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Manufacturing Technique and Nutritive Value of Soumbara (*Parkia biglobosa* Seeds) and Dark Seed of Korhogo (Côte d'Ivoire)

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Abstract

Soumbara is produced in an artisanal way. This product has a relatively strong odor that is not appreciated by some consumers in Côte d'Ivoire. From surveys of women and consumers, the manufacturing technique and the motivations for consumption of soumbara were revealed. For the chemical composition, the average water content is 13.33 ± 1.52 g/100 g MF, the average value of the ash content is 4 ± 0 g/100 g MS. The total protein and lipid levels are 16.37 ± 0.71 g/100 g DM and 21.55 ± 0.46 g/100 g DM respectively. Total carbohydrates, starch and total sugars are respectively 44.33 ± 1.46 g/100 g DM, 39.82 ± 32 g/100 g DM and 0.08 ± 0.01 mg glucose /mL. Concerning the phytochemical composition, the total polyphenols and total flavonoids have respectively contents of 2.74 ± 0.01 mg Eq AG mL of extract, and 0.82 ± 0.01 mg Eq Quer/mL of extract. The study notes that the iron and potassium contents are the most important with respectively 344.43 ± 1.20 µg/g and 174.5 ± 2.71 mg/g. The consumption survey revealed that soumbara produced in Côte d'Ivoire is relatively more consumed (55.77%) than that produced in other countries (44.23%). This artisanal product is appreciated for its taste (50.97%) and its therapeutic character (37.5%) in the form of grain (68.27%), powder (23.08%) or paste (8.65%). These data show that soumbara is very rich in nutrients, polyphenols and flavonoids. These results justify the numerous uses of this ingredient, both in food and in traditional medicine.

Keywords

Korhogo, *Parkia Biglobosa*, Soumbara, Néré Seeds, Manufacturing

Technique, Nutritional Value

1. Introduction

In rural areas of West Africa, spontaneous plant species have great importance related to their multiple uses [1]. These useful spontaneous plants and wild fruit species contribute to the food security of rural populations and are the subject of a flourishing trade whose main actors are women [2]. Among the savanna trees of the Sudanian region, Parkia biglobosa, commonly known as the dwarf tree or African carob tree, has great socioeconomic importance throughout the West African region [3]. The pods of Parkia biglobosa are consumed for their mealy and sweet pulp, but mainly for their seeds which are rich in protein, lipids, carbohydrates and calcium. Several studies have reported that these fermented seeds provide a condiment (Sonrou, Soumbara, Dawadawa, Nététu, etc.) used in African cuisine to season sauces and soups [4]. These condiments are said to regulate blood pressure, which favors their increasing consumption [5]. In Côte d'Ivoire, the main production centers of "Soumbara" are located in the extreme north of the country where Parkia biglobosa resources are abundant. Production activities are still artisanal and are carried out by women. The processing sites, the practices of the processors and the environment in which soumbara is sold on local markets constitute contamination risks that often make the product questionable for the health and safety of consumers [6]. In addition, fermentation is thought to alter the nutritional value, polyphenol content and subsequent antioxidant properties of Parkia biglobosa seeds [7]. The objective of this study is to contribute to the valorization of community-produced soumbara.

2. Materials and Methods

2.1. Biological Material

The seeds of néré and soumbara used in this study come from the city of Korhogo, in the north of Côte d'Ivoire. They were collected in the period from April to May of the year 2020.

2.2. Determination of the Stages of Soumbara Production

An observational survey conducted among three soumbara producers allowed us to determine and describe the different stages of soumbara production.

2.3. Processing of Néré Seeds and Soumbara

After production in Korhogo, the finished product (soumbara) and a sample of the seeds were stored in boxes at room temperature and transported to Abidjan. They were taken to the laboratory for analysis. The seeds were sorted, cleared of debris, and washed with distilled water. They were drained at laboratory temperature (20˚C) and dried in an oven (MEMMERT) at 60˚C for 72 hours. After drying, the seeds were crushed in a mortar and then ground using a micro-grinder (CULATTI) equipped with a 10 µm mesh sieve. The soumbara, purchased at the market, was ground with a grinder to obtain a powder that was submitted to the various analyses.

