Hindawi
Journal of Food Quality
Volume 2023, Article ID 2175685, 9 pages
https://doi.org/10.1155/2023/2175685

Research Article

Effect of Roasting on the Proximate Composition, Antioxidant Activity, and Functional Properties of *Afrostyrax lepidophyllus* (Country Onion) Seeds

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Received 1 September 2023; Revised 13 December 2023; Accepted 18 December 2023; Published 27 December 2023

Academic Editor: Rana Muhammad Aadil

Afrostyrax lepidophyllus seed is a nontimber forest product which has a strongly ferocious smell of garlic or onion. It is widely used in central and west Africa in traditional medicine and as spices. The seeds used as spices are generally roasted in order to improve their flavor or aroma. However, roasting conditions vary and also affect the quality of the final product. In order to define the best roasting conditions, *A. lepidophyllus* seeds were roasted using microwave (200, 300, and 450 W for 10 min), oven (10 and 20 min at 180°C), and pot (5, 10 and 15 min) and blended into flour. The proximate composition, physical, functional, and antioxidant activities of (control) and roasted flours were analyzed. Irrespective of the roasting method, there was a significant increase in fiber content (oven (0.5–1.20%), pot (0.47–1.27%), and microwave (0.50–0.93%)) with increase in time and temperature. The carbohydrate content increased (77.74–81.50%), while protein content dropped with roasting. A significant increase in ash, total phenolic contents (TPC), antioxidant activity (AOA), and functional properties compared to the control was recorded. Roasting *A. lepidophyllus* seeds in the pot at 250 ± 5°C, 15 min was found to be a good method which maintained or increased its functional and physicochemical properties. With the good TPC and AOA, *A. lepidophyllus* roasted flour can be a potential ingredient for nutraceutical food development.

1. Introduction

Afrostyrax lepidophyllus is a nontimber plant of the *Huaceae* family, locally known as "bush onion," country onion "Shirum," and "Mruu." It is a very popular spice growing traditionally in central and west African forests. *A. lepidophyllus* seed is a round shape nut with a strong flavor frequently found in the forests or markets in Nigeria, Congo, Cameroon, and the Central Republic of Africa [1]. *A. lepidophyllus* bark, fruits, leaves, and root have several medicinal uses. A decoction made from bark and root is used as anthelmintic against vomiting, urinary infections, enema, indigestions, and snake bites [2, 3]. It is also used as an antiseptic for the treatment of gastroenteric illnesses. The leaves are crushed, infused, and used as bath seat to fight against women hemorrhoids and as mouthwash to treat caries and toothache. The authors in [4] reported cytotoxic and antimicrobial activities of the essential oils from the *A. lepidophyllus* seeds. The polyphenol content of the hydroethanolic bark extract of this plant is greater than 28 mg/g with about 7 mg/g being flavonoids [4]. In the Central African Republic and in many other African countries, Cameroon included, the seeds are equally one of the most used spices as these possessed a strong garlic-onion flavor [5]. This strong and powerful garlic-onion flavor made the seeds to rise among the top spices used in the preparation of several traditional meals such as “nkui,” “nak npo,” and “Mbongo tchobi” just to name a few in Central and West Africa countries [1, 6].

During cooking, the seeds are usually either partially burned in the fire in the village, grilled in a frying pan or the stove, or microwaved in towns, in order to enhance their flavors.

Several authors revealed that the pretreatments of food products before cooking may affect negatively or positively the nutritional and functional properties of the final product [7–9]. Audu et al.[10] reported that heat has a positive effect on the nutritional value of white kidney beans by increasing the bioavailability of carbohydrates and proteins while decreasing the levels of antinutrients present. Amandikwa et al. [11], on the other hand, revealed that long heating time reduces the concentration of vitamin C and beta carotene content in some green vegetables. Given that the *A. lepidophyllus* seeds are mostly heated before being used in food preparation, knowing information about the roasted seed flours may increase their uses in food formulations and improve their consumption as well as the income generation of producers. Therefore, the main objective of this work was to evaluate the effect of the different preheating methods such as pot, oven, and microwave roasting on the physicochemical, antioxidant, and functional properties of *A. lepidophyllus* seed flours.

2. Materials and Methods

2.1. Raw Materials and Chemicals. *Afrostyrax lepidophyllus* seeds were purchased from a farmer from Akololinga (3° 46′ 57.9468″ N and 12° 14′ 56.652″ E), Center Region of Cameroon in November 2022.

All the chemicals and reagents used were of analytical grade.

