Food and Nutrition Sciences, 2022, 13, 373-386
https://www.scirp.org/journal/fns
ISSN Online: 2157-9458
ISSN Print: 2157-944X

Impact of Storage Conditions on the Physicochemical Characteristics of Baobab (*Adansonia digitata* L.) Seed Oil

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How to cite this paper: Ndiaye, E.M., Faye, P.G., Sow, A., Niane, K., Ndiaye, S., Baldé, S., Cisse, O.I.K., Ayessou, N.C. and Cisse, M. (2022) Impact of Storage Conditions on the Physicochemical Characteristics of Baobab (*Adansonia digitata* L.) Seed Oil. *Food and Nutrition Sciences*, **13**, 373-386.
https://doi.org/10.4236/fns.2022.134028

Received: March 1, 2022
Accepted: April 16, 2022
Published: April 19, 2022

Abstract

The evolution of some quality markers of baobab (*Adansonia digitata* L.) was studied. Baobab oil extracted by pressing was packaged in 30 mL non-amber glass bottles and stored at different temperatures: 20˚C, 30˚C and 45˚C. The physicochemical parameters (acid, peroxide, iodine, saponification, refraction and color indices) were determined during three months' storage. A significant 5% increase in acid, peroxide and saponification value was observed over time. However, the iodine value decreased. The yellowing and refractive index remained stable while storage at 45˚C caused the most significant changes in chemical parameters. The results obtained show that oils stored at 20˚C had the lowest acid (2.42 ± 0.26 mg KOH/g) and peroxide (0.82 ± 0.25 mEqO_2/Kg) value after three months of follow-up.

Keywords

Adansonia digitata L., Oil, Seeds, Physicochemical, Storage

1. Introduction

Adansonia digitata L., also called African baobab, is an emblematic tree of the African savannah [1] [2]. It belongs to the family Bombacaceae, order Malvales and plays an important social, environmental and economic role [3] [4]. The baobab fruit contains black to brown seeds covered with a whitish pulp. The baobab fruit weighs between 150 and 350 g in Senegal [1] and can reach over 496 g in Niger [5]. The seeds, which represent more than half of the dehusked fruit, are less exploited compared to the pulp [6] [7] [8]. However, baobab seeds contain also protein (18.4%), lipids (12.2%) and carbohydrates (45.1%) [9]. Nkafamiya *et al.* (2007) had reported mineral elements with a predominance of potassium, calcium and magnesium. Some mineral elements such as zinc, iron and copper were mentioned with low levels [9] [10]. The presence of vitamins B1, B2 and B3 have been noted in the seeds [11] such as A, D, E and K in the oil [12].

Today, the baobab seed oil is highly sought after by the cosmetic and pharmaceutical industries due to its biochemical composition [13] [14]. Indeed, baobab seed oil contains more than 60% of unsaturated fatty acids such as oleic acid (36.43%), linoleic acid (26.85%) and palmitoleic, margaroleic, α-linoleic and gadoleic acids [15]. However, like other vegetable oils, baobab seed oil undergoes a number of transformations during storage related to unsaturated fatty acids such as auto-oxidation reactions [16] [17]. It depends on several factors including the degree of unsaturation of the oil, free fatty acids, the content of minor compounds with pro or antioxidant activity (minerals, tocopherols, carotenes, chlorophylls) and storage conditions [16] [17] [18] [19].

The objective of the present work was to study the stability of baobab (*Adansonia digitata* L.) oils during storage by monitoring physico-chemical parameters characteristic of oxidation reactions of vegetable oils such as acid, peroxide, iodine, saponification, refraction and yellowing index.

2. Materials and Methods

2.1. Plant Material

The plant material consists of seeds from the fruit of baobab (*Adansonia digitata* L.), dehulled and pulped. The fruits were harvested in the region of Thies, Senegal (2019) (latitude: 14˚50'03" North; longitude: 17˚06'21" West). A total mass of 75 kg was divided into three batches of 25 kg.

2.2. Extraction of Oil from Baobab Seeds

Baobab fruits consist of seeds coated with whitish pulp (**Figure 1**). This dry pulp is removed by a 316N stainless steel pulping machine equipped with a 150 µm sieve. The pulped seeds are crushed by a mill with a capacity of 300 to 350 $kg \cdot h^{-1}$ with a power of 7.5 CV. The seeds are ground by a mill with a capacity of 300 to 350 $kg \cdot h^{-1}$ and a power of 7.5 HP, equipped with sieves with holes of diameter 1. The crushed material is then sieved (2 mm diameter) at a speed of 2800 rpm. Finally, the crude oil is extracted with a press of type KOMET, DD85G (IBG Monforts Ockotec GmbH, Germany). This press has a 10 mm die for a rotation speed of 25 rpm and an outlet headset at 105˚C for 25 min.