2.4. Protein Determination by the Kjeldahl Method

The determination of the protein content comes down to the determination of the total nitrogen of the sample. It includes a mineralization phase, followed by a distillation phase and a titration phase with sulfuric acid. The amount of total nitrogen is multiplied by 6.25 to obtain the total amount of protein in the sample [8].

2.5. Determination of Fat Content

A quantity of 3 g of the plant material (P_0) was introduced were introduced into an extraction cartridge. The cartridge was plugged with cotton to prevent the sample from being carried away during extraction. An empty glass flask (P_1) was also weighed and 300 mL of hexane was poured into it. The assembly consisting of cartridge and crucible was positioned on the extraction apparatus (Soxtherm Automatic Gerhardt, Germany). The extraction was done by the flow/reflux system during 6 hours. The extraction solvent (hexane) was evaporated in the evaporative rotator (Buchi Rotavapor R-215). The flask containing the fat was oven dried at 105˚C for 24 h to remove all traces of hexane and then allowed to cool in a desiccator for 5 min to avoid wetting the plant material. The flask containing the fat (P_2) was weighed [8].

$$\text{Content of fat} = \left(P_2 - P_1\right)/P_0 \times 100$$

2.6. Determination of Ash Content

Portions of plant material of 5 g (P_0) are introduced into crucibles of known weight (P_1). The whole set (crucible + plant material) was heated in a muffle furnace type Nabertherm-LT 11B180 (Germany) at 550˚C for 24 hours. The crucibles were removed from the oven and cooled in a borosilicate glass desiccator. The weight (P_2) of the crucible + ash assembly was determined by weighing [9].

$$\text{Content of ash} = \left(P_2 - P_1\right) \times 100/P_0$$

2.7. Determination of Sugar Content

The determination of sugars was performed in three steps. Firstly, the preparation of the solutions which consisted in the extraction of the hydrosoluble sugars, and in the preparation of the 3 - 5 dinitrosalicylic acid solution (DNS). Then, we proceeded to the determination of reducing sugars whose principle is based on the reducing property of simple sugars (glucose, fructose, galactose, etc.) [10]. Finally, the total sugars whose principle is based on the hydrolysis of the glycosidic bonds of carbohydrates in an acidic medium and at high temperature, and the intramolecular dehydration of the simple oses released which then form furfural derivatives [11].

2.8. Total Carbohydrate and Starch Content

The total carbohydrate and starch contents are calculated according to the calculation method recommended by [12] which takes into account the moisture, fat, protein and ash contents. Knowing the total carbohydrate and total sugar content of the plant material, the starch content is determined by the following expression:

$$\text{Total carbohydrate} = 100 - (\%A + \%B + \%C + \%D)$$

A: Moisture; B: fat; C: Protein; D: Ash.

2.9. Determination of Mineral Element Content

For the determination of the mineral element content, 0.4 g of powder of each sample (soumbara and néré seed) finely ground and oven-dried at 60˚C in a 30 mL porcelain crucible was used. This test sample was placed in the Nabertherm-Germany muffle furnace set at 550˚C for 5 hours. After cooling, 2 mL of 0.5 N chloridric acid was added to the resulting ash and then brought to complete evaporation on a sand bath. The final residue was filtered into a 100 ml volumetric flask and made up to the mark with distilled water. 5 ml of the filtrate from each sample was taken for the determination of mineral elements. Minerals such as iron (Fe), manganese (Mn), sodium (Na), zinc (Zn), magnesium (Mg), calcium (Ca) and potassium (K) were determined by atomic absorption spectrophotometer (GBC 904AA; Germany). Phosphorus determination was done by colorimetry.

2.10. Spectrophotometric Determination of Total Polyphenols

The colorimetric method [13] was used for the determination of total polyphenols. A volume of 2.5 mL of diluted (1/10) Folin-Ciocalteu reagent was added to 30 µL of extract. The mixture was kept for 2 min in the dark at room temperature, then 2 mL of calcium carbonate solution (75 g/L) was added. Then, the mixture was placed for 15 minutes in a water bath at 50˚C and then cooled rapidly. The absorbance was measured at 760 nm, with distilled water as a blank. A calibration line was performed with gallic acid at different concentrations. The analyses were performed in triplicate and the concentration of polyphenols was expressed in milligrams per milliliter of gallic acid equivalent extract (mg Eq GA/mL extract).

