

Monitoring Fatty Acid Profile and Polyphenol Content During Baobab's Oil Storage

Alioune Sow^{1,2,3,*}, Oumar Ibn Khatab Cissé^{3,4}, Edouard Mbarick Ndiaye³, Pape Guédel Faye^{3,6},
Delphine Margout-Jantac⁵, Samba Baldé³, Khadim Niane³, Patrick Poucheret⁵, Nicolas Ayessou^{3,6}, Mady Cissé^{3,6}

¹Laboratoire des Sciences Biologiques, Agronomiques, Alimentaires et de Modélisation des Systèmes Complexes (LaBAAM)

²UFR des Sciences Agronomiques, de l'Aquaculture et des Technologies Alimentaires (S2ATA), Université Gaston Berger de Saint-Louis, Route de Ngallèle, BP 234, Saint-Louis, Sénégal

³Laboratoire Eau, Energie, Environnement et Procédés Industriels (L3EPI), Ecole Supérieure Polytechnique, Université Cheikh Anta Diop, S-10700, Dakar-Fann, Sénégal

⁴Ecole Nationale Supérieure d'Agriculture (ENSA), Thiès, Sénégal

⁵Qualisud, Univ Montpellier, Avignon Université, CIRAD, Institut Agro, IRD, Université de La Réunion, 34093 Montpellier, France

⁶Centre d'études sur la sécurité alimentaire et les molécules fonctionnelles (CESAM)-ESP/UCAD

*Corresponding author: alioune.sow@ugb.edu.sn

Received August 19, 2025; Revised September 21, 2025; Accepted September 29, 2025

Abstract The objective of the study is to investigate the influence of baobab seed pretreatment operations, origin and type of packaging on the stability of baobab oils during the storage period at room temperature. Therefore, the fatty acid, tyrosol, hydroxytyrosol and caffeic acid contents of the oils extracted by cold pressing were evaluated. The results reveal an increase in the saturated fatty acid content and a decrease in the unsaturated and cyclic fatty acid contents. Indeed, after 14 months of storage at room temperature, unsaturated fatty acid losses varied with oils extracted from UKS (7.89 to 9.65%), UZS (0.89 to 4.18%), WBS (1.29 to 1.48%) and UBS (1.36 to 1.94%). However, cyclic fatty acid contents increased for oils from UKS (0.87% and 0.89%), UZS (0.77% and 1.36%), WBS (0.75% and 1.28%) and UBS (0.58% and 1.6%). Furthermore, the results show that the caffeic acid content of UKS oils packaged in amber bottles (0.590 ± 0.322 mg.L⁻¹) was slightly higher than those in transparent bottles (0.471 ± 0.139 mg.L⁻¹). A correlation analysis between the fatty acid and phenolic compound contents of the oils at the end of storage was carried out. Also, a principal component analysis on the composition of the identified and monitored compounds of the oils at the end of storage was also carried out. These results indicate the use of baobab fruit seeds collected in the Ziguinchor locality, and the packaging of the extracted oils in amber bottles.

Keywords: *Adansonia digitata* L., seeds, extraction, pressure, oil, storage, stability

Cite This Article: Alioune Sow, Oumar Ibn Khatab Cissé, Edouard Mbarick Ndiaye, Pape Guédel Faye, Delphine Margout-Jantac, Samba Baldé, Khadim Niane, Patrick Poucheret, Nicolas Ayessou, and Mady Cissé, "Monitoring Fatty Acid Profile and Polyphenol Content During Baobab's Oil Storage." *American Journal of Food Science and Technology*, vol. 13, no. 5 (2025): 122-129. doi: 10.12691/ajfst-13-5-3.

1. Introduction

The baobab (*Adansonia digitata* L.) is one of the most widespread and recognizable woody species [1,2]. This species is found in semi-arid and sub-humid regions south of the Sahara, with the exception of Liberia, Uganda, Djibouti, and Burundi [1,2,3]. In southern Africa, the wild baobab population is estimated at 28 million trees, with a total fruit production of between 190,104 and 712,890 tons per year [4,5]. Baobab fruit pulp has the potential to generate a billion dollars in Africa annually [5]. In Senegal, *Adansonia digitata* L. stands are found throughout the country [3] and fruit production was estimated at 2,940 tons in 2005, representing an economic value of 264.6 million FCFA [6]. Baobab seeds, long used in African traditional and culinary pharmacopoeia, are very rich in proteins, lipids, minerals, amino acids,