2.2. Methods

2.2.1. Sample Preparation. *A. lepidophyllus* seeds were sorted to remove stones, strange particles, and dead seeds. Unaffected seeds were then peeled and divided into four batches. One batch served as control when the three others were, respectively, roasted using pot (5, 10, and 15 min at about 250°C), oven (10 and 20 min at 180°C), and microwave (200, 300, and 450 W for 10 min). Roasted samples were individually ground and kept in a close polypropylene plastic bag for further analyses.

2.2.2. Proximate Composition. The AOAC [12] method was used to determine the moisture, ash, fat, and protein contents of country onion flours. Dilute acid and alkaline were used to hydrolyze 5 g of sample in order to evaluate the crude fiber content [13]. The carbohydrate content was computed by difference via equation (1) as described by Mohamed Ahmed et al. [14].

$$\% \text{ Carbohydrate} = 100 - \% \text{ (Moisture + Fat + Protein + Fiber + Ash)}. \quad (1)$$

2.2.3. Total Phenolic Content. The total phenolic content (TPC) of the different *A. lepidophyllus* flours was extracted by macerating 20 g of sample in 100 mL methanol for 24 h and filtrated using Whatman No. 1 filter paper. The extract was concentrated using a rotavapor, and the TPC was evaluated by the colorimetric method using the Folin–Ciocalteu reagent as described by Bekir et al. [15], with slight modifications. Briefly, in the mixture of 200 μL of the extract plus 800 μL of Folin–Ciocalteu (0.2 N), 2 mL of sodium carbonate (7.5% w/v) was added. The final mixture volume was made up to 7 mL with distilled water, stirred 2000 rpm for 5 min, and incubated at room temperature in darkness for 30 min. The absorbance was then taken at 765 nm. Gallic acid was used as the standard, and the result was expressed in mg of gallic acid equivalent per gram of dry weight.

2.2.4. Antioxidant Activity. The antioxidant activity of *A. lepidophyllus* sample was determined via the free radical 1, 1-diphenyl-2-picrylhydrazyl (DPPH) scavenging activity as described by Molyneux [16]. A volume of 3 mL diluted extract was mixed in the test tube with 1 mL of DPPH solution (0.1 mM, prepared in methanol). The mixture was incubated for 30 min at ambient temperature in darkness, and the optical density of the final solution was taken at 517 nm against blank (methanol). Tert-hydroquinone was used as the standard, and the antioxidant activity (AOA) was computed using the following equation:

$$\text{AOA (\%)} = \frac{(A_0 - A_s)}{A_0} \times 100, \quad (2)$$

where A_0 is the absorbance of the control and A_s is the absorbance of the sample.

2.2.5. Functional Properties

(1) Water Absorption Capacity. The water absorption capacity of the *A. lepidophyllus* flours was determined by the method described by Sosulski et al. [17]. In a centrifuge tube, 5 g of sample was mixed with 25 mL of distilled water and kept at room temperature for 30 min. The mixture was then centrifuged (4500 g, 25 min), and the sediment was weighed. The water absorption capacity was expressed as milliliter of water held per gram of the sample.

(2) Oil Holding Capacity. The oil holding capacity taken as the percentage of oil bound per gram of the *A. lepidophyllus* flour was examined using the method of Sosulski et al. [17].

A volume of 10 mL of vegetable oil was mixed with 1 g of sample and kept at room temperature for 30 min. The mixture was then centrifuged at 4500 g for 25 min. The oil holding capacity was expressed as milliliter of vegetable oil held per gram of the sample.

(3) Swelling Capacity. The modified method of Okaka and Potter [18] was used to evaluate the swelling capacity of the *A. lepidophyllus* seed flours. A 100 mL graduated cylinder was filled up to 10 mL mark with sample flour, and distilled water was added to make a total volume of 50 mL. The cylinder was tightly covered and thoroughly mixed for 30 min by inverting the cylinder. The cylinder was kept at room temperature for 30 min, and the volume occupied by the resulting sample was taken.

$$\text{Swelling Capacity} = \frac{\text{Mass of wet sediment}}{\text{Mass of dry matter in gel}}. \quad (3)$$

(4) Loose Bulk Density and Packed Bulk Density. The bulk density was determined according to the method described by Konak et al. [19]. Briefly, 50 g of country onion flour was measured and put into 100 mL graduated cylinder. The cylinder was tapped gently 10 to 15 min, until no perceptible change in volume. The loose bulk density (LBD) and packed bulk densities (PBD) also known as volumetric density were computed as the ratio of the mass of *A. lepidophyllus* flour (g) to the volume (mL) occupied by the flour before and after tapping.

