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ORIGINAL ARTICLE

Sanitary and nutritional quality of Tonou and Tchotou, traditional mustards produced in northern Togo, West Africa

Calidad sanitaria y nutricional del Tonou y el Tchotou, mostazas tradicionales producidas en el norte de Togo, África Occidental

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Abstract The traditional production of Tonou and Tchotou mustard in the Kara and Savannah regions of Togo remains artisanal, poorly standardized, and increasingly threatened by industrial seasoning cubes. This study evaluated production practices, physicochemical composition, and microbiological quality through surveys and laboratory analyses. The activity is carried out mainly by women and represents an important source of income, although training in good manufacturing practices is limited. Four types of mustard were identified, with the néré and soybean blend standing out for its mineral content. However, the samples showed high counts of aerobic microorganisms, yeasts, and molds, exceeding established limits, although *Salmonella* spp. was not detected. It was concluded that, despite their nutritional value, the microbiological quality of these products is unsatisfactory. Therefore, producers should receive training, hygienic conditions should be improved, and production processes should be standardized.

Keywords traditional fermented condiments, alkaline fermentation, nutritional composition, microbiological safety.

Resumen La producción tradicional de mostaza Tonou y Tchotou en las regiones de Kara y Savannah, Togo, continúa siendo artesanal, poco estandarizada y amenazada por los condimentos industriales. El estudio evaluó las prácticas productivas, la composición fisicoquímica y la calidad microbiológica mediante encuestas y análisis de laboratorio. La actividad es desarrollada principalmente por mujeres y representa una fuente importante de ingresos, aunque existe escasa capacitación en buenas prácticas de fabricación. Se identificaron cuatro tipos de mostaza, destacándose la mezcla de néré y soja por su contenido mineral. Sin embargo, las muestras presentaron elevados recuentos de microorganismos aerobios, levaduras y mohos, superiores a los límites establecidos, aunque no se detectó *Salmonella* spp. Se concluye que, pese a su valor nutricional, la calidad microbiológica es deficiente, por lo que se requiere capacitar a las productoras, mejorar las condiciones higiénicas y estandarizar los procesos de elaboración.

Palabras clave condimentos fermentados tradicionales, fermentación alcalina, composición nutricional, seguridad microbiológica.

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PUBLIS EDITORIAL

Introduction

African condiments include spices such as chilli, ginger, Guinea pepper, cardamom, and cloves, as well as specific products such as soumbala (fermented néré seeds) in West Africa. Néré is the common name for *Parkia biglobosa,* also known as the African locust bean tree. It is a perennial legume belonging to the Fabaceae family and has great value across tropical and subtropical Africa. *P. biglobosa* is appreciated for its nutritional, economic, cultural, and medicinal benefits (Musara et al., 2020). All parts of the *P. biglobosa* tree, including seeds, stems, bark, roots, and leaves, are used.

One of the derived products of *P. biglobosa* in Togo is Tchotou or Tonou or afiti, also known as Soumbala in Burkina Faso, dawadawa in Ghana, netetu in Senegal, afitin or sonru or iru in Benin (Compaoré et al., 2020), which is an important protein and nutrient source in areas dependent on carbohydrate-rich foods. These are handmade condiments that serve as both flavor enhancers and plant-based protein substitutes, and are produced through a process passed down through generations of women. They are sold primarily in local and regional markets, without regulatory oversight or standardized processes, and without formal market authorization, except for any health inspections or the often very limited checks conducted by the agencies responsible for food safety. Soumbala, dawadawa, netetu, afitin, sonru, iru, afiti, Tonou, or Tchotou are produced via alkaline fermentation of African locust bean or soybean seeds, enhancing traditional dishes with their strong aroma and rich amino acid content(Owusu-Kwarteng et al., 2022). According to Ouoba et al. (2003) and Alphonse (2026), traditional fermented condiments (TFC) such as soumbala or afiti have high contents of proteins, peptides, amino acids, vitamins, minerals, exopolysaccharides, organic acids, volatile compounds, and fatty acids or short-chain fatty acids (SCFAs), gamma-aminobutyric acid (GABA), conjugated linoleic acids (CLAs), and branched amino acids.

In Togo, afiti is used to season sauces and dishes and is renowned for its health benefits. There are various regional varieties, such as Tonou (among the Moba people in the Savannah region) and Tchotou (among the Kabyè people in the Kara region). It can be found in grain, ground, or ball form, offering a powerful taste and providing a powerful flavor to replace chemical seasoning cubes. Despite its nutritional and functional benefits, afiti remains underutilized from technological, economic, and scientific perspectives. Its production is largely artisanal and unregulated, which can compromise microbiological quality, food safety, shelf stability, and market competitiveness (Azokpota et al., 2006). Furthermore, scientific documentation regarding production processes, value chains, local practices, and socio-economic impacts remains limited in Togo, especially regarding the Tchotou and Tonou processes, nutritional composition, and sanitary aspects in the Kara and Savannah regions, which are the main production zones in the country. Thus, this study aimed to (i) scrutinize the conditions and practices of artisanal production of Tchotou and Tonou in the Kara and Savannah regions of Togo, (ii) determine their chemical and organoleptic characteristics, and (iii) appraise the microbiological safety of the products.

