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Nutritional and Sanitary Quality of Soybean (*Glycine max* (L.) Merr.) Seeds Produced and Marketed in Benin

Mouhamed Nazif Moutawakilou El-Hadji Alassane[1,2*], Thibaut Gbeyetin Fidèle Dohoue[3], Agossou Damien Pacôme Noumavo[1,4], Serge Candide Kponou[2], Yemissi Sandra Gaelle Amoussou[2], Lamine Baba-Moussa[4], Farid Baba-Moussa[1]

[1]Laboratory of Microbiology, Food Technology and Phytopathology, Faculty of Science and Technology, University of Abomey-Calavi, Abomey-Calavi, Benin
[2]Agro Sciences Laboratory (ASL), Abomey-Calavi, Benin
[3]Central Laboratory of Food Safety, Ministry of Agriculture, Livestock and Fisheries, Cotonou, Benin
[4]Laboratory of Biology and Molecular Typing in Microbiology, Faculty of Science and Technology, University of Abomey-Calavi, Abomey-Calavi, Benin
Email: *mouhamed1moutawakilou@gmail.com

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Abstract

Soybean (*Glycine max* (L.) Merr.) is an annual leguminous plant. It is widely consumed in Benin through its derived products, including soy milk, soy oil, soy flour, and especially soy cheese, which is very popular in the country. This study aimed to assess the nutritional and sanitary quality of soybean seeds produced and marketed in Benin. A total of 60 soybean seed samples were randomly collected from the twelve departments of the country. Nutritional parameters (moisture, lipids, proteins and fibers) were determined using standardized ISO methods. The sanitary assessment included counting the total mesophilic aerobic flora, detecting *Salmonella* spp., quantifying total aflatoxins and detecting genetically modified seeds. The results show that soybean seeds have good nutritional quality, with average contents of 6.79% (moisture), 18.88% (lipids), 38.32% (proteins) and 10.09% (fibers). However, the protein content remains slightly below Beninese standards. Microbiologically, a high average total mesophilic aerobic flora load was observed (3.43×10^6 CFU/g), with *Salmonella* spp. present in 20% of the samples, indicating a significant health risk. The average total aflatoxins levels (2.05 μg/kg) remained below regulatory limits, and no samples contained genetically modified soybean seeds. In conclusion, although the soybeans produced and marketed in Benin have a good nutritional profile, deficiencies in hygiene and microbiological safety persist. Strengthening good agricultural and post-harvest practices appears essential to ensure food safety and improve the overall quality of

this strategic crop.

Keywords

Soybean, Nutritional Quality, Health Safety, Aflatoxins, GMOs, Benin

1. Introduction

Soybean (*Glycine max* (L.) Merr.) is an annual plant of the Fabaceae family. Native to East Asia, soybeans are now cultivated worldwide for various purposes, including oil production, proteins for human and animal consumption, and as a raw material for biofuel production [1]. It is a highly nutritious legume, rich in proteins (of high quality), lipids (many unsaturated fatty acids), carbohydrates, minerals (potassium, phosphorus, magnesium, iron, zinc, and calcium), vitamins (B9, B1 and E), and contains isoflavones, antioxidants and other bioactive substances beneficial to health [2] [3]. Today, soybeans occupy a strategic position in global food systems due to their nutritional richness.

The evolution of eating habits, notably driven by consumers' growing desire to substitute animal proteins with plant-based proteins, is increasing global demand for soybeans [4]. These numerous potentials of soybean seeds have led to an exponential increase in their worldwide production.

Indeed, global soybean production increased by 22% over the decade (2016-2026), reaching a record 428 million tonnes in 2025 [5]. The main producers are Brazil, United States, Argentina, China and Paraguay, which alone account for more than 80% of the world's production. In Sub-Saharan Africa, soybean is the main source of protein for the most impoverished populations [6]. Regional production has shown strong growth in recent years, with 5.7 million tonnes produced in 2025, mainly driven by Nigeria, Benin and Togo.

In Benin, soybean production has increased significantly in recent years, reaching 520,929 tonnes in 2024 [7]. This production mainly relies on improved varieties, such as TGX (characterized by large grains and higher yields) and Jupiter (smaller grains) [8]. These varieties are preferred for their adaptation to local climatic and pedological conditions.