(5) Hausner Ratio and Porosity. The Hausner ratio (HR) and the porosity (P) of *A. lepidophyllus* flour were calculated from the value of packed and loose bulk densities using the following equations, respectively:

$$\text{HR} = \frac{\text{Packed bulk density}}{\text{Loos bulk density}}, \quad (4)$$

$$\text{Porosity (\%)} = 100 \times \left(\frac{\text{Packed density} - \text{Loose density}}{\text{Packed density}} \right). \quad (5)$$

2.2.6. Statistical Analysis. Results are represented in the form of means and standard deviations of at least triplicate determinations. Data were subjected to the analysis of variance (ANOVA) using Stat Graphics Centurion version XVI (StatPoint Technologies, Inc., Warrenton, Virginia, USA) to evaluate the statistically significant difference ($p < 0.05$) between means [20, 21]. Duncan's multiple range test was used to accomplish the separation of means.

3. Results and Discussion

3.1. Proximate Composition. The variation of moisture content (MC) of *A. lepidophyllus* with respect to different roasting treatments is presented in Table 1. Generally, the MC of all roasted samples was lower compared to the control (unroasted sample). The reduction of the MC is important as this prolongs the shelf life and the keeping quality of the seed flour. In fact, the reduction of MC is related to the reduction in water activity which governs the microbial proliferation and biochemical reactions, the main parameters responsible for food deterioration. The decrease in MC obtained in this study is probably due to the evaporation of water during the roasting treatments. A similar finding was observed by Santos et al. [9], during the roasting of defatted walnut flour. The lowest MC (7.30 g/100 g DW), which was not significantly different ($p < 0.05$) from the value recorded with samples roasted in the pot (8.56, 8.76 and 9.80 g/100 g DW, respectively), was found with oven roasting treatment at 180°C for 20 min. It should be noted that the highest temperature (250 ± 5°C) during roasting was set for pot roasting, and the slight difference between the MC of the oven and pot roasting treatment could be due to ventilation in the oven that contribute in reducing the MC of the sample.

Concerning the ash content, apart from the sample roasted in the pot for 15 min, there was no significant difference ($p < 0.05$) between the control and the roasted samples. The slight increase recorded could be attributed to the concentration of other constituents during roasting. In food matrix, ash content represents the mineral present. The ash content of the roasted *A. lepidophyllus* seed flours ranged from 1.73 to 2.20 g/100 g DW. These values are smaller than 3.9%, as pointed out by Khan and Saini [22], on the roasted flaxseed flour.

The protein content varied from 3.68 to 9.46 g/100 g DW. In general, there was a significant decrease ($p < 0.05$) in the protein content of *A. lepidophyllus* flours irrespective of the roasting method applied. This reduction could be due to the participation of proteins in the nonenzymatic browning reaction. The decrease in protein content could also be attributed to amino acid polymerization and protein denaturation during roasting [7]. A similar result was reported by Kumar et al. [23], who found a reduction in the protein content of black chickpea (*Cicer arietinum*) by 14.8% after roasting. The decrease in the protein content of defatted walnut flour and marble vine (*Dioclea reflexa*) was also reported, respectively, after roasting [7, 9].

The variation of fat content was within the range of 8.80 to 12.90%. The sample roasted in the oven 180°C for 10 min, pot for 10 min, and microwave 300 W for 10 min had a significantly higher fat content compared to the control. The increase in fat content could be attributed to the redistribution of nutrients and the disorganization of the food matrix due to high roasting temperature associated with the increase of the fat extraction yield [24]. The lower fat content (8.80 g/100 g DW) was obtained with microwave roasting 200 W for 10 min treatment, whereas the highest fat content was obtained with the sample roasted in the oven at 180°C for 10 min. The presence of fat in a food matrix is important as it has the ability to facilitate the absorption of fat-soluble vitamins in the human track [25].

The total crude fiber content of the roasted *A. lepidophyllus* flours varied from 0.50 to 1.27 g/100 g DW, while that of the unroasted sample was 0.67 g/100 g DW.

Table 1: Proximate composition (g/100 g DW) of *A. lepidophyllus* seed flour after different roasting treatments.

