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Research Article

Evaluation of the Microbiological Quality and Impurity Level of Table Salt in Three Prefectures of Northern Togo

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Abstract

Table salt represents a major public health vehicle for iodine delivery, playing a crucial role in preventing iodine deficiency disorders (IDDs) and promoting optimal nutritional status. However, its sanitary, physical, and nutritional quality can deteriorate along the supply chain, thereby compromising the effectiveness of iodine fortification programs. This study assessed the microbiological quality and impurity levels of table salt in three prefectures of Northern Togo (Binah, Doufelgou, and Kozah) using 631 samples collected from wholesalers, retailers, and households. Results revealed contamination by total aerobic mesophilic flora ($\geq 10^3$ CFU/g) in most samples, except for a few from wholesalers. Coagulase-positive staphylococci were detected among retailers (6.7 – 13.3%) and households (13.3 – 23.3%), indicating a potential risk of foodborne intoxications. Although impurity contents remained within Codex Alimentarius standards (< 0.3%), a significant increase was observed along the supply chain, for instance, in Binah, from $0.033\times10^{-3} \pm 0.05\times10^{-3}$ at wholesale to $0.251\times10^{-3} \pm 0.17\times10^{-3}$ and $0.291\times10^{-3} \pm 0.17\times10^{-3}$ at retail and household levels, respectively ($p < 0.001$). These results demonstrate a progressive deterioration of salt quality linked to reconditioning, inadequate packaging, transport, and storage conditions. Environmental exposure and human handling appear as major contributing factors, underscoring the urgent need to improve hygiene and conservation practices to ensure the microbiological safety and nutritional effectiveness of iodized salt in Togo.

Keywords

Table Salt, Impurities, Microbiological Contamination, Iodization, distribution chain, Northern Togo

1. Introduction

Cooking salt, one of the most widely consumed foods in the world and a basic culinary ingredient, serves as a primary carrier of iodine for the human body and a key instrument in public health programs aimed at preventing iodine deficiency disorders (IDDs). However, its sanitary, physical, and nutritional quality can be altered along the supply chain, thereby compromising the effectiveness of iodine fortification and, consequently, the prevention of iodine deficiency–related conditions such as goiter and neurocognitive impairments [1]. Iodine is indeed an essential micronutrient required for the synthesis of thyroid hormones, which regulate general metabolism, growth, and brain development, particularly in children and pregnant women [2]. Universal salt iodization, recommended since 1993 by the World Health Organization

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(WHO) and UNICEF, has significantly reduced the prevalence of iodine deficiency disorders in many countries [3, 4].

Nevertheless, beyond its nutritional role, the sanitary quality of cooking salt remains a major concern. Studies conducted in sub-Saharan Africa have shown that salt sold in local markets may contain physical impurities (sand, plant particles, various debris) and may present microbiological contamination due to inappropriate handling and packaging practices [5, 6]. These impurities not only compromise consumer safety but may also affect the stability of added iodine, thereby reducing the effectiveness of iodine deficiency control programs [7].

In Togo, as in many West African countries, salt passes through a complex supply chain, from wholesalers to households, with frequent reconditioning and often precarious storage conditions [8]. Each step of this chain represents a potential source of impurities and contamination, increasing the variability of the quality of the final product consumed. Yet, despite the importance of salt as a vehicle for iodization, few local studies have focused on characterizing its microbiological and physical quality in relation to the supply chain.

The present study aims to fill this gap by assessing the level of impurities and the microbiological quality of cooking salt in three prefectures of Northern Togo, comparing samples at the level of wholesalers, retailers, and households. It provides data that help better understand the impact of storage and distribution practices on salt quality, and consequently on the effectiveness of iodine nutrition programs and food safety for populations.

2. Material and Methods

2.1. Sampling

This is a cross-sectional and descriptive study carried out among households in the Kara region (Northern Togo), specifically in the prefectures of Binah, Doufelgou, and Kara (Figure 1). For sample collection, a simple random sampling method was chosen, replacing the classical probabilistic cluster sampling technique with a survey step. The advantage of this approach lies in its simplicity and feasibility in the field: it allows for the rapid identification of households to be included in the study while reducing the organizational requirements associated with cluster sampling. Although less robust from a statistical perspective, this method ensured a certain representativeness of households and salt selling points and made it possible to collect salt samples within the optimal timeframe.