2.11. Spectrophotometric Determination of Total Flavonoids

The method of [14] was used for the determination of total flavonoids. In a 25 mL flask, 0.75 mL of 5% (w/v) sodium nitrite ($NaNO_2$) was added to 2.5 mL of extract. To the mixture was added 0.75 mL of 10% (w/v) aluminum chloride ($AlCl_3$) and incubated for 6 min in the dark. After incubation, 5 mL of sodium hydroxide (1 N NaOH) was added and then the volume was made up to 25 mL.

The mixture was shaken vigorously before being assayed by UV-visible spectrophotometer. The reading was taken at 510 nm. The tests were performed in triplicate. Flavonoid content was expressed in milligrams per milliliter of quercetin equivalent extract (mgEqQuer./mL of extract).

2.12. Survey on the Consumption of Soumbara

Survey site: The survey based on direct questioning was carried out on the consumption of soumbara. It lasted for one month in the communes of Koumassi and Port-böuet located in the District of Abidjan. These communes were chosen because of the ethnic mix of the populations living in this area of the district.

Type of survey: A well-structured questionnaire on a survey form was developed to collect information (reasons, frequencies and preferences for consumption of soumbara). The sample of 104 people, including men and women, with ages ranging from 18 to 65 years, interviewed in French, allowed us to obtain the desired information.

Inclusion and exclusion criteria: In this study, all people who do not consume soumbara were excluded.

Statistical analysis: The results obtained were expressed as mean and standard deviation, then analyzed by 1-factor ANOVA, using STATISTICA software, version 7.1. Differences between means were determined using 5% F-test. The letters a and b in super script follow the means. On the same line, means with the same letters are not significantly different.

3. Results

3.1. Description of the Different Stages of Soumbara Production

The observational survey conducted among women soumbara producers in Korhogo made it possible to describe the production process, which includes all the techniques used from the seeds of the néré (raw material) to the soumbara (**Figure 1**). The *Parkia bioglobosa* seeds were sorted and well cleaned, and underwent the first cooking for 24 hours. After this cooking, the dehulled, sorted, washed and drained seeds underwent the second cooking for 4 to 5 hours. The obtained product will be drained and put in fermentation during 48 hours at 40˚C. The fermented product was dried and ground. The powder obtained was dried in the sun to obtain soumbara.

3.2. Information Collected by the Survey

The survey revealed three main reasons for consuming soumbara: health, taste and smell. 37.50% of the people surveyed consume soumbara to preserve their health and generally in cases of high blood pressure. The 50.97% of these people consume soumbara because of the taste. These people appreciate this condiment because of their eating habits which allowed them to know it and get used to the taste. Finally, 11.53% of the people surveyed consume soumbara because of its smell that they appreciate so much in the food (**Figure 2**).

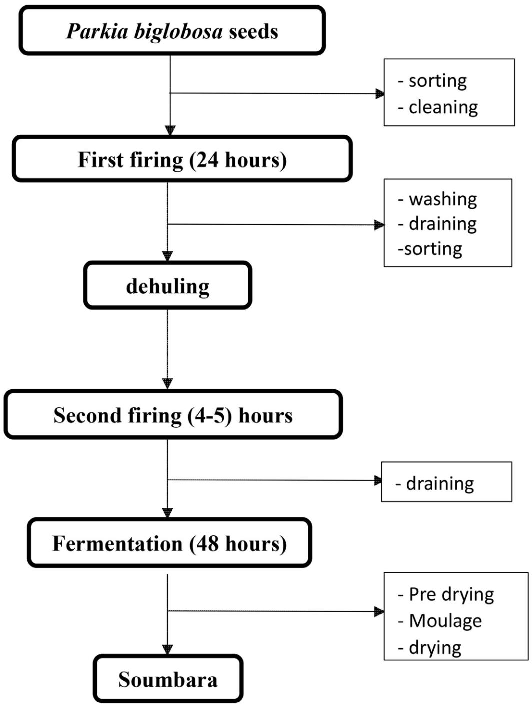

Figure 1. Different stages in the production of soumbara.