Treatments	Moisture	Ash	Protein	Fat	Fiber	Carbohydrate
Control	16.61 ± 0.78^{b}	1.67 ± 0.46^{a}	9.46 ± 2.97^{c}	10.20 ± 1.06^{ab}	0.67 ± 0.12^{ab}	77.74 ± 1.84^{a}
Oven roasting 180°C/10 min	9.36 ± 0.57^{a}	2.13 ± 0.12^{ab}	3.68 ± 0.74^{a}	12.90 ± 1.27^{c}	0.50 ± 0.42^{a}	80.82 ± 2.58^{ab}
Oven roasting 180°C/20 min	7.30 ± 0.03^{a}	2.13 ± 0.23^{ab}	6.30 ± 0.01^{b}	10.67 ± 1.02^{ab}	1.20 ± 0.72^{b}	79.6 ± 0.71^{ab}
Pot roasting 5 min	9.80 ± 1.32^{a}	1.73 ± 0.12^{ab}	6.30 ± 0.01^{b}	10.13 ± 0.42^{ab}	0.47 ± 0.31^{a}	81.5 ± 0.0^{b}
Pot roasting 10 min	8.76 ± 0.03^{a}	2.13 ± 0.31^{ab}	8.06 ± 0.61^{bcd}	11.30 ± 0.99^{bc}	1.27 ± 0.42^{b}	77.62 ± 0.88^{a}
Pot roasting 15 min	8.56 ± 0.32^{a}	2.20 ± 0.35^{b}	$7.88 \pm 0.74b^{cd}$	10.13 ± 1.01^{ab}	1.2 ± 0.2^{b}	79.02 ± 0.32^{ab}
Microwave roasting 200 W/10 min	10.22 ± 0.04^{a}	1.93 ± 0.11^{ab}	8.76 ± 1.61^{cd}	8.80 ± 0.53^{a}	0.50 ± 0.14^{a}	79.14 ± 0.92^{ab}
Microwave roasting 300 W/10 min	10.30 ± 0.76^{a}	2.00 ± 0.40^{ab}	8.41 ± 1.49^{bcd}	11.00 ± 1.06^{bc}	0.87 ± 0.12^{ab}	77.59 ± 2.33^{a}
Microwave roasting 450 W/10 min	9.78 ± 0.59^{a}	2.00 ± 0.20^{ab}	5.78 ± 0.74^{ab}	10.13 ± 1.97^{ab}	0.93 ± 0.12^{ab}	80.52 ± 2.58^{ab}

Mean values in the same column carrying the same superscript letters are not significantly different ($p > 0.05$).

As far as pot, microwave, and oven roasting were concerned, there was an increase in fiber content with the increase of the roasting time/temperature. The increases could be attributed to the evaporation of free water and some volatile compounds which caused the concentration of crude fiber. This finding is in accordance with that of Lawal et al. [8] and Mohamed Ahmed et al. [14], who found the increase in the fiber content of defatted sesame seed flours during toasting and Samh (*Mesembryanthemum forsskalei* H.) seeds during roasting, respectively. The best roasting method for the highest crude fiber content of the *A. lepidophyllus* seeds was pot roasting for 10 min.

Concerning the carbohydrate content (CC), the result ranged from 77.59 to 81.5 g/100 g DW. All the roasting methods affected the CC of the *A. lepidophyllus* seed flours. There was a significant reduction of the CC with the increase of the roasting time/temperature. The reduction in carbohydrate content found in these conditions could be due to the utilization of carbohydrate as a substrate in nonenzymatic browning reactions which occurred during roasting processes. A similar observation was reported by Tenyang et al. [26], who noticed a decrease in the carbohydrate content of two sesame varieties during boiling and roasting. Irrespective of the roasting method used, the final carbohydrate content was above 77 g/100 g DW which suggests that *A. lepidophyllus* could bring an added energy value. In fact, it is well known that carbohydrates are the first important energy source of the human diet [27].

3.2. Total Phenolic Content. The word polyphenol refers to natural plant substances mostly found in fruits and vegetables [28]. The result of the total phenolic content (TPC) of *A. lepidophyllus* with respect to the roasting treatment methods is presented in Figure 1.

Generally, the TPC increased with the couple time/temperature and microwave power. For all treatments, the couple time/temperature was the main factor which influences the increase in the TPC irrespective of the roasting treatments. The TPC ranged from 143.77 to 256.31 mg GAE/g with the lowest and highest values attributed to the sample roasted in the pot for 5 and 15 min, respectively. In plant materials, insoluble polyphenols are covalently bound to lignin. The thermal hydrolysis of these lignin-polyphenol acid bonds which may have taken place during the roasting treatment of samples could justify the increases of the quantity of the free phenolic compounds. Maillard and Berset [29] reported that, in plant tissues, the quantity of bound phenolic acids after thermal hydrolysis was twice higher than that of free phenolic compounds. Also, the thermal degradation of lignin could release more phenolic acids [28]. Several authors previously reported the increase of TPC with the increase in temperature [30, 31]. The increase of the TPC could be of great interest as these compounds are mostly correlated to several health benefits such as prevention against cancer and cardiovascular diseases [32, 33]. The lowest TPC found in this study is greater than that of Frédéric et al. [5], who reported a maximum value of 51.8 mg GAE/g in *A. lepidophyllus* seed extracts. This difference could be attributed to the variation in geographical zone, soil, climate, or/and the extraction method used. The important value of TPC found in this work is of great interest as these compounds in most cases are associated with health benefit.

