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RESEARCH PAPER

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Improving the microbiological quality of spices and spice blends using treatments accessible to SMEs/SMIs

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ABSTRACT

The aim of this study is to contribute to the safety of spices and spice blends through the use of simple treatments that can be applied in SMEs/SMIs. To this end, samples of fresh onion bulbs, par sley, ginger, chili peppers, turmeric, and garlic were collected for the production of treated and untreated powdered spices. Samples of powdered spices of the same type were also purchased commercially in order to compare the results. Four types of heat treatment were applied depending on the nature of the spice. These were blanching, roasting, oven heating, and tyndallization. Microbiological analyses were carried out using standardized methods and covered all samples. The moisture content of the spices was also determined. An overall assessment of the results of the analyses of total mesophilic aerobic flora, yeasts and molds, *Staphylococcus aureus*, sulfite-reducing *Clostridium*, *Bacillus cereus*, *Escherichia coli*, and *Salmonella* shows that, according to microbiological quality criteria, 75. 00 % of untreated powdered spices are of unsatisfactory quality, as are 71.43 % of commercial powdered spices. The treatments resulted in a reduction of between 0.06 and 6.15 log CFU/g, depending on the bacteria. This reduction resulted in satisfactory quality for 62.50 % of the treated spices and acceptable quality for 37.50 %. Blanching and roasting resulted in an acceptable quality blend of spices. However, heating in an oven did not significantly improve the microbiological quality of the spice blend. These simple treatments blanching and roasting could be applied in SMEs/SMIs processing companies to reduce the microbial load in spices and spice blends.

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INTRODUCTION

Spices are produced from various parts of plants such as fruits, roots, bark, seeds, etc., which are often dried and then ground into powder. They are therefore exposed to a wide range of environmental microbial contamination during collection, processing, and in retail markets from dust, wastewater, and animal and even human excrement (Banerjee and Sarkar, 2003).

Numerous studies on the microbiological quality of spices sold in several countries have shown the profiles of microorganisms, including total heterotrophs, *Bacillus cereus, Clostridium perfringens, Escherichia coli, Salmonella*, and toxigenic molds (Cicero *et al.*, 2022; Ogur, 2022; Abd El-Rahman, 2019; Parveen *et al.*, 2014). These studies have revealed that in several countries, the levels of pathogenic bacteria in the majority of dried spices were high and therefore of unacceptable microbiological quality. Indeed, spices contaminated with pathogenic germs have been sources of collective food poisoning (FDA, 2013, Garcia *et al.,* 2001, Geeta and Kulkarni, 1987). They pose public health problems when incorporated into foods without heat treatment or when consumed raw (Banerjee and Sarkar, 2003). Therefore, the production, processing, packaging, transportation, and storage of spices should be geared toward minimizing microbial risks to food safety (CAC/RCP 42-1995, rev 2014). Indeed, studies in some countries have found that the microbiological quality of spices and herbs is satisfactory, indicating good hygiene conditions in the production process of spices and herbs available on their markets (Cicero *et al.*, 2022; Garbowska *et al.*, 2015). These production processes often include treatments such as steam sterilization (Kurzeja *et al.*, 2012), gamma irradiation (Schweiggert *et al.,* 2007), UV irradiation, and ozone (O_3) treatment (Arcos-Limiñana *et al.*, 2025, Kucukoglu *et al.,* 2024). A comparative study of the effect of these different treatments showed the effectiveness of heat treatment and gamma irradiation in reducing germ in spices (Kucukoglu *et al.*, 2024). Of the two types of treatment, heat treatment is the most accessible for SMEs in Burkina Faso and also the most accepted by consumers. Currently, several Burkinabe entrepreneurs have embarked on the processing of local spices and condiments from spice blends in response to growing demand for alternatives to chemical broth and flavorings. Studies have therefore focused on the physicochemical characterization and formulation of condiments from spice blends (Tankoano *et al.*, 2025, Tankoano *et al.*, 2024, Taram, 2023). However, few studies have focused on the microbiological quality of spices and spice blends. Nevertheless, a study on microbial diversity in Soumbala in Burkina Faso identified *Bacillus subtilis, B. pumilus, B. cereus, and Brevibacillus bortilensis* as the main bacteria (Ouoba *et al.*, 2004). The aim of this study is not only to assess the microbiological quality of spices produced in Burkina Faso, but also to identify simple and accessible treatments for SMEs/SMIs to improve the microbiological quality of spices and spice blends in order to contribute to food safety.