Methodology

The current study was conducted among Tonou and Tchotou producers in the prefectures of Tône (Savannah region), Kéran, Binah, Doufelgou, and Kozah (Kara region) (Figure 1) regarding the survey on data collection from producers and analyzed at the Laboratoire des Sciences Agronomiques et Biologiques appliquées (LaSABA) for biochemical and microbiological analyses. This study was carried out from July 2023 to September 2024.

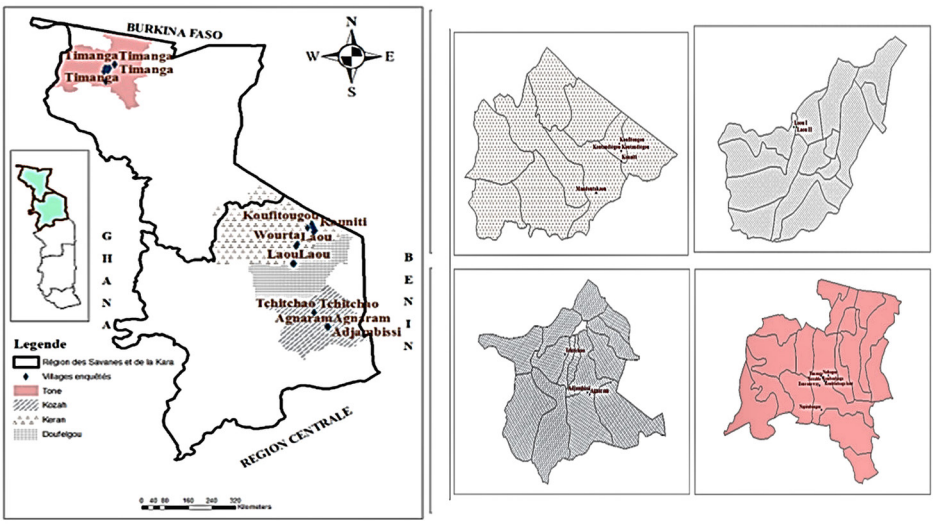

Figure 1. Map showing the study area.

The questionnaire for the study was designed to align with the socio-demographic characteristics and cultural contexts of people in these regions. The administered questionnaire comprised 48 questions, divided into several sections, including producers' educational level, raw seeds and materials used in Tonou production, mixing and fermentation, storage, and potential medical effects.

A cross-sectional survey was conducted with Tonou or Tchotou producers in the Savannah region (n = 15) and the Kara region (n = 45) (Figure 1). A total of 60 producers were surveyed.

Verbal consent was sought from traditional mustard producers after explaining the purpose of the study and reassuring them that the data would be kept confidential. Anonymity, confidentiality, and respect for human values were taken into account.

During the study, 38 samples of various traditional mustard types were collected (Table 1). Each sample weighed approximately 100 g.

Table 1. Traditional mustard collected samples

Traditional mustard	Region	Code	Number of samples
Néré Tonou	Savannah	N	6
Soybeans Tonou		S	5
Mixed soybeans and néré Tonou		N+S	7
Tchotou from a mixture of néré seeds and soybeans	Kara	AT	7
Tchotou from a mixture of kapok-baobab seeds		AL	6
Tchotou made with néré seeds		HJ	7
Total			38

Samples of Tchotou and Tonou were collected from producers. The collected samples were subjected to biochemical analysis (moisture and ash content, and mineral composition) and microbiological analysis by counting microbes (total flora, enterobacteria, yeasts, and molds). All analyses were done in triplicate.

Moisture and ash content were determined using the standard method described by the Association of Official Analytical Chemists (AOAC, 1980). Indeed, 5 g of each sample of Tonou and Tchotou was dried in an oven at 75 ºC and weighed every 30 min until a constant weight was reached. Moisture content was then calculated as the percentage of weight loss relative to the fresh sample. For ash content determination, 3 g was dried, ground into a fine powder, and incinerated in a muffle furnace at 550 °C for 6 h. The resulting ash was weighed, and ash content was expressed as a percentage of dry matter using the following equation:

$$C(\%) = \frac{m_2}{m_1} \times 100$$

Where m_1 is the mass of the test portion (g), and m_2 is the mass of ash (g).

Texture, aroma, taste, and color were assessed during data collection from producers. The texture of the different of Tonou and Tchotou was assessed by touch to determine their freshness, ripeness, or state of preparation, using the texture scale. Taste was assessed by the data collectors through tasting, smell through the olfactory approach, and color through visual inspection.

After incineration, the minerals contained in the ash were solubilized using nitric acid and analyzed by atomic absorption spectrophotometry using an atomic absorption spectrometer (PG Instruments, model PG990). The ash (3 g) was dissolved in 0.5 mL of concentrated nitric acid (65%), filtered using Whatman filter paper, and the final volume was adjusted to 100 mL with distilled water (stock solution). Calcium and magnesium were determined by complexometric titration using orthophenanthroline and ethylenediaminetetraacetic acid (AOAC, 2019). Iron and phosphorus contents were measured spectrophotometrically in the presence of hydroxylamine hydrochloride and molybdic acid, respectively (Kosse et al., 2001).

The microbiological quality of Tonou or Tchotou samples collected was assessed in accordance with standard microbiological norms as reported in Table 2.