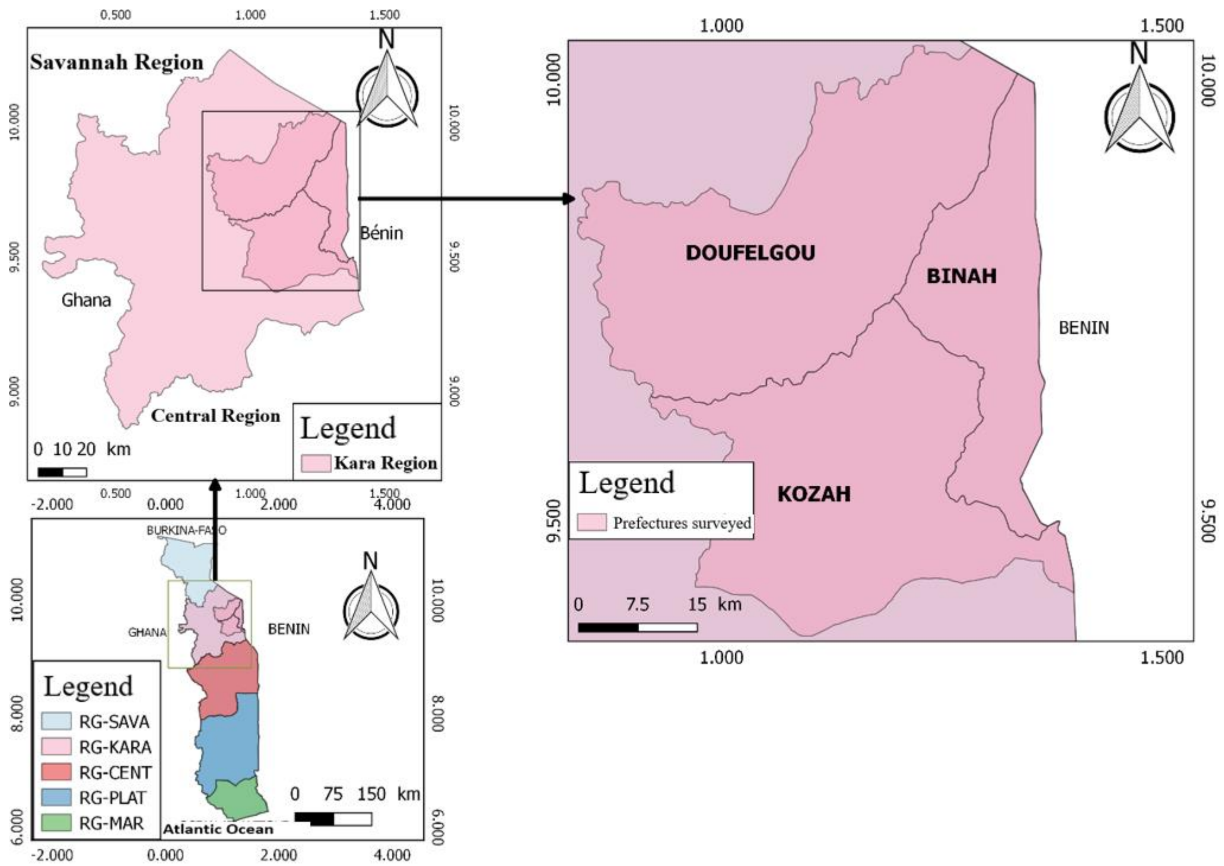

Figure 1. Map Indicating the Study Area.

The collection of edible salt samples (20–25 g) was carried out at three levels: within households, at retail outlets, and from wholesalers in the main markets of the surveyed prefectures. The sample size was determined based on the non-availability rate of iodized salt in households in the Kara Region, using Danely's formula. According to the MICS-6 survey conducted in 2017, the availability of iodized salt in households in this region was estimated at 65.4%.

$$n = \frac{t^2 \times p(1-p)}{e^2}$$

Where:
n: Sample size
t: 1.96 for a 95% confidence level
p: Proportion of households using iodized salt (65.4%)
e: Margin of error (5%)

The calculated sample size (N) was 348 samples. However, in order to ensure better representativeness, a total of 631 samples were collected between July and November 2019, distributed as follows: 32 samples from wholesalers, 169 samples from mobile retailers, and 430 samples from households. The samples were collected in white polyethylene bags, labeled for identification.