vitamins and phenolic compounds [7,8,9,10,11,12]. Baobab seed oils are very rich in palmitic, stearic, oleic and arachidic acids and in tyrosol, hydroxytyrosol and caffeic acid [13]. In recent years, this oil has been highly sought after by the pharmaceutical and cosmetic industries. Indeed, it is highly recognized for its antioxidant and emollient properties, its protective effects and its softening abilities on the skin and scalp [14]. In addition, this oil is an excellent source of unsaturated fatty acids. It mainly contains palmitic, oleic and linoleic acids [3,8,15]. Compared to other oils (sesame, peanut and olive), baobab oil is richer in palmitic and linoleic acids, and contains less oleic acid [16,17,18]. However, studies on the stability assessment of bioactive compounds in cold-pressed baobab oils packaged in different bottles and stored at room temperature for several months are almost nonexistent. Thus, the objective of this study is to investigate the effects of extraction processes, origin, packaging and duration on the fatty acid and phenolic

compound contents of baobab seed oils.

2. Material and Methods

2.1. Plant Material and Pre-treatments

The plant material consisted of baobab (*Adansonia digitata* L.) seeds from fruits collected at three locations: seeds from Kougueul (13°58'60" N and 14°48'0" W), Ziguinchor (12°33'50" N and 16°15'50" W) and Bignona (12°48'18" N and 16°14'4" W), Senegal. Three (3) batches of 50 kg of seeds from each source were used for oil extraction. Each batch was divided into two equal parts: 25 kg unwashed seeds and 25 kg washed seeds. Approximately 150 liters of water at room temperature (25°C) were used to wash the 75 kg of seeds, which were soaked and mixed for a total of two (2) hours. After washing, the seeds were dried in an oven at 65°C ± 1 °C for 24 hours. Six (6) samples of 25 kg of seed were then taken. The seeds from the different lots were ground separately in a mill and passed through a 1 mm mesh sieve.

2.2. Oil Extraction by Pressing

The baobab oil was extracted using a mechanical press (DD85G, IBG Monforts Oekotec GmbH, Mönchengladbach, Germany). The 10 mm spinner was used throughout the extraction, and the rotation speed of 25 rpm was maintained. The outlet head temperature was also maintained at 105°C throughout the procedure. The outlet head was previously heated to this temperature for approximately 25 minutes at the start of the extraction process. At the end of the extraction, the product obtained was a mixture of oil with rubbery impurities. The crude oil was immediately bottled in amber bottles for two days. After decanting, the oil was transferred to new bottles and centrifuged using a centrifuge (Hettich, Zentrifugen, Germany) at 4500 rpm for ten (10) minutes. The baobab oil obtained was stored at 4°C before analysis.

2.3. Physicochemical Analysis

2.3.1. Chemicals Reagents

In this section, all the reagents used were of analytical quality. These reagents were methanol, water and acetonitrile of HPLC quality, ammonium formate, formic acid, cyclohexane, hexane and potassium hydroxide. These reagents were also purchased from Sigma (St. Louis, MO, USA).

2.3.2. Fatty Acids Composition

2.3.2.1. Methyl Esters Méthyliques Préparation

To convert the oils to fatty acid methyl esters, 2 mL of hexane was added to a 20 µL volume of baobab oil. To this solution 100 µL of a 3 M methanolic solution of potassium hydroxide (KOH) was added and stirred at 40 rpm for five (5) minutes. After this stirring period the mixture was allowed to stand until a clear hexane phase was obtained. Gas chromatography was used to identify and quantify the fatty acids.

2.3.2.2. Analysis by Gas Chromatography- Mass Spectroscopy (GC -MS)

Fatty acids were analyzed using a gas chromatograph (Trace GC electron) coupled to a mass spectrometer (ISQ, Thermo Finnigan, Thermo Scientific, USA). The stationary phase is a capillary silica column SGE-BPX5 (30 m × 0.25 mm i.d., 0.25 µm thick). The mobile phase (carrier gas), consisting of helium (He), was injected at a flow rate of 1 mL.min⁻¹ in split 1/20 mode. For GC-MS detection, the ionisation energy was 70 eV in electron impact (EI) mode. The transfer and ion source temperatures were 200°C and 300°C, respectively. The oven temperature was set at 120°C for 20 minutes and then increased to 275°C at a rate of 5°C per minute. After dilution of the prepared methyl esters (1/20, v/v, in CHCl₃), a volume of 1 µL was injected into the GC-MS chromatograph in split mode. The m/z mass spectra were determined with ratios between 45 and 600. The total retention time was 60 min. Peak integration and chromatographic data processing were performed using Thermo Xcalibur software. Computer superposition of the mass spectra obtained with those of the standards and the NIST MS Search 2.0 spectral library allowed the identification of the compounds in baobab oil.

