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RESEARCH ARTICLE

MICROBIOLOGICAL QUALITY AND SAFETY OF INFANT CEREAL FLOURS: A COMPARATIVE STUDY OF PRODUCERS AND DISTRIBUTORS IN TOGO

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ABSTRACT

The microbiological quality of infant cereals is a major public health concern because infants are particularly vulnerable to foodborne infections. This study aimed to assess the microbiological quality of infant cereals produced and marketed in Togo by comparing samples collected from producers and distributors. A total of 20 samples were analyzed, including 10 from each group. Microbiological analyses focused on total mesophilic aerobic flora (TMAF), total coliforms, *Escherichia coli*, yeasts and molds, *Bacillus cereus*, and *Staphylococcus aureus*, while the presence of *Salmonella* spp. and *Cronobacter* spp. was also investigated.Total mesophilic aerobic flora showed the highest non-compliance rates, reaching 30% in producer samples and 40% in distributor samples. For total coliforms and yeasts and molds, non-compliance rates were 20% among producer samples and 30% among distributor samples. Similarly, non-compliance rates for *E. coli* and *B. cereus* were 10% and 20% in producer and distributor samples, respectively. *Salmonella* spp. was detected in one sample from each group, whereas *Cronobacter* spp. was detected in one distributor sample.Overall, distributor samples showed higher descriptive non-compliance rates for several microbiological parameters than producer samples. However, these differences do not establish a causal relationship between distribution practices and microbiological contamination. The findings nevertheless point to potential microbiological safety concerns and highlight the need to strengthen hygiene practices, quality control, and appropriate storage conditions throughout the production and distribution chain. Further studies involving larger and more representative sample sizes are needed to provide a more comprehensive assessment of the microbiological safety of infant cereals in Togo.

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INTRODUCTION

Infant nutrition is a fundamental determinant of growth, cognitive development, and long-term health. According to the World Health Organization (WHO), complementary feeding should be introduced at six months of age, when breast milk alone can no longer meet infants' increasing nutritional requirements, while breastfeeding should continue up to two years of age or beyond (WHO, 2023). This transitional period represents a critical window for ensuring adequate nutrient intake, preventing micronutrient deficiencies, and reducing the risk of growth faltering, particularly in low- and middle-income countries (WHO, 2023; ESPGHAN *et al*., 2024). In this context, infant cereals constitute an important component of complementary feeding, particularly in settings where locally available food resources are widely used. Generally formulated from cereals, legumes, and other locally sourced ingredients, these products provide essential nutrients, including carbohydrates, proteins, dietary fibre, and micronutrients. Combining different ingredients can improve their nutritional composition, enhance protein quality, and increase energy density, thereby contributing to meeting infants' nutritional requirements during this critical stage of development (Dewey & Brown, 2003; Bougma *et al*., 2022). However, their nutritional value alone does not guarantee their suitability for infant consumption. Given the particular susceptibility of infants to foodborne infections, ensuring the microbiological safety of complementary foods is equally important. According to the WHO, contaminated food causes approximately 600 million cases of foodborne diseases and 420,000 deaths worldwide each year, including 125,000 deaths among children under five years of age (WHO, 2015). In this age group, foodborne infections can cause diarrhoea, dehydration, and other serious complications, potentially

aggravating nutritional deficiencies and adversely affecting growth and development (WHO, 2015; WHO, 2023). Although infant cereals generally have a low moisture content, this characteristic does not necessarily guarantee their microbiological safety. Contamination can occur at various stages of the production and distribution chain, including the harvesting, transportation, and storage of raw materials, as well as processing, milling, packaging, handling, and distribution. Inadequately cleaned processing equipment, contaminated water, poor handling practices, and inappropriate storage conditions are among the factors that may contribute to microbiological contamination (WHO & FAO, 2012). Furthermore, certain pathogenic microorganisms can survive for prolonged periods in low-moisture foods, even when reduced water activity limits their multiplication. Thus, unfavourable conditions for microbial growth do not necessarily eliminate foodborne pathogens or ensure the safety of infant cereals (WHO & FAO, 2004). The microbiological assessment of infant cereals generally involves enumerating hygiene indicator microorganisms, such as total mesophilic aerobic flora, total coliforms, *Escherichia coli*, yeasts, and molds, alongside detecting or enumerating specific foodborne pathogens, including *Salmonella* spp., *Staphylococcus aureus*, and *Bacillus cereus*. These parameters provide valuable information about the hygienic quality of food products, help identify potential contamination, and contribute to assessing the microbiological risks associated with their consumption (Stenfors Arnesen *et al*., 2008; ICMSF, 2011; Hennekinne *et al*., 2012). Particular attention should also be given to toxigenic molds belonging to the genera *Aspergillus*, *Penicillium*, and *Fusarium*, which may contaminate cereal-based products and produce mycotoxins such as aflatoxins, ochratoxin A, and fumonisins. Some of these compounds can persist in food products and pose significant health risks, particularly to infants and young children (Bennett & Klich, 2003; Pitt & Hocking, 2009; Wild & Gong, 2010).