After packaging, the samples were carefully placed in an insulated cooler and transferred to the laboratory of the Department of Biochemistry at the University of Lome. They were stored under air conditioning at a controlled temperature of 20°C until analysis.

2.2. Material

Salt samples were collected at each level in transparent polyethylene bags. For the detection of total germs and staphylococci, microbiological analyses were carried out using sterile Petri dishes containing *Plate Count Agar* (PCA).

The assessment of the impurity level was conducted in accordance with the AFNOR standard, using filter papers, an oven, and a precision balance accurate to 10^{-5}. A camera was used to take photographs along the distribution chain in order to illustrate practices that could explain the quality of table salt observed in the three surveyed prefectures.

2.3. Methods

2.3.1. Technique for Determining the Impurity Content in the Collected Salt Samples

(i). Preparation of Material

The filter papers are first dried in an oven at 85°C for 72 hours to remove any trace of moisture. Each dried filter paper is then labeled with the number assigned to the corresponding salt sample.

(ii). Experimental Procedure

A 10 g sample of salt is placed into an Erlenmeyer flask and dissolved in 10 mL of distilled water under magnetic stirring until complete dissolution. The identified filter paper is first weighed using an analytical balance with a precision of 10^{-5} g (initial mass noted as m_1), then used to filter the obtained solution. After filtration, the filter paper is placed back in an oven at 85°C for an additional 72 hours to ensure complete drying, and then weighed again with the same precision (final mass noted as m_2).

(iii). Determination of Impurities Rate

The impurity rate (Ti) is determined from the difference in mass according to the following formula: $Ti = m_2 - m_1$.
where:

1) m_1 = initial mass of the dry filter paper (g),
2) m_2 = final mass of the filter paper after filtration and drying (g).

The value obtained corresponds to the mass of insoluble impurities present in the analyzed salt sample.

2.3.2. Microbiological Analysis of Salt Samples

The microbiological analysis covered all 32 samples collected from wholesalers. However, for the retailer and household levels in the three surveyed prefectures, only 30 samples were randomly selected per level and subjected to microbiological testing.

The analyses were carried out at the Laboratory of Microbiology and Food Quality Control (LAMICODA) of the University of Lome. Bacterial enumeration was performed using the dilution method described by Speck (1984). The total aerobic mesophilic flora (TAMF), determined according to the NF EN ISO 4833 standard, was used to assess the number of colony-forming units (CFU), i.e., the number of microorganisms present in the salt sample capable of multiplying in the presence of oxygen at temperatures between 25 and 40°C. For each sample, successive dilutions of 10^{-2} and 10^{-3} were prepared. One milliliter of each dilution was incorporated into approximately 15 mL of Plate Count Agar (PCA) poured into two sterile Petri dishes, and the mixture was homogenized. After solidification, a second layer of 5 mL of PCA was added. The plates thus prepared were incubated at 30°C for 72 ± 2 hours. Additionally, the enumeration of coagulase-positive staphylococci was performed on an appropriate selective medium. Bacterial contamination levels were considered acceptable when they ranged from 10^2 to 10^3 CFU/g.

Following the assessment of the microbiological quality and impurity content of the salt, a complementary survey was conducted to identify practices likely to influence these parameters. Photographic documentation was carried out at various stages along the distribution chain, from wholesalers to retailers, to illustrate the conditions and handling practices that may account for the quality of table salt observed in the three prefectures studied.

2.4. Statistical Analysis of Data

The obtained data were analyzed using GraphPad Prism software version 8.1.0. Differences were considered significant at a p-value < 0.05.

3. Results

3.1. Microbiological Characteristics of Salt Samples According to the Sampling Level in the Three Surveyed Prefectures

The results revealed that all salt samples were contaminated by total mesophilic flora, except for those obtained from wholesalers, where only two cases of contamination were recorded in the Binah prefecture (Table 1). The number of colony-forming units per gram (CFU/g) varied according to the origin of the salt but exceeded 10^3 CFU/g in almost all samples analyzed. Moreover, the detection of staphylococci, which are halophilic microorganisms, was positive in samples from retailers and households, with contamination rates ranging from 76.67% to 93.33% (Table 1).