Thus, the crude oil obtained is mixed with impurities. It is therefore left to

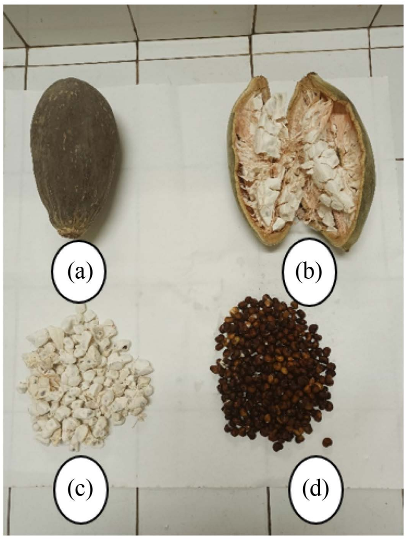

Figure 1. Illustration of baobabfruit (a), open baobab fruit (b), baobab seeds with pulp (c) and baobab seeds without pulp (d).

decant for several days and then filtered under vacuum using cloth filters. The light yellow oil is stored at 4˚C before the physico-chemical analysis.

2.3. Methods of Analysis

The refractive indices of yellowing, peroxide (NF T60-220), acid (NF T60-204), iodine (NF T60-203) and saponification (NF T60-206) were determined in order to evaluate the impact of storage on these quality markers of baobab seed oil (*Adansonia digitata* L.) [20]. Thus, the refractive index was determined with a refractometer (EXACTA-OPTECH, Mod-RMT, Germany. The yellowing index was evaluated with a colorimeter type CM-5, Konica Milnota Sensing Americas Inc, US.

2.4. Monitoring the Stability of Baobab Oil during Storage

The oxidation stability of baobab oil was monitored on three batches of oil at different storage temperatures (20˚C, 30˚C and 45˚C). For this purpose, the extracted oil is conditioned in transparent glass bottles of 30 mL and then analyzed at different times. This characterization allowed us to determine the initial quality of the oil and its evolution during three months of storage.

2.5. Statistical Analysis

The physico-chemical characteristics data were subjected to a principal component analysis (PCA) and numerical classification to verify the correlations between the storage conditions and the evaluated indices. Also, the one-factor analysis of variance and Fischer's LSD test at the 5% significance level were performed to compare the means. The results obtained represent the average of three analyses and R (version 4.1.1, 2021) and STATISTICA (version 7.1) software were used.

3. Results and Discussion

3.1. Initial Characteristics of Baobab Oil

The physicochemical parameters of the seed oil of *Adansonia digitata* L. fruit were initially determined before storage. The results of the measured indices are recorded in Table 1.

Baobab oil has a high yellowing index (85.15). This high value could be correlated with the content of unsaponifiable matter such as carotenoids [15]. In addition, the refractive index obtained (1.468 < Ir < 1.470) and iodine (89.20) allow us to say that baobab oil is non-drying. In addition, it is rich in unsaturated fatty acids. Baobab oil initially has a relatively low acid (0.5 mg KOH/g) and peroxide (0.5 $mEqO_2$/Kg) index. These levels reflect slight oxidation of the oil and low hydrolysis of triglycerides [21]. Finally, the saponification values 209.28 mg KOH/g shows its ability to transform the oil into soaps. These results obtained are in phase with those of Sow *et al.* (2017). The authors found the following values for the oil extracted from unwashed baobab seeds from Ziguinchor: 1.465 for the refractive index, 89.63 for the yellowness index, 2.94 $mEqO_2$/Kg for the peroxide value, 0.92 mg KOH/g for the acid value, 86.23 mgI_2/100g for the iodine value and finally, 201.49 mg KOH/g for the saponification value.

3.2. Evolution of the Physicochemical Characteristics of Baobab Oil during Storage

During storage, vegetable oils are subject to numerous physical and chemical transformations under the influence of certain factors such as light, heat, water and traces of metals [21]. The physicochemical characteristics of baobab oil stored in non-ambered glass bottles were monitored at different temperatures (20˚C, 30˚C and 45˚C) for three months.