In West Africa, several studies have highlighted microbiological deficiencies in locally produced and marketed complementary foods, including infant cereals. In Burkina Faso, Waré *et al*. (2018), in a study involving 199 samples, reported total mesophilic aerobic flora counts reaching 1.8×10^6 CFU/g, together with the detection of various bacterial and fungal contaminants of potential public health concern. Similarly, Bougma *et al*. (2022) reported considerable variability in the microbiological quality of infant cereals marketed in Ouagadougou, emphasizing the need to improve hygiene and quality control measures during production and distribution. In Togo, infant cereals prepared from locally available raw materials play an important role in diversifying complementary feeding and promoting the use of indigenous food resources. Nevertheless, differences in ingredient composition, processing methods, handling practices, and storage conditions may affect their microbiological quality and safety. Despite their nutritional and socioeconomic importance, scientific data on the microbiological status of these products in Togo remain limited. This knowledge gap underscores the need for systematic investigations to characterize their microbiological quality and assess their compliance with relevant microbiological reference criteria. Against this background, the present study aimed to assess the microbiological quality of selected infant cereals produced and marketed in Togo by enumerating hygiene indicator microorganisms and investigating the presence of selected potentially pathogenic microorganisms.

It also sought to evaluate the compliance of these products with applicable microbiological reference criteria and compare the results obtained from samples collected directly from producers with those purchased from distributors. The findings are expected to provide baseline data to support improvements in hygiene practices, microbiological quality control, and food safety throughout the production and distribution chain of infant cereals intended for infants and young children.

MATERIALS AND METHODS

Materials: The biological materials used in this study consisted of infant cereal samples produced from locally available raw materials and intended for the complementary feeding of infants and young children. A total of twenty (20) samples were analyzed, comprising ten (10) samples collected directly from producers and ten (10) samples obtained from distributors in Togo. These samples constituted the biological materials used to assess the microbiological quality of the products and compare their microbiological characteristics according to their source of collection. The laboratory materials included microbiological culture media, analytical reagents, sterile sampling containers, glassware, and laboratory equipment required for the enumeration of microbial populations and the detection of selected potentially pathogenic microorganisms. All materials and equipment were appropriate for the microbiological analyses performed.

Sampling and Collection of Infant Cereals: Infant cereal samples were collected from local production facilities and retail outlets in Togo. The sampling strategy involved two categories of collection sites: production facilities, from which ten (10) samples were obtained directly from producers, and distribution outlets, from which ten (10) samples were purchased from distributors. The products were selected based on their origin, formulation, ingredient composition, and packaging characteristics. Each sample was collected in its original packaging or, where applicable, transferred into an appropriate sterile container under aseptic conditions. Samples were individually labelled with a specific identification code to ensure traceability throughout the analytical process. Following collection, they were transported to the laboratory under appropriate conditions to minimize any alteration of their initial microbiological characteristics. Microbiological analyses were performed as soon as possible after receipt at the laboratory.

Preparation of Samples and Decimal Dilutions: Sample preparation was carried out under aseptic conditions to minimize the risk of external contamination. For each sample, 25 g of infant cereal flour was aseptically weighed and transferred into a sterile homogenization bag containing 225 mL of sterile buffered peptone water. The mixture was homogenized using a Stomacher-type homogenizer for approximately 1–2 minutes to obtain the initial suspension, corresponding to a 10^{-1} dilution. Subsequently, serial decimal dilutions were prepared by aseptically transferring 1 mL of the initial suspension into 9 mL of sterile diluent, followed by thorough mixing. This procedure was repeated as necessary to obtain the appropriate dilution levels for the enumeration of the target microorganisms. All microbiological analyses were performed at least in duplicate, with appropriate sterility controls to verify the absence of contamination from the culture media and laboratory materials.