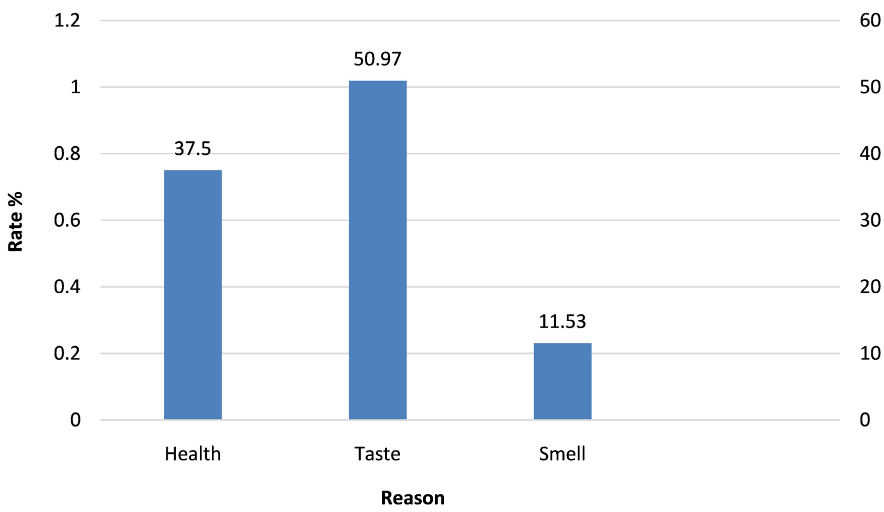

Figure 2. Reason for the consumption of soumbara.

The analysis of the results of the survey shows that soumbara is also consumed according to a preference for the form. The value of the rate of people who prefer this condiment in the form of grains is 68.27%. This value is 23.08% for the powder and 8.65% for the paste (Figure 3).

The frequency of consumption of soumbara is not the same for all people. The survey conducted during the present study revealed a high frequency of daily consumption (44.23%) and a low monthly frequency (7.7%). There are 33.65% of these people who consume it weekly and 14.42% of people occasionally (Figure 4).

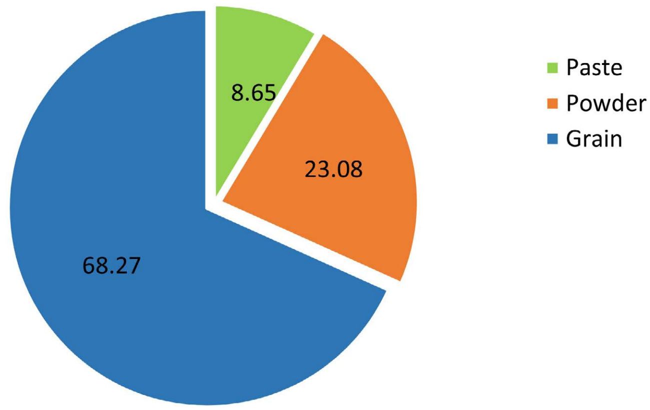

Figure 3. Consumption of soumbara by form.

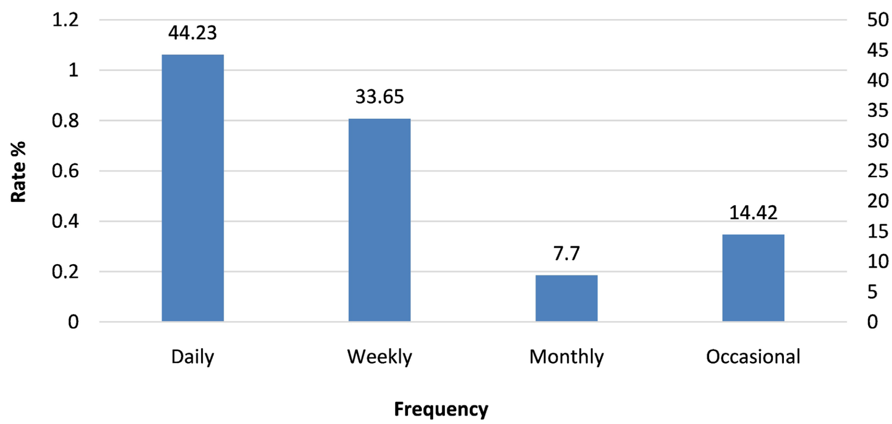

Figure 4. Frequency of soumbara consumption.