MATERIALS AND METHODS

The biological material consisted of fresh produce, such as onions and turmeric from the experimental fields of the Institute for the Environment and Agricultural Research in Burkina Faso; chili peppers, parsley, ginger, and garlic at a vegetable production site, in Kadiogo region; and soumbala from a processing unit.

Commercial powders of soumbala, onion, parsley, ginger, turmeric, chili pepper, and garlic were purchased from grocery stores and spice shops in Ouagadougou. A total of 32 samples of spices and spice blends were analyzed.

Treatments of spices and spices blend

Blanching treatment

Fresh spices, including onion, ginger, turmeric, and garlic, were cleaned, trimmed, washed, placed in stainless steel colanders, and immersed in water heated to boiling point (98 to 99°C) for 5 minutes. The parsley leaves were soaked under the same conditions for 2 minutes. After soaking and draining, the spices were dried in a Attesta dryer at temperatures of 50 to 60°C for 10 to 20 hours, depending on the spice.

Roasting treatment

The roasting process involved the soumbala and the spice mixture prepared from a blend of different spice powders. It consisted of heating the condiment in a pan on a hotplate set at a temperature of 180°C for 15 minutes. During the process, it was necessary to stir regularly to ensure an even temperature and to prevent the soumbala and spice mixture from burning.

Tyndallization treatment

This involved subjecting the fresh soumbala, stored in a jar, to several heating cycles in boiling water at approximately 98°C for 15 minutes, followed by incubation periods of 24 hours at room temperature. The operation was repeated every 24 hours for three days.

Oven heating treatment

This involved heating the spice mixture wrapped in aluminum foil in an oven at 150°C for 15 minutes.

Microbiological analyses

Total mesophilic aerobic flora (TMAF) counts were performed on Plate Count Agar (Liofilchem, Italy) after incubation at 30°C for 72 hours in accordance with ISO 4833-1 (2013), and yeasts and molds (YM) on Sabouraud agar (Liofilchem, Italy) after incubation at 25°C for 5 to 7 days in accordance with ISO 21527 (2008), sulfite-reducing *Clostridia* (SRC) on Tryptose Sulfite Cycloserine agar (Liofilchem, Italy) according to ISO 15213 (2023) after incubation in anaerobic conditions at 37°C for 24 to 48 hours. The black colonies, sometimes with a characteristic halo, characteristic of SRC were counted. *Staphylococcus aureus* were counted on Baird-Parker agar (Liofilchem, Italy) after incubation at 37°C for 24 to 48 hours according to ISO 6888-1 (2021). The typical black colonies with a clear halo were counted and then confirmed by the coagulase test. *Bacillus cereus* was counted on selective Brillance *Bacillus Cereus* agar (Liofilchem, Italy) after incubation at 30°C for 24 to 48 hours in accordance with ISO 7932 (2004). Typical *B. cereus* colonies appear as pink to red colonies often surrounded by an opalescent precipitate. *Escherichia coli* beta-glucuronidase positive on Tryptone Bile X-glucuronide agar (Liofilchem, Italy) after incubation at 44°C for 24 hours according to ISO 16649-2 (2001). The characteristic blue-green colonies were counted.

The search for *Salmonella spp.* was carried out in accordance with ISO 6579-1 (2017). After pre-enrichment, selective enrichment, and isolation on selective media, typical and atypical Salmonella colonies were subjected to confirmation tests.

The reduction in the number of germs after treatment was calculated by taking the logarithm of the difference between the load on the untreated spice and that on the treated spice.

Physicochemical analysis

The physicochemical analysis focused on water content. The water content of the samples was determined by weighing the sample before and after passage through an oven (Memmert) in accordance with ISO 712 (2024).

Data analysis

For the physicochemical and microbiological analyses, the data were entered using Microsoft Excel 2013 software. The microbiological results were compared with the microbiological quality criteria applicable to spices and spice blends to determine their quality. The physicochemical analyses were performed in triplicate and the analysis of variance was performed using the Tukey test. The results are expressed as mean values.

RESULTS AND DISCUSSION

Microbiological quality of commercial spice powders

Taking into account all the microbiological parameters analyzed, the results of analyses of commercially available spice powders revealed that only 28.57 % of samples (chili powder and ginger powder) were of acceptable quality (Table 1).