Microbial Enumeration

Enumeration of Total Mesophilic Aerobic Flora : The enumeration of total mesophilic aerobic flora (TMAF) was performed using the pour plate technique in accordance with ISO 4833-1. Briefly, 1 mL of each selected decimal dilution was aseptically transferred into sterile Petri dishes. Subsequently, approximately 15–20 mL of molten Plate Count Agar (PCA), previously cooled to approximately 44–47 °C, was poured into each dish. The inoculum and culture medium were gently mixed and allowed to solidify at room temperature. The inoculated plates were then incubated under aerobic conditions at 30 °C for 72 hours. Following incubation, colonies were counted on plates containing a countable number of colonies, and the results were expressed as colony-forming units per gram of sample (CFU/g).

Enumeration of Total Coliforms: The enumeration of total coliforms was performed in accordance with ISO 4832 using Violet Red Bile Lactose (VRBL) agar. Briefly, 1 mL of each appropriate decimal dilution was aseptically transferred into sterile Petri dishes, followed by the addition of molten VRBL agar. The inoculum was gently mixed with the culture medium and allowed to solidify. Where required by the analytical protocol, a second layer of VRBL agar was added to the solidified medium. The plates were subsequently incubated at 30 °C for 24 hours. After incubation, typical coliform colonies, characterized by their red to purplish coloration and, in some cases, a surrounding zone of bile salt precipitation, were counted. The results were expressed as colony-forming units per gram of sample (CFU/g).

Enumeration of *Escherichia coli:* The enumeration of *Escherichia coli* was carried out in accordance with ISO 16649-2 using Tryptone Bile X-glucuronide (TBX) agar. Briefly, 1 mL of each appropriate decimal dilution was inoculated into sterile Petri dishes, followed by the addition of molten TBX agar using the pour plate technique. After solidification, the plates were incubated at 44 °C for 18–24 hours. Following incubation, characteristic blue-green colonies, corresponding to β-glucuronidase-positive presumptive *E. coli*, were counted. The bacterial concentrations were expressed as colony-forming units per gram of sample (CFU/g).

Enumeration of Yeasts and Molds : The enumeration of yeasts and molds was performed in accordance with ISO 21527-1 or ISO 21527-2, depending on the water activity (aw) of the samples analyzed. Appropriate decimal dilutions were surface-inoculated onto Dichloran Rose Bengal Chloramphenicol (DRBC) agar or Dichloran 18% Glycerol (DG18) agar, as appropriate. The inoculated plates were incubated at 25 °C for 5–7 days. Following incubation, yeast and mold colonies were enumerated separately based on their macroscopic morphological characteristics. The results were expressed as colony-forming units per gram of sample (CFU/g).

Enumeration of Presumptive *Bacillus cereus :* The enumeration of presumptive *Bacillus cereus* was performed in accordance with ISO 7932 using Mannitol Egg Yolk Polymyxin (MYP) agar. Briefly, appropriate decimal dilutions were surface-inoculated onto the culture medium. The inoculated plates were incubated at 30 °C for 24 hours. After incubation, colonies displaying characteristics consistent with presumptive *B. cereus*, typically pink to red colonies surrounded by an opaque precipitation zone resulting from lecithinase activity, were counted. Presumptive colonies were subsequently subjected to appropriate biochemical confirmation tests. The results were expressed as colony-forming units per gram of sample (CFU/g).

Enumeration of Coagulase-Positive Staphylococci: The enumeration of coagulase-positive staphylococci was carried out according to ISO 6888-1 using Baird-Parker agar supplemented with egg yolk tellurite emulsion. Briefly, appropriate decimal dilutions of each sample were aseptically surface-inoculated onto the prepared culture medium. The inoculated plates were then incubated at 37 °C for 24–48 hours.After incubation, presumptive coagulase-positive staphylococcal colonies, typically characterized by a black or grey coloration, a shiny appearance, and surrounding clear or opaque zones, were enumerated. Representative presumptive colonies were subsequently subjected to confirmatory tests, including the coagulase test, to verify their identity. The results were expressed as colony-forming units per gram of sample (CFU/g).