2.3.3. Polyphenol Composition

2.3.3.1. LC-UV Analysis

The LC-UV analyses were performed on a Shimadzu LC 20AD instrument consisting of a quaternary pump, a solvent degasser, a thermostat column with a ZORBAX® SB-Phenyl column (250 mm × 4.6 mm, 5 µm) and an autosampler connected to an SPD-M20A DAD detector. LabSolutions LCMS software (Shimadzu) was used to evaluate the chromatograms. The chromatographic and UV conditions were optimised to obtain the appropriate sensitivity for the analysis of polyphenols as tyrosol (λ_{max} = 279 nm) or caffeic acid (λ_{max} = 325 nm). The mobile phase, consisting of a mixture of acetonitrile (solvent A) and 3 mM formate buffer, pH 3 (solvent B), was injected at a flow rate of 1 mL.min⁻¹. Chromatographic analysis was performed at 30 °C and the volume injected into the chromatographic system was 20 µL. Table 1 shows the variation in the proportions of solvents A and B.

Table 1. Elution gradient (%) for HPLC-UV analysis

Time (min)	Solvent A (%)	Solvent B (%)
0	0	100
4	0	100
12	60	40
15	60	40
16	100	0
18	100	0
19	0	100
20	0	100

2.3.3.2. Sample Preparation

The phenolic fraction of baobab oils was obtained by liquid-liquid extraction. A mass of 2.0 g of baobab oil weighed to the nearest 0.0001 g in a test tube. A volume of 1 mL of cyclohexane was added to the tube and

vortexed for 10 seconds. Three (3) mL of methanol was then added, and the mixture was mechanically stirred (Stuart SB3 rotator) for 5 minutes. The tube containing the mixture was immediately uncapped and centrifuged (P. Slecta centro 8-BL) at 1000 rpm for ten (10) minutes. The methanolic phase was then collected with a glass pasteur pipette and dried under a gentle nitrogen stream at 50°C and 50 kPa pressure. The final dry residue was taken up with 0.5 mL of mobile phase (acetonitrile/formate buffer). With gentle vortexing, the new mixture was withdrawn with a syringe and then filtered. This filtration was performed on Acrodisc (Pall GHP, Membrane Acrodisc 13 mm, Syringe Filter) 0.45 µm. To analyse the phenolic fraction, a volume of 200 µL was added to a vial with an insert.

2.4. Statistical Analysis

Principal component analysis (PCA) and hierarchical classification were performed on the data for acids and phenolic compounds in oils to find the best correlations between the random variables. Analyses of variance using Fisher's LSD test at 5% significance level were also performed to compare means. All analysis were performed using R software (version 4.4.3, 2025).

3. Results and Discussion

3.1. Evolution of Fatty Acid Contents

Table 2 lists the fatty acid contents of baobab oils at the beginning and end of storage at room temperature. For all species considered, vegetable oils differ in their fatty acid composition [19]. This fatty acid composition remains a factor characterizing the susceptibility of vegetable oils to oxidation [20]. This table indicates that the fatty acid composition varies in all baobab oils. It also shows an increase in the content of saturated fatty acids and a decrease in the contents of unsaturated and cyclic fatty acids. This decrease concerned oleic, linoleic, malvalic, stearic and cis-10-nonadecenoic acids. The quantities of unsaturated fatty acids, particularly oleic and linoleic acids, varied regardless of the origin of the baobab seeds and the nature of the glass bottle. Indeed, the initial amounts of oleic acid (29.98 to 40.66%) varied in the amber bottles (29.91 to 34.95%) and the transparent bottles (30.55 to 33.05%). The percentage of linoleic acid varied respectively from 20.14 to 23.68% and from 20.83 to 22.53% for the oils packaged in the amber bottles and the transparent bottles. In general, the decrease in oleic and linoleic acids would be linked to the initial composition of the baobab oils, the origin of the seeds and the light. These results highlight that light would cause the degradation of unsaturated fatty acids by photo-oxidation. Theoretically, the oils stored in the amber bottles should be less oxidized, but some different results were obtained at the end of storage. However, a correlation between the rate of fatty acid oxidation and the number of unsaturations was highlighted by Tekaya and Hassouna [21]. The variations in oleic and linoleic acid contents recorded follow almost the same logic as those reported by Li et al. [22] with olive oil. Indeed, they noted an increase in oleic acid content and a decrease in linoleic and linolenic acid