Table 1. *Microbiological Quality of Salt Samples According to the Sampling Level.*

Localities	Level of contamination	Sampling level (Wholesalers/Retailers/Households)		
		Wholesalers n = 09	Retailers/ mobile vendors n = 30	Households n = 30
	Total aerobic mesophilic count at 30°C			
	Presence n (%)	07 (77.78)	30 (100.00)	30 (100.00)
Binah	Absence n (%)	02 (22.22)	0 (0.00)	0 (0.00)
	Staphylococci			
	Presence n (%)	0 (0.00)	04 (13.33)	06 (20.00)
	Absence n (%)	09 (100.00)	26 (86.67)	24 (80.00)
		Wholesalers n = 07	Retailers/ mobile vendors n = 30	Households n = 30
	Total aerobic mesophilic count at 30°C			
	Presence n (%)	07 (100.00)	30 (100.00)	30 (100.00)
Doufelgou	Absence n (%)	0 (0.00)	0 (0.00)	0 (00.00)
	Staphylococci			
	Presence n (%)	0 (0.00)	02 (06.67)	04 (13.33)
	Absence n (%)	07 (100.00)	28 (93.33)	26 (86.67)
		Wholesalers n = 16	Retailers/ mobile vendors n = 30	Households n = 30
	Total aerobic mesophilic count at 30°C			
	Presence n (%)	16 (100.00)	30 (100.00)	30 (100.00)
Kozah	Absence n (%)	0 (0.00)	0 (0.00)	0 (0.00)
	Staphylococci			
	Presence n (%)	0 (0.00)	02 (06.67)	07 (23.33)
	Absence n (%)	16 (100.00)	28 (93.33)	23 (76.67)

3.2. Impurity Rate According to the Sampling Level in the Surveyed Prefectures

Although the impurity levels observed comply with both national standards and those of the Codex Alimentarius (< 0.3%), the present study revealed a significant variation in impurity levels along the table salt supply chain. These levels were found to be considerably lower among wholesalers than among retailers and households. This difference can be attributed to storage and preservation conditions (exposure to open air, the quality and tightness of packaging, and reconditioning practices) which tend to deteriorate progressively along the distribution chain.

In the Binah prefecture, for instance, the mean impurity levels were $0.033\times10^{-3} \pm 0.05\times10^{-3}$ among wholesalers, compared to $0.251\times10^{-3} \pm 0.17\times10^{-3}$ and $0.291\times10^{-3} \pm 0.17\times10^{-3}$ among retailers and households, respectively. The difference observed was highly significant ($p < 0.001$). Comparable results were obtained in the two other localities studied, confirming the same trend with a p-value < 0.001.

These higher impurity levels downstream in the chain represent a non-negligible risk factor, as they may promote microbiological contamination, as demonstrated by the analyses carried out in this study (Table 2).

Table 2. *Impurity Levels in the Salt Samples Analyzed According to the Different Grades.*

Localities	Impurity rate	Sampling level (Wholesalers/Retailers/Households)			*p* value
		Wholesalers n = 09	Retailers/ mobile vendors n = 47	Households n = 135	
	Minimum (%)	0.00	0.00	0.00	
Binah	Median (%)	0.00	$0.2.10^{-3}$	$0.3.10^{-3}$	$P < 0.001$
	Maximum (%)	$0.1.10^{-3}$	$0.6.10^{-3}$	1.10^{-3}	
	Mean ± SD (%)	$0.033.10^{-3} \pm 0.05.10^{-3}$	$0.251.10^{-3} \pm 0.17.10^{-3}$	$0.291.10^{-3} \pm 0.17.10^{-3}$	
		Wholesalers n = 07	Retailers/ mobile vendors n = 39	Households n = 143	
	Minimum	0.00	0.00	0.00	
Doufelgou	Median	0.00	$0.3.10^{-3}$	$0.3.10^{-3}$	$P < 0.001$
	Maximum	$0.2.10^{-3}$	$0.8.10^{-3}$	1.10^{-3}	
	Mean ± SD	$0.043.10^{-3} \pm 0.08.10^{-3}$	$0.264.10^{-3} \pm 0.17.10^{-3}$	$0.311.10^{-3} \pm 0.19.10^{-3}$	
		Wholesalers n = 16	Retailers/ mobile vendors n = 83	Households n = 152	
	Minimum	00.00	0.00	0.00	
Kozah	Median	00.00	$0.3.10^{-3}$	$0.3.10^{-3}$	$P < 0.001$
	Maximum	$0.2.10^{-3}$	$0.7.10^{-3}$	$0.9.10^{-3}$	
	Mean ± SD	$0.044.10^{-3} \pm 0.06.10^{-3}$	$0.258.10^{-3} \pm 0.18.10^{-3}$	$0.314.10^{-3} \pm 0.18.10^{-3}$	