Table 2. Referenced methods used to assess microbial quality of Tonou and Tchotou products

Target microorganisms	Culture medium	Incubation temperature (°C) / duration (h)	References
Total aerobic mesophilic flora	Plate Count Agar	37 / 24	ISO 4833-1 (2014)
Yeasts and molds	Sabouraud Chloramphenicol Agar	30 / 72	ISO 21527-2 (2008)
Enterobacteria	Hektoen Enteric Agar	37 / 72	ISO 21528-2 (2004)

The study utilized descriptive analyses to investigate the demographic attributes of producers and mineral composition by using XLSTAT 2019 version 2.2 ($p \leq 0.05$). ANOVA was used to differentiate nutritional profiles between regions and mustard types.

Results and discussion

The findings show that the majority of Tonou producers are between 30 and 40 years old (Figure 2). In this context, the results of this study confirm that although soumbala production is artisanal and labor-intensive, it plays a crucial role in the economic resilience of rural women. This finding aligns with observations by Yérobessor et al. (2020), who highlighted that soumbala processing in Burkina Faso is a female-dominated activity, primarily carried out by middle-aged women under rudimentary and often unhygienic working conditions. This activity represents a cornerstone of household economies, despite remaining largely informal and undervalued.

In our study, the women producers, all stay-at-home mothers, reported that they were able to save and reinvest a portion of their income from traditional mustard production, for example, to purchase livestock or other material goods. These findings demonstrate that this artisanal activity serves as a genuine source of financial independence and contributes to the household economy.

However, a concerning issue emerged from our survey: the complete absence of generational renewal, as no young girls were involved in the production process. This situation can be explained by several factors, including the arduous nature of the work, the lack of social recognition of the activity, and the absence of technical innovations that could make it more attractive. These observations corroborate the conclusions of Yami et al. (2024), who identified gender norms, limited access to training, and the lack of appropriate innovations as primary barriers to youth integration in agri-food value chains in Africa.

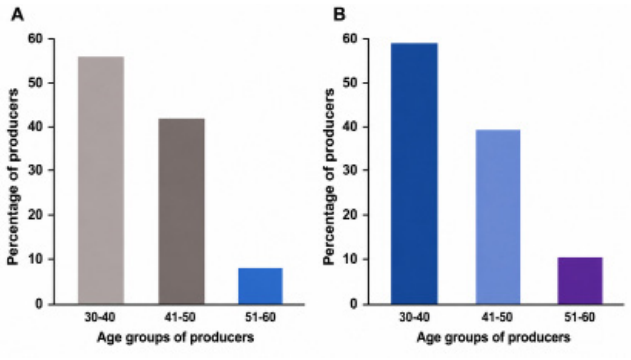

Figure 2. A) Age of Tchotou producers in Kara (n = 45); B) Age of Tonou producers in the Savannah regions (n = 15).

An analysis of the results shows that the majority of Tonou and Tchotou producers have not attended school (Figure 3). Indeed, the low level of education observed among the majority of producers represents a significant barrier to the qualitative and economic improvement of artisanal Tonou and Tchotou production. This educational gap limits their ability to adopt rigorous hygiene practices, master modern processing techniques, and adapt to the demands of structured markets. Studies on traditional fermented food processing in West Africa indicate that producers often rely on traditional methods, which, while effective for small-scale production, may limit product standardization and competitiveness in larger markets (Oladeji et al., 2025).

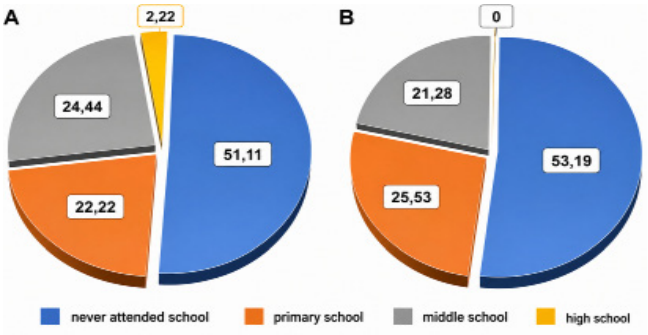

Figure 3. A) Education level of Tonou producers in the Savannah region (n = 15); B) Tchotou producers in the Kara region (n = 45).

Less educated producers continue to use traditional methods, which, while effective for small-scale production, impede product standardization and competitiveness in larger markets. Minimal education significantly enhances producers' ability to manage activities, understand value chains, and access marketing channels (Quisumbing et al., 2021; Maereka et al., 2023). It facilitates participation in training, adoption of innovations, and accounting practices, while strengthening negotiation power in agriculture. An educated producer can better formalize, participate in, and transmit knowledge, aiding in the professionalization of the sector and preservation of local know-how (Yami et al., 2024).

The data collected during face-to-face interviews with producers and observations made at production sites enabled us to draw up a diagram of Tchotou and Tonou production in the Kara and Savannah regions. The data collected shows various types of Tonou and Tchotou: Tchotou and Tonou produced solely from néré seeds (Figure 4A), Tchotou and Tonou produced from a mixture of néré and soybeans (Figure 4B), a mixture of Kapok (*Ceiba pentandra*) and baobab (*Adansonia digitata*) (Figure 4C), a mixture of soyabeans, néré seeds, and peanuts, and a mixture of néré seeds and peanuts. It appears that it takes an average of eight days to produce Tchotou or Tonou.