3.2.1. Effects of Storage Conditions on Physical Properties

The physical parameters studied are the yellowness index and the refractive index. The results obtained are presented in Figure 2 and Figure 3.

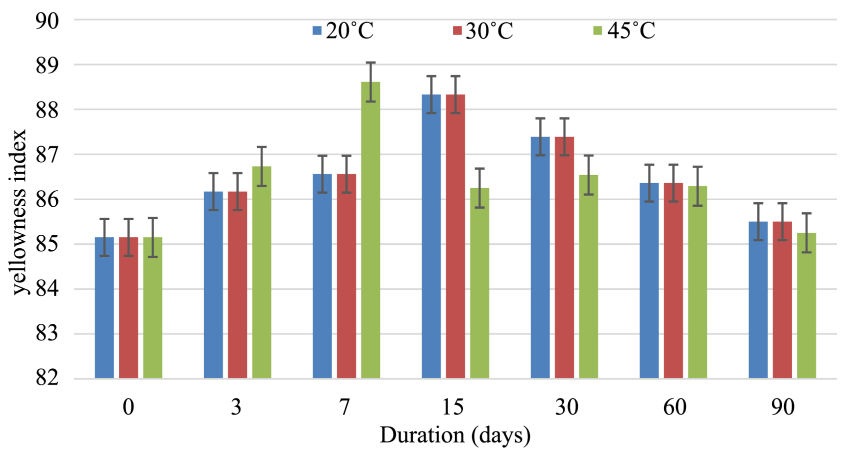

Figure 2. Evolution of the yellowness index of the seed oil of the fruit of *Adansonia digitata* L. stored at 20˚C, 30˚C and 45˚C over time.

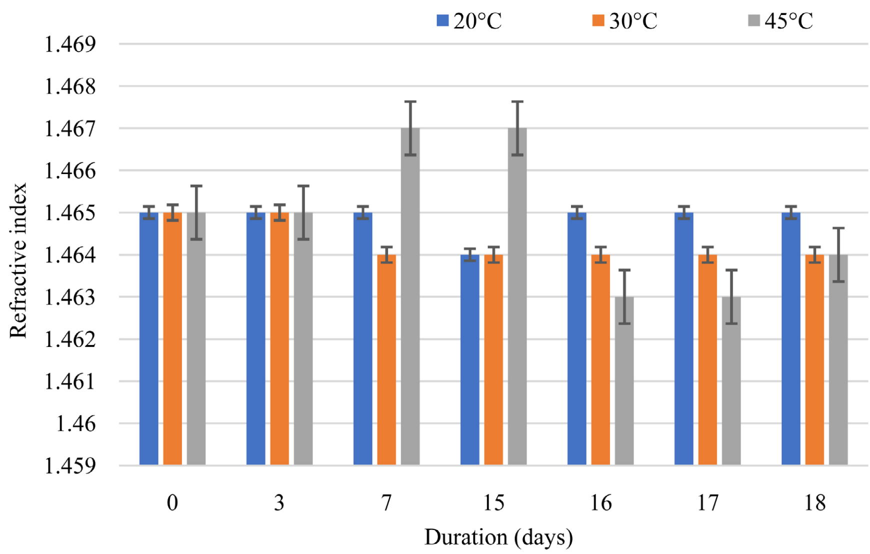

Figure 3. Evolution of the refractive index of the seed oil of the fruit of *Adansonia digitata* L. stored at 20˚C, 30˚C and 45˚C over time.

Table 1. Initial physico-chemical characteristics of baobab oil.

Characteristics	Baobab oil (*Adansonia digitata* L.)
Yellowing index	85.15 ± 0.05
Refractive index	1.465 ± 0.005
Acid value (mg KOH/g)	0.50 ± 0.06
Peroxide value (mEqO_2/Kg)	0.5 ± 0.00
Iodine value (mgI_2/100g)	89.20 ± 0.96
Saponification value (mg KOH/g)	209.28 ± 0.38

Yellowness index

The yellowing index gives an account of the yellow coloration of the oil. This coloration could be due to the presence of carotenoids. Correlations have been established between the concentration of carotenoids and the yellow coloration of oils [15] [22] [23]. After three months of storage at temperatures (20˚C, 30˚C and 45˚C), this parameter has hardly changed, showing that the carotenoids in baobab oil have remained stable and are only slightly altered during the 90 days of follow-up.

