American Journal of Food Science and Technology, 2021, Vol. 9, No. 2, 62-68
Available online at http://pubs.sciepub.com/ajfst/9/2/5
Published by Science and Education Publishing
DOI:10.12691/ajfst-9-2-5

Roasting Effect on Chemical Parameters, Antioxidant Capacity and Oxidative Stability of *Citrullus Lanatus* Kernels Oil

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Received May 22, 2021; Revised June 28, 2021; Accepted July 08, 2021

Abstract Due to its high content in linoleic acid, which is a polyunsaturated fatty acid, *Citrullus lanatus* oil is prone to oxidation. However, roasting generates Maillard reaction products having an antioxidant effect capable to preserve lipids against oxidation. Therefore, this study investigated the impact of roasting on *C. lanatus* kernels oil properties. The treatments consisted of roasted kernels in an oven at 180 °C for 20 min compared to unroasted kernels. Oil were extracted using a press coupled with a thermoregulator without heating (control), at 60 °C and 100 °C for unroasted kernels and without heating for those roasted. The chemical parameters, antioxidant capacity and oxidative stability of these oils were evaluated. The result showed that roasting did not significantly influence the pH of oils and the pH were acidulous (5.23 ± 0.00 to 5.50 ± 0.01). In addition, roasting increased oil acidity and peroxide value; while iodine and saponification values decreased. Roasting also increased the total phenol content, antioxidant capacity and oxidative stability of *C lanatus* kernels oil. Roasted kernels oil was of good quality and classified as "semi-drying or di-unsaturated oils" with the best resistance to auto- and thermo-oxidation. Our results suggest that roasting at 180°C for 20 min would extend the shelf life of *C. lanatus* kernels oil without compromising its quality.

Keywords: *Citrullus lanatus oil, roasting, pressing, antioxidant capacity, oxidative stability*

Cite This Article: Guede S. Serge, Bamba Bio S. Bruno, Soro Y. Réné, Gbogouri G. Albarin, and Brou Kouakou, "Roasting Effect on Chemical Parameters, Antioxidant Capacity and Oxidative Stability of *Citrullus Lanatus* Kernels Oil." *American Journal of Food Science and Technology*, vol. 9, no. 2 (2021): 62-68. doi: 10.12691/ajfst-9-2-5.

1. Introduction

Citrullus lanatus (Thunb.) Matsum. & Nakai is a plant species of the Cucurbitaceae family [1]. It is widespread in rural and urban areas of Sub-Saharan Africa. It is mainly grown in savannah regions and in pre-forest areas [2]. In Ivory Coast, Zoro Bi et al. [3] have described two distinct cultigroups called "wlêwlê" and "bébu" respectively.

The *C. lanatus* seeds are important sources of lipids and proteins [4,5]. In addition, its derived oil contain high content of linoleic acid, about 61 – 64% [6,7]. Indeed, linoleic acid is an essential fatty acid which cannot be synthetized by human body. Therefore, an intake of linoleic acid is provided through a suitable diet [8]. In addition, linoleic acid act as a metabolic precursor of the omega-6 family. It is likewise involved in many physiological functions, including immune system functioning, inflammatory response, and cell membrane manufacturing [9].

However, *C. lanatus* oil is prone to oxidation due to its high linoleic acid content [10]. Polyunsaturated fatty acids, such as linoleic acid, are susceptible to lipid peroxidation phenomenon. Linoleic acid reacts with oxygen in complex oxidative reactions. These reactions lead to the alteration of nutritional and organoleptic qualities of food (rancidity), which is characterized by the appearance of unpleasant taste and odor, and sometimes by a change in color [11]. Therefore, they contribute highly to reduction marketable value of food. Thus, to meet oil quality preservation demand, a *C. lanatus* oil production process that limits oxidative reactions should be developed.

Roasting is an capital unit operation commonly used to prepare oilseeds for human consumption. It promotes flavor, desired color and physicochemical changes [12,13,14] that increase overall palability of product. It improves microbiological safety, by destroying unwanted

microorganisms, and inactivates enzymes that alter the product during storage [15]. Likewise, it improves digestibility, sensory quality and shelf life of food products; and it facilitates oil extraction by destroying cellular barriers and toxic heat-labile substances in nuts and seeds [16]. In addition, Zou et al. [17] et Suri et al. [18] reported that melanoidins, from Maillard reaction products (MRPs) during roasting, improve oil oxidative stability. However, little research work has focused on stabilization issue of *C. lanatus* oil in a valuation perspective.