Table 1. Microbiological characteristics of commercially available spices

Nature of the sample	TMAF (CFU/g)	*B. cereus* (CFU/g)	YM (CFU/g)	*S. aureus* (CFU/g)	SRC (CFU/g)	*E. coli* (CFU/g)	*Salmonella* /25g	Overall quality
Commercial chili powder	1.3 x 10^5	<10	2.3 x 10^2	1.0 x 10^3	<10	<10	Absence	A
Commercial parsley powder	2.8 x 10^6	<10	3.8 x 10^2	1.2 x 10^3	<10	<10	Absence	NS
Commercial garlic powder	1.4 x 10^5	<10	1.0 x 10^3	1.9 x 10^3	<10	<10	Absence	NS
Commercial onion powder	9.6 x 10^2	<10	<10	1.1 x 10^3	<10	<10	Absence	NS
Commercial turmeric powder	1.9 x 10^6	<10	<10	9.1 x 10^2	<10	<10	Absence	NS
Commercial ginger powder	1.2 x 10^4	<10	1.5 x 10^3	9.2 x 10^2	<10	<10	Absence	A
Commercial Soumbala powder	9.0 x 10^{7*}	<10	1.4 x 10^2	1.1 x 10^5	7.0 x 10^3	<10	Absence	NS
m (JORA)	10^5	≤ 10^3	≤ 10^4	≤ 10^2	≤ 10^3	≤ 10^2	Absence	-
M (JORA)	10^6	≤ 10^4	≤ 10^5	≤ 10^3	≤ 10^4	≤ 10^3	Absence	-
Quality assessment by microbiological parameter (%)	S(33.34) A(33.33) NS(33.33)	S(100)	S(100)	S(0) A(42.86) NS(57.14)	S(85.71) A(14.29)	S(100)	S(100)	S(0) A(28.57) NS(71.43)

YM: yeasts and molds; CRS: *Clostridium* suffito reducer; CFU: Colony-forming unit; * Total flora not evaluated against quality criteria as fermented product; S: satisfactory; A: acceptable; NS: not satisfactory; m: number of germs present in one gram of analyzed product, which corresponds to the value below which the quality of the product is considered satisfactory; M: number of germs present in one gram of analyzed product, which corresponds to the value above which the quality of the product is considered unsatisfactory; JORA: Official Journal of the Algerian Republic.

The remaining 71.43 % of samples (parsley, garlic, onion, turmeric, and soumbala powders) were of unsatisfactory or unacceptable quality. Such high rates of unacceptable quality samples, 63.2 % and 87.03 %, were reported by Koohy-Kamaly-Dehkordy *et al.* (2013) in Iran and Ogur (2022) in Turkey.

However, studies by Garbowska *et al.* (2015) in Poland and Cicero *et al.* (2022) on spices imported and distributed on the European Union market showed that none of the spice and herb samples analyzed were of unsatisfactory quality.

An assessment based on microbiological parameters shows that all samples were of satisfactory quality for *B. cereus*, YM, *E. coli*, and salmonella. Furthermore, none of these germs were detected in commercial spices. A rate of 82.75 % of samples were free of SRC and therefore of satisfactory quality for this germ. SRC was found only in Soumbala powder.

With regard to TMAF, the number of bacteria varied between 9.6 x 10^2 and 9.0 x 10^7 CFU/g, with 33.44 % of samples being of unsatisfactory quality. These results are similar to those reported by Abd El-Rahman (2019) in Egypt, which were 3.5 x 10^2 to 2.5 x 10^8 CFU/g, and lower than those reported by Ogur (2022) in Turkey, which were 2.20 to 11.20 log CFU/g.

As for *S. aureus,* none of the samples were of satisfactory quality, 42.86 % of the samples were of acceptable quality, and 57.14 % were of unacceptable quality. The presence of *S. aureus* in all samples could be due to raw materials already contaminated with this germ, or to contamination during processing by handlers or equipment. *S. aureus* is transmitted to food by contaminated processing tools and poor practices by healthy carriers or sick individuals (ANSES, 2022). Strict adherence to good hygiene and manufacturing practices should be observed in order to minimize the risk of spice contamination and, consequently, reduce the health risks associated with spice consumption.