This nutritional and economic importance justifies the growing scientific interest in assessing the overall health quality of soybeans produced and marketed in Benin. Indeed, beyond its nutritional qualities, soybean can serve as a vector for microbiological, chemical and biotechnological hazards that could affect consumer health. In this context, evaluating nutritional quality is an essential preliminary step in assessing the value of the soy produced. However, an integrated approach to food safety also requires the identification and control of associated hazards, particularly microbiological, physico-chemical and biotechnological ones.

Regarding microbiological hazards, soy and soy-based products have been implicated in several foodborne illness outbreaks [9]. The presence of pathogenic bacteria in soy poses a real risk, as some derived products are consumed without sufficient thermal treatment. Therefore, the detection of microbiological pathogens is part of a preventive approach against collective food poisoning. Moreover, contamination of cereals and other staple crops by mycotoxins is a major public health concern. These toxins are produced by moulds and are recognized as genotoxic and carcinogenic [10]. It is therefore crucial to keep their levels in foodstuffs as low as possible. Consequently, mycotoxin quantification is an essential indicator of the sanitary quality and regulatory compliance of soybeans. Finally, the detection of Genetically Modified Organisms (GMOs) in soybeans is part of a dual requirement for food safety and transparency towards consumers. Indeed, soy is among the crops most affected by genetic modification worldwide. This raises questions about potential impacts on human health and the environment, as well as issues related to traceability and labelling. In this context, detecting GMOs in marketed plant products is essential to ensure regulatory compliance, inform consumers, and maintain control over agricultural supply chains.

In summary, the joint analysis of the nutritional quality and the microbiological, chemical, and biotechnological hazards of soybean seeds produced and marketed in Benin is part of a comprehensive food safety approach. It responds to the imperative of protecting public health, complying with international standards, and promoting local products within the context of globalized food trade. This study is conducted within this framework, which assesses the nutritional quality, microbiology and biotechnological aspects of soybean seeds produced and marketed in Benin.

2. Materials and Methods

2.1. Sampling

Soybean seed samples were randomly collected from wholesale vendors between 12th January and 24th February 2025. These wholesalers purchase lots of soybeans from farmers whom they themselves subsidize. A total of sixty (60) soybean seed samples were collected across the twelve (12) Departments of Benin, with five (05) samples taken from each Department. For each sample, 5 kg of soybean seeds were taken from a jute sack. These sacks were transported at room temperature to the laboratory for analysis.

2.2. Evaluation of Nutritional Quality

The nutritional composition of the soybean samples was assessed by determining moisture, lipids, proteins and dietary fiber using standardized analytical methods.

2.2.1. Moisture Content

The moisture content was determined in accordance with the standard ISO-771 [11]. The samples, previously ground and homogenized, were dried at 103˚C ± 2˚C until a constant mass was achieved. The mass loss recorded after drying was used to calculate the moisture content, expressed as a percentage of the fresh matter.

2.2.2. Lipid Content

The lipid content was determined by solvent extraction in accordance with ISO-734 [12]. A portion of the sample was subjected to continuous extraction with petroleum ether. After solvent evaporation, the lipid residue was dried, cooled in a desiccator and weighed. The results were expressed as a percentage of dry matter.

2.2.3. Crude Protein Content

The protein content was assessed using the Kjeldahl method [13]. This method involves a mineralization step of organic nitrogen in an acidic medium, followed by distillation of the released ammonia and titration with a standard acid solution. The nitrogen content was converted to protein using an appropriate conversion factor.

2.2.4. Fiber Content

Fibers were determined according to ISO 13906 and AOAC 985.29 methods. The samples were digested in an acid-detergent medium, then filtered, washed, dried, and weighed. The results were expressed as a percentage of dry matter.

2.3. Identification of Microbiological Hazards

The identification of microbiological hazards focused on detecting *Salmonella* spp. and enumerating the Total Mesophilic Aerobic Flora (TMAF).

2.3.1. Counting of Total Mesophilic Aerobic Flora

The enumeration of Total Mesophilic Aerobic Flora (TMAF) was carried out in accordance with ISO-4833-2 [14]. After preparing decimal dilutions, surface inoculation was performed on Plate Count Agar. Plates were incubated at 30˚C for 72 ± 3 hours. Colonies were counted, and results were expressed as Colony Forming Units per gram (CFU/g).

2.3.2. Detection of *Salmonella* spp.

Salmonella spp. detection was carried out in accordance with ISO-6579-1 [15]. The protocol proceeds in four successive phases, namely: pre-enrichment phase (buffered peptone water, 34˚C and 38˚C, 18 hours), enrichment phase (Rappaport Vassiliadis broth, 41.5˚C, 24 ± 3 hours; MKTTn broth, 37˚C, 24 ± 3 hours), isolation phase (xylose-lysine-deoxycholate agar, 37˚C, 24 hours), and a confirmation phase of suspect colonies through biochemical and serological tests. The results were expressed as the presence or absence in 25 g of the sample.