3.3. Potential Factors Contributing to Table Salt Contamination Observed in the three Surveyed Prefectures

The survey conducted along the distribution chain, from wholesalers and importers based in Lome to retailers in the prefectures of Doufelgou, Binah, and Kozah, revealed several practices likely to compromise the hygienic quality of iodized salt observed in these areas and, more broadly, across the country.

During transportation, salt is often carried in uncovered or partially covered vehicles, using porous, unlined, and poorly sealed bags (Figure 2). Such conditions expose the product to dust, heat, and humidity, thereby promoting the volatilization or oxidation of iodine, as well as the introduction of environmental impurities and microorganisms originating from air and contamnated surfaces.

At the packaging stage, the use of reused and non-hermetic bags, often poorly closed or perforated, without aluminum or plastic lining, together with manual handling without gloves, are common practices among distributors (Figure 3). These conditions promote cross-contamination from operators, equipment, and the surrounding environment, and facilitate the introduction of halotolerant microorganisms such as *Staphylococcus aureus*, *Bacillus*, *Micrococcus*, or halophilic spores.

Storage at the wholesale level in Lome generally takes place in humid, poorly ventilated areas exposed to sunlight or heat sources, with bags placed directly on the floor or against walls. The accumulation of organic debris and the sometimes unsanitary state of the premises, combined with open or loosely tied bags, further increase the risk of microbial contamination and physicochemical alteration of the salt (Figures 4 and 5).

Finally, at the household level, salt is often stored in poorly closed or humid containers, frequently placed near heat sources (for example, above the cooking stove), and handled with wet utensils. These practices promote moisture absorption, partial dissolution of the salt, and microbial proliferation, leading to a progressive degradation of product quality, characterized by a loss of iodine and a decline in its hygienic and nutritional value.

Figure 2. Transport of Table Salt Under Inadequate Conditions: Uncovered Vehicle with Poorly Sealed and Unlined Packaging.

Figure 3. Photographs Illustrating Inadequate Packaging Practices at the Retail Level, Including Manual Handling Without Gloves, the Use of Reused and Non-Hermetic Bags, the Absence of Aluminum or Plastic Linings, and Poorly Sealed or Perforated Bags.

Figure 4. Examples of Inadequate Storage Practices of Table Salt Showing Storage in Humid Environments, Direct Contact of Salt Bags with the Floor and Walls, and Poorly Sealed or Open Packages.

Figure 5. Inappropriate Storage Practices of Table Salt Illustrating Exposure to Sunlight and the Presence of Organic Debris in an Unsanitary Storage Environment.

Table 3. Environmental and human factors influencing the quality of iodized salt through impurities, microbial contamination, and iodine loss.