Microbiological quality of fresh spices used as raw materials

The results of analyses of fresh spice samples showed that only 28.57 % (turmeric and soumbala) were of unsatisfactory quality when all the microbiological parameters analyzed were taken into account (Table 2). The majority of raw materials were either of satisfactory quality or of acceptable quality in relation to quality standards. The assessment by parameter also shows that for all samples, the proportions of unsatisfactory samples are low at 14.29 % for *B. cereus* as well as for *E. coli, S. aureus*, and SRC. As for TMAF, YM, and salmonella, no samples were of unsatisfactory quality. The raw materials were harvested, packaged, and transported in accordance with good practices. These results also demonstrate the application of good farming practices by producers despite fairly high TMAF loads ranging from 1.2 x 10^4 to 1.4 x 10^7 CFU/g and the presence of certain pathogens such as *S. aureus*, *B. cereus*, and SRC. The natural microflora of fruits and vegetables is characterized by a highly diverse microbial flora composed of Gram-positive bacteria (*Micrococcus, Staphylococcus*, lactic acid bacteria, spore-forming bacteria of the genera *Bacillus* or *Clostridium)* or Gram-negative (Pseudomonas, Acinetobacter, Moraxella, Escherichia, Enterobacter), whether pathogenic or not, yeasts, and molds (Fessard, 2017).

Table 2. Microbiological characteristics of fresh spices

Nature of the sample	TMAF (CFU/g)	*B. cereus* (CFU/g)	YM (CFU/g)	*S. aureus* (CFU/g)	SRC (CFU/g)	*E. coli* (CFU/g)	*Salmonella* /25g	Quality
Fresh chili peppers	4.4 x 10^6	<10	1.6 x 10^2	<10	6.4 x 10^1	<10	Absence	S
Fresh parsley	6.0 x 10^4	<10	4.1 x 10^3	9.1 x 10^1	6.4 x 10^1	<10	Absence	S
Fresh garlic	1.6 x 10^4	<10	3.1 x 10^3	<10	<10	<10	Absence	S
Fresh onion	1.2 x 10^6	<10	2.1 x 10^4	<10	<10	<10	Absence	A
Fresh turmeric	5.0 x 10^6	1.4 x 10^4	4.3 x 10^2	<10	1.2 x 10^4	<10	Absence	NS
Fresh ginger	1.4 x 10^7	6.4 x 10^3	6.6 x 10^4	<10	6.4 x 10^3	<10	Absence	A
Fresh soumbala	1.1 x 10^{10*}	4.5 x 10^2	6.5 x 10^3	2.1 x 10^5	<10	1.0 x 10^4	Absence	NS
m (JORA)	5.10^6	≤ 10^3	≤ 10^4	≤ 10^2	≤ 10^3	≤ 10^2	Absence	-
M (JORA)	5.10^7	≤ 10^4	≤ 10^5	≤ 10^3	≤ 10^4	≤ 10^3	Absence	-
Quality assessment by microbiological parameter (%)	S(83.33) A(16.67) NS(0)	S(71.42) A(14.29) NS(14.29)	S(71.43) A(28.57) NS(0)	S(85.71) A(0) NS(14.29)	S(71.42) A(14.29) NS(14.29)	S(85.71) A(0) NS(14.29)	S(100)	S(42.86) A(28.57) NS(28.57)

YM: yeasts and molds; CRS: *Clostridium* suffito reducer; CFU: Colony Forming Unit; * Total flora not evaluated against quality criteria as fermented product; S: satisfactory; A: acceptable; NS: not satisfactory; m: number of germs present in one gram of analyzed product, which corresponds to the value below which the quality of the product is considered satisfactory; M: number of germs present in one gram of analyzed product, which corresponds to the value above which the quality of the product is considered unsatisfactory; JORA: Official Journal of the Algerian Republic.

