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Research article

Mineral content in commercially branded and local salt in selected villages from Bahi, Iramba, Manyoni, and Singida urban districts, Tanzania

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ABSTRACT

The study examines the mineral content of table salts used by households in villages adjacent to the production areas. A total of 210 samples from commercial and local salts were collected, and analyzed using iodometry titration, spectrophotometry, colorimetry, and atomic absorption spectroscopy (AAS) techniques, followed by a household interview for salt type preference. The lowest detectable concentration LOD, lowest quantifiable concentration LOQ and, recovery of methods ranged (0.32–2.155 μg/kg), (0.117–6.387 μg/kg) and, (94.2–103.6 %), respectively. Significant differences in mineral contents were observed within and between local and commercially branded salts ($p < 0.001$). The mean iodine in the local salt samples from Kitangiri (SA), Singidani (SB), Kindai (SC), Chibumagwa (SD), and Sulunga (SE) ranged from 10.5 ± 0,02 to 16.9 ± 0.01 mg/Kg, with only SA and SC in the World Health Organization (WHO) limits, while commercially branded salt samples SF (Malindi), and SG (Dar es salaam) ranged from 23.4 ± 0.01 to 35.9 ± 0,02 mg/kg that were in the Tanzania Bureau of Standards (TBS) and WHO agreed range. Other ions recorded were nitrate (3.3–4.4 mg/kg, 5.45–7.40 mg/kg), phosphate (0.02–0.48 mg/kg, 0.03 mg/kg), sulphate (0.31–0.42 mg/kg, 0.03–0.07 mg/kg), ammonia (0.5 mg/kg, 0.5 mg/kg to 0.6 mg/kg), copper (1.0–2.0 mg/kg, 0.9–2.0 mg/kg), iron (0.5–1.8 mg/kg, 0.9 mg/kg), and manganese (0.5–1.8 mg/kg, 0.9 mg/kg) for local and commercially branded salt, respectively. Households preferred local to commercial-branded salts: Nkonkilangi 163 (69.9, 32.1 %), Mangwanjuki 96 (17.2, 82.8 %), Unyanga 54 (26.7, 73.3 %), Chibumagwa 106 (63.0, 37.0 %), and Chali Igongo 51 (74.6, 25.4 %), respectively. Public health interventions are recommended to promote the consumption of adequately iodized salt for informed dietary choices.

1. Introduction

Table salt, chemically known by the name sodium chloride (NaCl), is a substance composed of sodium ($Na+$) and chloride ($Cl-$) ions [1], which typically appear as small, white, crystalline granules or as a fine powder, soluble in water, and have a salty taste [2,3]. Salt is a ubiquitous dietary component consumed worldwide for human health and nutrition [4–6]. However, the quality and mineral content of salt vary significantly depending on its source [7], storage conditions [8], production, and processing methods [9–11]. Several studies have examined the mineral content of salt and its implications for human health [12–15]. Research on salt quality and iodine deficiency has primarily focused on the effectiveness of iodization programs [9,16,17], providing the status of iodine in nutrition [18,

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19]; few have investigated the mineral content disparities between different types of salt available to consumers [12]. In other parts of the world, studies comparing the mineral content of commercially branded and local table salt have yielded varying results [20]. [21] found significant differences in iodine content, with locally sourced salt often containing lower levels of iodine compared to commercially branded varieties from Jimma town in Ethiopia. Other studies have reported comparable iodine levels between the two types of salt [12,22,23].