Among soumbara consumers, there is also a preference for consumption based on the production area. 55.77% of those interviewed preferred soumbara produced in Côte d'Ivoire and 44.23% preferred soumbara produced in other countries (**Figure 5**).

3.3. Chemical Composition of Soumbara and Néré Seeds

The moisture content of soumbara and néré seeds is 13.33 ± 1.52 g/100 g MF and 11 ± 0 g/100 g MF respectively. The moisture content of soumbara is significantly higher than that of néré seed. On the other hand, the ash levels of the two matrices are statistically equal (4 ± 0 g/100 g DM). Concerning fat, the soumbara has a rate (21.55 ± 0.46 g/1000 DM) significantly higher than that of the néré seeds (15.52 ± 0.05 g/100 g DM). Soumbara has less total carbohydrate and starch (44.33 ± 1.46 and 39.82 ± 1.32 g/100 g DM) than cowpea seeds (53.91 ± 0.11 g/100 g DM and 48.45 ± 0.09 g DM) respectively. The total carbohydrate and starch levels of cowpea seeds were statistically higher than those of soumbara. Soumbara and cowpea seeds had the same total sugar levels (0.08 ± 0.08 mg glucose/mL and 0.08 ± 0.005 mg glucose/mL) respectively. The total sugar levels in soumbara and cowpea seeds are statistically equal. The levels of reducing sugars are very low or undetectable (ND) in soumbara and seeds (**Table 1**).

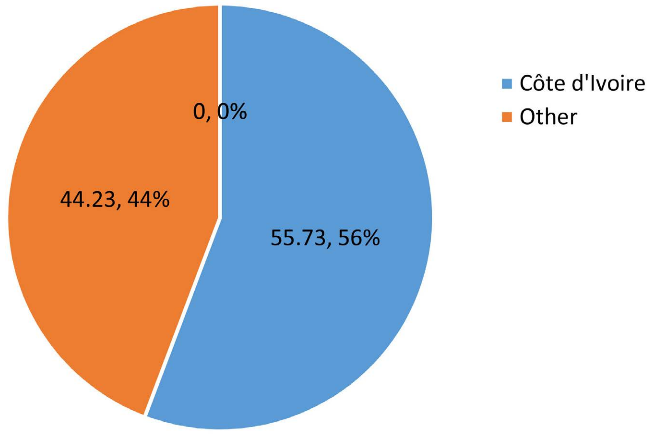

Figure 5. Consumption of soumbara according to production erea

Table 1. Chemical composition of soumbara and néré seeds.

Parameters	Soumbara	Néré seeds
Moisture (g/100 g, MF)	13.33 ± 1.52[a]	11 ± 0[a]
Protein (g/100 g, DM)	16.37 ± 0.7[a]	15.55 ± 0.06[b]
Total carbohydrates (g/100 g, DM)	44.33 ± 1.46[a]	53.91 ± 0.11[b]
Starch (g/100 g, DM)	39.82 ± 1.32[a]	48.45 ± 0.09[b]
Totalsugars (mg de glucose/mL)	0.08 ± 0.01[a]	0.08 ± 0.005[a]
Reducingsugars(mg de glucose/mL)	ND	ND
Fats (g/100 g, DM)	21.55 ± 0.46[a]	15.52 ± 0.05[b]
Ash (g/100 g, DM)	4 ± 0[a]	4 ± 0[a]

The letters a and b in super script follow the averages. On the same line, means with the same letters are not significantly different. ND: Not detected.

