

Full Length Research Paper

Study of the nutritional values and sanitary quality of soumbala collected from six regions of Burkina Faso

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Soumbala is regularly consumed as a condiment in most households in Burkina Faso. The purpose of this study was, therefore, to assess its nutritional and sanitary quality. To achieve this purpose, samples of soumbala have been analysed for the determination of pH, water and ash contents, biochemical parameters, mineral elements, and aflatoxin contents. Results showed that Fada N’Gourma soumbala had the highest water content (6.72%) and the highest pH value (7.04), while Pô soumbala had the highest ash content (4.68%). The highest protein content was found in the samples from Ouagadougou (48.03%). For lipids, the highest contents were found in the samples from Fada N’Gourma (48.16%). The samples taken from Gaoua were found to have the highest content of carbohydrates (17.16%). As for the mineral elements, the samples with the highest contents of zinc (9.33 mg/100 g) and selenium (4.83 mg/100 g) were those from Fada N’Gourma. The samples from Ouahigouya had the highest content of iron (6.28 mg/100 g). Aflatoxin B2 was found in the Pô and Fada N’Gourma samples with contents of 0.47 ppb and 0.48 ppb respectively. The results showed that soumbala is a good dietary supplement even if some disparities in the levels of secondary metabolites have been observed between regions. Extension of this study to all the regions of the country will serve as a database for the project to establish the table of nutritional values of foodstuffs currently underway in Burkina Faso.

Key words: Burkina Faso, soumbala, nutritional, quality.

INTRODUCTION

Parkia biglobosa, commonly known as ‘nééré’ in Burkina Faso, is a leguminous plant found in most West African countries (Figure 1). Its distribution extends from the Atlantic coast of Senegal to Southern Sudan and Northern Uganda (Lamien and Bamba, 2008). It is planted

mainly for its fruits nutritional value and its many virtues (Burlando et al., 2019):

(i) Its fresh, sweet and edible pulp is used, after fermentation, in the production of soft drinks;

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Figure 1. A Picture of *Parkia biglobosa* tree.
Source: https://www.inaturalist.org/guide_taxa/842109

- (ii) its leaves are used to treat burns and haemorrhoids;
- (iii) its bark is used in the production of various remedies against violent colic(s), vomiting (s), diarrhoea(s), sterility, pneumonia, leprosy, tooth decay(s)/ caries, and dermatosis/dermatoses;
- (iv) Its ashes are prized in indigo and soap making;
- (v) Its seeds, rich in lipids and proteins, are transformed into a very tasty vegetable cheese, called *soumbala* for the seasoning of sauces.

Soumbala is a traditionally hand-made product and a strictly hand-made product. Its manufacture varies according to countries and ethnic groups (Figure 2). Each ethnic group has its specific know-how to carry out the fermentation process, which is a very sensitive operation during the production of *soumbala* (Somda et al., 2014). But in general, *soumbala* is obtained by a set of technological unit operations consisting of three essential steps, including the elimination of undesirable elements by sifting and washing, cooking and fermentation (Somda et al., 2014).

Fermentation is one of the oldest methods of food

preservation ; in the case of the « *néré* » seeds, it results in a modification of the physical, chemical and nutritional characteristics of the seeds leading to interesting nutritional properties (Akanda et al., 2018). *Bacillus* and *Staphylococcus* strains are commonly involved in the fermentation of *soumbala* (Somda et al., 2014). The initial fermentation of the « *néré* » seeds, characterized by the excretion of exopolysaccharides and lipopeptides, is carried out by the genus *Bacillus* (Savadogo et al., 2011). The strains of *Staphylococcus* are responsible for the genesis of specific flavours (Somda et al., 2014). These bacteria, using enzymes, hydrolyze the proteins into amino acids and ammonia during fermentation, thus increasing the pH. *Soumbala* is also characterized by a strong ammonia smell resulting from alkaline fermentation, a cheese taste due to glutamic acid, and a dark brown colour. *Soumbala* is a good source of nutrients because of its content in amino acids, lipids acids, and B-group vitamins (Ouoba, 2017; Yagoub et al. 2004).

It has previously been established that the final microbiological quality and nutritional quality of



Figure 2. Picture of ready-for-use soumbala.
Source: <https://www.flickr.com/photos/dashis/16184967101>

substances spontaneously derived from fermented food products are influenced by the quality of the raw material (Somda et al., 2011), the production process (Sadiku, 2010) and the hygiene of personnel practising the art of fermentation (Ouoba, 2017; Glover et al., 2018). In Burkina Faso, soumbala is regularly consumed as a condiment for sauces in most households and restaurants (Dabiré et al., 2020). It is, therefore, important to monitor the sanitary quality of this food seasoning on the one hand and to assess its nutritional value on the other. This study was therefore initiated to produce scientific data on the nutritional value and health quality of the soumbala produced in Burkina Faso. This study will result in making it possible to establish a point mapping of the biochemical, mineral, and sanitary composition of this Burkinabè product.

MATERIALS AND METHODS

Framework of the study

The study was carried out at the National Laboratory of Public Health, and Biochemistry Laboratory of Joseph KI ZERBO University.

Type and period of study

This work was a cross-sectional, descriptive, and analytical study that took place from November 2018 to October 2019.