Detection of Selected Foodborne Pathogens

Detection of *Salmonella* spp: The detection of *Salmonella* spp. was performed in accordance with ISO 6579-1. Briefly, 25 g of infant cereal flour were aseptically weighed and transferred into 225 mL of sterile buffered peptone water (BPW), followed by homogenization. The resulting suspension was incubated at 37 °C for 18 hours to allow non-selective pre-enrichment and recovery of potentially injured bacterial cells.
Following pre-enrichment, aliquots of the culture were transferred into two selective enrichment broths: Rappaport-Vassiliadis broth with soya (RVS) and Müller-Kauffmann tetrathionate-novobiocin broth (MKTTn). The RVS broth was incubated at 41.5 °C, while the MKTTn broth was incubated at 37 °C, under the conditions specified by the standard.After selective enrichment, the cultures were streaked onto selective agar media, including Xylose Lysine Deoxycholate (XLD) agar. Following incubation, presumptive *Salmonella* colonies were examined and subjected to appropriate biochemical and serological confirmation tests.The results were expressed as the presence or absence of *Salmonella* spp. in 25 g of infant cereal flour.

Detection of *Cronobacter* spp : The detection of *Cronobacter* spp. was performed in accordance with ISO 22964:2017. Briefly, 10 g of infant cereal flour were aseptically weighed and transferred into 90 mL of sterile buffered peptone water (BPW) to obtain the primary suspension. The mixture was homogenized and incubated at 34–38 °C for 18 ± 2 h for non-selective pre-enrichment. Following incubation, 0.1 mL of the pre-enrichment culture was transferred into 10 mL of *Cronobacter* Selective Broth (CSB) and incubated at 41.5 ± 1 °C for 24 ± 2 h.After selective enrichment, a loopful (10 µL) of the culture was streaked onto Chromogenic *Cronobacter* Isolation (CCI) agar and incubated at 41.5 ± 1 °C for 24 ± 2 h. Presumptive *Cronobacter* colonies, typically appearing blue to blue-green on CCI agar, were selected and subjected to confirmatory biochemical tests in accordance with the standard. The results were expressed as the presence or absence of *Cronobacter* spp. in 10 g of infant cereal flour.

Reporting and Interpretation of Results: The results of the microbiological counts were reported in colony-forming units per gram of flour (CFU/g) and then converted to a decimal logarithm (log_{10} CFU/g) to facilitate statistical analysis. For each microorganism tested, the results were compared to the microbiological reference criteria established for the study. Tests for Salmonella spp. and *Cronobacter* spp. were interpreted, respectively, in terms of presence or absence in the 25-g and 10-g test samples.The overall microbiological quality of the flours was assessed by taking into account all the parameters analyzed, their origin, and their compliance with the previously defined interpretation criteria.

RESULTS

Proportions of Acceptable and Non-compliant Infant Cereal Samples : A total of 20 infant cereal samples representing 10 brands were analyzed, including 10 samples collected from producers and 10 from distributors (Table 2).
The proportions of non-compliant samples varied according to the microorganisms tested and the source of the samples. Among producer samples, the highest non-compliance rate was observed for the total mesophilic aerobic florat (TMAF), at 30%, followed by total coliforms and yeasts and moulds (20% each). Similarly, among distributor samples, TMAF showed the highest non-compliance rate (40%), followed by total coliforms and yeasts and moulds (30% each). For Escherichia coli and Bacillus cereus, non-compliance rates were 10% each among producer samples, compared with 20% each among distributor samples. *Staphylococcus aureus* and *Salmonella* spp. each showed a non-compliance rate of 10% in both groups. Finally, no producer samples were non-compliant for Cronobacter spp., whereas one distributor sample (10%) exceeded the specified criterion.

Comparison of Non-compliance Rates Between Producers and Distributors : The comparison presented in Table 3 reveals that the proportions of non-compliant samples were 10 percentage points higher among distributors than among producers for total mesophilic aerobic flora (TMAF), total coliforms, *Escherichia coli*, yeasts and moulds, and *Bacillus cereus*. In contrast, identical non-compliance rates were observed for *Staphylococcus aureus* and *Salmonella* spp. No non-compliant samples for *Cronobacter* spp. were identified among producers, compared with one sample (10%) among distributors. Overall, samples collected from distributors showed slightly higher non-compliance rates for most of the microorganisms investigated. However, given the limited sample size (10 samples per group), these differences should be interpreted descriptively and do not establish a statistically significant difference in microbiological quality between the two groups.