3.4. Mineral Composition of Soumbara and Néré Seeds

The iron, potassium, magnesium and calcium contents of soumbara (344, 43 ± 1.20 µg/g, DM; 174.5± 2.71 mg/g; 22.74 ± 2.31 mg/g) are significantly higher than those of cowpea seeds (78.37 ± 1.26 µg/g, DM; 14.25 ± 1.47 mg/g; 9.31 ± 0.17 µmg/g) respectively. However, the manganese content of cowpea seeds (18.11 ± 0.41 µg/g, DM) is significantly higher than that of soumbara (12.2 ± 0.32 µg/g, DM). Soumbara contains zinc (10.5 ± 0.91 µg/g, DM) and low levels of phosphorus (0.30 ± 0.04 mg/g), whereas néré seeds do not (Table 2).

3.5. Total Ployphenol and Flavonoid Content of Soumbara and Néré Seeds

Soumbara and néré seeds contain total polyphenols and total flavonoids. However, their values vary from one element to another. The total polyphenol content of soumbara (2.74 ± 0.01 mg Eq AG/mL extract) is significantly higher than that of néré seed (0.36 ± 0.0 mg EqQuer./mL extract). The same is true for the flavonoid content (Table 3).

Table 2. Mineral composition of soumbara and néré seeds.

Mineral	Soumbara	Néré seeds
Iron (µg/g)	344.43 ± 1.20^{a}	78.37 ± 1.26^{b}
Zinc (µg/g)	10.5 ± 0.91	ND
Manganese (µg/g)	12.2 ± 0.32^{a}	18.11 ± 0.41^{b}
Potassium (mg/g)	174.5 ± 2.71^{a}	14.25 ± 1.47^{b}
Magnesium (mg/g)	5.99 ± 0.38^{a}	0.45 ± 0.03^{a}
Phosphorus (mg/g)	0.30 ± 0.04	ND
Calcium (mg/g)	22.74 ± 2.31^{a}	9.31 ± 0.17^{a}

The letters a and b in super script follow the averages. On the same line, means with the same letters are not significantly different. ND: Not detected.

Table 3. Total ployphenol and flavonoid content of soumbara and néré seeds.

Parameters	Soumbara	néré Seeds
Totalpolyphenols (Eq AG/mL extract)	2.74 ± 0.01^{a}	0.36 ± 0.0^{b}
Total flavonoids (mg EqQuer./mL extract)	0.82 ± 0.01^{a}	0.63 ± 0.005^{b}

The letters a and b in super script follow the means. On the same line, the means with the same letters are not significantly different.

4. Discussion

The manufacture of soumbara requires know-how and special attention in each stage, especially the fermentation stage, in order to obtain a product of very good quality. The survey shows that 50.97% of people appreciate this condiment because of their eating habits, which allowed them to get used to the taste. A survey by [15] indicates that this food is anchored in the consumption habits of the population to such an extent that it conquers foreign dishes. 37.50% of people surveyed consume soumbara to preserve their health and generally in cases of high blood pressure. This result corroborates with that of [15] who also showed that through a survey that many individuals consume it because according to them it could provide vitamins and elements necessary for the proper functioning of the body and within this sample, some even mentioned the fact that soumbara is good for health while supporting its good for blood pressure. The high daily consumption (44.23%) of soumbara observed in the survey shows that soumbara is a complement to other broths. [16] confirmed this thesis and showed that soumbara and broth cubes are complementary products whose different uses depend on the dish prepared. The protein and fat contents in soumbara are higher than those in cowpea seed. This increase is thought to be due to the length of time the cotyledons are fermented during manufacture, as the longer the fermentation process, the higher the amount of certain nutrients in the soumbara due to the multiplication of bacterial strains [17] [18].

The protein content of this powder is similar to those reported by [19] who obtained a protein content of fermented *P. biglobosa* seeds from Côte d'Ivoire between 28.47% and 28.84%. This high protein content of *P. biglobosa* powder could help prevent protein-energy malnutrition in children [20] [21].