Sampling

The regions were selected so as to cover the vast majority of the

country's communities on the one hand and, on the other hand, for reasons of easily obtaining samples from the city of Ouagadougou (Figure 3). In these regions, the producers' selection was based on the information received from a focal point. In total, samples were taken from the Central-South Region; Northern Region; Southwest Region; « Hauts-Bassins » Region; Central Region and Eastern Region (Figure 3). Plastic bags were used to collect various samples of soumbala. The quantity of samples taken was about 1000 g. They were then sent to the laboratory to be processed and analyzed.

Reagents and standards

All the solutions were prepared with the double de-ionized water provided by the Milli Q water purification system (LAB TOWER AFT, Thermo scientific). Nitric acid 69% and hydrochloric acid 37% (HYPERPUR, Panreact AppliChem) for mineral elements analysis were used to clean glassware, carrying out wet digestion and solutions preparation. An individual stock standard solution containing 1000 mg/L of iron, zinc, and selenium purchased from MERK (Germany) were used for the preparation of solutions in order to standardize calibration. A mixture standard of aflatoxins B1, B2, G1, and G2 in acetonitrile (Fluka, Sigma Aldrich) was used for aflatoxins quantification.

Solvents (methanol, acetonitrile) were High Performance Liquid Chromatography (HPLC) grade and were purchased from ChromaSolv, Sigma Aldrich. The reagents including Phosphate buffered saline (Sigma Aldrich), sodium hydroxide (Panreact), sodium chloride (Sigma Aldrich) and Catalyseur Kjltab (Thomson and Capper) were used.

Sample processing

Soumbala was homogenized by using stainless steel blender obtained from IKA (WERKE, type M20). In order to avoid the contamination risks, the mill was first cleaned after each crushing. The resulting soumbala powders were stored at room temperature. All the analyses were carried out in triplicate.

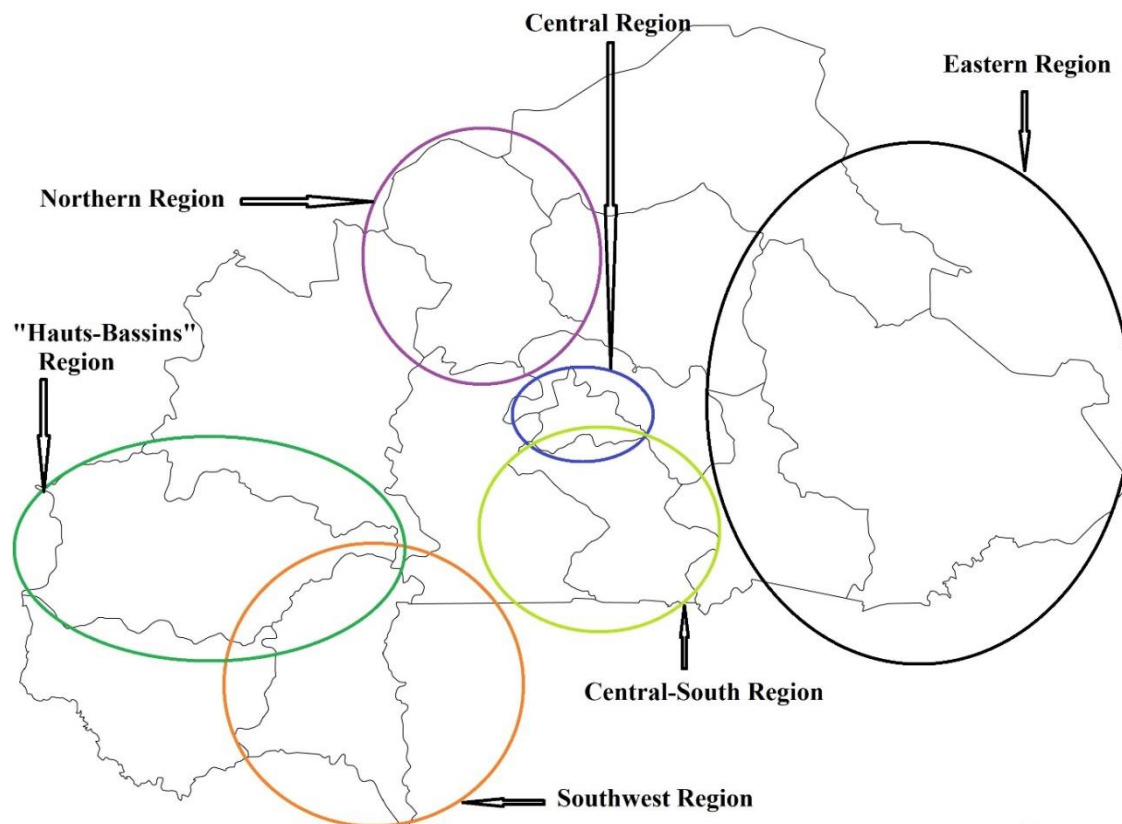


Figure 3. Location of the regions that were selected for the study on Burkina Faso map.

General parameters determination: pH, humidity and ash content

Determination of the pH

Five gram of sample were dissolved in 50 ml of distilled water. The obtained solution was filtered out with Whatman paper. The pH of the solution was measured using a pH metre WTW pH 330 model.