3.3. DPPH Radical Scavenging Activity. The result of the antioxidant activity of the *A. lepidophyllus* seed flours evaluated in terms of free radical scavenging activity is shown in Figure 2. All the studied samples exhibited antioxidant activity (AOA) with different intensities. This corroborated the result of Frédéric et al. [5], who found that the methanol extract of the *A. lepidophyllus* seeds possessed AOA. Generally, for the same roasting method, the AOA increased with the concentration of the sample used irrespective of the roasting treatment applied. With the exception of the oven roasting methods, where the decrease in AOA was observed with the maintaining of the thermal exposition of the sample, there was a general increase in AOA with the increase of the temperature. This increase could be explained by the releases of the free phenolic acids with high AOA potentiality. The finding could be confirmed with the trend of the result recorded with the evaluation of the TPC presented in paragraph 3.2. Moukette et al. [4] previously studied the TPC of *A. lepidophyllus* and discovered that they were mainly made up of flavonoids which are powerful antioxidant compounds. The best method which exhibited the highest AOA was found to be pot roasting for 15 min.

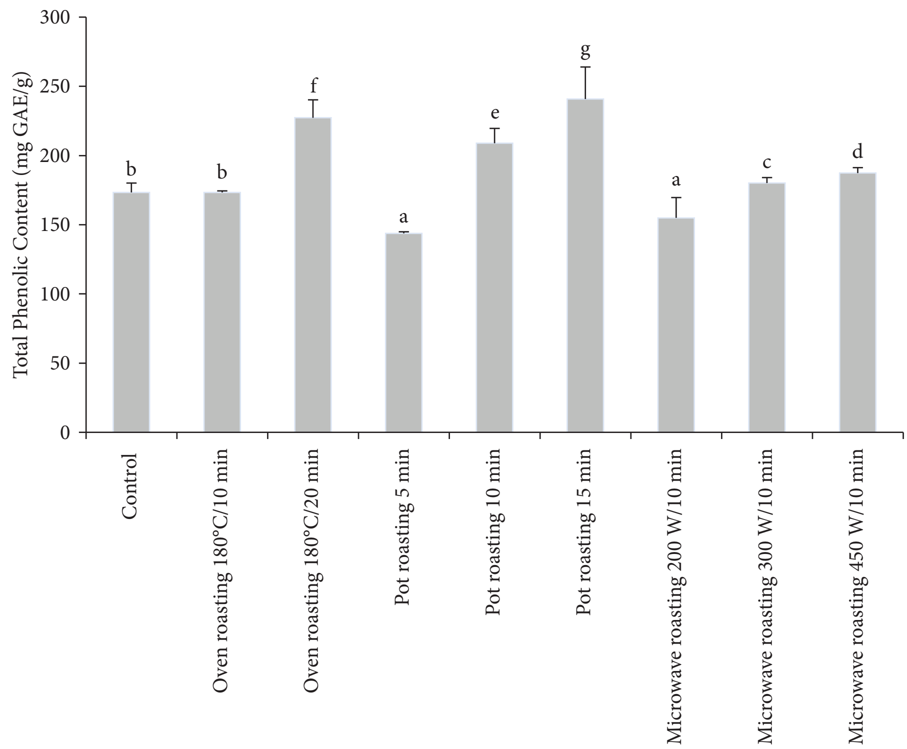

Figure 1: Variation of the TPC of the *A. lepidophyllus* seed flour during roasting methods.