Like many other developing countries, iodine deficiency in Tanzania remains a significant public health concern, with adverse effects on cognitive development and growth, particularly among vulnerable populations such as pregnant women and children [9,12,16]. The government has implemented various strategies to combat iodine deficiency, including the mandatory iodization of commercially branded salt. Tanzanian law requires salt to fortified with potassium iodate (KIO_3) or iodide [24–27] to promote optimal iodine intake [6,28]. In regions where iodine deficiency is prevalent, consumers prioritize commercially branded salts for their potential health benefits [29,30,31]. Despite these efforts, variation in the mineral content of salt, particularly between commercially branded and locally sourced varieties, persists, and the vast majority of micro- and small-scale businesses do not fortify their salt. This suggests that non-iodate salts are most likely present in the public environment, undermining the effectiveness of iodization programs and exacerbating nutritional deficiencies among the population [9,12]. Other minerals such as Nitrate (NO_3^-), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), iron (Fe^{2+} or Fe^{3+}), manganese (Mn^{2+}), ammonium (NH_4^+), and copper (Cu^{2+}) are necessary for general health and nutrition [8,16,32,33], their deficiencies have profound effects on increased risk of anemia, osteoporosis, and cardiovascular disease [34].

Preferences for salt type are shaped by a complex interplay of cultural, economic, and nutritional factors [35,36]. While some consumers favor commercially branded salts for their perceived quality, safety, and iodine fortification, others prefer locally sourced salts due to cultural and traditional practices, authenticity, or perceived nutritional richness [33,37–39]. According to Ref. [40], locally sourced salts may be perceived as more natural or authentic, reflecting cultural values and practices passed down through generations. Conversely, in urban areas or regions with access to a diverse range of products, consumers may gravitate towards commercially branded salts due to factors such as convenience, and consistency, [29,41,42]. Commercially branded salts often undergo standardized processing and iodization, which may be perceived as ensuring safety and quality compared to locally sourced salts [9,37,23]. Commercially branded salts are subject to regulatory standards and quality control measures; locally sourced salts vary in terms of purity and mineral content [8,9,12]. However, perceptions of quality and safety are subjective and may vary depending on individual preferences and experiences [43,44].

The sample preparation method followed the procedure described in Ref. [45], which involves drying samples, grinding them to a fine powder, weighing them, dissolving them in deionized water, filtering, and dilution to ensure accurate measurement of components, and ensuring the concentration of analytes falls within the calibration range of the instruments used. According to [46], inductively coupled plasma (ICP), using an argon plasma to ionize the sample is used for the detection of trace metals in salt samples by detecting ions based on their emission spectra. The sample solution is introduced into the ICP instrument, where the plasma ionizes the sample and the emitted light is measured by a detector. Each element emits light at a characteristic wavelength, which is used to identify and quantify the elements present. The microwave plasma atomic emission spectroscopy (MP-AES) described by Ref. [46], a technique for analyzing metal content in salt. It uses microwave-induced plasma to excite the atoms in the sample, causing them to emit light at characteristic wavelengths. The sample solution is introduced into the plasma generated by microwaves. The excited atoms emit light, which is measured by a spectrometer. The intensity of the emitted light is proportional to the concentration of the element in the sample [47]. describes ion chromatography (IC), a method used to determine the concentration of various anions and cations in salt samples. It separates ions based on their interaction with a resin. The solution sample is injected into the ion chromatograph. As the solution passes through the column, ions are separated based on their affinity for the resin. They are then detected by a conductivity detector.

According to Ref. [47], atomic absorption spectroscopy (AAS) analyzes specific metals in salt samples by measuring the absorbance of light in the gaseous state which is proportional to the amount of the element. The aspirated solution is placed into a flame furnace, converting the metal ions to free atoms and a light beam of a specific wavelength passes through the vapor [48]. describes colorimetry as a technique used to determine the concentration of colored compounds in solution, used for substances that produce a color change when reacting with specific reagents. The method is based on the absorbance of light by colored compounds as per Beer-Lambert's law, where the intensity of the color corresponds exactly to the concentration of the colored compound. This study evaluates the mineral content of commercial and local table salt in Nkonkilangi, Mangwanjuki, Unyanga, Chibumagwa, and Chali Igongo to determine if they adhered to health standards, identifying regional differences. The knowledge of the nutritional profiles of salts ensures that consumers have access to high-quality, safe salt products. The findings aim to improve salt quality, address iodine deficiency disorders (IDDs), and promote health and well-being in the community.