Determination of the water content

The samples were submitted to forced-air oven drying according to AOAC 950.46 method (1997) using a forced-air oven MEMMERT (Germany). Briefly, 5 g of sample were weighted in aluminium plates placed in the oven maintained at 103°C as long as a constant weight is obtained after cooling in the desiccator. The water content was determined by gravimetry.

Determination of ash content

The ash content was determined according to the AOAC 920.153 method (1997). It consists in incinerating 5 g of sample in the muffle furnace at a temperature of 550°C for thirteen hours. The ash content was determined by gravimetry.

Procedures for biochemical parameters determination

Determination of the total protein content

The total protein content of soumbala was determined using the

KJELDAHL AOAC 979.09 method (1999). This method consists in mineralizing the organic nitrogen into ammonium by mixing 0.2 g of soumbala powder with 1 digestion tablet (consisting of 3.5 g of potassium sulphate, 4 g of copper sulphate) and 10 ml of sulphuric acid. The total protein content is determined by acidimetry. Determination of the protein fraction content (Albumins, Globulins, Prolamins, and Glutelins).

Extraction of protein fractions

The extraction of protein fractions from the different samples was carried out by using the technique of Ragab et al. (2004). Briefly, soumbala flour (3.5 g) was extracted twice with 50 ml of distilled water for 30 min at room temperature. The extract was centrifuged at 3000 g for 30 min and the supernatant was used for the determination of a water-soluble protein (albumin). The residue was then extracted successively in a similar manner with 1.0 M NaCl, 70% ethanol or 0.2% NaOH. The supernatant of each extract was separately collected and used to estimate the salt- (globulin), alcohol- (prolamin) or alkali- (glutelin) soluble fractions.

Determination of the protein fractions

The content in the protein fractions in each sample was estimated by using Bradford's method (Bradford, 1976). This method is based on the interaction between proteins and a dye Coomassie blue. This dye binds to proteins to form a complex with a maximum absorbance wavelength between 465 and 595 nm. The amount of Coomassie blue that binds to proteins is proportional to their

concentration in the solution. Specifically, 10 µl of protein solution was added to 200 µl of Bradford's reagent (bioquant kit, merck). The mixture obtained was incubated for 15 min and then the colour was read at 595 nm wavelength by using a microplate Spectrophotometer purchased from Bioteck Epoch (USA).

Determination of total lipids

The amount of total lipids was obtained by Soxhlet extraction according to the AOAC 985.15 method (1990). Briefly, the method is based on the extraction of total lipids from 5 g of soumbala flour by using 250 ml of petroleum ether as an extraction solvent and the Soxhlet apparatus. After extraction, the solvent was separated from lipids by reduced pressure evaporation with a rotavapor. The total lipids content is obtained by gravimetry.

Determination of carbohydrates content

Carbohydrates contents were determined by the differential method described by Musaiger et al. (1998). This method consists of deducting the carbohydrate content from the water, fat, protein and ash contents using the following formula:

$$C (\%) = 100 - (H + MG + Pr + Cn)$$

C: Carbohydrate (%); H: Moisture content (%) ; MG : Fat content (%) ; Pr : Protein content (%) ; Cn : Ash content (%).

Determination of mineral elements (Iron, Zinc and Selenium)

Samples were digested by the method described by Demirel et al. (2008). This method consists of mixing 0.5 g of samples in a mixture of 10 ml of nitric and hydrochloric acid solutions (3/1) (v/v). The mixture obtained is heated to 150°C and then filtered with wattman paper. The final volume is made up to 20 ml with deionized water. These solutions were used to determine mineral elements (iron, zinc, and selenium) on a VARIAN AA 240 FS atomic absorption spectrometer (Australia).

Determination of total aflatoxins

To extract aflatoxins, 5 g of soumbala flour have been added to 25 ml of a mixture of methanol and distilled water (70/30 v/v). B1, B2, G1, G2 Aflatoxins are purified by passing extraction solution through an immunoaffinity column. The column contains specific antibodies attached to a solid support. As the sample passes through the column, the antibodies selectively bind to the different aflatoxins and form an anti-body-antigen complex. All the other components of the sample matrix are removed from the column by water. B1, B2, G1, G2 Aflatoxins are then eluted from the column. The eluate was analyzed by using a UHPLC system Diomex Ultimate 3000 purchased from TERMO SCIENTIFIC with a fluorescence detector associated with a post-column derivation.

Statistical analysis

The XLSTAT statistical software was used for survey data processing. To compare data on soumbala quality from different regions, the one way ANOVA statistical test was used at a significant level of 0.05. The normality of the data was verified by the shapiro test. For the data that were not normal, a square root transformation was performed to match the ANOVA application

criteria.

RESULTS

Humidity, ash and pH measurement

Table 1 shows the results of the general parameters (humidity rate, ashes content, pH) of the collected soumbala. Humidity rate and pH value were higher in the Fada N'Gourma soumbala. In contrast, the Ouahigouya sample had the lowest ash content. For all these parameters, no significant difference were observed between the 6 regions ($F = 0.06$; $p = 0.85 > 0.05$ for humidity content, $F = 0.12$; $p = 0.34 > 0.05$ for ash content and $F = 0.27$; $p = 0.63 > 0.05$ for pH values).