Microbiological quality of untreated and treated spice powders

The microbial loads in the spice samples before and after heat treatment are shown in Table 3. The results showed that for untreated spice powders, only 12.50 % of the samples were of satisfactory quality, 12.50 % were of acceptable quality, and 75.00 % were of unsatisfactory quality, considering all the microbiological parameters analyzed. An assessment by parameter showed that all samples were of satisfactory quality for YM and salmonella. For the parameters *B. cereus*, SRC, and *E. coli*, 75.00 to 87.50 % of the samples were of satisfactory quality. As for TMAF, 33.44 % of the samples were of satisfactory quality. However, only 12.50 % were of satisfactory quality for *S. aureus*. The microbiological quality of untreated spice powders is fairly similar to that of spice powders sold on the market. They are characterized not only by a high rate of spices of unsatisfactory quality according to microbiological quality criteria, but also by microorganisms of the genus *S. aureus*, which are frequently found at unacceptable levels. However, the majority of raw materials (75%) were of satisfactory quality with regard to *S. aureus* and, even better, the detection threshold for the germ had not been reached in these fresh products. Secondary contamination from surfaces, the environment, or handlers during processing could explain the high final loads of *S. aureus*. Numerous studies have reported that handlers in contact with food are often healthy carriers of *S. aureus,* particularly on their hands and in their nasal cavities (Phan *et al.,* 2025; Zheng *et al.,* 2025; Fernandes *et al.*, 2022; Kadariya *et al.*, 2014).

No samples of unsatisfactory quality were detected in the treated spice powders. A total of 62.50 % of the samples were of satisfactory quality and 37.50 % were of acceptable quality.

The treatments brought all spices of unsatisfactory quality to satisfactory quality for parsley, turmeric, and ginger, or to acceptable quality for chili pepper and soumbala.

Table 3. Microbiological characteristics of untreated and treated spices

Nature of the sample		TMAF (CFU/g)	*B. cereus* (CFU/g)	YM (CFU/g)	*S. aureus* (CFU/g)	SRC (CFU/g)	*E. coli* (CFU/g)	*Salmonella* /25g	Quality
Chili powder	Unbleached	2.3×10^8	2.0×10^3	6.4×10^1	8.0×10^2	<10	<10	Absence	NS
	Bleached	1.6×10^5	<10	9.1×10^1	<10	<10	<10	Absence	A
Parsley powder	Unbleached	1.3×10^5	<10	$8,0 \times 10^2$	5.5×10^3	<10	<10	Absence	NS
	Bleached	7.6×10^2	<10	<10	<10	<10	<10	Absence	S
Garlic powder Garlic	Unblanched	4.5×10^3	<10	<10	<10	<10	<10	Absence	S
	Bleached	1.0×10^2	<10	<10	<10	<10	<10	Absence	S
Onion powder	Unbleached	1.0×10^5	1.7×10^3	2.2×10^2	5.0×10^2	<10	<10	Absence	A
	Bleached	5.0×10^2	<10	3.0×10^2	<10	<10	<10	Absence	S
Turmeric powder	Unbleached	1.4×10^6	1.0×10^3	7.3×10^1	8.4×10^2	<10	<10	Absence	NS
	Bleached	<10	<10	<10	<10	<10	<10	Absence	S
Ginger powder	Unbleached	1.7×10^6	<10	<10	7.5×10^2	<10	<10	Absence	NS
	Bleached	5.0×10^2	<10	<10	<10	<10	<10	Absence	S
Soumbala	Fresh	$1.1 \times 10^{10*}$	4.5×10^2	6.5×10^3	2.1×10^5	<10	10^4	Absence	NS
	Tyndallized	$5.5 \times 10^{8*}$	<10	5.7×10^3	2.7×10^2	<10	<10	Absence	A
	Powder	$9.0 \times 10^{7*}$	<10	1.4×10^2	1.1×10^5	7.0×10^3	<10	Absence	NS
	Roasted powder	$5.9 \times 10^{7*}$	<10	<10	6.0×10^2	9.1×10^1	<10	Absence	A
m (JORA)		10^5	$\leq 10^3$	$\leq 10^4$	$\leq 10^2$	$\leq 10^3$	$\leq 10^2$	Absence	-
M (JORA)		10^6	$\leq 10^4$	$\leq 10^5$	$\leq 10^3$	$\leq 10^4$	$\leq 10^3$	Absence	-
Overall assessment of the quality of untreated spices by microbiological parameter (%)		S(33.33) A(16.67) NS(50.00)	S(75.00) A(25.00) NS(0)	S(100)	S(12.50) A(50.00) NS(37.50)	S(87.50) A(12.50) NS(0)	S(87.50) A(0) NS(12.5)	S (100)	S(12.50) A(12.50) NS(75.00)
Overall assessment of spice quality by microbiological parameter (%)		S(83.33) A(16.67) NS(0)	S(85.71) A(14.29) NS(0)	S(100)	S(75.00) A(25.00) NS(0)	S(100)	S (100)	S (100)	S(62.50) A(37.50) NS(0)