2.4. Identification of Mycotoxinogenic and Biotechnological Hazards

The assessment of mycotoxinogenic and biotechnological hazards in soybean seeds consisted, respectively, of the detection of total aflatoxins (B1, B2, G1 and

G2) and Genetically Modified Organisms.

2.4.1. Determination of Total Aflatoxins

Total aflatoxins (B1, B2, G1 and G2) were determined using a competitive immuno-enzymatic method (Symmetric Green Series). This method relies on a specific antigen–antibody interaction and a colorimetric detection, the intensity of which is inversely proportional to the concentration of mycotoxins present in the sample. The results were expressed in µg/kg.

2.4.2. Detection of Genetically Modified Organisms

The detection of GMOs was carried out in accordance with the ISO-21572 [16] standard, using an immunochromatographic strip test. After protein extraction, the sample was subjected to capillary electrophoresis on a membrane coated with specific antibodies. The presence of GMOs was indicated by the appearance of a colored band, signifying a positive result.

2.5. Data Processing and Statistical Analyses

The statistical analysis of the data consisted of performing descriptive statistics (mean and Standard Deviation) using Excel 2013. An analysis of variance (ANOVA) was then carried out to detect the nature of the differences in values (significant or not) between the Departments, using the R software (R Core Team 2024). When the ANOVA indicated a significant difference, the Student-Newman-Keuls (SNK) test was applied to precisely identify the distinct groups.

3. Results

3.1. Nutritional Quality of Soybean Seeds

The results of the nutritional analysis of soybean seeds produced and marketed in Benin are presented in **Table 1**. The results obtained show that the nutritional composition of the analyzed soybean seeds is generally homogeneous across the different departments. This is reflected by the non-significant difference ($p > 0.05$) noted for all the nutritional parameters studied (moisture, Lipids, proteins and fibers).

The average moisture content (6.79% ± 0.60%) is well below the maximum limit of 13% set by the beninese standard. It also complies with the international standard ICS 67.060. This low moisture content is a favorable indicator of microbiological stability and good seed preservation. It reduces the risks of mold development and mycotoxin production. The lipid contents (18.88% ± 0.57%) meet the normative requirements (≥15%), confirming the energy richness of soybeans. These results support soy's status as an important source of fatty acids, particularly unsaturated ones. Conversely, the average protein content (38.32% ± 0.34%) is slightly below the beninese standard (≥40%). Although this difference is minor, it suggests variability related to agronomic factors such as the cultivated variety, pedoclimatic conditions or farming practices. Regarding dietary fibers (10.09% ± 0.46%), the values obtained are generally close to the recommended limit (≤ 10%).

Table 1. Nutritional value of soybean seeds by production departments.

Departments	Alibori	Atacora	Atlantique	Borgou	Collines	Couffo	Donga	Littoral	Mono	Ouémé	Plateau	Zou	pvalue	Global	Normative Limit	Reference
	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$	$\bar{x} \pm \bar{\sigma}_x$		$\bar{x} \pm \bar{\sigma}_x$		
Moisture (%)	6.24 ± 0.72	6.96 ± 1.20	5.95 ± 1.65	7.46 ± 0.542	6.72 ± 1.00	6.61 ± 0.88	6.17 ± 1.08	7.17 ± 1.55	6.17 ± 1.23	7.16 ± 1.22	8.00 ± 1.77	6.93 ± 1.13	NS	6.79 ± 0.60	≤13	NB 01.07.004 (2021)
Lipids (%)	19.5 ± 2.02	18.65 ± 1.32	18.8 ± 0.89	18.61 ± 0.81	18.55 ± 0.32	19.61 ± 1.26	18.07 ± 0.45	18.37 ± 0.50	19.05 ± 1.66	19.5 ± 1.48	19.7 ± 1.99	18.19 ± 0.59	NS	18.88 ± 0.57	≥15	NB 01.07.004 (2021)
Proteins (%)	38.68 ± 1.38	38.14± 1.65	38.05 ± 0.26	38.18 ± 1.34	38.01 ± 1.17	38.69 ± 1.72	38.19 ± 0.87	38.07 ± 0.59	38.15 ± 0.54	38.87 ± 1.72	38.87 ± 1.13	37.98 ± 0.74	NS	38.32 ± 0.34	≥40	NB 01.07.004 (2021)
Fibers (%)	10.24 ± 1.55	10.20 ± 1.35	10.83 ± 1.93	10.00 ± 0.99	9.36 ± 0.50	10.22 ± 0.89	9.40 ± 0.83	10.43 ± 0.85	10.22 ± 0.80	10.78 ± 1.02	10.56 ± 0.58	94.50 ± 0.57	NS	10.09 ± 0.46	≤10	CXS 174 (2022)