Accordingly, this study aimed to assess the effect of roasting on chemical parameters, antioxidant capacity and oxidative stability of the oil extracted from *C. lanatus* kernels. The pressing temperature effect was also studied.

2. Material and Methods

2.1. Material and Chemicals

The seeds of the cultigroup "bébu" (local name in Côte d'Ivoire) of the species *Citrullus lanatus* were used in this study. They are flat and oval in shape with a thick and rough edge (Figure 1). The seeds were collected from producers in the Dikodougou department (latitude 9°04'03.3 "N, longitude 5 ° 46'20.0" W) located in the north of Ivory Coast.

All chemicals and reagents used in the experiment were of analytical grade and were products of VWR International, Leuven, Belgium. The chemicals were obtained from Equipment Laboratoire Chimie, Abidjan, Ivory Coast.

Figure 1. Seeds of cultigroupe "bebu" of *Citrullus lanatus* ([3])

2.2. Methods

2.2.1. Seed Processing

Seeds were sent to the Laboratory of Genetics and Plant Improvement of Nangui Abrogoua University (Ivory Coast). They were sorted, soaked in tepid water for 15 min, and then mannually dehulled. After been washed with tap water and dried in an oven (UFB 400, Memmert, Schwabach, Germany) at 40 °C for 2 h, the dried kernels were divided into unroasted (batch 1) and roasted (batch 2) batches. Prior to roasting, batch 2 was carefully spread in an uniform thin layer over stainless steel trays. The roasting process consisted of heating the kernels at 180°C for 20 min, while stirring them every 2 min in a natural convection oven (Memmert Gmbh and Co. KG, Schwabach, Germany) under continuous aeration. Roasted kernels were immediately cooled to room temperature in a desiccator. Subsequently, each batch was packaged in airtight plastic bags and stored away from moisture and light for extractions.

2.2.2. Oil Extraction Process

Oil was mechanically extracted from kernels according to the method described by [19] using Komet screw press (CA 59 G, IBG Monforts Oekotec, Mönchengladbach, Germany) coupled to Störk-Tronic thermoregulator (Störk, Stuttgart, Germany) consisting of a ceramic heating strip (Figure 2). Before setting the press screw rotation speed at 20 rpm, a 4 mm diameter nozzle was placed in the screw head hole and the pressing chamber was heated to the desired temperature by means of a heating strip placed on the screw head.

Then a small amount of kernels was introduced into the press through the feed hopper. As soon as the cake came out to the screw head and the oil started to flow from the hole cylinder, the hopper was filled with about 1 kg of kernels and pressing continued until the oil stopped flowing. Oils were extracted from unroasted kernels without heating (control), and with heating at 60°C and 100°C, while that from roasted kernels was extracted only without heating (Table 1). The resulting crude oils were centrifuged at 6000 rpm at 25°C for 15 min using the Hermle centrifuge (Z 300 K, Hermle Labortechnik, Wehingen, Germany). The clarified oils obtained were then packaged in bottles coated with aluminum foil, hermetically sealed, and then stored at 4°C in a refrigerator for further processing and/or analysis.

Figure 2. Komet press (CA 59 G, IBG Monforts Oekotec, Mönchengladbach, Germany) coupled to a heating system: a: feed hopper; b: perforated cylinder; c: strip heater; d: screw head; e: outlet nozzle of presscake; f: thermoregulator; g: gear transmission; h: start button; i: gearbox; j: moter; k: oil collection container

Table 1. Experimental Scheme of Processing Conditions for Kernels and Oil Obtained

Type of kernels	Pressing temperature	Oil obtained
Roasted	Pressing without heating	UKO
Unroasted	Pressing without heating	UKO (control)
Unroasted	Pressing at 60 °C	UKO60
Unroasted	Pressing at 100 °C	UKO100

RKO: roasted kernels oil extracted without heating; UKO, UKO60 and UKO100: unroasted kernels oils extracted without heating, at pressing temperatures of 60 °C and 100 °C respectively.

2.2.3. Chemical Parameters of Oils

The acid (AV), peroxide (PV), iodine and saponification values were determined according to the official AOCS methods [20]. However, ester value was determined by the difference between the saponification and acid values.