Refractive index

The measured values (1.464 - 1.465 ± 0.0005) are in agreement with those found by Sow (2019) (1.4648 ± 0.0002. The refractive index (1.464 - 1.465 ± 0.0005) and iodine value (88.95±) obtained show that baobab oil is nondrying and is comparable to olive oil which displays (81.23 ± 0.40) iodine value and (1.471 ± 0.001) refractive index [15] [23]. The analysis of variances at the 5% threshold does not reveal a significant difference in the refractive index. Similarly, we can say that the storage temperature has no major effect on the refractive index of baobab oil stored for 3 months at (20˚C, 30˚C and 45˚C). The refractive index remains stable and averages between 1.464 and 1.465. These values attest to the low level of trimers in the oil studied.

3.2.2. Effects of Storage Conditions on Chemical Parameters

Acid value

The acid value allows us to assess the degree of alteration by hydrolysis of an oil and the value of technological operations that led to its obtaining [24]. It corresponds to the free fatty acids present in the oil. The acidity of baobab oil stored at 20˚C, 30˚C and 45˚C in the oven, increases over time (**Figure 4**).

The oil stored at 20˚C shows a regular evolution of the acid value with the duration of storage. However, at 30˚C and 45˚C, the increase in acid value is strong. Indeed, the greatest variation in acidity between the second and third month of storage (0.74 to 2.42 mg KOH/g; 1 to 3.26 mg KOH/g and 1.21 to 4.55 mg KOH/g). Dandjouma *et al.* (2008) found for *C. Schweinfurthii* oil stored at room temperature, an acid value of 6.93 mg KOH/g on the first day of storage, 7.41 mg $KOH{\cdot}g^{-1}$ at the first month of storage and 8.34 mg $KOH{\cdot}g^{-1}$ at the second month against 6.93 mg $KOH{\cdot}g^{-1}$ at the first day of storage, 7.14 mg $KOH{\cdot}g^{-1}$ at the first month and 7.41 mg $KOH{\cdot}g^{-1}$ at the second month of storage of *C. Schweinfurthii* oil at 4˚C. These results confirm the effect of temperature and time on the acid value.

The acid indices of the samples found, except for the one stored at 45˚C, are lower than the limit value (4 mg KOH/g oil) set for oils obtained by cold pressing and virgin oils [25]. In sum, the storage conditions and time have a significant influence at the 5% threshold on the free fatty acid content of oils. Indeed, the increase in the acid value of the third month would be accentuated by the presence of chlorophyll. The latter, by degrading, produces acidic compounds that would contribute to the increase of the acidity of the oil. The results obtained are in agreement with those indicated by [18].

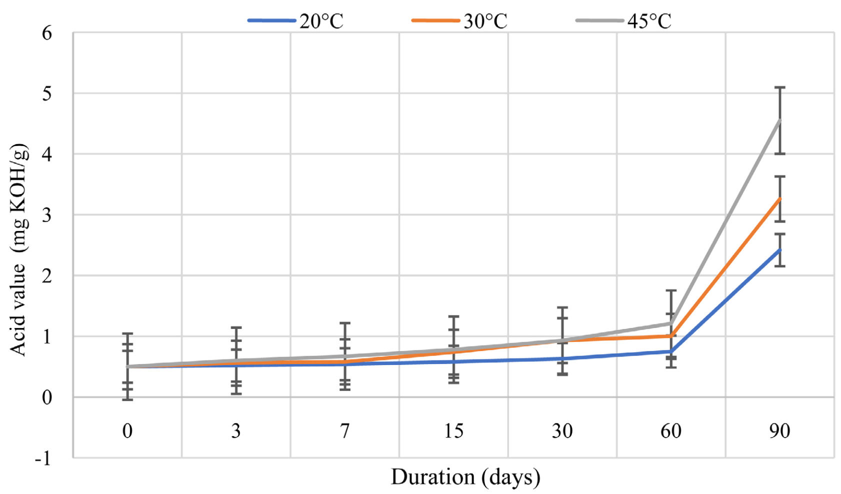

Figure 4. Evolution of the acid value of the seed oil of the fruit of fruit of *Adansonia digitata* L. stored at 20˚C, 30˚C and 45˚C over time.