2. Materials and methods

2.1. Study site

This study was conducted in Nkonkilangi, Mangwanjuki, Unyanga, Chibumagwa, and Kinyambwa villages adjacent to Kitangiri, Singidani, Kindai, Chibumagwa, and Sulunga lakes, respectively located in Singida (4.8170°S and 34.7500°E) and Dodoma (6.1630°S and 35.7516°E) regions. The lakes are known for their high salinity levels, and salt extraction has been practiced in their surrounding areas, serving these communities for their dietary requirements.

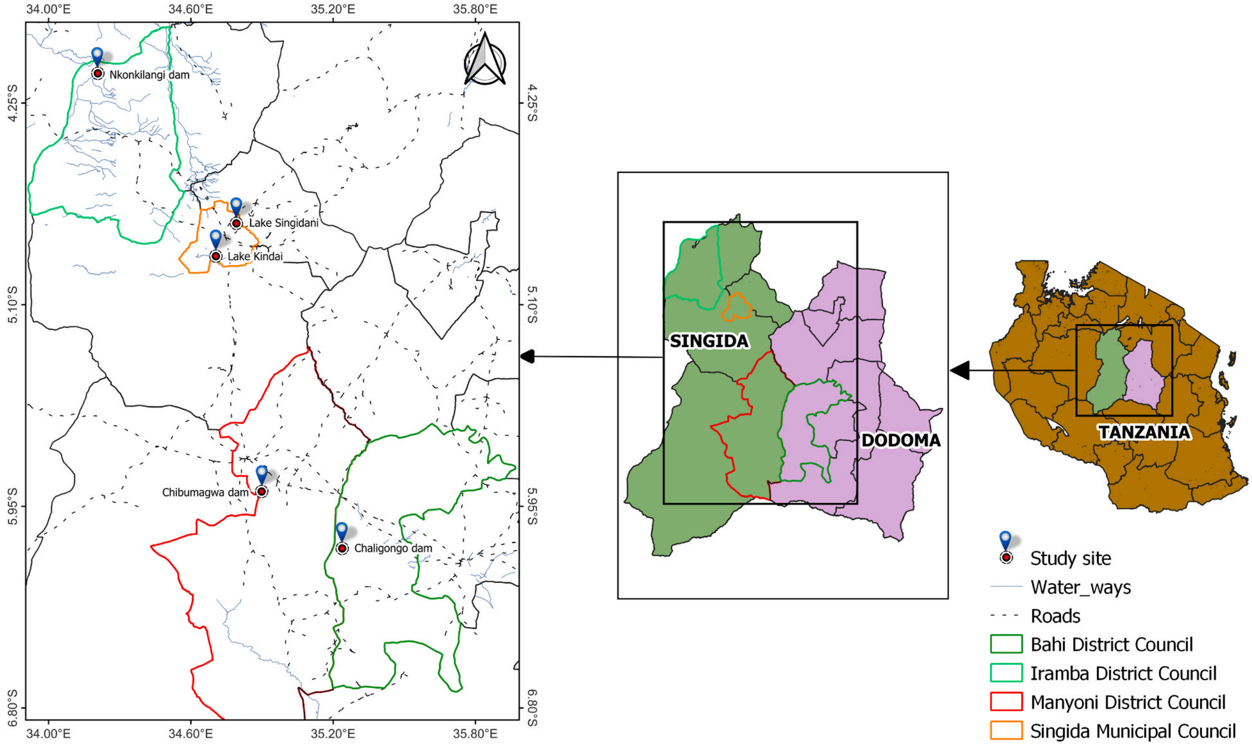

Fig. 1. Map of the Dodoma and Singida regions showing salt sampling sites.

2.2. Study design

A systematic sampling approach was employed, whereby locally sourced samples of salt were collected from local producers at production sites (Fig. 1). Commercially branded samples of salt were collected from retailers at markets and shops in closed packets. To study preferences for salt type, stratified sampling was used, whereby an equal proportion of households from each village were selected using random sampling within each stratum (village) from Iramba, Singida Urban, Manyoni, and Bahi districts. Household members willing to give their consent and identify their salt type were enrolled in the study. In addition, household income, education level, and occupation were assessed.