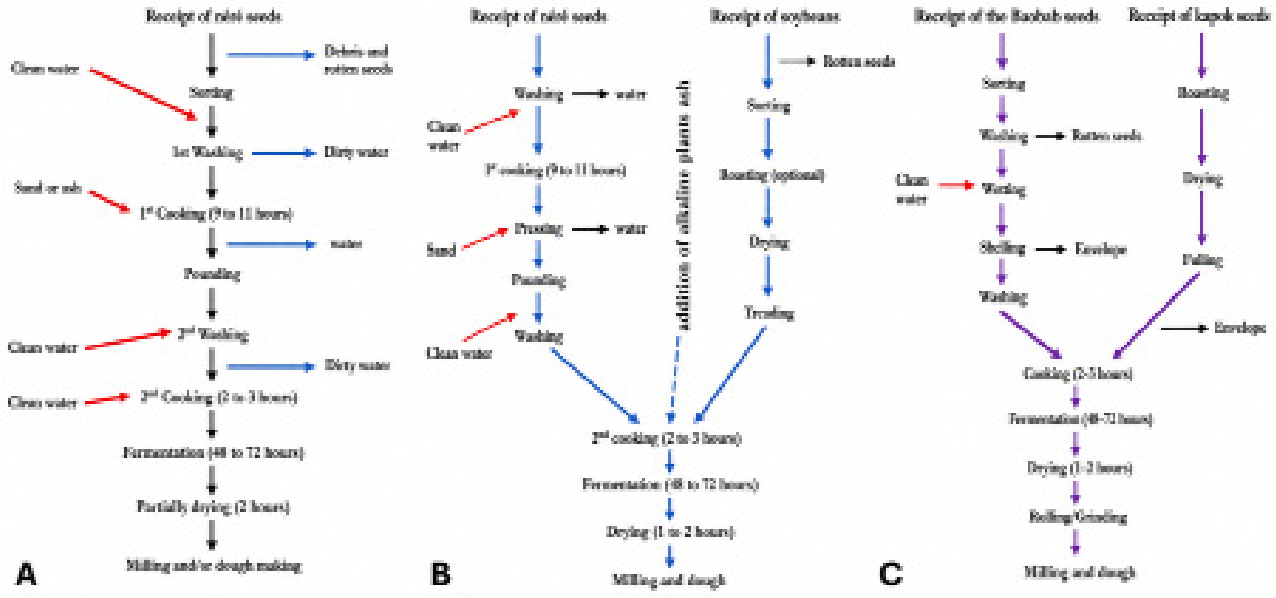

Figure 4. Production diagram of Tonou and Tchotou: A) Néré; B) Mixed néré and soybean; C) Mixed baobab and kapok seeds.

Figure 5 depicts the various traditional mustards studied, highlighting their variations in color, texture, and overall appearance.

The organoleptic characteristics of the different types of Tchotou, including texture, taste, aroma, and color, are summarized in Table 3. Soybean Tonou (Figure 5) is a smooth to slightly grainy paste, ranging in color from light beige to pale yellow. Its texture is soft and creamy, making it easy to spread and incorporate into culinary preparations. In terms of flavor, it has a slightly spicy taste, combined with a mild bitterness and aromas reminiscent of lightly roasted seeds. Its aroma is moderate but characteristic of fermented legumes. On the palate, it offers a creamy mouthfeel with a pleasant lingering aftertaste.

Tonou and Tchotou made from néré (*P. biglobosa*) seeds have a firm exterior and a softer interior when shaped into balls, or a dense, slightly grainy paste after grinding. Its color ranges from light brown to dark brown, depending on the degree of fermentation and drying. Its aroma is intense and characteristic of alkaline fermented products. The taste is

Figure 5. Types of Tchotou and Tonou. A) Tchotou produced by a mixture of néré and soybean; B) Tchotou produced from kapok baobab seed mixture; C) Tchotou produced only with néré seeds; D) Tonou produced with a mixture of soybeans, néré seeds, and peanuts; E) Tonou produced with a mixture of néré seeds and peanuts.

Table 3. Comparison of texture, taste, aroma, and color of different types of Tchotou and Tonou

Type of Tchotou and Tonou	Ingredients	Texture	Taste	Aroma	Color
Néré	Fermented néré seeds	Dense, slightly granular, malleable	Intense umami, slightly salty, and spicy	Fermented, strong, typical of soumbala	Dark brown light brown
Soybean	Fermented soybean seeds	Creamy, smooth, slightly granular	Sweet, slightly spicy, less bitter than néré	Subtle, nutty	Light beige pale yellow
Baobab and Kapok	Baobab and kapok seeds	Dense, slightly granular, firm	Sweet-bitter, mildly spicy	Roasted and herbal notes, light	Light beige light brown
Néré-soybean blend	Néré and soybean seeds	Creamy but slightly granular	Balanced umami with soybean sweetness	Fermented but less intense than néré alone	Light brown, medium brown
Kapok-baobab-soybean (optional)	Kapok, baobab, and soybean seeds	Dense and pliable, slightly granular	Sweet-bitter with moderate umami	Roasted, herbal, subtle	Medium beige light brown

pronounced, simultaneously salty, slightly bitter, and pungent, with a strong aftertaste linked to compounds produced by protein breakdown.

Tchotou and Tonou, prepared from a mixture of néré and soybeans, have an intermediate texture, both creamy and slightly grainy. It is pliable and easy to handle, while retaining some heterogeneity due to the néré particles. Its color ranges from dark beige to light brown. The flavor profile is balanced, combining the umami and salty flavor of néré with the relative mildness of soybeans and a slight bitterness. The aroma results from the combination of néré's fermented compounds and the milder aromatic compounds of soybeans. On the palate, the texture is creamy with moderate aromatic persistence.