contents. After 14 months of storage at room temperature, an increase in sterculic, dihydrosterculic, arachidic, and behenic acid levels was also noted in baobab oils. These increases were more noticeable in oils extracted from unwashed seeds and then stored in amber bottles. Therefore, darkness and certain elements of baobab pulp are likely to be significant factors in the formation of these minority fatty acids. The results obtained also reveal the appearance or even disappearance, over time, of certain fatty acids absent (or in trace amounts) at the beginning of the conservation of baobab oils. These variations can be reasonably explained by transformation or biosynthesis reactions during conservation. Concerning the majority of saturated fatty acids, the contents of stearic and arachidic acids underwent a variation in all baobab oils (Table 2). Indeed, after 14 months of storage at room temperature, the stearic acid contents (2.32 to 3.75%) increased from (2.45 to 2.92%) and from (2.44 to 3.22%) when packaged in amber bottles and transparent bottles respectively.

At this date, the arachidic acid contents of the oils varied from 3.70 to 5.24% in amber bottles and from 4.05 to 4.48% in transparent bottles. Regardless of the appearance of the bottle and the origin of the fruits, baobab oils from unwashed seeds displayed the highest percentages of arachidic acid. Therefore, oils from unwashed seeds and packaged in amber bottles are the most stable during storage. These different results show that oils from unwashed baobab seeds would be less sensitive to deterioration by oxidation than those from washed seeds. Indeed, light would be the primary factor promoting oxidation by triggering autooxidation and photo-oxidation [22]. During this photo-oxidation, singlet oxygen binds to the double bonds of unsaturated fatty acids leading to the production of very unstable hydroperoxides sensitive to decomposition [23,24,25]. At the end of storage at room temperature, the composition of saturated, unsaturated and cyclic fatty acids has significantly changed in all oils. The results obtained also demonstrate a significant decrease in the total unsaturated fatty acid (UFA) contents of the oils at the beginning of storage (Table 3). This decrease was accentuated with exposure to light. Losses of unsaturated fatty acids varied with oils extracted from UKS (7.89 to 9.65%), UZS (0.89 to 4.18%), WBS (1.29 to 1.48%) and UBS (1.36 to 1.94%). Therefore, the use of amber bottles would allow the prevention of photo-oxidation during the storage of oils. Similarly, the total contents of saturated fatty acids (SFA) decreased for oils from WZS (2.08% and 2.38%), UZS (0.31% and 2.38%), WBS (2.24% and 3.28%) and UBS (1.56% and 3.76%). However, the cyclic fatty acid contents increased for oils from UKS (0.87% and 0.89%), UZS (0.77% and 1.36%), WBS (0.75% and 1.28%) and UBS (0.58% and 1.6%). These results show that oils from unwashed baobab seeds, with storage duration, are richer in cyclic fatty acids than those from washed seeds. Nevertheless, these values obtained remain significantly lower than those indicated by Andrianaiivo-Rafehivola et al. [26] and Razafimamonjison et al. [27] for baobab oils. According to Razafimamonjison et al. [27], baobab oil is reported to contain malvilic acid (1.77-3.87%), sterculic acid (0.42-1.68%), and dihydrosterculic acid (1.74-3.86%). These cyclic fatty acids make crude baobab oil unfit for consumption. Some studies suggest refining the oil before

consumption to significantly reduce these cyclic fatty acids [26].

3.2. Evolution of Phenolic Compound Contents

To estimate the stability of baobab oils, the phenolic compound contents were determined. Table 4 illustrates the phenolic compound contents of baobab oils.

Analysis of the phenolic fractions of the oils did not reveal the presence of gallic acid and quercetin, as at the beginning of storage. On the other hand, an evolution of the tyrosol, hydroxytyrosol and caffeic acid contents was observed in all the oils after these 14 months of storage. These results show that the caffeic acid content of UKS oils packaged in amber bottles ($0.590 \pm 0.322 \text{ mg.L}^{-1}$) was slightly higher than those in transparent bottles ($0.471 \pm 0.139 \text{ mg.L}^{-1}$). This decrease in caffeic acid could suggest its participation against the oxidation of the oil during storage and/or its degradation under the effect of light. It should be noted, however, that the other oil samples had caffeic acid contents below the limits of quantification (LOQ) and detection (LOD). Indeed, caffeic acid (3,4-dihydroxycinnamic acid), a powerful antioxidant, interacts with free radicals to protect oils against oxidation [28,29]. Chen and Ho [28] had demonstrated that the antioxidant capacity of thermal decomposition products of caffeic acid was stronger than that of caffeic acid. However, caffeic acid exhibits an antioxidant effect at low levels and a pro-oxidant effect at high levels [30].