The pH was determined according to the method described by [21]. pH value was read in 2 mL of oil sample dissolved in 15 mL of n-hexane using a digital pH-meter (HI 8915, Hanna Instruments, Lingolsheim, France) at 25℃.

The total phenol content was determined according to the colorimetric method described by [22] using the Folin-Ciocalteus reagent, and gallic acid (from 0 to 1 mg) as a standard.

2.2.4. Antioxidant Capacity of Oils

Radical scavenging activity (RSA) of oil was determined by measuring the reduction of 2,2-diphenylpicrylhydrazyl (DPPH) radical, according to the protocol described by [23], and then compared to that of α-tocopherol, used as standard antioxidant. To be done, oil and α-tocopherol samples were prepared at different concentrations (0 to 5 g/L) in isooctane and mixed with 1 ml of 0.1 mM DPPH solution prepared in isooctane in tubes. The tubes were vigorously shaken and left in the dark for 30 min; then the absorbance was measured at 517 nm against isooctane, using a UV-Visible spectrophotometer (V-530, Jasco International, Tokyo, Japan). The percent inhibition of DPPH (PI) was calculated using Equation 1:

$$PI(\%) = \frac{(A_0 - A) \times 100}{A_0} \quad (1)$$

where A_0 and A are the absorbances of control tube (without oil or standard antioxidant) and test tube, respectively.

2.2.5. Auto-oxidative Stability of Oils

The auto-oxidative stability of oil was determined according to the method of [24] by monitoring the alteration parameters during storage. Briefly, 100 g of each type oils were poured into a transparent bottle with a cap, and placed in dark at room temperature (≈ 25 ℃) for 180 days. Acidity and peroxide value (PV) were then determined on first day and each fifteen days according to the method previously indicated [20].

2.2.6. Thermo-oxidative Stability of Oils

Oil thermo-oxidative stability was evaluated by the oven test method described by [17]. Therefore, 50 g of sample preweighed in a transparent bottle fitted with a cap were storaged at 60 ± 0.5 ℃ for 21 days in an oven (UFB 400, Memmert, Schwabach, Germany). Peroxide value (PV) were then determined on first day and each three days according to the method previously indicated [20].

2.2.7. Statistical Treatment of Results

All experiments were carried out in triplicate and the values obtained were expressed as mean ± standard deviation. One-way analyses of variance (ANOVA) were conducted, followed by LSD (Least Significant Difference) test to identify where the differences occurred between means. Statistical analyses were performed using Statistica 7.1 software [25]. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Chemical Parameters of Oils

The chemical parameters of the *Citrullus lanatus* oils are presented in Table 2. The results showed that the pH values of oils were not significantly different ($p > 0.05$) and were between 5.23 ± 0.00 and 5.50 ± 0.01. Nevertheless, Roasted kernels oil (RKO) showed a slightly higher pH value than unroasted kernels oil (UKO) under the same pressing conditions which was without heating.

However, RKO had significantly ($p < 0.05$) higher acid value (2.22 ± 0.01 mg KOH/g) and acidity (1.12 ± 0.00%) than those of unroasted kernels oils regardless of the pressing temperature (UKO, UKO60 and UKO100). In addition, RKO demonstrated approximately 3 times higher peroxide value (1.97 ± 0.03 meq O_2/kg), and lower iodine (113.10 ± 0.20 g I_2/100 g) and saponification (179.52 ± 0.04 mg KOH/g) values than UKO, UKO60 and UKO100.

The total phenol content of RKO which was the highest (around 13.79 ± 0.15 mg/100 g) was approximately twice higher than that of UKO extracted under the same pressing conditions.

Furthermore, the pressing temperature did not have a significant ($p > 0.05$) influence on chemical properties of unroasted kernels oil regardless of the pressing temperature. Acid, peroxide, iodine, saponification and ester values, acidity and total phenol content were approximately 1.10 mg KOH/g, 0.6 meq O_2/kg, 123.38 g I_2/100 g, 198.46 mg KOH/g, 197.36 mg KOH/g, 0.55% and 6.66 mg/100 g, respectively.