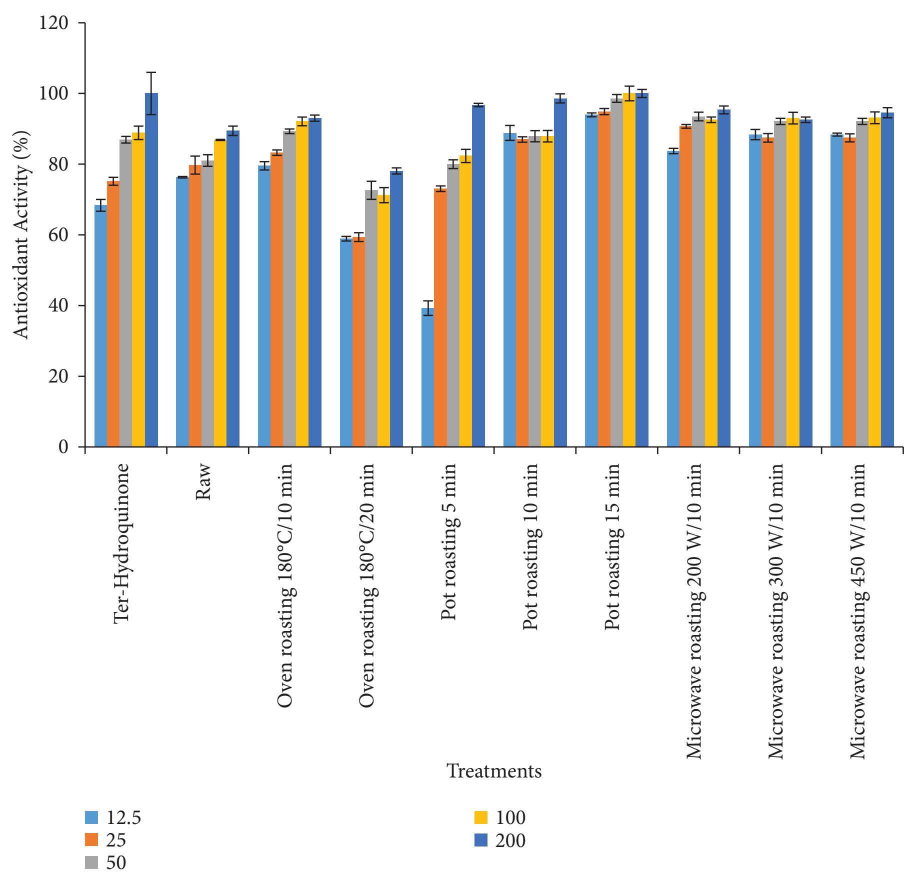

Figure 2: Effect of different roasting treatments on the antioxidant activity of *A. lepidophyllus* seed flour.

3.4. Functional Properties. The functional properties of food flours are parameters that determine its taste, flavor, processing method, transportation, and storage time [34]. Different functional properties of *A. lepidophyllus* flour were evaluated, and the results are presented in Table 2.

3.4.1. Water and Oil Holding Capacities. The result of water holding capacity (WHC) of the roasted *A. lepidophyllus* revealed that irrespective of the applied roasting methods, the value increased significantly as compared to the control (unroasted sample). Microwave roasting resulted in the highest increase in WHC (20.1%), followed by pot roasting (19.5%), while the oven roasting had the lowest (16.3%) increase in WHC. For the same roasting method, there was a proportional increase in WHC with time and temperature. The increase in WHC could be accredited to the formation of the porous structures within the flour matrix during the roasting process due to heat, which may therefore increase the capacity of the sample to absorb water. Additionally, the gelatinization of the starch content of the sample which is proportional to the processing temperature could increase the WHC. In fact, the WHC of the starch granules increases with the process of gelatinization [35, 36]. Jogihalli et al. [37] reported an increase in WHC of the chickpeas roasted in the microwave due to starch gelatinization. The value of WHC found in this study is lower than 132 to 176% reported by Chandra et al. [38], in composite biscuit flours and 199.60 to 336.58% obtained by Ohizua et al. [39], in unripe cooking banana, pigeon pea, and sweet potato flour blends. These differences can be attributed to the difference in starch content between *A. lepidophyllus* flours and those food flours.

The result of oil holding capacity (OHC) (Table 1) revealed a significant increase after roasting processes. The OHC of the roasted sample ranged from 8.05 to 8.50% with the highest value found with the sample roasted in the microwave 450 W for 10 min. This variation could be attributed to the solubilization of the subunits of proteins resulting from the thermal dissociation during the roasting process. In fact, previous research found that, during thermal treatment, proteins dissociate and become more soluble, modifying their polarity which contribute to the increase in the OHC [40]. This increase in OHC could also be explained by the augmentation of the sample porosity due to the evaporation of some constituent during processes. This result suggests that *A. lepidophyllus* roasted flours can be used for food formulation as their important OHC will increase the palatability and the ability of retaining flavors. However, the roasting conditions should be well defined and controlled in order to take benefit of these properties.

3.4.2. Swelling Capacity. The swelling capacity (SC) is one of the important technological parameters in food processing. The higher the SC, the lower is the bonding energy between molecules that constitute a food system [39]. The effect of different roasting methods on the SC of *A. lepidophyllus* was evaluated, and the result is presented in Table 2. There was a significant increase ($p < 0.05$) in SC compared to the control. The different roasting methods improved the SC of *A. lepidophyllus* flour. This result is in line with that of Djikeng et al. [20], who found that thermal processing positively affects the SC of the *Archachatina maginata* powder meat. This increase can be attributed to the reorganization of the proteins during heating. In fact, according to Li et al. [40], heat treatment destabilized the aggregation of protein molecules which favor the establishment of the cross-linking network between peptide bonds and side chains. The formation of this network contributes significantly to water retention and therefore increases the SC. The value of the SC found in this study is higher compared to 9.91 to 12.71% as obtained by Ocheme et al. [41], on wheat and groundnut protein concentrate flour blends.