$\bar{x}$: mean; $\bar{\sigma}_x$: standard deviation; NS: Not Significant ($p > 0.05$); NB: Beninese Standard; CXS: Codex Standard.

Overall, these results attest to the good nutritional quality of the soybean seeds produced and marketed in Benin, despite a slight protein deficiency compared to national standards.

3.2. Microbiological Risks Associated with Soybean Seeds

The results of the enumeration of Total Mesophilic Aerobic Flora (TMAF) and the detection of *Salmonella* spp. in soybean seeds are presented in Table 2. It appears from this table that the TMAF loads show significant variability across departments ($p < 0.001$), with an overall average of 3.43×10^6 CFU/g. Some particularly high values (up to 10^{12} CFU/g in Ouémé) indicate substantial contamination, likely related to inadequate hygiene conditions during handling, transport, or storage. These levels of contamination in TMAF generally exceed the recommended thresholds for dry goods, indicating an overall microbiological quality that is unsatisfactory. A high microbial load can compromise seed quality and increase the risk of contamination by pathogenic microorganisms.

Salmonella spp. were not detected in soybean samples from the departments of Atacora, Donga, Borgou, Collines, Mono, Couffo and Plateau. These samples are therefore considered satisfactory in terms of microbiological quality, in accordance with regulatory requirements. However, 40% of samples from the departments of Alibori, Zou, Littoral and Ouémé contained *Salmonella* spp. The risk is even higher in the department of Atlantique, where 80% of samples were contaminated with *Salmonella* spp. These results exceed acceptable microbiological limits, and the respective batches are classified as unsatisfactory. The presence of *Salmonella* spp. in 20% of samples is concerning. The detection of this pathogenic bacteria indicates significant sanitary non-compliance. The high rates observed in certain departments suggest failures in hygiene and food safety practices.

Table 2. Microbiological profile of soybean seeds.

Departments	Total Mesophilic Aerobic Flora (CFU/g)			*Salmonella* spp. in 25 g				
	Mean	Standard deviation	Normative Limit	Number of Samples	Positive sample	Percentage	Normative Limit	Reference
Alibori	$6.45.10^{7a}$	1.86		05	02	40		
Atacora	$6.98.10^{5b}$	0.98		05	00	00		
Atlantique	$4.90.10^{5cd}$	1.23		05	04	80		
Borgou	$6.12.10^{10e}$	2.01		05	00	00		
Collines	$4.35.10^{5}$	1.87		05	00	00		
Couffo	$4.98.10^{6c}$	0.76		05	00	00		
Donga	$6.32.10^{5f}$	2.40	10^5 CFU/g (Codex Alimentarius, [17])	05	00	00	Absent in 25 g	NB 01.07.004 (2021)
Littoral	$4.28.10^{5bd}$	1.07		05	02	40		
Mono	$4.98.10^{5bcd}$	1.21		05	00	00		
Ouémé	$2.98.10^{12h}$	0.89		05	02	40		
Plateau	$4.35.10^{5c}$	0.45		05	00	00		
Zou	$5.25.10^{5bcd}$	1.32		05	02	40		
Global	$3.43.10^{6}$	1.05		60	12	20		

CFU: Colony Forming Unit; NB: Beninese Standard; In the same column, the means marked with different letters are significantly different at the 5% level according to the Student-Newman-Keuls test.

Table 3. Total aflatoxin contents and proportion of genetically modified soybeans.

Departments	Total aflatoxins (μg/kg)				Proportion of GMO soybean seeds		
	Mean	Standard deviation	Normative Limit	Reference	Number of Samples	Positive sample	Percentage
Alibori	2.44^{b}	1.12			05	00	00
Atacora	3.72^{a}	0.68			05	00	00
Atlantique	1.53^{c}	0.84			05	00	00
Borgou	1.61^{c}	0.05			05	00	00
Collines	1.34^{c}	0.33			05	00	00
Couffo	1.61^{c}	0.14			05	00	00
Donga	2.63^{b}	0.09	4 μg/kg	EC1881(2006)	05	00	00
Littoral	3.58^{a}	0.42			05	00	00
Mono	1.37^{c}	0.13			05	00	00
Ouémé	1.95^{b}	0.9			05	00	00
Plateau	1.62^{c}	0.24			05	00	00
Zou	1.28^{c}	0.06			05	00	00
Global	2.05	0.85			60	00	00

EC: European Commission; In the same column, the means marked with different letters are significantly different at the 5% level according to the Student-Newman-Keuls test.