Biochemical parameters

Protein, lipids, and total carbohydrates contents

The macronutrients in the different samples were presented in Figure 4. The lowest total lipids and carbohydrates contents were observed in the samples of Ouagadougou and Fada N'Gourma respectively. The former had the highest total protein content. However, the results were not statistically different between the regions for all the biochemical parameters ($F = 0.02$; $p = 0.99 > 0.05$ for lipids content, $F = 0.11$; $p = 0.98 > 0.05$ for carbohydrates content, and $F = 0.18$; $p = 0.96 > 0.05$ for proteins content).

Proteinic fractions contents

The results of soluble vegetable proteins contents in the various samples were shown in Table 2. Among the soumbala samples analyzed, only one contained prolamin. Glutelins and globulins contents were strongly represented in Pô soumbala ; albumins in Fada N'Gourma soumbala. But no significant differences were observed between the regions for the 04 proteinic fractions contents ($F = 0.02$; $p = 0.99 > 0.05$ for Glutelins content, $F = 0.04$; $p = 0.99$ for globulins content, $F = 0.05$; $p = 0.99 > 0.05$ for albumins and $F = 0.13$; $p = 0.98 > 0.05$ for prolamins).

Iron, zinc and selenium content

These results showed that the Fada N'Gourma sample had higher selenium content. In contrast, the Bobo-Dioulasso sample contained a lower iron and zinc content (Figure 5). In general, no significant differences were notified between regions as regards mineral elements contents ($F = 0.86$; $p = 0.53 > 0.05$ for iron contents, $F = 0.79$; $p = 0.57 > 0.05$ for zinc contents, and $F = 0.47$; $p =$

Table 1. Results for general parameters (humidity rate, ashes content and pH) determination (for humidity rate and ashes content, results are expressed in percentages).

Origin sample	Humidity rate (%)	Ashes content (%)	pH
Pô	3.09 ± 1.95	5.14 ± 2.01	6.13
Ouahigouya	4.09 ± 0.01	3.14 ± 0.03	6.54
Gaoua	4.29 ± 0.15	3.15 ± 0.02	6.84
Bobo-Dioulasso	4.06 ± 0.28	3.63 ± 0.07	6.94
Ouagadougou	5.02 ± 0.32	3.88 ± 0.11	6.03
Fada N'Gourma	6.72 ± 0.17	4.68 ± 0.09	7.04

Table 2. Results for protein fractions (albumins, globulins, prolamins, glutellins) contents. Results are expressed in equivalent grams of BSA per 100 g (gBSA/100 g) of protein.

Origin samples	Albumin content ± SD	Globulin content ± SD	Prolamin Content ± SD	Glutelin content ± SD	Total
Pô	1.73 ± 0.1	6.82 ± 0.33	ND	36.36 ± 4.05	44.91
Ouahigouya	2.24 ± 0.2	0.92 ± 0.31	ND	29.2 ± 0.94	32.36
Gaoua	4.06 ± 0.4	1.34 ± 0.04	0.11 ± 0.7	29.68 ± 1.02	35.19
Bobo-Dioulasso	2.3 ± 0.29	1.09 ± 0.51	ND	33.16 ± 0.37	36.55
Ouagadougou	1.17 ± 0.25	1.86 ± 1.3	ND	29.67 ± 1.61	32.7
Fada N'Gourma	4.86 ± 0.28	2.05 ± 0.53	ND	26.12 ± 1.79	33.03

ND: Not detected.

Table 3. Total aflatoxin composition of soumbala from different regions of Burkina Faso (ppb/100 g of fresh soumbala material).

Origin samples	AFB1 content (ppb)	AFB2 content (ppb)	AFG1 content (ppb)	AFG2 content (ppb)
Pô	ND	0.47	ND	ND
Ouahigouya	ND	ND	ND	ND
Gaoua	ND	ND	ND	ND
Bobo-Dioulasso	ND	ND	ND	ND
Ouagadougou	ND	ND	ND	ND
Fada N'Gourma	ND	0.48	ND	ND

ND: Not detected, AFB1 : Aflatoxine B1, AFB2 : Aflatoxine B2, AFG1 : Aflatoxine G1, AFG2 : Aflatoxine G2.

0.97 > 0.05 for selenium contents).

B1, B2, G1, and G2 Aflatoxin levels

Table 3 gives the results of the total aflatoxins composition of the collected samples. The results showed that only the Pô (0.47 ppb) and Fada N'Gourma (0.48 ppb) samples contained aflatoxin B2.

DISCUSSION

Soumbala is a condiment highly prized by the people of West Africa. It is used to season several types of dishes.

In Benin and Burkina Faso, in addition to their use to enhance the taste of food, its seeds are thought to be suitable for complementary formulations against infant malnutrition, especially as a source of protein and non-heme iron (Chadare et al., 2018). In this study, several parameters related to soumbala nutritional value and sanitary quality were identified.