DISCUSSION

Microbiological Quality of Infant Cereals: The predominance of non-compliant samples for the total mesophilic aerobic count (TMAC), particularly among distributor samples (40%), may reflect inadequate control of hygiene practices during processing, packaging, transportation, or storage. TMAF is commonly used as an indicator of the overall microbiological status of food products and the hygienic conditions prevailing during their handling. Similar findings were reported by Waré *et al*. (2018) in Burkina Faso, where aerobic mesophilic counts reached 1.8×10^6 CFU/g in infant cereal samples, although only approximately 2% exceeded the microbiological threshold adopted in their study.
The detection of total coliforms and *Escherichia coli* in some samples also raises concerns about hygiene practices and possible contamination during processing, handling, or distribution. Coliforms are commonly used as indicators of process hygiene, while the presence of *E. coli* may suggest faecal contamination, depending on the strain and the context of detection. In a study involving 102 samples of locally produced infant flours marketed in Ouagadougou, Bougma *et al*. (2022) reported total coliform counts reaching 2.8×10^3 CFU/g, although no confirmed *E. coli* colonies were detected. These findings highlight the importance of strengthening hygiene controls throughout the production and distribution chain of infant cereals.The non-compliance rates observed for yeasts and moulds (20% among producer samples and 30% among distributor samples) also deserve particular attention. Their occurrence may be associated with inadequate drying, residual moisture, or improper storage conditions. Beyond their potential to compromise the microbiological and organoleptic quality of infant flours, certain mould species may produce mycotoxins that pose health risks to consumers. In this regard, Waré *et al*. (2018) identified fungal species belonging to the genera *Aspergillus*, *Penicillium*, and *Fusarium* in infant flours produced in Burkina Faso, including species associated with the production of aflatoxins, ochratoxin A, and fumonisins.

The detection of *Bacillus cereus* in 10% of producer samples and 20% of distributor samples is another important finding. This ubiquitous environmental bacterium can contaminate cereal-based raw materials through soil, dust, and handling. Its ability to form heat-resistant spores enables it to survive certain processing treatments and potentially persist in finished products. Under favourable conditions, some strains may produce toxins responsible for foodborne illness. Similarly, Bayala-Yaï *et al*. (2024) reported microbiological non-compliance in infant flours produced in Ouagadougou, highlighting the importance of controlling microbial hazards throughout the production process. Furthermore, the presence of Staphylococcus aureus in one sample from each group could be associated with contamination during handling, particularly by staff.

The detection of Salmonella spp. in both groups is particularly concerning, given the pathogenic nature of this bacterium and the vulnerability of young consumers. Finally, the detection of *Cronobacter* spp. in a sample from retailers warrants special attention. Waré *et al*. (2018) also reported the presence of *Cronobacter* spp. among the enterobacteria isolated from infant formula in Burkina Faso. The slightly higher rates of non-compliance observed among distributors could be related to the conditions under which products are transported, stored, and handled. However, the available data do not allow for a direct determination of the source of contamination or a conclusion that distribution necessarily constitutes a higher-risk stage. This hypothesis should be verified through a study of hygiene practices and storage conditions.Overall, these results underscore the importance of microbiological monitoring throughout the entire production and distribution chain for infant cereal.These findings reinforce the recommendations of the Codex Alimentarius regarding the implementation of good hygiene practices and preventive measures to control microbiological hazards in foods intended for infants and young children (FAO/WHO, 2023).