YM: Yeasts and molds; CRS: *Clostridium* suffito reducer; CFU: Colony Forming Unit; * Total flora not evaluated against quality criteria as fermented product; S: satisfactory; A: acceptable; NS: not satisfactory; m: number of germs present in one gram of analyzed product, which corresponds to the value below which the quality of the product is considered satisfactory; M: number of germs present in one gram of analyzed product, which corresponds to the value above which the quality of the product is considered unsatisfactory; JORA: Official Journal of the Algerian Republic.

Effect of treatments on the microbiological quality of spice powders

A comparison of the results for treated and untreated spice powders allows the effect of the treatments on the different germs to be assessed.

Bleaching reduced the TMAF for all spices. The smallest reduction, 1.65 log CFU/g, was observed with garlic, and the largest reduction, 6.15 CFU/g, with turmeric (Fig. 1). Most of the TMAF was destroyed by heat. *B. cereus* and *S. aureus* were reduced to undetectable levels. The blanched spice powders were indeed free of these pathogens (Table 3). The reductions were in the range of 2.69 to 3.74 log CFU/g for *S. aureus* and 3.00 to 3.30 log CFU/g for *B. cereus* (Fig. 1). Blanching thus prevented secondary contamination of the powders with *S. aureus*. This could be due to the fact that the heat of blanching also disinfected the equipment that came into contact with the fresh blanched spices.The effect of blanching on yeasts and molds were mixed. A reduction to the non-detectable threshold was observed with turmeric and parsley. The reductions were in the order of 1.90 to 2.90 log CFU/g respectively. However, a slight increase in loads of around 0.13 to 0.15 log CFU/g was observed in onion and chili pepper respectively. Heat treatments applied at over 98°C for 2 to 5 minutes, depending on the spice, are sufficient to eliminate the vegetative forms of sporogenic microorganisms. In fact, heating to 70°C at the core eliminates the majority of vegetative forms of microorganisms. The elimination of sporogenic microorganisms by blanching suggests that they are present in vegetative form in fresh spices at the time of heat treatment. Certain spices such as turmeric, garlic, and ginger also have antifungal and antibacterial properties (WADA *et al.*, 2021; Paramasivam *et al.*, 2017, Schraufstatter and Bernt, 1949), blanching with hot water could promote the extraction of active ingredients and contribute to the elimination of germs.

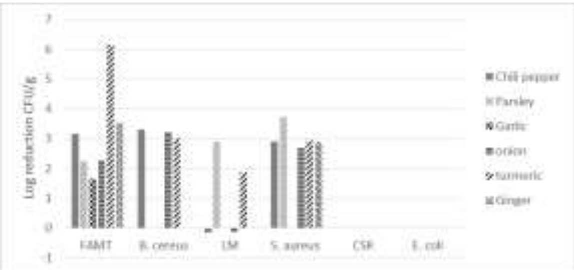

Fig. 1. Reduction in the number of germs in spices through blanching

All samples, whether treated or untreated, were free of *E. coli,* SRC, and salmonella. This could be explained by the fact that the raw materials used to manufacture the spices did not contain *E. coli* or salmonella. As for SRC, which was present in the raw materials but absent in the finished products, the manufacturing process, certainly through washing and trimming operations, eliminated this germ. In fact, unprocessed food products are often protected from the external environment by envelopes (husks, skin, shells, etc.) that act as a natural barrier to the penetration of microorganisms. The number of these microorganisms on the surface can be reduced by applying good hygiene practices during washing and trimming operations.

Roasting and tyndallization have been used to treat soumbala. Soumbala is a fermented condiment from West Africa made from *Parkia biglobosa* seeds. Tyndallization resulted in reductions of approximately 1.30 log CFU/g, 0.06 log CFU/g, 2.65 log CFU/g, 2.89 log CFU/g, and 4.00 log CFU/g for TMAF, YM, *B. cereus*, *S. aureus*, and *E.* coli, respectively (Fig. 2). Fresh soumbala was of unsatisfactory quality for *S. aureus* and *E. coli*. Following tyndallization, *E. coli* was reduced to undetectable levels and *S. aureus* to an acceptable level, allowing soumbala to move from unsatisfactory to acceptable quality.