Also, the addition of caffeic acid to olive oil can increase its nutritional value [31]. Concerning the amber bottles, the tyrosol (4-hydroxyphenylethanol) content increased in all baobab oils at the end of the storage period, with the exception of UBS oil. On the other hand, a decrease was observed for baobab oils packaged in transparent bottles. This difference indicates, on the one hand, the pro-oxidant effect of light in the oxidation of oils, and on the other hand, the antioxidant effect of tyrosol in the oxidative stability of these oils. Also, these results indicate that the tyrosol content of oils extracted from unwashed seeds is higher than that of washed seeds. The explanation would come from the fact that oils extracted from unwashed seeds had the highest tyrosol contents at the beginning of storage. Indeed, the pulp contains tyrosol molecules that are found in the oils at the time of extraction by pressing. Theoretically, tyrosol, a powerful antioxidant, would protect oils with high levels from oxidation. Therefore, oxidation of oils extracted from unwashed seeds should be slower than those

extracted from washed seeds. However, the determined peroxide values reveal slightly more pronounced oxidation with oils extracted from unwashed seeds. According to Li et al. [32], phenolic compounds, at very high concentrations, are more sensitive to oxidation than other antioxidants. Indeed, antioxidants that can protect lipids from oxidation are preventive antioxidants and chain-breaking antioxidants [23,33]. Regarding chain-breaking antioxidants, they prevent oxidation by transferring hydrogen radicals to peroxy, alkoxy, and alkyl radicals [33,34]. As with tyrosol, the hydroxytyrosol content of the oils increased and decreased at the end of storage. These variations are difficult to attribute to the effect of light and to the washing or not of the seeds used for the cold-pressing extraction of these oils. However, the observed variations in hydroxytyrosol contents are consistent with the trends reported by Cinquanta et al. [35] on olive oils at 6 and 12 months of storage. According to them, the increase in tyrosol and hydroxytyrosol contents would result from the hydrolysis of complex phenols leading to the formation of hydroxytyrosol and tyrosol.

3.3. Principal Component Analysis

Principal component analysis (PCA) was performed to evaluate the effects of baobab seed washing, fruit collection area, and light on the stability of extracted oils at the end of storage. The first dimension (Dim 1) contributed 38.47% and the second (Dim 2) 23.52%. These first two dimensions (Dim 1 and Dim 2) presented the highest eigenvalues (3.07 and 1.88) (Table 5).

However, the third dimension (Dim 3), the fourth dimension (Dim 4) and the fifth dimension (Dim 5) have contributions of 17.69; 9.99 and 7.37%, respectively, and eigenvalues of 1.41, 0.79 and 0.58. In order to simplify the initial matrix and reduce information loss, the principal components were chosen. Thus, the first two dimensions (Dim 1 and Dim 2) selected express 61.99% of the total variance. The monounsaturated fatty acid (0.747), saturated fatty acid (0.781), tyrosol (0.590), hydroxytyrosol (0.630) and caffeic acid (0.721) content variables are positively correlated with the first dimension (Dim 1), while the saturated fatty acid (-0.798) content variable is negatively correlated. The unsaturated fatty acid (0.513) and cyclic (0.717) content variables are positively correlated with the second dimension (Dim 2), while the tyrosol (-0.684) and hydroxytyrosol (0.581) content variables are negatively correlated with it. After storage at room temperature, the cold-pressed baobab oils were grouped into three classes (Figure 1 and Figure 2).

Table 2. Fatty acid contents (%) of baobab oils extracted by pressing at the start and end of storage at room temperature in amber bottles and transparent bottles

M.F.	WZS			UZS			WBS			WBS			UKS		
	Start	End		Start	End		Start	End		Start	End		Start	End	
		A.B.	T.B.		A.B.	T.B.		A.B.	T.B.		A.B.	T.B.		A.B.	T.B.
C16:1n-7	0.78	0.76	0.79	0.21	0.47	0.69	0.21	0.95	0.62	0.49	0.77	0.57	0.39	0.78	0.54
C16:0	20.13	22.05	21.70	21.59	20.41	21.65	24.63	21.31	22.31	23.78	20.54	22.89	14.01	18.37	22.21
C17:1n-7	2.21	1.94	1.92	1.11	1.64	2.30	1.10	2.41	1.94	1.40	2.47	1.88	1.39	2.11	0.94
C17:0	0.62	0.00	0.50	0.21	0.34	0.48	0.24	0.59	0.44	0.36	0.54	0.47	0.35	0.55	0.38
C18:CE	1.57	0.95	1.23	1.47	1.20	1.44	1.47	1.06	1.09	1.37	1.79	1.41	0.72	0.90	1.62
C18:2n-	21.59	21.44	21.64	26.57	23.68	22.53	24.01	20.14	20.83	22.91	20.86	21.41	24.02	20.51	21.88