Tchotou, made from baobab and kapok seeds, has a dense and slightly grainy texture. Its color ranges from light beige to light brown. The taste is characterized by a slight bitterness combined with moderate spiciness. This product also has a relatively high-water content, which influences its texture and may affect its stability during storage.

According to our findings, Tonou and Tchotou are commonly used as food condiments in all types of sauces served with cereal-based doughs. These include viscous sauces (made from okra, adémé, or baobab leaves), as well as leafy vegetable sauces (such as gboma, basil, and Guinea sorrel). Furthermore, they could be consumed fresh, uncooked, or served with rice. In some cases, it is incorporated directly into the cooking process, for example, in tomato-based sauces (Fatoumata et al., 2016).

The biochemical analyses focused on moisture content, ash content, and mineral composition, as these parameters are recognized as essential for evaluating nutritional quality. Moisture content directly influences microbial growth, while ash content and the mineral profile provide an overall characterization of the product's mineral composition, which is critical for food quality and safety (Rahman, 2020). Moisture and mineral composition of Tchotou from the Kara region and Tonou produced in the Savannah are reported in Table 4. Statistical analysis showed significant differences among Tonou and Tchotou formulations for all variables evaluated ($p \leq 0.05$).

Table 4. Moisture and mineral composition of Tchotou from the Kara region and Tonou produced in the Savannah

Sample	Moisture (%)	Ash (%)	Mg (mg/100 g)	Ca (mg/100 g)	Fe (mg/100 g)	P (mg/100 g)
Tonou (n = 18)						
N	31.33± 0.26	4.36 ± 0.49	303.45±0.68	234.39±0.24	18.40± 0.34	152.95±0.16
N+S	33.76± 0.35	3.06 ± 0.07	321.80± 0.34	233.09± 0.10	20.05± 0.16	162.70±0.34
S	30.95± 0.47	2.99 ± 0.07	287.30± 0.36	28.72 ± 0.59	13.55 ±0.54	112.33±0.15
Tchotou (n = 20)						
HJ	14.36 ± 0.13	5.12 ± 0.06	138.30 ± 0.65	217.30 ± 0.65	13.32 ± 0.91	121.22±0.20
AT	17.37 ± 0.36	3.85 ± 0.16	179.40 ± 0.81	229.87 ± 0.99	17.32 ± 0.06	112.07±0.01
AL	34.68 ± 0.12	5.86 ± 0.15	129.40 ± 0.78	220.82 ± 0.20	10.82 ± 0.74	110.57±0.71

n: number of samples. Each analysis was carried out in triplicate.

N: néré Tonou; N+S: mixed soyabeans and néré Tonou; S: soybeans Tonou; HJ: Tchotou made with néré seeds; AT: Tchotou made with a mixture of néré seeds and soyabeans; AL: Tchotou made with a mixture of kapok-baobab seeds.

ANOVA confirmed that sample type and processing method significantly influenced the biochemical characteristics and mineral composition of the products.

Moisture content in the samples ranged from 14.36% (HJ, Kara) to 34.68% (AL, Kara). Tchotou from the Kara region exhibited higher moisture levels, particularly a mixture of néré seeds and soyabeans Tchotou, while all Tonou samples from the Savannah region showed moisture contents between 30.95 and 33.76%. Several studies conducted in various West African countries gave similar results. Guissou et al. (2020), Kambire et al. (2021), and Kouamé et al. (2021) found 5.02, 7.3 to 24.7%, and 16.50 to 19.28% for the moisture content of soumbala produced by home technology in Burkina Faso and Côte d'Ivoire, respectively. This discrepancy may be explained by shorter drying times, higher ambient humidity in the Kara and Savannah regions, or prolonged fermentation leading to greater water retention.

Ash content, which reflects the overall mineral richness, varied from 2.99% (soybeans Tonou from Savannah) to 5.86% (Tchotou made with a mixture of kapok-baobab seeds from the Kara region). Guissou et al. (2020) and Marcel et al. (2022) had reported 3.42% and 4.00% of ash content of soumbara produced in Burkina Faso and in Korhogo (Côte d'Ivoire). The Tchotou samples with the highest ash content indicate good mineral availability, likely due to the use of unhusked néré seeds or longer fermentation periods, which may promote the release of minerals. Furthermore, the addition of ash and other seeds or ingredients (soyabeans, peanuts, kapok seeds) during the production of Tchotou and Tonou could contribute to the increase in the ash content of the produced mustards. Ash is mainly composed of minerals.

Minerals are essential inorganic nutrients obtained from food, required for body functions like bone building, fluid balance, and metabolism. Iron content of Tchotou and Tonou ranged from 10.82 ± 0.74 to 17.32 ± 0.06 mg/ 100 g, and from 13.55 ± 0.54 to 20.05 mg/100 g, respectively, for each product. The value of iron was lower than 26.27 mg/100 g and 34.44 mg/100 g, reported by Guissou et al. (2020) in Burkina Faso and Marcel et al. (2022) in Côte d'Ivoire, respectively, for soumbala nutritional composition. This variation in iron content of traditional mustards observed from one country to another could be explained by differences in seed content due to soil composition and/or climate, as well as traditional processing methods. Magnesium is particularly important because of its central role in over 300 enzymatic reactions, particularly those related to energy metabolism, neuromuscular function, and bone health (Fatima et al., 2024). Tonou and Tchotou contained magnesium ranging from 129.40 ± 0.78 mg/100 g to 321.80 ± 0.34 mg/100 g. The calcium content of Tonou and Tchotou ranged respectively from 28.72 ± 0.59 to 234.39±0.24 mg/100 g and from 217.30 ± 0.65 to 229.87 ± 0.99 mg/100 g.