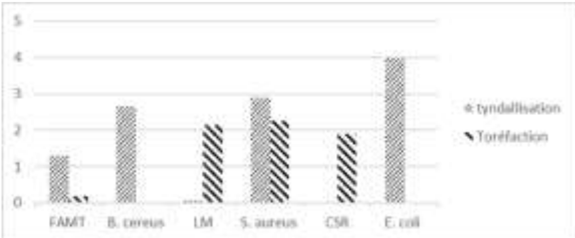

Fig. 2. Reduction in the number of germs in spices through tyndallization and roasting

Roasting resulted in reductions of 0.18 log CFU/g, 2.15 log CFU/g, 2.26 log CFU/g, and 1.89 log CFU/g for TMAF, YM, *S. aureus*, and SRC, respectively (Fig. 2). Commercial powdered soumbala was of unsatisfactory quality for *S. aureus*, but after roasting, *S. aureus* was reduced to an acceptable level, allowing soumbala to go from unsatisfactory to acceptable quality. According to Clem, 1992, dry heat kills microorganisms by combining the oxidation of proteins by oxygen in the air and the removal of water, which is essential for maintaining protein structure.

A comparison of the quality of treated and commercialized spices shows that while 71.43 % of commercial samples were of unacceptable quality, no samples (0%) of unacceptable quality were found in the treated samples. Similarly, while no samples (0%) of satisfactory quality were found among the commercial samples, 62.50 % of the treated spice samples were of satisfactory quality. These results show that treated spices are of better quality than commercial spices. The adoption of these treatments, particularly blanching and roasting, by SMEs/SMIs involved in spice processing could improve the microbiological quality of commercially available spices.

Effect of treatments on the microbiological quality of spice blends

The microbial loads in the untreated and treated spice blends samples are shown in Table 4. The results show almost similar microbial loads between the untreated condiment and the oven-baked condiment, which means that the heat treatment carried out in the oven at 150°C for 15 minutes did not significantly reduce the microbial load. It has been proven that this sterilization technique is only effective at temperatures of 180°C and above on spore-forming bacteria, *B. cereus*, and *C. perfringens* (Benayad and Meziane, 2021). The TMAF, *S. aureus*, and SRC loads of the blanched and roasted spice blends are lower than those of the untreated spice blend, demonstrating the effectiveness of blanching and roasting in reducing the microbial load of the condiment. However, despite the use of blanched spices of satisfactory microbiological quality in its manufacture, the blanched condiment is of acceptable quality.

This is mainly due to the addition of roasted soumbala of acceptable quality to the mixture, which had an *S. aureus* load of 6.0 x 10^2 CFU/g. Soumbala, being a traditionally fermented product, is often produced under conditions of poor hygiene control, which promotes the development and persistence of microorganisms of human or environmental origin. When incorporated into the mixture, this contaminated component therefore altered the bleaching effect applied to the other spices, leading to an increase in the overall load of the spice mixture, particularly for *S. aureus*.

Table 4. Microbiological characteristics of spice mixtures

Sample code	TMAF (CFU/g)	*B. cereus* (CFU/g)	YM (CFU/g)	*S. aureus* (CFU/g)	SRC (CFU/g)	*E. coli* (CFU/g)	*Salmonella* /25g	Quality
MeNT	1,7x 10^7	<10	1.5 x 10^2	2.0 x 10^4	1.4 x 10^3	<10	Absence	NS
MeF	1.1 x 10^7	<10	1.5 x 10^2	8.5 x 10^4	3.0 x 10^2	<10	Absence	NS
MeB	2.2 x 10^6	<10	3.2 x 10^2	3.0 x 10^2	7.3 x 10^1	<10	Absence	A
MeTo	2.1 x 10^6	<10	2.7 x 10^1	5.0 x 10^2	<10	<10	Absence	A
JORA (m)	*	10^3	10^4	10^2	10^3	10^2	Absence	
JORA (M)	*	10^4	10^5	10^3	10^4	10^3	Absence	

MeNT: untreated spice powder mixture ; MeF: spice powder mixture; MeB: bleached spice powder mixture; MeTo: torrefied spice powder mixture; YM: yeasts and molds; CRS: *Clostridium* suffito reducer; CFU: colony-forming unit; * Total flora not evaluated against quality criteria as fermented product; A: acceptable; NS: not satisfactory; m: number of germs present in one gram of product analyzed, which corresponds to the value below which the quality of the product is considered satisfactory; M: number of germs present in one gram of analyzed product, which corresponds to the value above which the quality of the product is considered unsatisfactory; JORA: Official Journal of the Algerian Republic.