M.F.	WZS			UZS			WBS			WBS			UKS		
	Start	End		Start	End		Start	End		Start	End		Start	End	
		A.B.	T.B.		A.B.	T.B.		A.B.	T.B.		A.B.	T.B.		A.B.	T.B.
6															
C18:1n-9	29.98	31.50	31.32	36.55	34.95	30.55	35.39	31.82	32.67	34.92	29.91	31.40	40.66	32.73	33.05
C18:0	2.32	2.45	2.44	3.75	2.82	2.92	3.47	2.92	3.25	3.22	2.72	3.22	2.85	2.62	2.92
C19:CE	2.65	2.79	1.85	0.56	1.19	1.77	0.64	2.32	1.29	1.50	1.87	1.27	1.24	1.77	1.13
C19:CA	1.01	1.08	1.09	0.55	0.95	0.71	0.56	0.58	1.04	0.20	1.02	0.98	0.90	1.06	0.96
C19:1n-9	8.08	6.82	7.13	3.18	5.66	6.98	4.15	7.93	7.04	4.71	8.59	6.97	6.38	8.35	6.83
C20:1n-9	1.33	1.14	1.11	0.48	0.75	0.88	0.50	0.65	0.98	0.64	1.13	0.92	1.05	1.52	1.00
C20:0	4.45	4.22	4.28	2.34	3.70	4.48	2.34	4.45	4.15	2.77	4.81	4.16	3.56	5.24	4.05
C22:0	1.90	1.65	1.71	0.88	1.31	1.59	0.82	1.58	1.26	0.91	1.64	1.40	1.37	1.87	1.54
C23:0	0.20	0.14	0.19	0.10	0.11	0.18	0.00	0.18	0.16	0.12	0.24	0.15	0.16	0.21	0.13
C24:0	0.95	0.83	0.92	0.44	0.69	0.82	0.45	0.95	0.79	0.53	0.91	0.75	0.76	1.04	0.72
C25:0	0.09	0.12	0.06	0.00	0.09	0.06	0.00	0.12	0.13	0.08	0.09	0.07	0.07	0.17	0.09
C26:0	0.12	0.13	0.09	0.00	0.05	0.00	0.00	0.07	0.00	0.06	0.10	0.08	0.11	0.19	0.00

M.F.: Molecular Formula; WZS: Washed Ziguinchor Seeds; UZS: Unwashed Ziguinchor Seeds; WBS: Washed Bignona Seeds; UBS: Unwashed Bignona Seeds; UKS: Unwashed Kounghoul Seed; A.B.: Amber Bottles; T.B.: Transparent Bottles. C16:1n-7; Palmitoleic acid; C16:0; Palmitic acid; C17:1n-7; *cis*-10-Heptadécénoic acid; 17:0; Margaric acid; C18:CE; Malvalic acid; C18:2n-6; Linoleic acid; C18:1n-9; Oleic acid; C18:0; Stearic acid; C19:CE; Sterculic acid; C19:CA; Dihydrosterculic acid; C19:1n-9; *cis*-10-Nonadécénoic acid; C20:1n-9; Gondoic acid; C20:0; Arachidic acid; C22:0; Behenic acid; C23:0; Tricosylic acid; C24:0; Lignoceric acid; C25:0; Hyenic acid; C26:0; Cerotic acid.