Peroxide value

The peroxide value allows us to follow the stages of deterioration by oxidation of the oil. It indicates the number of fatty acids already rancid and information on the duration of storage because the longer the storage, the higher it is [26]. The peroxide value is therefore an important parameter for monitoring oils. Whatever the storage temperature, an increase in the peroxide value is noted (**Figure 5**). However, slow evolution of the peroxide value for the sample stored at 20˚C (0.5 ± 0.00a to 0.82 ± 0.25ab mEqO_2/Kg) is noted. This increase was more noticeable from the thirtieth day of storage with the oils stored at 30 (1.15 ± 0.46bc to 3.68 ± 0.40g mEqO_2/Kg) and 45˚C (2.95 ± 0.39f to 5.33 ± 0.45 mEqO_2/kg). Nevertheless, the values of the peroxide value found at the end of storage (third month) for all oils remain below the threshold value (15 mEqO_2/kg) set by codex (1999). The analysis of variance at the 5% threshold shows the effect of temperature on the degradation of oils. The results obtained are in agreement with those reported by Dandjouma *et al.* (2008). The effect of storage (time temperature and light) on the peroxide value is confirmed by the work of Dandjouma *et al.* (2008). The authors found a peroxide value of *C. Schweinfurthii* oil equal to 3.40 mEqO_2/kg on the first day of storage, 7.83 mEqO_2/kg on the first month and 12.35 mEqO_2/kg on the second month of storage at room temperature against 3.40 mEqO_2/kg on the first day of storage, 5.51 on the first month and 9.05 mEqO_2/kg on the second month of storage at 4˚C.

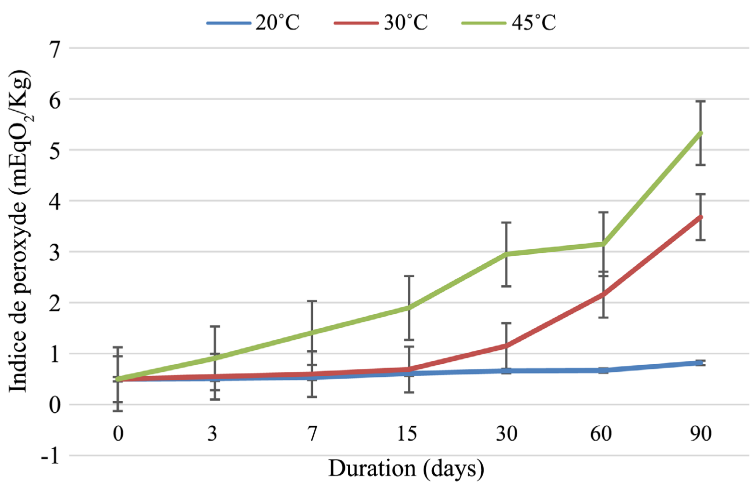

Figure 5. Evolution of the peroxide value of the seed oil of the fruit of fruit of *Adansonia digitata* L. stored at 20˚C, 30˚C and 45˚C over time.

Iodine value

The iodine value determines the degree of unsaturation of vegetable oil and assesses its stability during storage. **Figure 6** shows the evolution of the iodine value of baobab oil stored at different temperatures (20˚C, 30˚C and 45˚C) for three (3) months. These results show that the iodine value varies significantly with the storage conditions. It decreases with the increase of the storage temperature and passes from 89.20 ± 0.96a to 70.53 ± 0.34j mg I_2/100g of oil for the

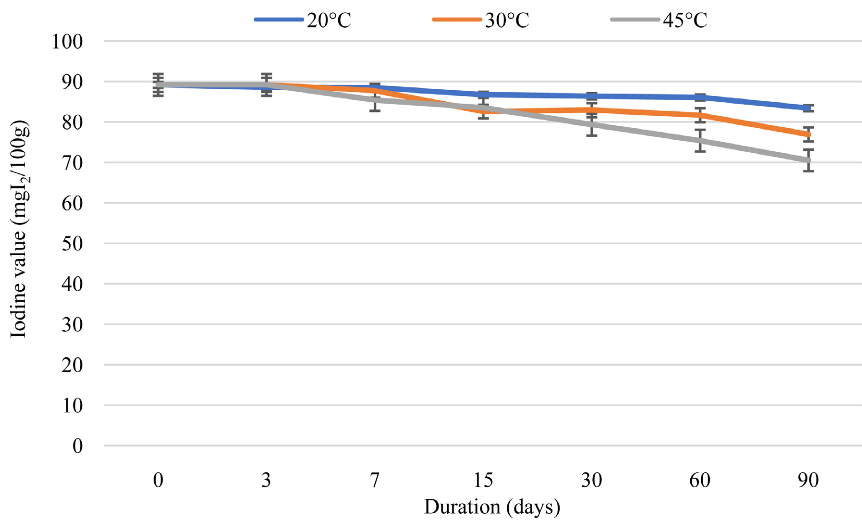

Figure 6. Evolution of the iodine value of *Adansonia digitata* L. seed oil fruit of *Adansonia digitata* L. stored at 20˚C, 30˚C and 45˚C over time.