Water content of spices

The water content of spices and the limit values set by the standards are shown in Table 5. The water content of all powdered spices ranged from 4.02 to 12.48 %. The water content of commercially available spices ranged from 4.60 to 9.26 %, that of untreated spices from 4.60 to 10.60 %, and that of treated spices from 4.02 to 12.48%. The water content of all commercially available spices complied with the specification standards for each product (ISO 1003, 2025; CXS 359, 2024; CXS 353, 2022; CXS 347, 2019; ISO 20377, 2018; NBF 01-197, 2014; ISO-5559, 1995). This implies that stakeholders have mastered drying technology. In fact, Burkinabe stakeholders began searching for improved fruit and vegetable drying technologies for export in the late 1980s (Thuillier and Traoré, 2012) and have thus acquired extensive experience in drying. With regard to the spices dried in the Attesta dryer for the experiment, the water content of two spices, namely onion and garlic powder, did not comply with specific standards. The water contents obtained were higher than those recommended by the standards. These high contents could be due to insufficient drying or rehydration of the onion and garlic powders through contact with water vapor in the air, as these powders are highly hygroscopic.

Table 5. Water content of spices

Nature of sample		Water content (%)	Limit value (%)	References
Chili pepper	Unblanched powder	7.14 ± 0.55^{fg}	11	CXS 353, 2022
	Blanched powder	6.58 ± 0.14^{de}		
	Commercial powder	4.79 ± 0.03^{b}		
Parsley	Unbleached powder	7.23 ± 0.15^{f}	8	ISO 20377, 2018
	Blanched powder	7.21 ± 0.08^{f}		
	Commercial powder	5.16 ± 0.15^{c}		
Garlic	Unbleached powder	8.35 ± 0.07^{j}	7	CXS 347, 2019
	Blanched powder	12.48 ± 0.09^{n}		
	Commercial powder	6.71 ± 0.02^{e}		
Onion	Unbleached powder	10.60 ± 0.06^{m}	6	ISO-5559, 1995
	Blanched powder	8.25 ± 0.01^{j}		
	Commercial powder	6.76 ± 0.01^{e}		
Turmeric	Unbleached powder	7.85 ± 0.10^{k}	10	CXS 359, 2024
	Bleached powder	9.55 ± 0.08^{l}		
	Commercial powder	9.26 ± 0.05$_{k}$		
Ginger	Unbleached powder	7.89 ± 0.01^{i}	11	ISO 1003, 2025
	Bleached powder	7.64 ± 0.01^{gh}		
	Commercial powder	6.37 ± 0.17^{d}		
Soumbala	Untreated powder	4.60 ± 0.00^{b}	8	NBF 01-197, 2014
	Roasted powder	4.02 ± 0.03^{a}		
	Tyndallized powder	6.42 ± 0.03^{d}		

Results with the same superscript letters in column are not significantly different according to Tukey's HSD test.

CONCLUSION

The work carried out as part of this study initially revealed that the majority of spices sold on the market were of unsatisfactory microbiological quality. These results highlight the need to find suitable treatment methods to improve the microbiological quality of commercially available spices. Secondly, the study demonstrated the effectiveness of treatments in improving the microbiological quality of spices. Bleaching the fresh raw material used to make powdered spices effectively reduced the microbial load, particularly total mesophilic aerobic flora, yeasts and moulds, as well as pathogenic germs such as Staphylococcus aureus, Bacillus cereus, and sulphite-reducing Clostridium, thereby improving the microbiological quality of the bleached spices. Tyndallisation also improved the quality of fresh soumbala. To improve the quality of spices or spice blends in powder form, roasting is the most suitable treatment and also reduces the microbial load of various germs. These simple treatment methods, particularly blanching and roasting, could be used in SMEs to improve the quality of spices produced in Burkina Faso.

RECOMMENDATIONS

We recommend that those involved in the processing of spices and spice blends adopt the treatment techniques used in this study in order to improve the microbiological quality of the spices produced.

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