Table 2. Chemical Parameters of Oils Extracted from *Citrullus Lanatus* Kernels

Chemical parameters	*Citrullus lanatus* kernels oils			
	RKO	UKO	UKO60	UKO100
pH at 25 ℃	5.50 ± 0.01[a]	5.23 ± 0.00[a]	5.33 ± 0.01[a]	5.40 ± 0.01[a]
Acid value (mg KOH/g oil)	2.22 ± 0.01[a]	1.00 ± 0.00[b]	1.11 ± 0.01[b]	1.19 ± 0.01[b]
Acidity (%)	1.12 ± 0.00[a]	0.50 ± 0.00[b]	0.56 ± 0.00[b]	0.60 ± 0.01[b]
Peroxide value (meq O_2/kg oil)	1.97 ± 0.03[a]	0.59 ± 0.00[b]	0.60 ± 0.00[b]	0.61 ± 0.00[b]
Iodine value (g I_2/100 g oil)	113.10 ± 0.20[b]	124.58 ± 0.35[a]	123.92 ± 0.19[a]	121.65 ± 0.22[a]
Saponification value (mg KOH/g oil)	179.52 ± 0.04[b]	199.56 ± 0.03[a]	198.45 ± 0.03[a]	197.37 ± 0.07[a]
Ester value (mg KOH/g oil)	177.30 ± 0.05[b]	198.55 ± 0.03[a]	197.34 ± 0.03[a]	196.18 ± 0.08[a]
Total phenol (mg/100 g oil)	13.79 ± 0.15[a]	7.00 ± 0.04[b]	6.53 ± 0.11[b]	6.44 ± 0.14[b]

RKO: roasted kernels oil extracted without heating; UKO, UKO60 and UKO100: unroasted kernels oils extracted without heating, at pressing temperatures of 60 ℃ and 100 ℃ respectively.

3.2. Antioxidant Capacity of Oils

Figure 3 shows the radical scavenging activity of *Citrullus lanatus* kernels oils compared to that of α-tocopherol, taken as the standard antioxidant. The results revealed that DPPH percent inhibition increased with increasing oil and α-tocopherol concentrations. From 0 to 1 g/L, percent inhibition sharply increased, then became progressive up to 5 g/L. α-Tocopherol demonstrated the highest percent inhibition (73.12%) with 5 g/L, followed by RKO (59.07%); while UKO100 exhibited the lowest percent inhibition (41.84%). Furthermore, percent inhibition of UKO and UKO60 were quite close regardless of oil concentration. The values obtained at 5 g/L were 46.85% and 45.36%, respectively for UKO and UKO60.

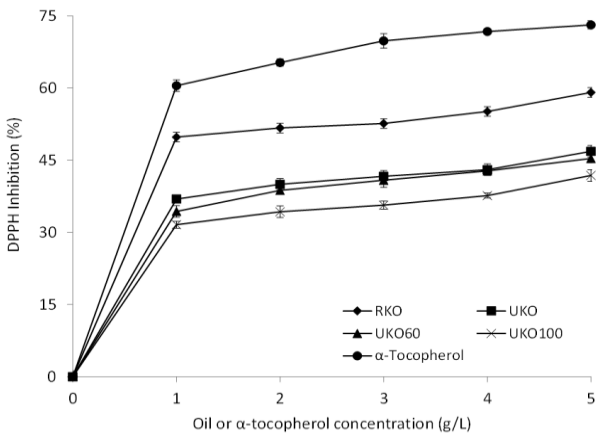

Figure 3. Radical scavenging activity of *Citrullus lanatus* kernels oils compared to that of α-tocopherol

3.3. Auto-oxidative Stability of Oils

The change in acidity of *Citrullus lanatus* kernels oils over 180 days of storage at room temperature (25 ℃) is shown in Figure 4. The results indicated that oil acidity gradually increased between 0 and 165th day, and then stabilized. The maximum values reached were 9.02, 11.65, 11.91 and 11.94% for RKO, UKO, UKO60 and UKO100, respectively. Additionally, RKO exhibited the lowest increase in acidity. However, pressing temperature did not significantly affect ($p > 0.05$) the change in acidity of *C. lanatus* oil during storage at room temperature.