3.3. Mycotoxinogenic and Biotechnological Risks Associated with Soybean Seeds

The total aflatoxin levels and the proportion of genetically modified soybeans in the soybean seeds produced and marketed in Benin are shown in **Table 3**.

Total aflatoxin levels vary significantly across departments ($p < 0.05$), with an overall mean of 2.05 ± 0.85 µg/kg. All values remain below the maximum limit of 4 µg/kg set by European regulations, indicating overall compliance. However, higher levels observed in certain departments (3.72 µg/kg in Atacora, 3.58 µg/kg in the Littoral) suggest an increased risk to food safety if no measures are taken. The departments of Alibori, Donga and Ouémé show intermediate levels, while the other departments have considerably lower levels.

The results of the detection of genetically modified soybeans revealed a complete absence of GMOs in the analyzed samples (0%). This either indicates a low adoption of transgenic varieties in Benin or good traceability of the supply chains. This result is significant in a context where issues related to GMOs concern both health safety and consumer preferences.

4. Discussion

The results regarding nutritional composition are generally in accordance with normative requirements and those reported in the literature. These results demonstrate the good quality of the seeds used by farmers and adherence to good production and drying practices.

The low moisture content observed could be explained, among other factors, by the fact that soybean seed sampling was carried out in March, a period of strong sunshine, across almost all regions of Benin. This result corroborates that of Bermegui Boni [18], who found moisture content in beninese soybean seeds ranging from 8 to 13%. The low moisture observed in this study is a favourable indicator of stability. Soybean seeds should be less susceptible to microbial development. Qin, *et al.* [1] emphasise the importance of this parameter in seed stability and the prevention of fungal contamination. Studies conducted in South America and Europe highlight that a rate below 13% significantly limits fungal and bacterial growth [19].

The analyzed soybean seeds have an average lipid content of 18.88%. This result complies with the beninese standard. It also conforms to the ARS 872 (2014) standard, which specifies a normal lipid content of 15% to 20%. The lipid content observed in our study is comparable to that reported by Bilyeu, *et al.* [2]. Studies conducted by Erliana [20] on 20 soybean lines in Indonesia revealed fat contents ranging from 19.28% to 21.95%. This high-lipid content confirms soy's role as a major source of essential fatty acids with high energy value.

The protein contents (38.32%, average) observed in this study, although slightly below the beninese standard (≥40%), are in line with regional (ARS 872:2014) and international (ICS 67.060) standards, which set the normal protein content between 35% and 40%. In West Africa, studies indicate that contents range from 35% to 42%, reflecting variability influenced by cultivated varieties and agroecological conditions [6]. This variability is also confirmed globally, where factors such as soil fertility, farming practices, and environmental stresses influence protein biosynthesis [21].

The dietary fiber content of the soybean seeds obtained in this study (10.09%, average) is slightly above the Codex guideline limit (≤10%). These observed values are consistent with those reported in several international studies. Indeed, the fiber content of soybeans generally ranges from 8% to 12%, depending on variety and growing conditions (Yuhui Wang *et al.*, 2021). The TGX soybean variety cultivated in Benin is very high in fiber. Thus, nutritionally, the soybean seeds produced and marketed in Benin meet international standards.

Conversely, the high levels of contamination of soybean seeds by TMAF observed in this study exceed those reported in certain african studies. For example, a study conducted in Nigeria by Adeyeye, *et al.* [22] showed significantly lower microbial loads. These differences may be explained by less rigorous post-harvest practices at local beninese markets. Indeed, the TMAF load is a good indicator of hygiene, which allows for an assessment of microbial pollution and the overall quality of food products [23].

The presence of *Salmonella* spp. in 20% of the samples is concerning and aligns with the observations of Ferrari *et al.* [9], who documented cases of soybean contamination involved in food poisoning incidents. This result highlights the need to strengthen hygiene measures and good harvesting and storage practices throughout the soybean value chain.

