≥ 2500 µm
Oil content of the filtrate (T_{fc})	$62.72^{a} \pm 1.52$	$76.76^{b} \pm 0.60$	0
Sludge content of the filtrate (T_{sc})	$37.29^{b} \pm 1.52$	$23.25^{a} \pm 0.60$	0
Residual oil content	$29.17^{b} \pm 1.64$	$7.50^{a} \pm 1.13$	0
Oil yield	$2.70^{a} \pm 0.07$	$13.58^{b} \pm 0.59$	0
Pressing efficiency	$8.03^{a} \pm 0.21$	$62.67^{b} \pm 1.23$	0

On the same line, means bearing the same letter are not significantly different at the 5% threshold. Pd: Particle diameter.

These results show that particle samples with a size range of 0 - 1000 µm and 1000 - 2500 µm yield filtrate oil contents of 62.72% ± 1.52% and 76.76% ± 0.60%, respectively. However, particles larger than 2500 µm do not allow for oil drainage and extrusion. Indeed, the fraction with a particle size of 2500 µm or greater consisted primarily of hulls. Being quite hard, these hulls clog the die, thereby preventing the discharge of the press cake under these operating conditions. Several studies have highlighted that, depending on the type of seeds and mechanical presses used, optimal amounts of hulls and moisture facilitate grinding, pressing, and oil extrusion [20]-[22]. Furthermore, the oil extraction yields were 2.70% ± 0.07% and 13.58% ± 0.59% for particles with sizes between 0 - 1000 µm and 1000 - 2500 µm, respectively. The extraction rate is superior for the 1000 - 2500 µm range, as the residual oil content in the press cake is higher for particles smaller than 1000 µm (29.17% ± 1.64%) than for those in the 1000 - 2500 µm range (7.50% ± 1.13%). This difference in oil yields can reasonably be attributed to an optimal quantity of hulls, which facilitates better drainage, or even expulsion, of the oil from the crushed baobab seeds. Indeed, sieving would tend to alter the shell/almond proportions as well as the particle size. To optimize the process based on particle size, it would be advisable to utilize the 1000 - 1500 µm, 1500 - 2000 µm, and 2000-2500 µm ranges.

3.3. Effect of Particle Size on the Quality of Extracted Oils

3.3.1. Effect on Physical Properties

For both extracted oils, the parameters studied were refractive index and color. The results obtained are presented in Table 2. They indicate that particle size has no influence on the refractive index; indeed, the refractive index was 1.4648 ±

0.0003 for both extracted oils. These results suggest that the two oils contain similar levels of long-chain fatty acids and share the same degrees of purity, unsaturation, and conjugation [23]. These measured values are higher than those reported in the literature for baobab oils [24]-[26]. The iodine values (89.53 ± 0.98 and 90.49 ± 0.79) and refractive index (1.4648 ± 0.0003) obtained indicate that these oils are non-drying and comparable to olive oil, which has an iodine value of 81.23 ± 0.40 and a refractive index of 1.471 ± 0.001 [27].

Table 2. Physicochemical properties of oils extracted from baobab seeds of different particle sizes.

Parameters	0 < Pd < 1000 µm	1000 ≤ Pd < 2500 µm
Refractive index	1.4648^{a} ± 0.0003	1.4648^{a} ± 0.0003
Saponification value (mgKOH·g^{-1})	210.07^{a} ± 1.39	212.63^{a} ± 0.41
Peroxide value (mEq·kg^{-1})	5.48^{a} ± 1.02	5.69^{a} ± 0.24
Acid value (mgKOH·g^{-1})	0.72^{a} ± 0.05	0.85^{a} ± 0.06
Iodine value (mgI$_2$·100g^{-1})	90.49^{a} ± 0.79	89.53^{a} ± 0.98
Unsaponifiable content (%)	1.687^{a} ± 0.140	1.751^{a} ± 0.192
L*	95.58^{b} ± 0.06	96.32^{a} ± 0.01
a*	-12.70^{b} ± 0.05	-11.64^{a} ± 0.01
b*	90.54^{b} ± 0.08	106.92^{a} ± 0.03
Y1	85.15^{b} ± 0.05	91.01^{a} ± 0.01
c*	91.43^{b} ± 0.08	107.55^{a} ± 0.03
h	97.98^{a} ± 0.03	96.21^{b} ± 0.00

In the same row, means sharing the same letter do not differ significantly at the 5% level.

Table 2 shows that particle size affects the color of cold-pressed oils. Analysis of variance indicates significant differences (at the 5% level) among these color indices. Specifically, the color parameters L*, a*, b*, Y1, c*, and h for oils derived from particles sized 0 - 1000 µm and 1000 - 2500 µm are 95.58 and 96.32; −12.70 and −11.64; 90.54 and 106.92; 85.15 and 91.01; 91.43 and 107.55; and 97.98 and 96.21, respectively. The L* parameter, which reflects sample lightness, indicates that the oil obtained from the intermediate fraction (1000 ≤ Dp < 2500 µm) reflects more light. Furthermore, the b* color parameter, indicating the color shade between blue and yellow, is higher for the oil from this fraction. The Y1 yellowness index confirms this more pronounced yellow coloration. Consequently, this oil likely contains a higher level of carotenoids; indeed, Borchani *et al.* [27] and Shao *et al.* [28] established a positive correlation between carotenoid content and the yellow coloration of oils.