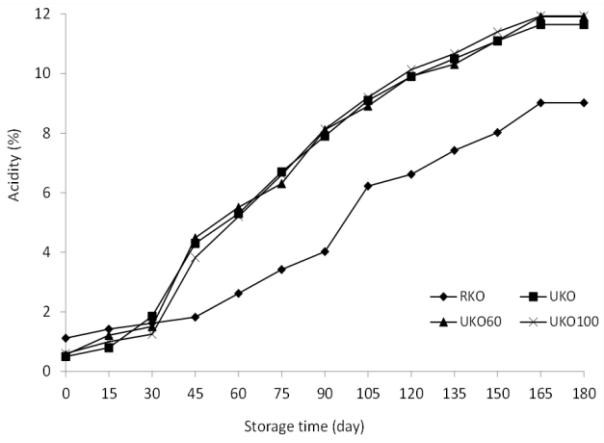

Figure 4. Change in acidity of *Citrullus lanatus* kernels oils during storage at room temperature (25 ℃)

Figure 5 presented the change in peroxide value of *Citrullus lanatus* kernels oils over 180 days of storage at room temperature (25 ℃). As shown in Figure 5, peroxide value gradually increased with storage time and stabilized after 165th day. Before 60 days, the increase in peroxide value of RKO was the highest, and then this trend was reversed in favor of unroasted kernels oils (UKO, UKO60 and UKO100). The maximum values reached were of 16.00, 21.89, 22.00 and 22.41 meq O_2/kg respectively for RKO, UKO, UKO60 and UKO100. However, the pressing temperature did not have a significant ($p > 0.05$) effect on the change in peroxide value of *C. lanatus* oil during storage at room temperature.

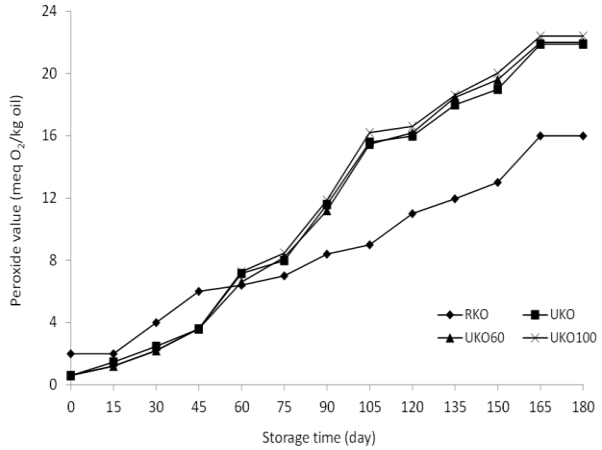

Figure 5. Change in peroxide value of *Citrullus lanatus* kernels oils during storage at room temperature (25 ℃)

3.4. Thermo-oxidative Stability of Oils

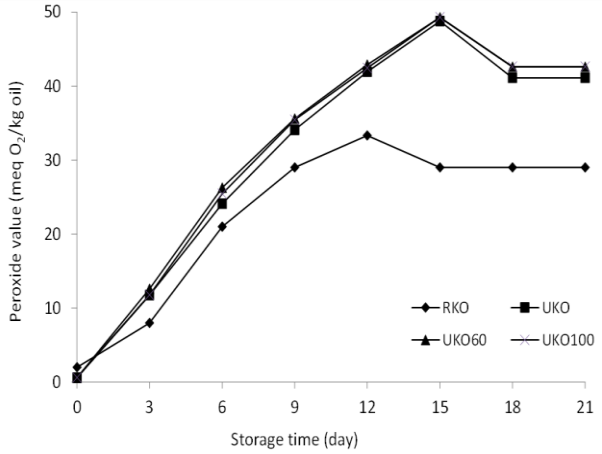

Figure 6. Change in peroxide value of *Citrullus lanatus* kernels oils during storage in an oven at 60 ℃

The change in peroxide value of *Citrullus lanatus* kernels oils stored in an oven at 60 ℃ for 21 days is illustrated in Figure 6. The results showed that the peroxide value gradually increased over time from 0 to 12 days for RKO and from 0 to 15 days for unroasted kernels oils (UKO, UKO60 and UKO100), then decreased before stabilizing. The maximum values achieved were 33.33 meq O_2/kg for RKO, compared to 48.78; 49.27 and 49.29 meq O_2/kg for UKO, UKO60 and UKO100, respectively. However, after 21 days of storage, peroxide value were 29.00 meq O_2/kg for RKO; and 41.11; 42.60

and 42.62 meq O_2/kg for UKO, UKO60 and UKO100, respectively. As for the pressing temperature, it did not significantly ($p > 0.05$) influence the change in peroxide value of *C. lanatus* oil during 21 day of storage in the oven at 60 ℃.