3.4.3. Hausner Ratio and Porosity. The Hausner ratio which indirectly measured the property of a bulk density of material to reduce its volume in case of mechanical influence was calculated by taking the ratio of loose bulk density to the apparent density after tamping [42]. The HR value ranged from 1.12 to 1.37 (Table 2), indicating that the *A. lepidophyllus* flours have low interparticle friction; therefore, it will exhibit a high degree of flowability. In fact, according to Chinwan and Castell-Perez [43], flours with HR > 1.45 have poor flowing behavior. This lower HR could be due to the poor moisture content of the different samples [41]. In fact, during drying, the formation of pores which controls the variation of the HR is proportional to the quantity of evaporated water. The highest HR obtained in this study is smaller compared to the least value (1.40), as reported by Amankwah et al. [44], in a composite flour made of wheat-rain tree.

The porosity of a food flour is related to the particle size, shape, and density of the flour. It guides the type of the packaging material required as well as the storage condition [11]. The porosity of *A. lepidophyllus* ranged from 12.84 to 34.54%. The different roasting methods significantly affected the porosity except for the sample roasted in the pot for 5 min. The porosity increased with the heating time, irrespective of the treatment method. This could be attributed to evaporation of the free water which allowed the material to settle well and increased the porosity. The highest porosity was recorded with the sample roasted in a microwave at 450 W for 10 min, which contributes in justifying the highest water holding activity obtained with the same sample. High porosity is technologically important as porous samples are lighter and suitable for packaging and transport [45].

3.4.4. Loose and Packed Bulk Density. The loose and packed densities are two important parameters that determine the packaging system and the packaging material of a food flour [46]. The bulk densities of *A. lepidophyllus* varied from 0.75 to 0.85 g/mL (loose bulk density) and from 0.95 to 1.07 g/mL (packed bulk density) (Figure 3). The bulk densities obtained in this study follow the same trend of the moisture content. This corroborated the finding of Chandra et al. [38], who reported the dependency of the bulk density on the initial

Table 2: Functional and physical properties of *A. lepidophyllus* flours with respect to different roasting treatments.

	WHC (%)	OHC (%)	Swelling capacity (%)	Hausner ratio	Porosity (%)
Control	13.2 ± 0.4^{a}	8 ± 0^{a}	12.75 ± 0.35^{a}	1.18 ± 0.06^{a}	17.32 ± 1.86^{abc}
Oven roasting 180°C/10 min	15 ± 0^{b}	8.05 ± 0.07^{bc}	19.51 ± 1.87^{cd}	1.31 ± 0.08^{bcd}	12.84 ± 1.80^{a}
Oven roasting 180°C/20 min	16.3 ± 0.4^{c}	8.17 ± 0.11^{bc}	26.14 ± 1.61^{e}	1.21 ± 0.13^{ab}	21.10 ± 1.95^{c}
Pot roasting 5 min	15 ± 0^{b}	8.22 ± 0.03^{cd}	16.59 ± 2.25^{abc}	1.26 ± 0.03^{abcd}	17.06 ± 3.37^{abc}
Pot roasting 10 min	16 ± 0^{c}	8.37 ± 0.18^{de}	23.21 ± 1.12^{de}	1.23 ± 0.03^{abc}	18.97 ± 4.11^{bc}
Pot roasting 15 min	19.5 ± 0.7^{d}	8.45 ± 0.03^{e}	30.45 ± 0.64^{f}	1.35 ± 0.01^{cd}	26.95 ± 2.23^{d}
Microwave roasting 200 W/10 min	15 ± 0^{b}	8.05 ± 0.08^{bc}	14.60 ± 1.36^{ab}	1.27 ± 0.04^{abcd}	$14.50 \pm 1.64a^{b}$
Microwave roasting 300 W/10 min	19.5 ± 0.7^{d}	8.45 ± 0.03^{e}	17.09 ± 1.54^{bc}	1.34 ± 0.02^{bcd}	28.36 ± 1.37^{d}
Microwave roasting 450 W/10 min	20.1 ± 0.3^{d}	8.50 ± 0.03^{f}	17.12 ± 2.99^{bc}	1.37 ± 0.00^{d}	34.54 ± 0.55^{e}

Mean values in the same column carrying the same superscript letters are not significantly different ($p > 0.05$). WHC (water holding capacity), OHC (oil holding capacity), and SC (swelling capacity).