stored at 45˚C; from 89.20 ± 0.96a to 76.93 ± 0.63h mg I_2/100g of oil for the samples stored at 30˚C and finally from 89.20 ± 0.96a to 83.41 ± 0.86e mg I_2/100g of oil for those stored at 20˚C. Indeed, this decrease in iodine value is correlated to the degradation of unsaturated fatty acids by heat. Iodine values below 100 mg I_2/100g of oil classify baobab oil as a non-drying oil [27]. Finally, baobab oil is comparable to olive oil (75 - 94 mg I_2/100g oil) widely used in the cosmetic and pharmaceutical industries [2] [28].

Saponification value

The saponification value is the mass (in milligrams) of potassium hydroxide (KOH) required to saponify one gram of fat. The saponification value initially measured was 209.28 ± 0.86a mg KOH/g. After three months of steaming at 20˚C, 30˚C and 45˚C, this value increased to 210.69 ± 0.05bcd, 232.65 ± 0.39h, and 248.48 ± 0.05i mg KOH/g respectively (**Figure 7**). This increase describes the aging of the oil which is manifested by the increase in rancid odor. The significant difference noted between the three samples monitored can be attributed to the storage temperature, light [16]. These results obtained also indicate that the saponification index of baobab oil is higher than those of argan oil (190.88 mgKOH/g), *Persea Americana* oil (35.76 mg KOH/g), and olive oil (97.94 mg KOH/g) [2] [23].

In sum, these results confirm the effect of temperature and time on the quality of vegetable oils (**Table 2**).

3.3. Statistical Analysis

3.3.1. Correlation between Temperature, Time and the Studied Quality Indices of Baobab Oil

The correlation study between temperature, storage time and physicochemical properties of baobab seed oil (**Table 3**), shows that storage time and temperature have positive correlations with acid, peroxide and saponification value and

Table 2. Pearson's correlation coefficients between storage temperature, duration and physicochemical properties of baobab oil (*Adansonia digitata* L.).

Variables	Time/temperature	Acid value	Peroxide value	Iodine value	Saponification value	Refraction index	Yellowness value
Acid value	0.64						
Peroxide value	**0.71**	**0.74**					
Iodine value	**−0.84**	**−0.71**	**−0.94**				
Saponification value	0.67	**0.75**	**0.94**	**−0.92**			
Refractive indix	−0.37	−0.19	−0.33	0.45	−0.46		
Yellowness index	−0.04	−0.37	−0.27	0.21	−0.32	0.05	1

Table 3. Correlations between components and variables.

Variables	Components	
	Dim 1	Dim 2
Refraction index	−0.485	**0.607**
Jaunissement index	−0.390	**−0.743**
Acid value	**0.829**	0.255
Peroxyde value	**0.950**	−0.019
Iodine value	−0.949	0.147
Saponification value	**0.969**	−0.052
Eigenvalue	10.78	20.68
Variance (%)	63.616	16.860
Cumulative variance (%)	63.616	80.476

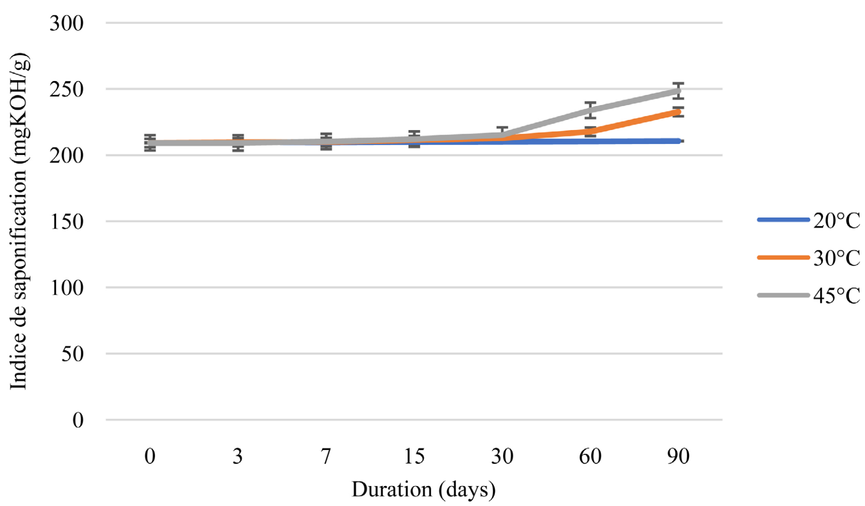

Figure 7. Evolution of the saponification value of *Adansonia digitata* L. fruit seed oil stored at 20˚C, 30˚C and 45˚C over time.