4. Discussion

4.1. Effect of Roasting on Chemical Parameters of *Citrullus Lanatus* Kernels Oil

Roasting did not significantly influence the pH of *C. lanatus* kernels oil. This similar result is reported by [26] on oil from orange seeds (*Citrus sinensis*) roasted. In contrast, Adeyanju *et al*. [27] observed that pH of coconut oil decreased when roasting temperature and time increased. These results showed roasting effect on oil pH depend on plant material and roasting conditions. In addition, pH values, which were ranged from 5.23 ± 0.00 to 5.50 ± 0.01, indicate that oils were acidulous. This property could be used in cosmetic creams formulation based on its compatibility with skin pH, which is between 5.2 and 7 [28].

In addition, roasting significantly increased oil acidity of *C. lanatus*. This result is consistent with previous work on peanut [18], coconut [27], pine nut [29] and rapeseed [30] oils. The increase in acidity could be due to the release of fatty acid resulting from triglycerides hydrolysis which are the main components of vegetable oils, triggering oil oxidative degradation reactions due to the prooxidant action of free fatty acid [31].

Roasting led to significant increase of peroxide value of *C. lanatus* kernels oil. Similar results were reported in literature on rapeseed [30], walnut [32] and argan [33] oils when seeds roasting temperature increase. The increase in peroxide value could be attributed to the accumulation of hydro-peroxides as a result of free radical attack on unsaturated fatty acids. However, acid and peroxide values of all these oils were less than 4 mg KOH/g and 15 meq O_2/kg respectively which are the maximum values recommended by FAO/WHO for virgin vegetable oils [34]. Consequently, low acidity and peroxide value indicate low level of free fatty acids and hydroperoxides, and therefore good oil quality.

Roasting reduced iodine and saponification values of *C lanatus* kernels oil. In their previous work on peanut, Damame *et al*. [35] also reported similar result for iodine but saponification value was not affected. However, Li *et al*. [36] did not observe significant differences in iodine and saponification values for raw and roasted peanut oils at different temperatures. Indeed, iodine value is generally used to assess the degree of unsaturation of oil. Therefore, its decrease could be explained by the rupture of the double bonds due to the hydrolytic and/or oxidative action of the heat treatments. However, based on iodine values between 100 and 150 g I_2/100 g, these oils might be classified as "Semi-drying or di-unsaturated oils" [37]. In addition, based on saponification values between 180 – 200 mg KOH/g, these oils could be suitable for the manufacture of soaps, creams and shampoos [38].

Roasting caused an increase in total phenol content of *C. lanatus* kernels oil. Similar results were reported on wheat germ [17], pine nuts [29], argan [33] and *Pistacia terebinthus* [39]. Authors observed that total phenols content increased considerably with roasting temperature and time. The increase in total phenol content could resulted from the facilitation of their transfer from seeds to oil and also from the accumulation of MRPs with reductone-type structure or phenol-like complexes formed during the roasting process [17]. However, Vujasinovic *et al*. [40] have suggested that total phenol content between oilcake and oil is strongly dependent on its hydrosolubility, which is regulated by distribution coefficients.

4.2. Effect of Roasting on the Capacity Antioxidant of *Citrullus Lanatus* Kernels Oil

Roasting increased radical scavenging activity (RSA) of *C. lanatus* kernels oil. Similar result was reported by [17] on the antioxidant capacity of wheat germ oil. They found significantly increase of both DPPH and ABTS RSA when increasing roasting time. Likewise, Suri *et al*. [18] reported that rosating peanut at 180 ℃ for 10 min led to high RSA of oil extracted compared to unroasted peanut oils. The increase in RSA can be attributed to the release of phenolics compounds or MRPs such as hydroxymethylfurfural in the oil-phase caused by high-temperature roasting [43]. These compounds are known to have strong antioxidant properties [17]. However, roasted kernels oil demonstrated lower RSA than α-tocopherol.

4.3. Effect of Roasting on the Oxidative Stability of *Citrullus Lanatus* Kernels Oil

The acidity and peroxide value of oil continuously increased during storage at room temperature over 180 days. The increase in acidity of *C. lanatus* kernels oils could be attributed to triglycerides hydrolysis [24]. As far as concern peroxide value, its increase could indicate the production of primary oxidizing compounds such as hydroperoxides and epoxides in *C. lanatus* kernels oils [44].