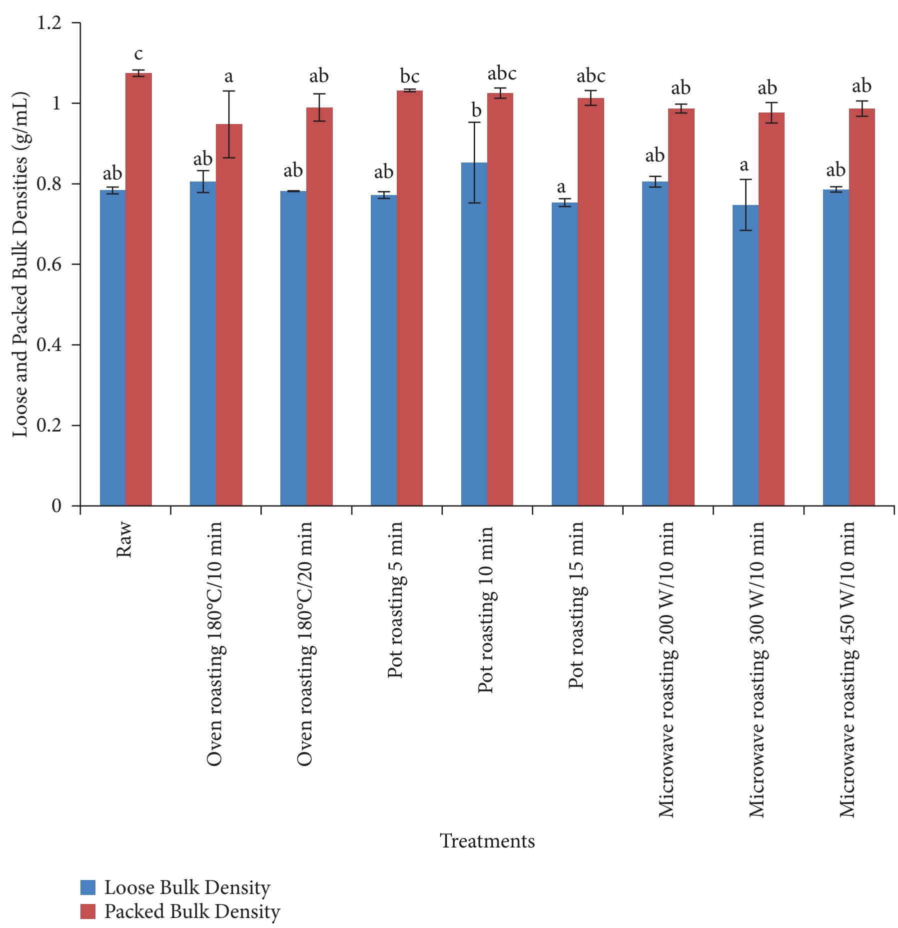

Figure 3: Variation of the loose and packed bulk densities of *A. lepidophyllus* with respect to different roasting methods. The histogram of the loose and packed bulk densities, respectively, carrying the same superscript letters, is not significantly different.

moisture content of the food flour. According to David et al. [47], food flour with a high value of bulk density can be conveniently used for food preparation. The higher bulk densities found in this study suggest that *A. lepidophyllus* flours could be used as a thickening agent in food formulation. Low bulk density flours, on the other hand, are more suitable for formulation of complementary foods as it may promote easy digestibility and promote nutrients availability [41]. The value of bulk density obtained was higher than 0.40 to 0.52 g/mL and 0.57 to 0.77 g/mL, as pointed out by Awuchi et al. [48], respectively, in Mole ranchero, Piquin chilli, Guajillo chilli, and Arbol chilli.

4. Conclusion

In this study, *A. lepidophyllus* flours were produced after different roasting methods. Results revealed that these methods influenced the nutrient, functional, and antioxidant properties of these flours. The total phenolic content as well as the antioxidant activity of the produced flours showed a significant increase after roasting treatments. These flours have slightly low moisture and protein contents compared to the unroasted sample. Pot roasting (15 min at $250 \pm 5^{\circ}C$) treatment was found to be better maintained or increased antioxidant activity, moisture, ash and total phenolic contents, water holding and swelling capacities, and Hausner ratio.

The *A. lepidophyllus* flour has good health potential and could be used to develop nutraceutical foods. However, further studies need to be conducted on toxicity, overall acceptability, and levels of insertion for new product development.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors acknowledge the Catholic University Institute of Buea for providing the necessities for sample analyses during this research work.

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