According to Laetitia et al. (2022), condiments made from oilseeds are known for their calcium content, which is an essential mineral for acid-base balance and energy metabolism. Furthermore, calcium is an essential component of teeth and bones, promoting robust bone development and growth in children who regularly consume it. Yérobessor et al. (2022) reported that Soumbala is a significant source of calcium, protein, fat, carbohydrates, B vitamins, and minerals such as iron and phosphorus. Their findings coincide with those of the present work, since the samples from Tonou and Tchotou showed relatively acceptable levels of phosphorus. Indeed, phosphorus content varied from 110.57 mg/100 g (Tchotou) to 162.70 mg/100 g (Tonou). These results indicate that formulations made from the néré-soybean mixture may offer better phosphorus availability, likely due to the nutritional complementarity of the two seed types.

Samples from the Savannah region showed uniform moisture and mineral content, while Kara samples had greater variability and higher moisture levels. The combination of néré (*P. biglobosa*) and soybean improved moisture and mineral levels. Thus, Tonou and Tchotou significantly contribute to nutritional security by enhancing protein bioavailability and supplying essential amino acids, vitamins, fatty acids, and minerals, which are critical in regions like Kara and Savannah reliant on carbohydrate-rich staples (Djoudi et al., 2022; Obafemi et al., 2022).

Table 5. Microbiological quality of Tonou and Tchotou samples

Sample	Total aerobic mesophilic flora (CFU/g)	Yeasts and molds (CFU/g)	*Salmonella* spp. (per 10 g)
Tonou			
N (n = 6)	2.02×10^{6}	1.23×10^{3}	Absent
N+S (n = 7)	2.45×10^{7}	2.76×10^{4}	Absent
S (n = 5)	2.25×10^{7}	2.95×10^{4}	Absent
Tchotou			
HJ (n = 7)	1.70×10^{7}	3.86×10^{3}	Absent
AT (n = 7)	2.93×10^{7}	3.43×10^{3}	Absent
AL (n = 6)	2.89×10^{8}	2.27×10^{4}	Absent

n: number of samples.

Microbiological analyses focused on total aerobic mesophilic flora, yeasts and molds, and Salmonella spp. (Table 5).Due to the physicochemical characteristics of mustard (acidic pH, low water activity, possible presence of preservatives), which are generally unfavorable for the growth of many pathogenic microorganisms. This analytical approach enables a relevant assessment of the hygienic quality and microbiological safety of the product. It complies with the criteria established by Regulation No. 2073/2005 of the European Commission (European Commission, 2005) on microbiological criteria for foodstuffs.

Microbiological analyses of Tchotou and Tonou from the Kara and Savannah regions in Togo showed TAMF counts ranging from 2.02×10^6 to 2.89×10^8 CFU/g, well above the EU limit of 5×10^4 CFU/g (EC, 2005). These results align with TMF levels reported in other traditional fermented products in West Africa (Kambire et al., 2021). However, some samples had higher microbial loads, indicating possible differences in local production practices or hygiene controls. It is recommended that the authorities implement training programs in Good Manufacturing Practices for producers.

Yeast and mold counts ranged from 1.23×10^3 to 2.95×10^4 CFU/g, indicating intense fermentative activity. Similar findings were reported by Souley et al. (2020), who observed yeast and mold counts between 5.0×10^2 and 1.2×10^4 CFU/g in soumbala from Niger. Although these microorganisms are generally non-pathogenic, their presence is considered technologically beneficial. Indeed, yeasts and molds play an active role in fermentation by contributing to macronutrient breakdown, to the production of volatile compounds, and the development of sensory characteristics such as aroma, flavor, and texture in fermented condiments (Yérobessor et al., 2022).

Salmonella spp. were absent in all analyzed samples, which is consistent with findings reported by Fatoumata et al. (2016) on fermented condiments produced from P. biglobosa and Glycine max in Côte d'Ivoire. This absence may reflect good hygienic practices during production and storage, as well as the inhibitory effects of fermentation processes, contributing to the microbiological safety of the final products.

Tchotou and Tonou are traditional West African condiments widely used not only for their sensory properties but also for their medicinal benefits. According to the survey, 99% of the women producers interviewed reported using this condiment in the treatment of high blood pressure, 60.23% for abdominal pain, and 43.45% in the management of malaria. According to Law et al. (2024), the known medical effects of seeds, condiments, afitin, soumbala, or netetu are their potential antihypertensive effects, which have been observed in populations with long-term consumption. In light of the results obtained, it would be advisable for public health studies to prioritize the consumption of Tchotou and Tonou.