3.3.2. Effect on Chemical Properties

The chemical properties of baobab oils extracted from the fine fraction (0 ≤ Dp < 1000 µm) and the medium fraction (1000 ≤ Dp < 2500 µm) are listed in Table 2.

The unsaponifiable content and the iodine, peroxide, saponification, and acid values for oils extracted from the fine and medium fractions are, respectively: 1.687% and 1.751%; 90.49 and 89.53 mg $I_2 \cdot 100g^{-1}$; 5.48 and 5.69 $mEq \cdot kg^{-1}$; 210.07 and 212.63 mg $KOH \cdot g^{-1}$; and 0.72 and 0.85. The unsaponifiable fraction of baobab oil consists of non-saponifiable molecules such as carotenoids, tocopherols, and phytosterols. This content is higher in the $1000 \leq Dp < 2500$ µm fraction. Consequently, the oil extracted from this medium fraction likely possesses greater biological activity than the oil extracted from the fine fraction; indeed, studies on the unsaponifiable fraction of olive oil have demonstrated antioxidant and anti-inflammatory properties [29]. These unsaponifiable levels correlate with the yellowness index, which reflects the carotenoid content of the oils. The iodine value, used to assess the degree of unsaturation of a vegetable oil and its stability during storage, was not significantly affected by particle diameter.

Indeed, analysis of variance indicates no significant difference in iodine values at the 5% level. Consequently, these oils, being very rich in unsaturated fatty acids, would be less resistant to oxidation and would also have shorter shelf lives. Iodine values below 100 mg $I_2 \cdot 100g^{-1}$ classify the extracted baobab oils as non-drying oils. The peroxide value, which measures the degree of unsaturated fatty acid oxidation and oil deterioration during extraction and/or storage, is very low for both baobab oils. Indeed, the oxidation of vegetable oils leads to the formation of hydroperoxides, the primary products of oxidation. Thus, the peroxide value is defined as the amount of active peroxide oxygen (in grams) contained in one gram of fat that is capable of oxidizing potassium iodide to release iodine. The table shows that particle size did not significantly affect the oxidation state of the oils during pressing. The peroxide values obtained are below the 10 $mEq \cdot kg^{-1}$ limit set by the *Codex alimentarius* [30] for refined oils. The relatively high peroxide values (5.48 ± 1.02 $mEq \cdot kg^{-1}$ and 5.69 ± 0.24 $mEq \cdot kg^{-1}$) are likely attributable to the temperature reached by the screw head during screw-press extraction. The acid value reflects the degree of oil degradation by measuring the amount of free fatty acids formed during extraction and/or storage. The very low values obtained were 0.72 ± 0.05 mg $KOH \cdot g^{-1}$ and 0.85 ± 0.06 mg $KOH \cdot g^{-1}$ for the fine fraction ($0 \leq Dp < 1000$ µm) and the medium fraction ($1000 \leq Dp < 2500$ µm), respectively. Analysis of variance revealed no significant differences at the 5% level. Furthermore, the recorded acid values are well below the 4 mg $KOH \cdot g^{-1}$ limit required by the cosmetics industry [31] and the 0.6 limit for refined edible oils [30]. However, screw-press oil extraction promotes an increase in phosphorus and free fatty acid content, as well as improved oxidative stability [32]. The saponification value corresponds to the mass (in milligrams) of potassium hydroxide (KOH) required to saponify the fatty acids in one gram of fat. The determined saponification values were 210.07 ± 1.39 mg $KOH \cdot g^{-1}$ and 212.63 ± 0.41 mg $KOH \cdot g^{-1}$ for the fine fraction ($0 \leq Dp < 1000$ µm) and the medium fraction ($1000 \leq Dp < 2500$ µm). However, analysis of variance reveals no significant difference at the 5% level. The high saponification values indicate a strong potential for using baobab oil in soap making.

4. Conclusion

This study demonstrates that particle size influenced extraction yield and cold-pressing efficiency. Specifically, for particles ranging from 1000 to 2500 μm, the oil content of the filtrate and the oil yield were 76.76% and 13.58%, respectively. Conversely, a particle size exceeding 2500 μm, consisting primarily of relatively hard shells, prevented oil drainage and extrusion; this particle size clogged the die and obstructed the discharge of the press cake. Furthermore, the pressing process proved efficient within the 1000 - 2500 μm range, while also preserving the oil's physicochemical characteristics. Consequently, this study could help improve cold-pressing extraction conditions for baobab seeds, benefiting both industry and consumers. However, future research should focus on optimizing shell and impurity levels as well as operating conditions to increase extraction yield and reduce residual oil content in the press cake.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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