index. However, with refractive, yellowing and iodine value, temperature, time and light have negative correlations. The relationship between physicochemical indices reported a strong positive correlation of peroxide and saponification indices with the acid value. The saponification value is positively highly correlated with the peroxide index and negatively highly correlated with the iodine value. The latter is negatively correlated with the peroxide and acid value.

3.3.2. Principal Component Analysis

A principal component analysis (PCA) was conducted to assess the impact of storage conditions on baobab oil quality. The first two dimensions (D1 and D2) express 80.48% of the total inertia (**Table 3**). Thus, the first dimension (Dim1) alone contributes 63.62% and the second (Dim2) 16.86%. The variables acid value (0.829), peroxide value (0.950) and saponification value (0.969) are positively correlated very well with the first dimension while the variables refractive index (−0.485), yellowness index (−0.390) and iodine value (−0.949) are negatively correlated. The second dimension is characterized by the variable refractive index (0.607) which is positively correlated and the variable yellowness index (−0.743) which is negatively correlated.

The baobab oil samples analyzed were grouped into three classes (**Figure 2** and **Figure 3**). Class 1 consists of oils stored at temperatures 20˚C on days (JO, D3, D7, D30, D60, D90), 30˚C hang (D0, D3), and 45˚C hang (D0, D3, D7, D15)

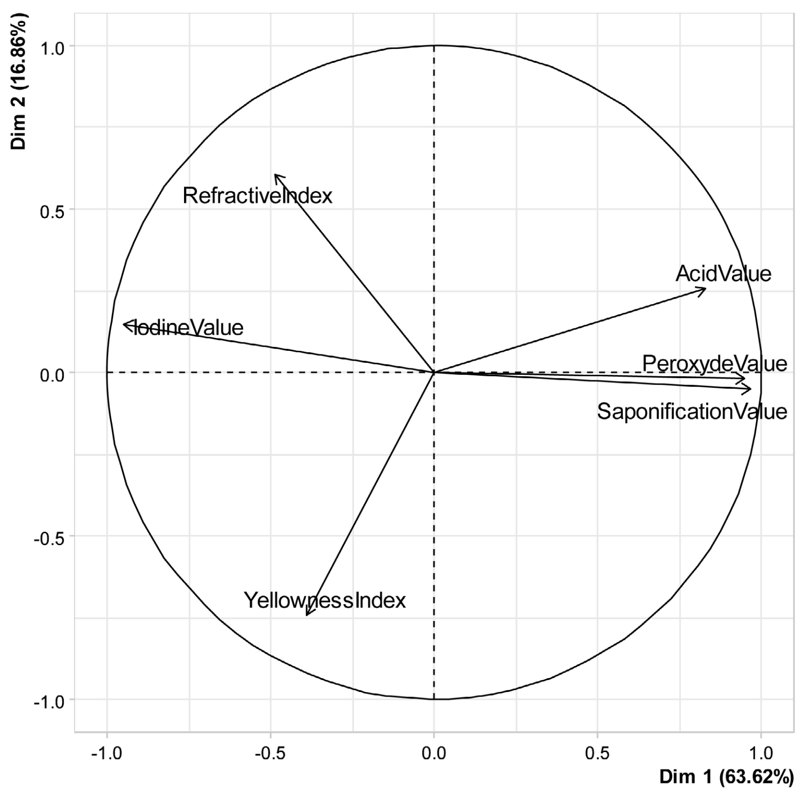

Figure 8. Correlation between the physicochemical properties of baobab oil and the first two dimensions of the PCA.