2.3. Ethical clearance

The study received ethical approval from the University of Dodoma, under reference number MA.84/261/02. All participants provided written, informed consent. The participants had the option to withdraw from the study at any time if it made them uncomfortable, and the surveys were anonymized.

2.4. Sample collection

A total of 210 samples from seven types of salt (2 commercially branded and 5 local salts) in seven sampling sites-10 samples per site-were picked for one type of salt. In each pack, three samples from the bottom, middle, and top of the package (in total, 30 samples per site) were randomly selected in stores and households from the villages of Nkonkilangi, Mangwanjuki, Unyanga, Chibumagwa, and Kinyambwa. Locally sourced products from Kitangiri, Singidani, Kindai, Chibumagwa, and Sulunga lakes were labelled SA, SB, SC, SD, and SE, respectively, while branded popular products available in both regions were labelled SF (Kaysalt from Malindi, Kenya) and SG (Néel Premium from Dar es Salaam, Tanzania). The samples were categorized, packed in clean, moisture-free plastic containers with covers, labelled with the date of sampling, source, batch number, and transported for laboratory analysis.

2.5. Materials and equipment

A local and commercially branded salt sample, distilled water purchased from a local supplier in villages, potassium iodide (KI) Fisher Scientific USA solution, sodium thiosulphate ($Na_2S_2O_3$) Sigma-Aldrich USA solution (titrant), and starch Fisher Scientific USA solution (indicator) of analytical grade purity (>99 %) were purchased from Labquip (T) Limited, Dar es Salaam, Tanzania. Quality control measures were implemented to verify the integrity and reliability of the reagents throughout the analysis process. Acetylene

Table 1
Validation parameters for an analytical method used.

Parameter	Description	Result
LOD	Lowest detectable concentration	0.01 mg/L
LOQ	Lowest quantifiable concentration	0.05 mg/L
Recovery	Accuracy of method	98.5 %
RSD	Precision of the method	2.5 %
Linearity (R^2)	Correlation coefficient of the calibration curve	0.999
Range	Concentration range validated	0.05–100 mg/L
Robustness	Consistency under varied conditions	Consistent across variations
Specificity	Measure analyte without interference	No significant interference

gas purchased from Chemico (T) Limited, Dar es Salaam, Tanzania, was used for atomic absorption (AA) analysis. Calibration of the AA instrument was performed using this gas according to established protocols. PerkinElmer 2380 Atomic Absorption Spectrophotometer, USA; Lovibond MD 640 Colorimeter Kit 214140, Germany; cuvettes Hellma, Germany; pipettes Thermo Fisher Scientific, USA; and burettes BrandTech Scientific, Germany; volumetric flasks Pyrex-USA and a stopwatch Casio, Country: Japan, were used.

2.6. Procedure

The iodine concentration in the salt sample was assessed through iodometric titration methods and MBI rapid test kits, India [49]. The PerkinElmer 2380 Atomic Absorption Spectrophotometer USA and, the Lovibond MD 640 Colorimeter Kit 214140 Germany were used to analyze ions in the salt samples [50,51]. Furthermore, households were interviewed about their preferred type of salt used at home.

2.6.1. Rapid test kits (RTK) determination of iodine content

According to Ref. [52], RTK involves preparing materials, dissolving salt in clean water, applying the solution, and observing the color change on the test strip or reaction pad. The iodine concentration value was then compared to the provided color chart on the RTK packaging. The test was performed in a well-lit area, and materials were cleaned up after dissolving the salt. The process ensured an accurate comparison of color changes and avoided contamination. The reaction between iodine and starch, forming a starch-iodine complex, was used to determine the iodine amount in salt. The process involves a test solution containing an acidic reducing agent buffer, which oxidizes potassium iodate (KIO_3) into elemental iodine (I_2). The elemental iodine then reacts with iodide ions (I^-) to produce tri-iodide anions (I^{3-}), and further reacts to form penta-iodide anions (I_5^-). These penta-iodide anions (I_5^-) create a visible blue-black complex with the amylose in the starch. The salt iodine levels were classified using a color chart, with the levels expressed in parts per million (mg/Kg) as follows: sufficient at $\geq$15 mg/kg, medium at $<$15 mg/kg, and no iodine at 0 mg/kg [16].