Table 1. Summary of the Microorganisms Investigated and Their Indicative Microbiological Criteria for Interpretation

Microorganisms Tested	Result Unit	Criterion (Codex Alimentarius, Standard CXS 74-1981)*	Public Health Significance
Total Mesophilic Aerobic flora (TMAF)	UFC/g	≤ 10^5 UFC/g	General indicator of microbiological quality.
Total Coliforms (TC)	UFC/g	≤ 10^2 UFC/g	Process hygiene indicator.
Escherichia coli (E. coli)	UFC/g	< 10 UFC/g	Indicator of faecal contamination.
Yeasts and Moulds (Y&M)	UFC/g	≤ 10^3 UFC/g	Indicator of spoilage and storage conditions.
Bacillus cereus	UFC/g	≤ 10^3 UFC/g	Risk associated with spores and potential toxin production.
Staphylococcus aureus	UFC/g	≤ 10^2 UFC/g	Indicator of contamination, particularly associated with handling.
Salmonella spp.	*Presence in 25 g*	*Absence in 25 g*	Pathogen requiring specific testing.
Cronobacter spp.	*Presence in 10 g*	*Absence in 10 g*	Pathogen of particular concern in certain powdered infant formula products.

Codex Alimentarius, Standard CXS 74-1981: Standard for Processed Cereal-Based Foods for Infants and Young Children.

Table 2. Proportions of Compliant and Non-compliant Samples According to the Microorganisms Tested

Microorganism Tested	Indicative Criterion	Producers: Non-compliant n (%)	Producers: Compliant n (%)	Distributors: Non-compliant n (%)	Distributors: Compliant n (%)
Total Mesophilic Aerobic Count (TMAC)	≤ 10^5 UFC/g	3 (30 %)	7 (70 %)	4 (40 %)	6 (60 %)
Total Coliforms (TC)	≤ 10^2 UFC/g	2 (20 %)	8 (80 %)	3 (30 %)	7 (70 %)
Escherichia coli (E. coli)	< 10 UFC/g	1 (10 %)	9 (90 %)	2 (20 %)	8 (80 %)
Yeasts and Moulds (Y&M)	≤ 10^3 UFC/g	2 (20 %)	8 (80 %)	3 (30 %)	7 (70 %)
Bacillus cereus	≤ 10^3 UFC/g	1 (10 %)	9 (90 %)	2 (20 %)	8 (80 %)
Staphylococcus aureus	≤ 10^2 UFC/g	1 (10 %)	9 (90 %)	1 (10 %)	9 (90 %)
Salmonella spp.	Absence dans 25 g	1 (10 %)	9 (90 %)	1 (10 %)	9 (90 %)
Cronobacter spp.	Absence dans 10 g	0 (0 %)	10 (100 %)	1 (10 %)	9 (90 %)

Table 3. Comparison of Non-compliance Rates Between Producers and Distributors

Microorganisms Tested	Producers: Non-compliant n (%)	Distributors: Non-compliant n (%)	Descriptive Difference (Percentage Points)
Total Mesophilic Aerobic Count (TMAC)	3 (30 %)	4 (40 %)	+10
Total Coliforms	2 (20 %)	3 (30 %)	+10
Escherichia coli	1 (10 %)	2 (20 %)	+10
Yeasts and Moulds	2 (20 %)	3 (30 %)	+10
Bacillus cereus	1 (10 %)	2 (20 %)	+10
Staphylococcus aureus	1 (10 %)	1 (10 %)	0
Salmonella spp.	1 (10 %)	1 (10 %)	0
Cronobacter spp.	0 (0 %)	1 (10 %)	+10

Potential Contamination Factors and Health Risks Associated with Pathogenic Microorganisms: The detection of total coliforms, *Escherichia coli*, and *Bacillus cereus* in some samples may reflect inadequate hygiene practices during processing and handling, or contamination of raw materials. Similar observations were reported by Bougma *et al*. (2022) and Bayala-Yaï *et al*. (2024) in studies of locally produced infant flours in Burkina Faso. Furthermore, the occurrence of yeasts and moulds in 20–30% of the samples may be associated with insufficient drying, excessive residual moisture, or inappropriate storage conditions. Beyond their potential effects on product quality and shelf life, certain mould species may produce mycotoxins, which represent a potential health hazard, particularly for infants and young children (Waré *et al*., 2018). The presence of these microorganisms therefore highlights the need to strengthen hygiene controls at every stage of the production and distribution chain, particularly through appropriate raw-material selection, effective drying, hygienic packaging, and adequate storage conditions.The detection of *Salmonella* spp. in both groups (10%) and *Cronobacter* spp. among distributors (10%) is of particular public health concern, considering the increased susceptibility of infants to foodborne infections. Similar findings were reported by Waré *et al*. (2018), who detected *Cronobacter* spp. in infant cereals in Burkina Faso.