The results that were presented showed that the soumbala samples had pH values between 6.94 and 7.04. They are similar to those of Azokpota et al. (2005a) and Camara et al. (2016), who found pH values between 5.2 to 8.7 and 6.60 ± 0.13 to 7.45 ± 0.18 respectively in their studies. The high pH values obtained in this study would be due to the high protein contents (39.23 to 48.03%) of soumbala, which would result in an increase

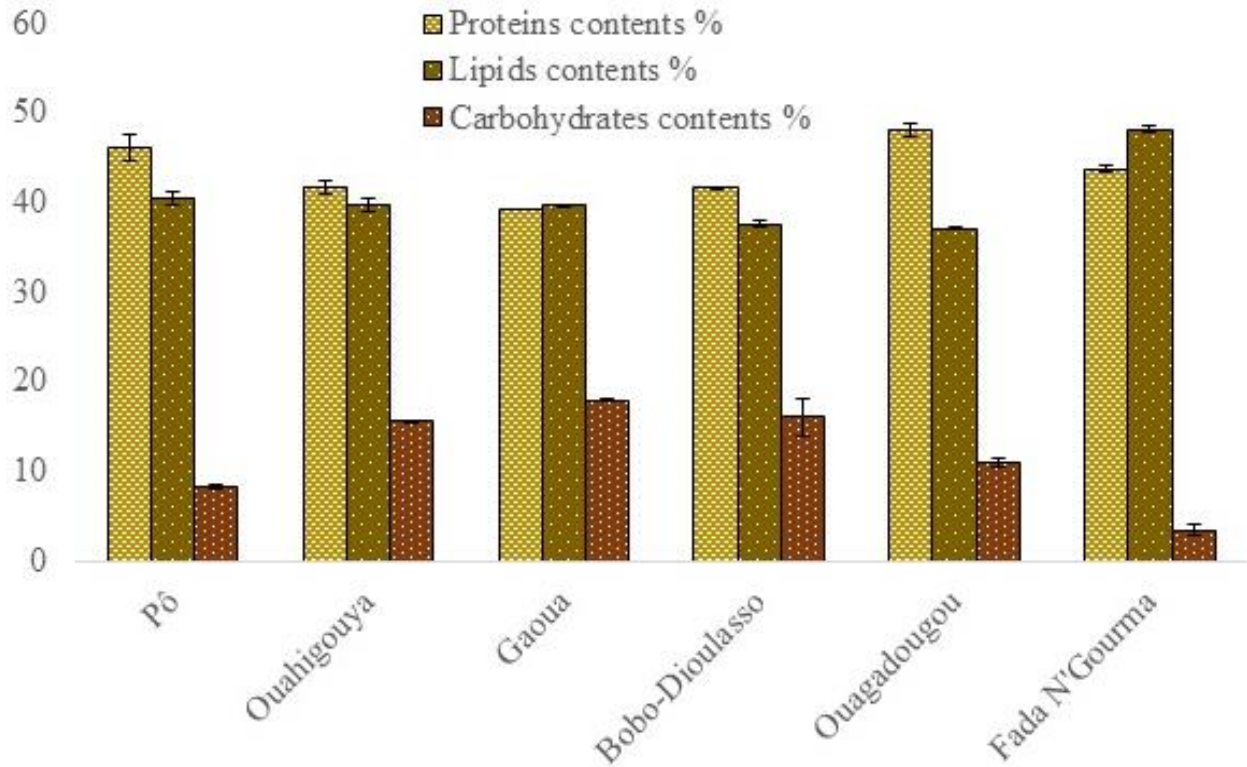


Figure 4. Proteins, lipids, and carbohydrates contents. Results are expressed in percentages.