2.6.2. Titration (preparation of sample and standard iodine solution)

The procedure described in Refs. [53,49] was followed to determine iodine in salt, where 25 g of potassium iodide (KI) from Fisher Scientific USA was weighed and dissolved in 100 ml of distilled water. Three drops of starch solution were added to create a starch-iodine complex. An excess KI solution was added to the sample to ensure that all the iodine in the sample reacted to form iodide ions. The solution was titrated with sodium thiosulphate ($Na_2S_2O_3$) Sigma-Aldrich USA solution to the endpoint until the blue color disappeared, and the volume used was recorded. Each sample was analyzed in triplicate.

Equation: $2KI\ (aq) + Na_2S_2O_3(aq) \rightarrow I_2(aq) + 2NaI(aq) + Na_2S_4O_6(aq)$

The chemical symbols denote the following compounds: KI stands for potassium iodide solution, $Na_2S_2O_3$ denotes sodium thiosulfate solution, I_2 indicates elemental iodine, NaI represents sodium iodide, and $Na_2S_4O_6$ signifies sodium tetrathionate.

Quality control (QC) samples were used to ensure the ongoing accuracy and precision of an analytical method. Samples are analyzed alongside unknown samples and compared to known values. Common QC samples include: Blank samples contain no analyte used to check for contamination. Spiked samples with known quantities of analyte were added to ensure accuracy. Replicates are multiple samples from the same source to assess precision. Table 1 provides a summary of validation parameters for the analytical method used. The parameters and their corresponding results collectively demonstrate that the analytical method is sensitive, accurate, precise, linear over a wide range, robust, and specific, making it reliable for its intended use [48,54,55].

2.6.3. Procedure for the measurement of other minerals

[56] describes the procedure for measuring minerals, which involves collecting salt samples, grinding them into a fine powder, calibrating analytical instruments, and analyzing them using flame photometry and an atomic absorption spectrophotometer. Quality control and safety precautions were adhered to in order to maintain accurate measurements. Atomic Absorption Spectroscopy (AAS), equipped with a light source, an atomizer, a monochromator, and a detector, quantitatively determines elements in samples, including salt samples. According to Ref. [47], the operating conditions depend on the element and lamp, with wavelengths specific to the element. Calibration involved preparing standard solutions of known concentrations and measuring absorbance for each standard. Sample extraction involved using a microwave to remove organic matter. Samples were filtered to remove particulate matter.

Table 2
Amount of iodine available in commercial – branded, and local salt.

Sample	**RTK** Iodine (mg/Kg) ± SD, n = 3	p - value	Iodiometric Titration Iodine (mg/Kg) ± SD, n = 3	p - value
SA	≥15	<0.001	15.90 ± 0.10	<0.001
SB	<15	<0.001	10.50 ± 0.10	<0.001
SC	≥15	<0.001	16.90 ± 0.10	<0.001
SD	<15	<0.001	11.80 ± 0.20	<0.001
SE	<15	<0.001	10.70 ± 0.10	<0.001
SF	≥15	<0.001	23.40 ± 0.20	<0.001
SG	≥15	<0.001	35.90 ± 0.10	<0.001

Rapid Test Kits (RTK): sufficient at ≥ 15 mg/kg, medium at <15 mg/kg, and no iodine at 0 mg/kg [52]. Iodiometric Titration: 30–60 [53], 15–30 [1].

Validation compared standard reference materials, evaluated precision, and ensured linearity. The limit of quantification (LOQ) and limit of detection (LOD) were determined by analyzing the samples standard deviation and calibration curve, followed by recovery and interference studies to detect spectral and chemical interferences.