The assessment of the organoleptic quality of the various types of traditional mustard studied was not carried out by a panel of tasters, but rather by visual inspection for color, by smell for odor, and by touch for texture. The production diagrams show that the production methods for Tonou and Tchotou are not standardized. Furthermore, specific pathogens such as *Staphylococcus aureus, Bacillus cereus*, and mycotoxin-producing fungi were not taken into account in this study. However, these aforementioned limitations do not detract from the relevance of the results, which constitute an essential step in guiding corrective measures and future work. Further studies incorporating microbiological analyses for *S. aureus, B. cereus*, and mycotoxin-producing fungi, as well as the biochemical and molecular identification of the various isolated pathogens, would help to better document the actual level of consumer exposure to the various causes of mass foodborne infections.

Conclusions

Tchotou and Tonou, produced from *P. biglobosa*, *G. max*, *C. pentandra*, and *A. digitata* seeds, constitute nutrient-dense traditional condiments with significant socio-economic importance for rural women in Northern Togo. Physicochemical analyses revealed high levels of essential minerals, while microbiological assessments indicated an overall acceptable level of safety despite active fermentation processes. These findings highlight the need to improve artisanal processing techniques and hygiene practices by training producers to ensure better product quality and standardization. Future research should explore the impact of implementing standardized production protocols and targeted training programs for producers, with the aim of enhancing nutritional value, improving food safety, and supporting the sustainability of this traditional food system. Furthermore, we plan to isolate strains with probiotic properties and also to optimize the fermentation process.

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References

Alphonse, L. (2026). Bioactive metabolites and probiotic microorganisms in traditional fermented condiments:

Insights on prevention and treatment of cancer. *Applied Food Research, 6*(1), Article 101614. https://doi.org/10.1016/j.afres.2025.101614

AOAC. (1980). *Official methods of analysis*. Association of Official Analytical Chemists.

AOAC. (2019). *Official methods of analysis of AOAC International* (21st ed., Vol. 1). AOAC International.

Azokpota, P., Hounhouigan, D. J., & Nago, M. C. (2006). 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*(3). https://doi.org/10.1016/j.ijfoodmicro.2005.10.026

Compaoré, C. S., Tapsoba, F. W., Parkouda, C., Tamboura, D., Traoré, E. M. A., Diawara, B., ... & Sawadogo-Lingani, H. (2020). Development of starter cultures carrier for the production of high quality soumbala, a food condiment based on *Parkia biglobosa* seeds. *African Journal of Biotechnology, 19*(11), 820–828. https://doi.org/10.5897/AJB2020.17244

Djoudi, H., Locatelli, B., Pehou, C., Colloff, M. J., Elias, M., Gautier, D., ... & Zida, M. (2022). Trees as brokers in social networks: Cascades of rights and benefits from a Cultural Keystone Species. *Ambio, 51*(10), 2137–2154. https://doi.org/10.1007/s13280-022-01733-z

European Commission. (2005). *Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs*. *Official Journal of the European Union, 338*, 1–26.

Fatima, G., Dzupina, A., Alhmadi, H. B., Magomedova, A., Siddiqui, Z., Mehdi, A., & Hadi, N. (2024). Magnesium matters: A comprehensive review of its vital role in health and diseases. *Cureus, 16*(10). https://doi.org/10.7759/cureus.71392

Fatoumata, C., Soronikpoho, S., Souleymane, T., Kouakou, B., & Marcellin, D. K. (2016). Caractéristiques biochimiques et microbiologiques de moutardes africaines produites à base de graines fermentées de *Parkia biglobosa* et de *Glycine max*, vendues en Côte d'Ivoire. *International Journal of Biological and Chemical Sciences, 10*(2). https://doi.org/10.4314/ijbcs.v10i2.5

Guissou, A. W. D. B., Parkouda, C., Anaïs, C. K., Korotimi, T., Oboulbiga, E. B., & Savadogo, A. (2020). Fermentation effect on the nutrient and antinutrient composition of *Senegalia macrostachya* and *Parkia biglobosa* seeds: A comparative study. *Food and Nutrition Sciences, 11*(7). https://doi.org/10.4236/fns.2020.117052

ISO 4833-1. (2014). *Microbiology of the food chain—Horizontal method for the enumeration of microorganisms—Part 1: Colony count at 30 °C by the pour plate technique*. International Organization for Standardization.

ISO 21527-2. (2008). *Microbiology of food and animal feeding stuffs—Horizontal method for the enumeration of yeasts and moulds—Part 2: Colony count technique in products with water activity less than or equal to 0.95*. International Organization for Standardization.

ISO 21528-2. (2004). *Microbiology of food and animal feeding stuffs—Horizontal methods for the detection and enumeration of Enterobacteriaceae—Part 2: Colony-count method*. International Organization for Standardization.

Kambire, O., Yao, K. M., Sika, A. E., Coulibaly, A., Boli, Z. B. I. A., & Koffi-Nevry, R. (2021). Microbiological and physicochemical characteristics of three types of "soumbara" from seeds of African locust bean in Korhogo markets, Côte d'Ivoire. *International Journal of Food Science, 2021*, Article 5572300. https://doi.org/10.1155/2021/5572300

Kosse, J. S., Yeung, A. C., Gil, A. I., & Miller, D. D. (2001). A rapid method for iron determination in fortified foods. *Food Chemistry, 75*(3), 371–376. https://doi.org/10.1016/S0308-8146%2801%2900215-1

Kouamé, K. A., Bouatenin, K. M. J. P., Coulibaly, W. H., & Marcellin, D. K. (2021). Biochemical and microbiological characterization of "Soumbara" from African locust bean (*Parkia biglobosa*) seeds consumed in Abidjan (Côte d'Ivoire). *North African Journal of Food and Nutrition Research, 5*(11). https://doi.org/10.51745/najfnr.5.11.35-42