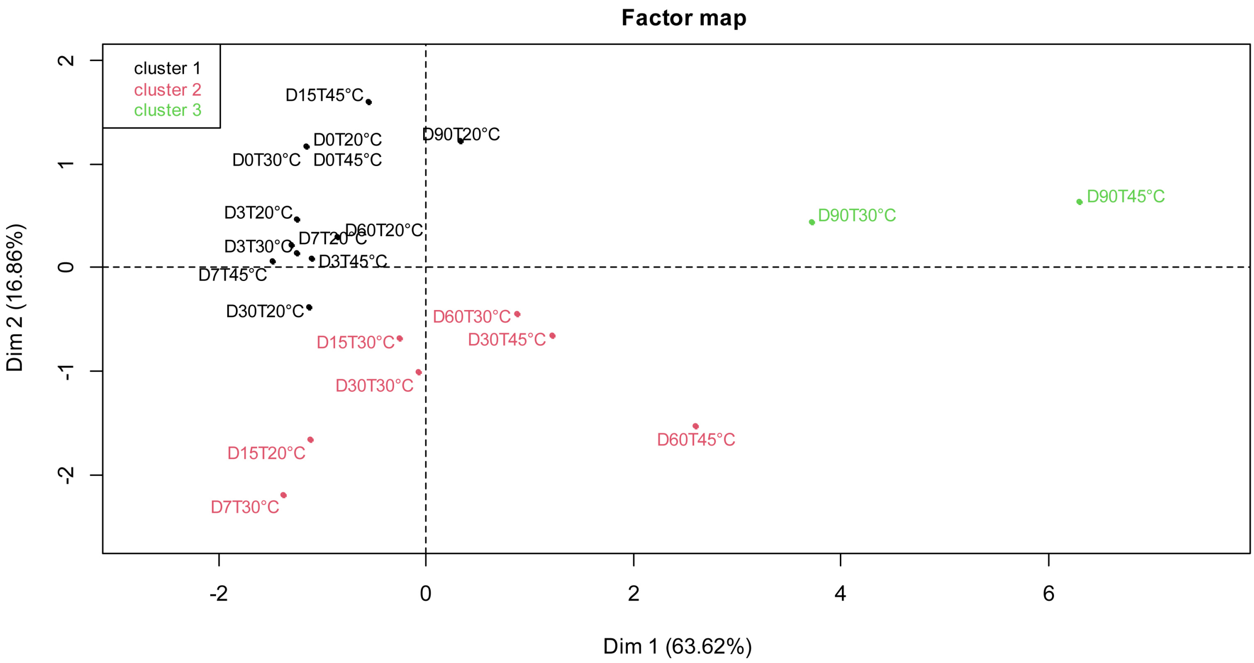

Figure 9. Projection of the different storage temperatures associated with the days of according to the physicochemical properties of the oil extracted from baobab seeds in the baobab seeds in the factorial plane of the PCA.

with an iodine value (V. test ≥ 2, p ≤ 0.05) and refractive index (V. test ≥ 2, p ≤ 0.05) and a low peroxide value (V. test ≤ −2, p ≤ 0.05) and saponification value (V. test ≤ −2, p ≤ 0.05). A high yellowness index (V. test ≥ 2, p ≤ 0.05) and a low refractive index (V. test ≤ 2) characterizes the second class consisting of oils stored at temperatures 20˚C during (15 days), 30˚C during (7, 15, 30 and 60 days) and 45˚C during (30 and 60 days). Finally, the third class, which represents baobab oils stored at 30˚C and 45˚C for 90 days, is characterized by high acidity, acid value (V. test ≥ 2, p ≤ 0.05), peroxide value (V. test ≥ 2, p ≤ 0.05), and saponification value (V. test ≥ 2, p ≤ 0.05), and low iodine value (V. test ≥ 2, p ≤ 0.05). In sum, from these analyses, it can be seen that oils stored at low temperatures for a long time and oils stored at high temperatures for a very short time are better in terms of quality for the processing industries (cosmetics and pharmaceuticals) (**Figure 8** and **Figure 9**).

4. Conclusion

During this study, the quality index of different samples of baobab oil stored at 20˚C, 30˚C and 45˚C for three (3) months were determined. The study of the stability of baobab oil showed that the duration and conditions of storage have a significant influence on the quality of the oil. The different quality parameters studied showed different evolutions according to the storage conditions. The most important quality degradations were observed with oils stored at 45˚C. Indeed, the temperature, light, dissolved oxygen content and the presence of pro-oxidants promote the hydrolysis and oxidation of triglycerides. This degradation of fats leads to the formation of oxidation compounds, polymerization, isomerization and hydrolysis [29]. However, all the results obtained allow us to say that this oil is of good quality after three months of storage and that the conservation at 20˚C is more suitable than that at 30˚C and 45˚C.

Acknowledgements

The authors gratefully acknowledge Pierre-Gilles COMMEAT from Baobab flavors Company and Professor Hicham HARHAR for their technical assistance.

Conflicts of Interest

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

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