Type of Condition	Observed Factors or Practices	Possible Consequences	Nature of Degradation
Transport	Direct exposure to sunlight or heat Transport in uncovered vehicles Poorly closed, porous and unlined bags	Volatilization or oxidation of iodine Moisture absorption and partial dissolution of salt Deposition of dust, sand, and debris Introduction of microbes from the environment or contaminated surfaces	Loss of iodine Presence of impurities Microbial contamination
Packaging	Use of reused or non-hermetic bags Absence of aluminum or plastic inner lining Poorly closed and/or perforated bags Manual handling without gloves	Gas exchange and iodine loss Contamination by dust, metals, or chemical residues Contamination by *Staphylococcus aureus*, *Bacillus*, *Micrococcus* or halophilic spores	Loss of iodine Presence of impurities Microbiological contamination
Storage (wholesalers/retailers)	Storage in humid or poorly ventilated areas Exposure to sunlight and/or heat sources Direct contact with the ground Presence of organic debris Open or poorly sealed bags	Oxidation and volatilization of iodine Moisture migration and salt degradation Contamination by dust, debris, or microorganisms Development of halophilic staphylococci or molds	Loss of iodine Presence of impurities Microbial contamination
Household storage	Storage in poorly closed or humid containers Use of wet utensils to scoop salt Repeated re-packaging Prolonged exposure to open air	Reduction in available iodine content Microbial contamination from human handling Risk of partial dissolution and clumping	Loss of iodine Microbial contamination

4. Discussion

4.1. Microbiological Characteristics of Salt Samples According to the Sampling Level in the Three Surveyed Prefectures

The obtained results highlight a widespread contamination of table salt by total mesophilic flora, except for a few samples collected from wholesalers in the Binah region. This finding suggests that the level of contamination increases along the distribution chain, probably due to poorly controlled storage, transport, and repackaging conditions in local markets [9].

The observed microbial load, exceeding 10^3 CFU/g in almost all samples, is a cause for concern from a food hygiene standpoint. Although salt is known for its antimicrobial properties through osmotic effects, the persistent presence of microorganisms indicates either secondary contamination or the survival ability of certain halotolerant species [10].

The detection of halophilic staphylococci in samples collected from retailers and households, with high contamination rates ranging from 76.67% to 93.33%, represents a significant public health concern. *Staphylococci*, particularly *Staphylococcus aureus*, are well known for their involvement in foodborne intoxications through the production of thermostable enterotoxins [11]. The high prevalence observed suggests that table salt may serve as a potential vector for pathogenic microorganisms, especially under inadequate hygiene conditions. This contamination could be attributed to unhygienic storage environments at wholesale outlets, as indicated in this study, as well as to frequent human handling during retailing and domestic use, which together facilitate microbial persistence and cross – contamination.

These findings are consistent with studies conducted in other developing countries, which have shown that the microbiological quality of unrefined or poorly packaged salt is often compromised by inadequate harvesting and distribution practices [12-14]. They emphasize the need to strengthen good manufacturing and marketing practices (GMP), including airtight packaging, regular microbiological quality control, and awareness-raising among traders and consumers about proper hygiene and storage practices.

These data therefore highlight a food safety issue. The implementation of corrective measures at the levels of production, distribution, and domestic use is essential to reduce contamination risks and protect public health.

4.2. Impurity Rate According to the Sampling Level in the Surveyed Prefectures

The significant increase in the levels of impurities in table salt along the supply chain, from wholesalers to households, indicates a progressive deterioration of salt quality as it is handled, repackaged, and stored under often inadequate conditions.

The relatively low impurity content observed at the wholesale level may be attributed to the fact that salt is typically stored in large, sealed bags, which minimize exposure to external contaminants. Conversely, at the retail and household levels, salt is frequently repackaged into smaller portions, sometimes without adherence to good hygiene practices, thereby increasing the risk of contamination by solid particles, dust, or microorganisms [15].

Previous studies have reported that exposure of table salt to open air, humidity, and non-hermetic packaging facilitates the accumulation of impurities and microbiological contamination [5, 6]. In similar West African settings, marketing and storage conditions have been shown to influence not only impurity levels but also the efficiency of salt as a vehicle for iodine fortification, potentially compromising iodine-deficiency control programs [1, 3].

The rise in impurity levels observed in this study is particularly concerning because it coincides with a heightened risk of microbial contamination. Certain microorganisms may adhere to sand or dust particles present in salt, making its consumption potentially harmful to human health [7]. This finding aligns with that of [5], who demonstrated a correlation between impurity content and microbial load in unrefined salts sold in West African markets.

Overall, these findings highlight the urgent need to adopt improved packaging and storage practices throughout the salt distribution chain, in line with international food safety standards [16, 17]. Continuous quality control through regular inspections and awareness campaigns targeting key stakeholders remains essential not only to ensure the microbiological safety of table salt [13] but also to guarantee its nutritional effectiveness in meeting population iodine requirements [18] and supporting public health objectives.