The Codex Alimentarius Commission recommends the absence of these two pathogens in specified sample quantities (25 g for *Salmonella* spp. and 10 g for *Cronobacter* spp.) in powdered infant formula products covered by its microbiological criteria (FAO/WHO, 2008). Nevertheless, these requirements should not be directly extrapolated to cereal-based complementary foods without considering their specific regulatory scope and applicable microbiological standards. The findings therefore highlight the need to strengthen good hygiene practices, implement effective microbiological monitoring, and ensure appropriate preventive controls throughout the production, handling, storage, and distribution chains of infant cereals (WHO/FAO, 2007).

Comparison Between Producers and Distributors and Implications for Food Safety Control: The proportion of non-compliant samples was consistently 10 percentage points higher among distributors than among producers for total aerobic mesophilic flora (TAMF), total coliforms, *Escherichia coli*, yeasts and molds, and *Bacillus cereus*. This pattern may reflect differences in storage, transportation, handling, and packaging conditions along the distribution chain. Indeed, the Codex Alimentarius emphasizes the importance of implementing effective measures to control microbiological hazards at every stage of the food chain, from production to final consumption (FAO/WHO, 2023). In particular,

inadequate storage conditions, exposure to moisture, and compromised packaging may facilitate microbial contamination or deterioration, thereby affecting the microbiological quality and safety of dry food products (WHO/FAO, 2007). Nevertheless, these differences should be interpreted with caution, as they are descriptive and do not establish a causal relationship between distribution practices and the observed microbiological contamination. This limitation is particularly relevant because the samples collected from producers and distributors may originate from different production batches.

A longitudinal approach involving paired samples collected from the same batches at the production site and at different stages of distribution would provide more reliable evidence of potential changes in microbiological quality along the supply chain. Furthermore, the relatively small sample size (10 samples per group) limits the statistical power of the comparison and the extent to which these findings can be generalized to the wider market of infant cereal products in Togo. Larger-scale studies involving more producers, distributors, and geographical locations are therefore needed to confirm these observations and better identify critical points requiring strengthened food safety control.

CONCLUSION

This study, based on the microbiological analysis of 20 samples representing 10 brands of infant cereal products, including 10 samples collected from producers and 10 from distributors, revealed varying levels of microbiological non-compliance. Total aerobic mesophilic flora (TAMF) showed the highest non-compliance rates, reaching 30% among producer samples and 40% among distributor samples. Non-compliance was also observed for total coliforms, yeasts and molds, *Escherichia coli*, and *Bacillus cereus*. Furthermore, the detection of *Salmonella* spp. in both groups and *Cronobacter* spp. in one sample from distributors raises public health concerns, given the particular vulnerability of infants and young children to foodborne infections. Although distributor samples generally exhibited higher non-compliance rates for several microbiological parameters, the limited sample size and absence of paired samples from identical production batches prevent any causal attribution to distribution practices.

These findings nevertheless highlight the need to strengthen good hygiene and manufacturing practices, improve the hygienic quality of raw materials, ensure appropriate handling, packaging, storage, and transportation conditions, and reinforce microbiological surveillance throughout the production and distribution chain. Further studies involving larger and more representative samples, covering more brands and geographical regions and incorporating paired sampling strategies, are needed to provide a more comprehensive assessment of the microbiological safety of infant cereals in Togo. Such investigations would also help identify critical points along the production and distribution chain and guide the implementation of targeted preventive and corrective measures to protect the health of infants and young children.

CONFLICT OF INTEREST : The authors declare that they have no conflicts of interest regarding the publication of this article.

AUTHOR CONTRIBUTIONS

KILIMOU Pyalo Magnoudewa: Conceptualization, methodology, investigation, data collection and analysis, and manuscript drafting.HANI Achehona, DANDONOUGBO Koffi, KADANGA Mawabena, and DOMANCHIN Napo: Investigation, data collection and processing, and contribution to manuscript writing and review.AMEYRAN Koami and SOUHO Tiatou: Methodological contributions, scientific supervision, and critical revision of the manuscript.MELILA Mamatchi: Conceptualization, methodology, interpretation of results, and critical revision of the manuscript.AMOUZOU Kou'santa: Overall supervision, scientific guidance, and critical revision of the manuscript.All authors read and approved the final version of the MANUSCRIPT.

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