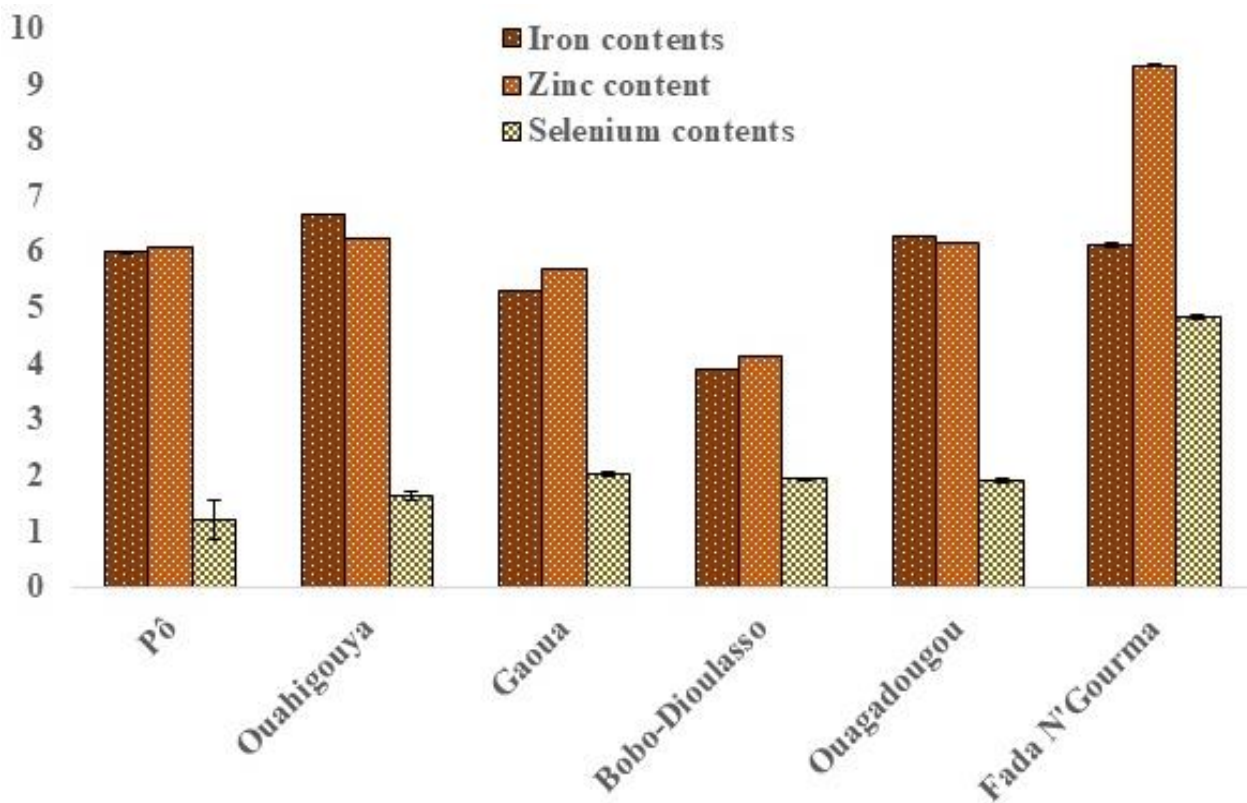


Figure 5. Iron, Zinc, and Selenium contents. Results are expressed in mg/100 g of soumbala dry matter.

in ammonia (NH₃) production (Allagheny et al., 1996). Indeed, the results reported by Antai and Ibrahim (1986) and Odunfa (1981) showed that an increase in pH during fermentation was accompanied by an increase in the ammonia odour of 'nééré' seeds. There would, therefore, be a correlation between the increase in pH and NH₃ production. NH₃ comes from the degradation of amino acids resulting from proteolysis. Many species of the genus *Bacillus* are capable of producing proteases (Odonfa, 1985) that break down proteins into peptides and then amino acids. The catabolism of these amino acids would lead to an increase in NH₃ levels and, therefore, an increase in pH.

The water contents of soumbala varied between $3.09 \pm 1.95\%$ and $6.72 \pm 0.17\%$. These values are lower than those reported by Camara et al. (2016) which were $15.35 \pm 3.28\%$ to $27.53 \pm 2.33\%$. These differences could be justified by the fermentation process. Indeed, Camara et al. (2016) used in their study, a spontaneous fermentation in which not only are several strains of *Bacillus* involved, but also other microorganisms such as staphylococci are. Results reported by Obizola and Atu (1993) indicated that the increase in water content during fermentation could be due to an increase in the fermentation activity of microorganisms that would release water molecules. The difference in humidity levels can also be related to drying techniques, the artisanal nature of the process, and the degree of control of the process by the female producers. Indeed, there were variations in humidity rate from one production to another but, these variations were not statistically significant. Three unit operations influence the humidity rate of soumbala: cooking, fermentation and traditional preservation methods.

The current analysis showed a total ash rate between $3.14 \pm 0.03\%$ and $5.14 \pm 2.01\%$. These values are consistent with those of Camara et al. (2016) who found a grade of $2.81 \pm 0.06\%$ to $4.93 \pm 0.08\%$ of ash contents. However, some differences were observed between soumbala in different regions. These differences, which were statistically not significant could be explained by the diversity of manufacturing processes and good hygiene practices (dust contamination) (Akanda et al., 2018). Also, for fermentation, some producers covered the seeds with charcoals and cereal flour, while others covered them with ash. The protein contents found ($39.23 \pm 0.04\%$ to $48.03 \pm 0.73\%$) were similar to those reported by Azokpota et al. (2005b) in their study ($41.3 \pm 0.2\%$ to $43.9 \pm 0.1\%$). However, they differ from one region to another.

Lipids contents ($37.14 \pm 0.02\%$ to $48.16 \pm 0.3\%$) were higher than those obtained by Azokpota et al. (2011) (31.3 to 40.2%). The high total protein and total lipids content of soumbala could be due to the high protein and lipids content of *Parkia biglobosa* seeds. Indeed, in the life cycle of seed plants called spermatophytes, the seed is the structure that contains and protects the plant embryo

(Khan, 2001). It is often contained in a fruit that allows it to spread. It has a role in protecting new individuals thanks to its hardened envelope and in nutrition thanks to reserves of nourishing substances. The seeds have the property of accumulating in a form that is easy to preserve, reserves intended for the future development of the embryo, including proteins, carbohydrates, and lipids (Khan, 2001). Therefore, they are a source of food sought by animals (granivorous diet). Indeed, given the high rainfall and fertile nature of the soils in the Eastern and Central-South regions, soumbala produced in Fada N'Gourma and Pô had slightly higher values in protein and total lipids than the one produced in the other regions, but differences were not statistically significant. If in Pô and Fada N'Gourma the seeds used for the manufacture of soumbala come from these regions, in Ouagadougou, the seeds can come from all the regions of Burkina Faso which could explain the higher levels of protein and total lipids of soumbala produced there despite a lower rainfall and soil fertility in the Central region. For proteins, another hypothesis that could explain the variation in levels observed between the different regions could be the increase in the number of microorganisms during fermentation (Laokole, 1994), which differs from one region to another. Indeed, microorganisms contain proteins in their structure; an increase in their number leads to an increase in the level of bacterial proteins and therefore an increase in that of total proteins.