Laetitia, K. A. J., Severin, K. K. A., Joseph, K. N., Carine, A. E., Tia, G., & Sebastien, N. (2022). Production of highly nutritious enriched infant flours from a traditional ready-to-eat dish: The plantain Dockounou. *Journal of Food Research, 11*(3), 1–10. https://doi.org/10.5539/jfr.v11n3p1

Law, G. Y., Chong, L. C., & Tang, Y. Q. (2024). Antihypertensive effects of condiments prepared from fermented legumes: A review. *International Food Research Journal, 31*(1). https://doi.org/10.47836/ifrj.31.1.01

Maereka, E. K., Nchanji, E. B., Nyamolo, V., Cosmas, L. K., & Chataika, B. Y. (2023). Women's visibility and bargaining power in the common bean value chain in Mozambique. *CABI Agriculture and Bioscience, 4*(1). https://doi.org/10.1186/s43170-023-00197-9

Marcel, A. G., Théodore, A. K., Losséni, B., & Ernest, A. K. (2022). Manufacturing technique and nutritive value of Soumbara (*Parkia biglobosa* seeds) and dark seed of Korhogo (Côte d'Ivoire). *Open Journal of Applied Sciences, 12*(10). https://doi.org/10.4236/ojapps.2022.1210114

Musara, C., Aladejana, E. B., Mudyiwa, S. M., & Karavina, C. (2020). *Parkia biglobosa* (Mimosaceae): Botany, uses, phytochemical properties and pharmacological potential. *Journal of Pharmacy and Nutrition Sciences, 10*(3), 101–115. https://doi.org/10.29169/1927-5951.2020.10.03.4

Obafemi, Y. D., Oranusi, S. U., Ajanaku, K. O., Akinduti, P. A., Leech, J., & Cotter, P. D. (2022). African fermented

foods: Overview, emerging benefits, and novel approaches to microbiome profiling. *npj Science of Food, 6* (1), 15. https://doi.org/10.1038/s41538-022-00130-w

Oladeji, O. A., Taiwo, K. A., Ogidi, C. O., & Faturoti, A. O. (2025). Production, nutritional benefits, limitations and strategies for enhancing the national value of fermented native condiments from selected legumes and wild seeds in Nigeria. *Discover Food, 5*, 142. https://doi.org/10.1007/s44187-025-00409-3

Ouoba, L. I. I., Rechinger, K. B., Barkholt, V., Diawara, B., Traore, A. S., & Jakobsen, M. (2003). Degradation of proteins during the fermentation of African locust bean (*Parkia biglobosa*) by strains of *Bacillus subtilis* and *Bacillus pumilus* for production of Soumbala. *Journal of Applied Microbiology, 94*(3). https://doi.org/10.1046/j.1365-2672.2003.01845.x

Owusu-Kwarteng, J., Agyei, D., Akabanda, F., Atuna, R. A., & Amagloh, F. K. (2022). Plant-based alkaline fermented foods as sustainable sources of nutrients and health-promoting bioactive compounds. *Frontiers in Sustainable Food Systems, 6*, 885328. https://doi.org/10.3389/fsufs.2022.885328

Quisumbing, A., Heckert, J., Faas, S., Ramani, G., Raghunathan, K., Malapit, H., ... & Seymour, G. (2021). Women's empowerment and gender equality in agricultural value chains: Evidence from four countries in Asia and Africa. *Food Security, 13*(5). https://doi.org/10.1007/s12571-021-01193-5

Rahman, M. S. (2020). *Handbook of food preservation*. https://doi.org/10.1201/9780429091483

Souley, R. A., Diadié, H. O., Abdelkader, A. S., Yacoubou, B., & Balla, A. (2020). Caractérisation biochimique et microbiologique de Soumbala de néré (*Parkia biglobosa*) et d'oseille de Guinée (*Hibiscus sabdariffa*) produits au Niger. *European Scientific Journal, 16*(3). https://doi.org/10.19044/esj.2020.v16n3p224

Yami, M., Abioye, O., Sore, S. Z., Mugisho, A., & Abdoulaye, T. (2024). Factors influencing gender and youth integration in agricultural research and innovation in Africa. *CABI Agriculture and Bioscience, 5*(1), 12. https://doi.org/10.1186/s43170-024-00215-4

Yérobessor, D., Iliassou, M., Marius, K. S., Jerry, O. U., Lewis, I. E., Mamoudou, H. D., & Alfred, S. T. (2020). Production technique, safety and quality of soumbala, a local food condiment sold and consumed in Burkina Faso. *African Journal of Food Science, 14*(2). https://doi.org/10.5897/AJFS2019.1891

Yérobessor, D., Somda, N. S., Somda, M. K., Compaoré, C. B., Mogmenga, I., Ezeogu, L. I., ... & Dicko, M. H. (2022). Assessment of probiotic and technological properties of *Bacillus* spp. isolated from Burkinabe Soumbala. *BMC Microbiology, 22*(1). https://doi.org/10.1186/s12866-022-02642-7

Conflicts of interest

The authors declare that they have no conflicts of interest.

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Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Statement on the use of AI

The authors acknowledge the use of generative AI and AI-assisted technologies to improve the readability and clarity of the article.

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