4.3. Potential Factors Contributing to Table Salt Contamination Observed in the Three Surveyed Prefectures

The findings of this study highlight that the quality deterioration of iodized salt observed along the distribution chain in Togo results from a combination of environmental and anthropogenic factors. Poor transport conditions, such as exposure to sunlight, heat, and humidity, combined with the use of porous and unlined bags, favor the oxidation and volatilization of iodine, which is inherently unstable under high temperature and humidity. Several studies have shown that iodine loss can exceed 30% during transport and storage when the salt is not adequately protected from moisture and air exposure [19].

The reuse of non-hermetic packaging materials, absence of inner linings, and frequent manual handling without gloves at the packaging and retail stages further increase the risk of cross-contamination by microorganisms such as *Staphylococcus aureus, Bacillus, and Micrococcus*. These halotolerant or halophilic species can survive in high-salt environments, particularly when humidity levels exceed 70%, favoring microbial persistence and potential toxin production [20, 21]. The detection of such microorganisms in salt is not surprising, as they have been previously isolated from marine and industrial salts under inadequate handling and packaging conditions [22].

Storage practices observed at both wholesale and retail levels were often unsanitary, with salt stored in poorly ventilated and humid environments or placed directly on the ground. These conditions enhance moisture absorption, leading to agglomeration, microbial proliferation, and impurity accumulation from organic and inorganic debris [16]. The combined effect of humidity and high temperature not only promotes microbial growth but also accelerates the chemical degradation of iodine compounds, especially iodate and iodide, reducing the effective iodine concentration available for human nutrition [23-25].

At the household level, additional losses occur due to improper storage and handling, such as keeping salt in open or humid containers, exposure to kitchen heat, and the use of wet utensils. These practices promote partial dissolution, recrystallization, and leaching of iodine, particularly in tropical climates where ambient humidity is high [26]. The cumulative impact of these factors along the distribution chain ultimately compromises the effectiveness of salt iodization programs, which are critical for the prevention of iodine deficiency disorders [27].

Overall, the observed contamination by impurities and microorganisms, combined with the progressive loss of iodine content, underscores the need for improved packaging materials, strict hygiene standards, and regular monitoring of iodine levels at different stages of the distribution chain. Strengthening regulatory control and providing training to distributors and retailers on proper handling and storage practices could significantly reduce iodine losses and microbial contamination, thereby ensuring that iodized salt remains an effective vehicle for micronutrient fortification.

5. Conclusion

The present study demonstrated that the quality of table salt significantly deteriorates along the supply chain, with a progressive increase in impurity levels from wholesalers to households. This degradation, attributable to reconditioning practices, storage conditions, and inadequate packaging, is accompanied by an increased risk of microbiological contamination. These findings confirm the importance of strict quality control of salt and highlight the need to improve conservation and distribution practices to ensure both the sanitary safety and nutritional effectiveness of this strategic product. By strengthening hygiene and packaging measures throughout the supply chain, it will be possible to preserve not only the safety of the salt consumed but also the sustainability of programs aimed at combating iodine deficiency disorders.

This study demonstrates that the deterioration of iodized salt quality in Togo results from combined environmental and human factors along the distribution chain. Inadequate transport and storage conditions, the use of porous and non-hermetic packaging, and unhygienic handling practices promote both iodine loss—through oxidation and volatilization—and microbial contamination by halotolerant species such as *Staphylococcus aureus*, *Bacillus*, and *Micrococcus*. These issues compromise the effectiveness of salt iodization programs essential for preventing iodine deficiency disorders. Strengthening regulatory control, improving packaging and storage conditions, and training distributors and retailers in hygienic handling are crucial to preserving iodine stability and ensuring the microbiological safety of table salt.

Abbreviations

IDDs	Iodine Deficiency Disorders

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Author Contributions

Melila Mamatchi and Payaguele Kodjo Pyabalo: Conceptualization, Formal Analysis, Writing – original draft

Banakinao Toussaint Bawou: Formal Analysis

Vieira-Dalode Generose and Amouzou Sabiba Kou'santa: Supervision, Validation

Conflicts of Interest

The authors declare no conflicts of interest.

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