In addition, during storage, roasted kernels oil generally had lower acidity and peroxide value than unroasted kernels oils. Indeed, Onyeike and Acheru [45] reported that the tolerable acidity limit value for edible vegetable oils is 3%. This value was reached after 38 and 67 storage days for unroasted and roasted kernels oils, respectively. Concerning the peroxide value, its limit value for edible vegetable oils is 15 meq O_2/kg [34]. This value was reached after 102 and 162 storage days for unroasted and roasted kernels oils. Accordingly, these observations clearly suggest that roasting followed by mechanical pressing limited the alterability of *C. lanatus* kernels oil such as delaying oil rancidity process. These results were in agreement with those of [46] and [47] who revealed that roasting safflower, sesame and argan seeds before oil extraction improved auto-oxidative stability of oils. This suggests that roasting inactivated lipase or lipoxygenase. Indeed, Ö zcan *et al*. [48] and Sudha *et al*. [49] observed that thermal treatment of wheat germs inactivated lipases

and lipoxygenase of 78 and 92% respectively. As a result, few triglycerides were hydrolyzed or oxidized leading to the slowing of acidity and peroxide value in roasted kernels oil.

Oil thermo-oxidation occurring during storage at 60 ℃ for 21 days showed that peroxide value increased to a maximum value before decreasing. On the one hand, the increase in peroxide value could be related to the production of hydro peroxides following the sudden rise in temperature [50]; on the other hand, the subsequent decrease could be due to their instability at high temperatures [51]. The results of the oven test suggest that roasting has improved the oxidative stability of *C. lanatus* kernels oil under accelerated oxidizing conditions. Our results were also consistent with those previously reported for oils of wheat germ [17], pine nut [29], cashew nut [52] and perilla [53]. These studies also showed that the roasting process increases the oxidative stability of oils. Although some intrinsic native antioxidants such as tocopherols and carotenoids slightly decreased during roasting, the increased oxidative stability of *C. lanatus* kernels oil could be attributed to the release of more phenolic compounds, the neo-formed products through Maillard reaction, as well as the inactivation of lipolytic enzymes [17]. Furthermore, this oxidative stability study has shown that roasted kernels oil demonstrated better resistance against oxidation (auto or thermo) than unroasted kernels oils.

4.4. Effect of Pressing Temperature on the Extracted Oil

The pressing temperature did not significantly affect the chemical parameters and oxidative stability of *C. lanatus* kernels oil. Indeed, pressing of 1 kg of *C lanatus* kernels lasted about 25 min and led to oil having temperature between 30 and 50 ℃, clearly much lower than that applied to the screw head (60 and 100 ℃). Consequently, the short contact time between the pressed material and the cylinder would have limited the effect of the pressing temperature on the extracted oil. However, the pressing temperature of 100 ℃ resulted in a decrease in the RSA of *C. lanatus* kernels oil. This reduction would be due to the thermal degradation of some antioxidant substances, naturally present in oil, such as carotenoids and tocopherols [54]. Based on these results, it would not be advisable to heat the press above 60 ℃ in order to preserve the antioxidant capacity of *C lanatus* kernels oil.

5. Conclusion

This study evaluated the impact of roasting on the chemical parameters, antioxidant capacity and oxidative stability of *Citrullus lanatus* kernels oil. Roasting did not change the pH of *C lanatus* kernels oil. The oils were acidulous. In addition, Roasting increased acidity and peroxide value of *C lanatus* kernels oil. However, the roasted kernels oil had good quality since acid and peroxide values were significantly lower than the maximum values recommended by FAO/WHO for virgin vegetable oils. Roasting reduced iodine and saponification values of *C lanatus* kernels oil. Based on iodine value was between 100 and 150 g I_2/100 g, roasted kernels oil was classified as "Semi-drying or di-unsaturated oils". Moreover, Roasting increased the total phenol content, RSA and oxidative stability of *C lanatus* kernels oil giving roasted kernels oil better resistance against auto- and thermo-oxidation. These results suggest that roasting at 180 ℃ for 20 min would extend the shelf life of *C. lanatus* kernels oil without compromising its quality and unsaturation degree. In addition, this oil would be suitable for food use (seasoning, cooking, frying, etc.).

Statement of Competing Interests

The authors have no competing interest in relation to their work.

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