The increase in temperature from 26˚C to 46˚C corresponds to an increase in the microbial population and pH from 7.1 to 7.9 resulting in a high concentration of these macronutrients. This microbial population consists of *Bacillu*s, *Staphylococcus*, *Streptococcus*, yeasts and molds. These microorganisms were isolated from the soumbara samples, so could be assimilated to the fermentation flora. Two *Bacillus* (*B. subtilis* and *B. pumilus*) are thought to be involved in the fermentation of Néré soumbara. These strains of technological interest would probably be responsible for the excretion of metabolites (enzymes, exopolysaccharides, lipopeptides, ...) and the genesis of aroma compounds during fermentation [22]. These compounds would give the final products (soumbara), the taste, odor and aroma characteristic and would be responsible for antibiosis phenomenon [23]. These antibiosis phenomena would contribute to the elimination of pathogenic flora on the fermentation medium, thus improving the quality of soumbara [22] [24]. [15] studies on soumbara reported that the fermentation step is the most important and determines the quality of the finished product in terms of taste.

Phytochemical analysis of soumbara and néré seeds revealed the presence of polyphenols and flavonoids. These results are in line with those of [25] and [26], who reported that these secondary metabolites detected in the organs of this species are involved in the antioxidant properties attributed to the organs in common use. These bioactive molecules being considered as first class antioxidant agents, contribute very effectively to the prevention of some metabolic diseases, some cancers and cardiovascular diseases. They also have an anti-aging action by their action against oxidative stress. The presence of polyphenols in the powder studied would be an asset for consumers because they protect the body against the deleterious effects of free radicals that can accelerate cellular aging [27]. Moreover, the action against oxidative stress could be enhanced by the presence of flavonoids which are powerful antioxidants [28] [29]. Thus, a daily consumption of soumbara would be beneficial for the consumer

The fermented seeds of *P. biglobosa* studied, have a water content of 13.3%. This value is higher than that obtained by [30]. These authors found values between 5.1 and 10.2% on fermented seeds of *P. biglobosa* in Nigeria. The high iron content could explain the therapeutic virtues attributed to soumbara. An FAO study by [31] indicates that 100 g of dry soumbara provides the body with 378 mg of iron, which is essential to life as it is the basis of hemoglobin, the vehicle for cell oxygen. This good availability of iron in soumbara could bring a beneficial effect for the consumer in iron deficiency. The very low content of certain minerals in soumbara such as phosphorus (0.30 mg/g ± 0.04) and magnesium (5.99 mg/g ± 0.38) would be due to the production process. The work of [32] noted that the manufacturing processes could cause some losses of minerals.

In addition, analysis of the mineral composition of the fermented *P. biglobosa* seed powder revealed a high presence of potassium (62.40 g/kg), magnesium (32.85 g/kg) and calcium (15.45 g/kg). These obtained contents are lower than those reported by [33] with a potassium level of 86.4 g/kg, a magnesium level of 65.2 g/kg and a calcium level that is 138.2 g/kg dry matter. The potassium present in the studied fermented *Parkia biglobosa* seed powder could be useful in the regulation of blood pressure, proper functioning of the nervous system and muscles [34] [35]. Magnesium is considered the natural anti-stress present in foods [36]. It is involved in neuromuscular transmission of impulses and regulation of heart rhythm. Recent studies have shown the interest of an adequate intake of magnesium, which is 6 mg/kg of body weight, in the prevention of cardiovascular diseases [37]. In addition, the calcium present in the powder of *P. biglobosa* seeds would be beneficial for the consumer because it promotes bone growth, skeletal strength and tooth hardness in children and adolescents. Moreover, in adults, calcium helps maintain bone capital and prevent osteoporosis. It also helps reduce the risk of colorectal cancer [38]. In addition, a sufficient intake of calcium in accordance with the recommended dietary allowance of 500 to 1200 mg/day would have a preventive effect on hypertension [39].

5. Conclusion

The present study has allowed us to understand the different stages of soumbara production that are carried out in an artisanal manner in Korhogo. The physicochemical analyses of soumbara showed that soumbara is rich in protein and fat; the mineral and phytochemical compositions confirmed the considerable nutritional potential of soumbara with high iron, polyphenol and total flavonoid content. Due to its nutrient content, soumbara can be used in the nutritional balance of humans to overcome many nutritional deficiencies.

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Conflicts of Interest

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

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