Soumbala had an iron content of 3.91 mg/100 g to 6.67 mg/100 g; zinc content of 4.13 mg/100 g to 9.33 mg/100 g and selenium content of 1.21 mg/100 g to 4.83 mg/100 g in relation to dry matter. Mineral elements contents varied from one sample to another but statistically, these differences were not significant. However, the variations could be explained by the nature, pH, and composition of the soils on which these different varieties of *P. biglobosa* grew. Indeed, the mineral composition of plants depends on the nature of the soil. Thus, Fondio et al. (1999) in their study had shown that the mineral composition of plant fruits in general and okra, in particular, was a function of the nature of the soil. This hypothesis could be reinforced by the results of an analysis of the mineral composition of soils in the different regions of Burkina Faso. In addition, an approach was made to the National Soil Office (BUNASOL) to obtain these data. However, this approach was unsuccessful because this government agency could not make them available.

The total aflatoxin assay (B1, B2, G1, G2) did not reveal a contamination in all the samples considered except for those from Pô (0.47 ppb) and Fada N'Gourma (0.48 ppb). In addition, these values were below the threshold one for spices (5 µg/kg) established by the European Union. The main genera of fungi producing these toxins are *A. parasiticus*, *A. flavus* (Belkacem, 2008). The extrinsic factors favouring the growth of these fungi are water activity ($0.85 \leq a_w \leq 0.95$), temperature

(between 0 and 35°C), gaseous composition of the medium (aerobiosis), and high levels of protein products (Laokole, 1994). Guiraud and Rosec (2004) showed that the growth and/or production of toxins were significantly reduced in an acidic environment (pH ≤ 4.5). Thus, the high pH of Fada N'Gourma soumbala (7.04) and the high protein content of the protein fractions of the Pô sample (44.91%) would constitute favourable conditions for the growth of these germs.

Conclusion

This study examined the nutritional and health values of soumbala from six regions of Burkina Faso to determine the general parameters, biochemical, mineral, and aflatoxin composition of soumbala. These objectives were intended to verify two hypothesis : the sanitary quality of this food condiment and to assess its nutritional value.

In terms of nutritional values in general, soumbala in the different regions was rich in total proteins, total lipids, and minerals. To analyze the quality of soumbala, aflatoxins were measured and the results obtained showed that Pô soumbala and that of Fada N'Gourma were contaminated by this toxin but at levels below the threshold value for spices (5 µg/kg) established by the European Union.

To serve as a reference for the project to establish the nutritional value table for food in Burkina Faso, this study should be extended to all soumbala producing regions of the country. Also, for an intensive use in agricultural activities, it would be necessary to look for pesticide residues in the seeds of *Parkia biglobosa* intended for the preparation of soumbala.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