Table 3. Fatty acid contents of baobab oils packaged in amber and transparent bottles at the beginning and end of storage at room temperature

	Oils	SFA	MUFA	PUFA	CFA	UFA
Content (%) at start of storage	UKS	23.24	49.87	24.02	2.87	73.89
	WZS	30.80	42.38	21.59	5.23	63.97
	UZS	29.31	41.54	26.57	2.57	68.11
	WBS	31.96	41.36	24.01	2.67	65.37
	UBS	31.83	42.18	22.91	3.08	65.09
Content (%) at t=14 months AB	UKS	26.23	45.49	20.51	3.74	66.00
	WZS	28.72	45.49	21.44	4.82	66.93
	UZS	26.93	43.46	23.68	3.34	67.15
	WBS	28.68	43.75	20.14	3.95	63.89
	UBS	28.07	42.87	20.86	4.68	63.73
Content (%) at t=14 months TB	UKS	29.18	42.36	21.88	3.72	64.24
	WZS	28.42	42.28	21.64	4.18	63.92
	UZS	29.00	41.40	22.53	3.93	63.93
	WBS	29.72	43.25	20.83	3.42	64.08
	UBS	30.27	41.74	21.41	3.66	63.15

SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids; CFA: Cyclic Fatty Acids; UFA: Unsaturated Fatty Acids; WZS: Washed Ziguinchor Seeds; UZS: Unwashed Ziguinchor Seeds; WBS: Washed Bignona Seeds; UBS: Unwashed Bignona Seeds; UKS: Unwashed Kounghoul Seed; A.B.: Amber Bottles; T.B.: Transparent Bottles.

Table 4. Evolution of phenolic compound contents (mg.L⁻¹) of baobab oils extracted by pressing at the beginning and end of storage at room temperature in amber bottles and transparent bottles

Parameters		Amber Bottles			Transparent Bottles		
Oils	Duration	Tyrosol	Hydroxytyrosol	Cafeic acid	Tyrosol	Hydroxytyrosol	Cafeic acid
WZS	Start	0.992 ± 0.879	< LOD	< LOQ	0.992 ± 0.879	< LOD	< LOQ
	End	1.754 ± 0.816	< LOD	< LOD	0.373 ± 0.317	0.370 ± 0.299	< LOD
UZS	Début	2.417 ± 2.408	0.730 ± 0.229	< LOQ	2.417 ± 2.408	0.730 ± 0.229	< LOQ
	Fin	0.929 ± 0.044	0.786 ± 0.211	< LOQ	0.530 ± 0.040	1.272 ± 0.317	< LOQ
WBS	Début	< LOQ	0.660 ± 0.640	< LOQ	< LOQ	0.660 ± 0.640	< LOQ
	Fin	0.349 ± 0.006	< LOQ	< LOD	< LOD	< LOD	< LOD
UBS	Début	0.397 ± 0.243	0.585 ± 0.281	< LOQ	0.397 ± 0.243	0.585 ± 0.281	< LOQ
	Fin	0.602 ± 0.117	0.331 ± 0.076	< LOQ	1.541 ± 0.730	0.577 ± 0.209	< LOQ
UKS	Début	0.725 ± 0.388	3.595 ± 1.874	0.639 ± 0.228	0.725 ± 0.388	3.595 ± 1.874	0.639 ± 0.228
	Fin	1.451 ± 0.392	3.480 ± 1.940	0.590 ± 0.322	0.509 ± 0.017	3.388 ± 0.623	0.471 ± 0.139

Mean values and standard deviations are obtained over three repetitions. WZS: Washed Ziguinchor Seeds; UZS: Unwashed Ziguinchor Seeds; WBS: Washed Bignona Seeds; UBS: Unwashed Bignona Seeds; UKS: Unwashed Kounghoul Seed; LOQ: Limit Of Quantification; LOD: Limit Of Detection.

Table 5. Correlations between components and variables

Variables	Principal Component				
	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5
SFA	-0.798	-0.020	-0.125	0.411	-0.290
MUFA	0.747	0.513	-0.196	-0.245	-0.241
PUFA	0.061	-0.234	0.921	0.199	0.220
CFA	-0.013	0.717	-0.324	0.222	0.566
UFA	0.781	0.336	0.475	-0.097	-0.077
Tyr.	0.590	0.359	0.034	0.656	-0.222
HTyr.	0.630	-0.684	-0.263	0.147	0.126
C.A.	0.721	-0.581	-0.333	0.136	0.076
Eigenvalue	3.078	1.881	1.415	0.799	0.589
Variance (%)	38.475	23.522	17.693	9.991	7.371
Cumulative variance (%)	38.475	61.997	79.691	89.683	97.054

SFA: Saturated Fatty Acids; **MUFA:** Monounsaturated Fatty Acids; **PUFA:** Polyunsaturated Fatty Acids; **CFA:** Cyclic Fatty Acids; **UFA:** Unsaturated Fatty Acids; **Tyr.:** Tyrosol; **HTyr.:** Hydroxytyrosol; **C.A.:** Caffeic acid.