From a health perspective, soybeans pose a significant health risk due to the pathogenicity of *Salmonella* spp. Indeed, this pathogenic bacterium is among the main causes of foodborne illnesses worldwide [24]. This bacterium can cause various health problems, ranging from mild gastroenteritis to severe systemic conditions such as typhoid fever [25]. Globally, non-typhoidal *Salmonella* spp. infections are estimated to cause 938 million cases of gastroenteritis and approximately 155,000 deaths each year (Majowicz *et al.*, 2010). Meanwhile, typhoid fever, caused by *S. typhi*, is responsible for 119 million cases and 128,000 deaths annually [26]. The impact of these diseases is particularly significant in low- or middle-income countries [27].

Regarding aflatoxins, the results are below the national and international standard threshold (4 µg/kg). However, our values are much lower than those reported in certain tropical regions, where concentrations exceeding 10 µg/kg have been observed [10]. This could be explained by less favourable local climatic conditions or relatively effective drying practices. The low level of total aflatoxins in beninese soybeans is a positive aspect, given their harmfulness. Indeed, contamination by mycotoxins, including aflatoxins, poses a food safety issue for cereals and other staple crops. Aflatoxins are secondary metabolites produced by *Aspergillus flavus*, *A. parasiticus* and *A. nomius* [28]. They contaminate a wide variety of foodstuffs, including cereals, nuts, dried fruits, spices, oilseeds, dried peas, beans and fruits [29]. Aflatoxins have been linked to liver lesions and cancer [30]. The contribution of aflatoxins to hepatocellular lesions is estimated at 4.6% - 28.2% in Sub-Saharan Africa, South-East Asia and China [31]. Consumption of aflatoxins also leads to other health issues, such as acute aflatoxicosis, immune deficiency and malnutrition-related disorders such as stunted growth [30].

Finally, the absence of genetically modified soy among the analysed samples contrasts with global trends, where more than 70% of soy is genetically modified [5]. However, this result is consistent with the agricultural policies of many African countries, where the adoption of transgenic crops remains limited. This situation reflects, among other factors, a low adoption of agricultural biotechnologies in West Africa, often linked to regulatory, economic, and societal constraints.

5. Conclusion

This study highlights the good nutritional quality of soybean seeds marketed in Benin, characterized by low moisture content, high lipid content and relatively high protein levels. However, microbiological deficiencies are observed, with elevated contamination levels and *Salmonella* spp. detected in a significant proportion of samples, posing a risk to public health. Aflatoxin levels remain within international standards, and no targeted GM markers detected. These results emphasise the need to strengthen good hygiene and storage practices throughout the entire production and marketing chain.

Limitation

The sampling of soybeans was carried out over a period of less than two months (January to February). This was a period of high temperatures. What about other periods of the year?

Authors' Contributions

Conceptualisation: L.B.-M., F.B.-M., M.N.E.A.M., T.F.G.D., C.S.K., and H.L.; Methodology: M.N.E.A.M., T.F.G.D., C.S.K. and A.D.P.N.; Software: M.N.E.A.M., T.F.G.D., C.S.K. and A.D.P.N.; Validation, M.N.E.A.M., T.F.G.D., C.S.K. and H.L. ; Formal Analysis: M.N.E.A.M., T.F.G.D., C.S.K., H.L. and A.D.P.N.; Investigation: M.N.E.A.M., T.F.G.D., C.S.K. and H.L.; Resources: M.N.E.A.M., T.F.G.D., C.S.K. and H.L. ; Data Retention: M.N.E.A.M., T.F.G.D., C.S.K. and H.L.; Writing: preparation of the original version: M.N.E.A.M., T.F.G.D., C.S.K., H.L. and A.D.P.N.; Proofreading and Editing: M.N.E.A.M., T.F.G.D., C.S.K., H.L and A.D.P.N.; Visualization: M.N.E.A.M., T.F.G.D., C.S.K., H.L., and F.B.-M.; Supervision: M.N.E.A.M., T.F.G.D., C.S.K., H.L., L.B.-M. and F.B.-M.; Project Administration: M.N.E.A.M., T.F.G.D. and C.S.K.; Search for funding: M.N.E.A.M., T.F.G.D. and C.S.K.

All authors have read and agreed to the published version of the manuscript.

Statement of the Institutional Ethics Committee

The experimental protocol was approved by the Scientific Ethics Committee of

the Doctoral School (Life Sciences) of the University of Abomey-Calavi (UAC), Benin, under number UAC/FAST/EDSVT/10037907.

Conflicts of Interest

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

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