- Akanda F, Parkouda C, Suurbaar J, Donkor AM, Owusu-Kwarteng J (2018). Effects of mechanical dehulling on microbiological characteristics and chemical changes during processing of *Parkia biglobosa* seeds into dawadawa, a West African alkaline fermented condiment. *Journal of the Ghana Science Association* 17:13-19.
- Allagheny N, Obanu ZA, Campbell P, Owens JD (1996). Control of ammonia during *Bacillus subtilis* fermentation of legumes. *International Journal of Food Microbiology* 29:321-33.
- AOAC 185.15. (1990). Determination of lipid in meat and poultry products. In P Cunnif (ed.). *Official methods of analysis of the Association of Official Analytical Chemists*. 15th ed. Arlington, VA, USA.
- AOAC 920.153. (1997). Ash of meat. In P. Cunnif (ed.). *Official methods of analysis of the Association of Official Analytical Chemists*. 16th ed. Washington, DC, USA
- AOAC 950.46. (1997). Moisture in meat. In P. Cunnif (ed.), *Official methods of analysis of the Association of Official Analytical Chemists*. 16th ed. Washington, DC, USA.
- AOAC 979.09. (1999). Determination of protein in flour. In P. Champain (ed.). *Official Method of Analysis of the Association of Official Analytical Chemists*. 17th ed Washington DC, USA.
- Antai S, Ibrahim M (1986). Microorganisms associated with African locust bean (*Parkia filicoidea* Welw) fermentation for « dawadawa » production. *Journal of Applied Bacteriology* 61:662-671.
- Azokpota P, Hougbo Y, Akissoe H (2011). Stabilizing ability of traditional preservatives of afitin, an African condiment based on nere seeds (*Parkia biglobosa* Jack. P. Br). *Cahiers/Agriculture* 20:494 – 499.
- Azokpota P, Hounhouigan J, Nago C (2005a). Microbiological and chemical changes during the fermentation of African locust bean (*Parkia biglobosa*) to produce afitin, iru and sonru, three traditional condiments produced in Benin. *International Journal of Food Microbiology* 107:304-309.
- Azokpota P, Hounhouigan J, Nago C, Jakobsen M (2005b). Esterase and protease activities of *Bacillus* spp. From afitin, iru and sonru; three African locust bean (*Parkia biglobosa*) condiments from Benin. *African Journal of Biotechnology* 5:265-272.
- Belkacem N (2008). Mycotoxins : production and biosynthesis pathway. Master 2's thesis. Institut National Polytechnique de Toulouse. 75 p.
- Burlando B, Palmero S, Cornara L (2019). Nutritional and medicinal properties of underexploited legume trees from West Africa. *Critical Reviews in Food Science and Nutrition* 59:78-188.
- Chadare F, Madode YE, Fanou-Fogny N et al. (2018). Indigenous food ingredients for complementary food formulations to combat infant malnutrition in Benin. A review. *Journal of the Science of Food and Agriculture* 98:439-455.
- Camara F, Soro S, Traore S, Brou K, Dje K (2016). Biochemical and microbiological characteristics of African mustards produced from fermented seeds of *Parkia biglobosa* and Glycine max, sold in Côte d'Ivoire. *International Journal of Biology and Chemistry Sciences* 10:506-518.
- Dabiré Y, Mogmenga I, Somda MK, Ugwuanyi JO, Ezeogu LI, Dicko MH, Traoré AS (2020). Production technique, safety and quality of soumbala, a local food condiment sold and consumed in Burkina Faso. *African Journal of Food Science* 14:38-52.
- Demirel S, Tuzen M, Saracoglu S, Soylyak M (2008). Evaluation of various digestion procedure for trace element contents of food materials. *Journal of Hazardous Materials* 152:1020-1026.
- Fondio L, Kouame C, Traore D, Djidji AH (1999). Seedling densities, growth and production of two lines of okra (*Abelmoschus* spp.) in Côte d'Ivoire. *Cahiers/Agriculture* 8:413.
- Glover RKL, Madilo FK, Terlabie JL, Ametefe EN, Jespersen L (2018). Some technological properties of selected strains of *Bacillus* spp. associated with kantong production in Ghana. *International Food Research Journal* 25:602-611.
- Guiraud J and Rosec J (2004). *Pratiques des normes en microbiologie alimentaire*. AFNOR. 175-220.
- Khan A (2001). *Plant anatomy*. India : Kalpaz Publication, 322p.
- Lamien N, Bamba A (2008). Valuation of Non-timber Forest Products in Burkina Faso : Current situation and prospects. *Income Improvement and Food Security Program (ARSA): Component "Profitable Harvesting of Non-Timber Forest Products (NTFP)". 155p.*
- Laokole J (1994). Contribution to the biochemical and microbiological study of soumbala. D.E.A thesis in Applied Microbiology, FAST, University of Ouagadougou. 77p.
- Musaiger AO, Al-Saad JA, Al-Hooti DS, Khunji ZA (1998). Chemical composition of fermented dairy products consumed in Bahrain. *Food Chemistry* 61:49-52.
- Obizola IC, Atu LN (1993). Production and chemical evaluation of some of food condiments of Nigeria. *Plant Foods for Human Nutrition*

- 44:249-254.
- Odunfa S (1981). Microorganismes associated with African locust (*Parkia filicoidea*) during « iru » preparation. *Journal of Plant Foods* 3:245-250.
- Odunfa SA (1985). Biochemical changes during « iru » fermentation. *Journal of Food Technology*. 20 : 295-303. <https://doi.org/10.1006/fmic.1999.0332>
- Ouoba LI (2017). Traditional alkaline fermented foods : Selection of functional *Bacillus* starter cultures for soumbala production. In: Speranza B, Bevilacqua A, Corbo MR, Sinigaglia M (1st Edition), *Starter cultures in food production*. Ltd: Hoboken, New Jersey (NJ), United States: John Wiley & Sons. pp. 370-383. <https://doi.org/10.1002/9781118933794.ch18>
- Ragab DM, Babiker EE, Eltinay AH (2004). Fractionation, solubility and functional properties of cowpea (*Vigna unguiculata*) protein as affected by pH and/or salt concentration. *Food Chemistry* 84:207-212.
- Sadiku OA (2010). Processing methods influence the quality of fermented African locust bean (iru/ogiri/dadawa) *Parkia biglobosa*. *Journal of Applied Sciences and Research* 6:1656–1661.
- Savadogo A, Tapi A, Chollet M, Wathelet B, Traoré S, Jacques P (2011). Identification of surfactin producing strains in Soumbala and Bikalga fermented condiments using Polymerase Chain Reaction and Matrix Assisted Laser Desorption/Ionization-Mass Spectrometry methods. *International Journal of Food and Microbiology* 151:299-306.
- Somda KM, Savadogo A, Barro N, Thonart P and Traoré AS (2011). Effect of mineral salts in fermentation process using mango residues as carbon source for bioethanol production. *Asian Journal of Industrial Engineering* 3:29-38.
- Somda KM, Savadogo A, Tapsoba F, Ouédraogo N, Zongo C, Traoré S (2014). Impact of Traditional Process on Hygienic Quality of Soumbala a Fermented Cooked Condiment in Burkina Faso. *Journal of Food Security* 2:59-64.
- Yagoub A, Mohamed BE, Ahmed A, El Tinay AH (2004). Study on Furundu, a traditional sudanese fermented roselle (*Hibiscus sabdariffa*) seed : effect on in vitro protein digestibility, chemical composition and functional properties of the total proteins. *Journal of Agriculture and Food Chemistry* 52:6143–6150.