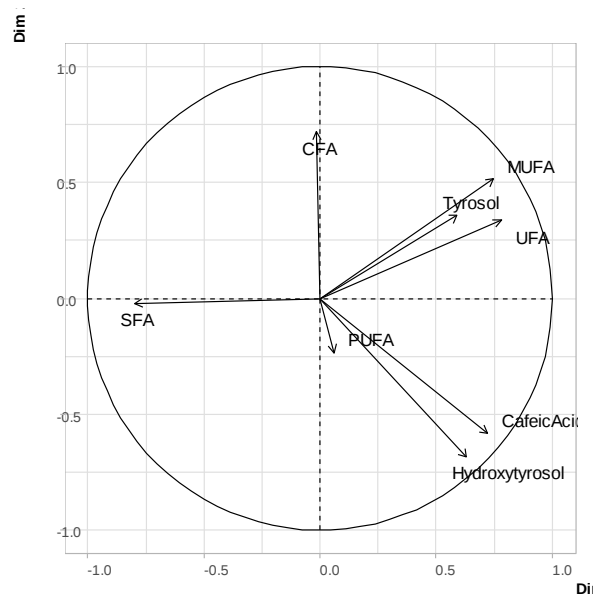


Figure 1. Correlation between fatty acid and phenolic compound contents of baobab oils and the first two dimensions of PCA

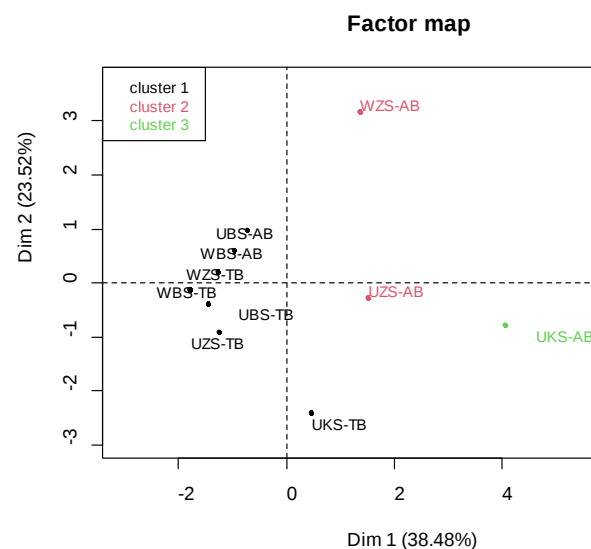


Figure 2. Projection of different oils after storage according to the fatty acid and phenolic compound contents in the factorial plane of the PCA

Class 1 (WBS-TB, UBS-TB, WZS-TB, UZS-TB, UKS-TB, WBS-AB, UBS-AB) is characterized by a high content of saturated fatty acids (V.test = 2.098; $p = 0.0358$), and low contents of tyrosol (V.test = -2.032; $p = 0.0421$), monounsaturated fatty acids (V.test = -2.355; $p = 0.0184$) and unsaturated fatty acids (V.test = -2.878; $p =$

0.0039). Ziguinchor seed oils (WZS-AB, UZS-AB) constitute class 2 characterized by a high content of unsaturated fatty acids (V.test = 2.263; $p = 0.0236$). Class 3, represented by Kounghoul seed oils packaged in amber bottles (UKS-AB), is characterized by a high caffeic acid content (V.test = 2.263; $p = 0.0236$) and a low saturated fatty acid content (V.test = -1.993; $p = 0.0462$). From these results, it is clear that Ziguinchor seed oils packaged in amber bottles are less altered after storage at room temperature. In addition, the choice of producing baobab oil from fruits collected in this locality would help preserve the quality and stability of the extracted oils.

4. Conclusion

In this study, the influence of baobab seed pretreatment operations, fruit origin and packaging type on the stability of oils extracted by pressing after storage at room temperature was evaluated. According to the results noted, there is a variation in the contents of phenolic compounds. Indeed, after fourteen (14) months of storage at room temperature, an increase in the levels of sterculic, dihydrosterculic, arachidic and behenic acids was noted in all baobab oils. These increases were more noticeable in oils extracted from unwashed seeds then stored in amber bottles. Therefore, these results suggest the use of seeds from the locality of Ziguinchor and the packaging of the extracted oils in amber bottles. Furthermore, further work will be required for a complete characterization of the different baobab oils extracted by pressing in order to evaluate the biological effects of these oils and their unsaponifiable fractions.

Conflicts of Interest

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

ACKNOWLEDGEMENTS

The authors would like to thank the CEA AGRISAN for funding the team through the "Adding value to non-timber forest products" project.

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