2.6.3.1. Determination of sulphate, phosphate, and nitrate. Barium Chloride ($BaCl_2$) Sigma-Aldrich USA solution, which forms a white precipitate of Barium Sulphate ($BaSO_4$) Sigma-Aldrich, USA, and turbidimetric agents, methylthymol blue, were used to estimate sulphate ions in the salt from the working solution prepared. The presence and concentration of phosphate (PO_4^{3-}) were determined by the colorimetric method, whereby phosphate ions were detected using colorimetric assays [47]. Nitrate (NO_3^-) was determined by the colorimetric method, where nitrate ions were detected using colorimetric assays by the Griess reaction, which formed a colored azo dye product that was measured spectrophotometrically by the PerkinElmer 2380 Atomic Absorption Spectrophotometer USA [50]. Each sample was analyzed in triplicate.

2.6.3.2. Determination of iron, manganese, and ammonium. Iron (Fe^{2+}/Fe^{3+}) was determined by the colorimetric method, in which iron ions were detected colorimetrically using 1, 10-phenanthroline, which formed colored complexes with iron and were measured spectrophotometrically. The PerkinElmer 2380 Atomic Absorption Spectrophotometer USA was used to determine manganese in the salt. Ammonium (NH_4^+) was determined by the colorimetric method, in which ammonium ions were detected colorimetrically using Nessler's Fisher Scientific USA reagent, which formed a yellow to brown-colored complex with ammonium ions [47,57]. Each sample was analyzed in triplicate.

2.7. Determination of household salt type prevalence

A survey was conducted in the selected households to gather data on the prevalence of different types of salt (commercially branded vs. local), usage patterns, socio-economic factors influencing choices, reasons for their choice, and frequency of use.

2.8. Statistical analysis

The study employed several statistical methods for detailed data analysis [58–61]. Descriptive statistics were used to summarize the basic features of the data, including measures of central tendency (mean, median) and dispersion (standard deviation, range) [58]. The Shapiro-Wilk test determined data normality [61], and comparative analysis was conducted using t-tests to determine significant differences between the mineral contents of commercially branded and local salts [60]. The data were further subjected to ANOVA (analysis of variance) to assess variations across different villages and districts [59]. The statistical significance was set at a p-value of less than 0.05. These methods provided an understanding of the mineral content variations and helped in identifying specific patterns and differences. The analysis ensured the validity and reliability of the findings, contributing to public health and nutrition policies in the Dodoma and Singida regions.

3. Results and discussion

Table 2 presents the concentrations of iodine present in commercial-branded and local salt samples collected from different sources. Samples SA, SC, SF, and SG met the regulatory standards set by the WHO for iodine, but SB, SD, and SE didn't comply. There were significant differences in iodine content for salt samples in five villages for the RTK and titration ($p < 0.001$) methods. Local salt samples exhibited lower iodine content than commercially branded samples; this observation agrees with the study of [62], who reported salt iodine content for retail shop and household in Shebe town, south-west Ethiopia, ranged from 0 to 75 mg/kg. Household (81 %) and shop salt samples (82 %) had iodine levels lower than the limits of the Ethiopia Quality and Standard Authority. The iodine content varied across the samples, ranging from 10.50 mg/kg to 35.90 mg/kg and 13.16 mg/kg average for local salt and from 23.40 mg/kg to 35.90 mg/kg and 29.65 mg/kg mean for commercially branded salt. The same findings were reported by Ref. [63] on varying household iodized salt use in Ghana based on a standard of 15 mg/kg iodine content or more to indicate the adequacy of iodization. Samples SB, SD, and SE concentrations were lower than the range recommended; on the other hand, samples SA, SC, SF, and FG met the WHO (15–30 mg/kg) range for iodized salt.

Table 3
Amount of nitrate, phosphate, and sulphate available in commercial-branded and local salt.

Sample	Nitrate (mg/Kg) ± SD, n = 3	Phosphate (mg/Kg) ± SD, n = 3	Sulphate (mg/Kg) ± SD, n = 3	p - value
SA	4.40 ± 0.20	0.11 ± 0.01	0.42 ± 0.02	<0.001
SB	3.30 ± 0.10	0.13 ± 0.02	0.37 ± 0.02	<0.001
SC	3.50 ± 0.10	0.17 ± 0.01	0.31 ± 0.01	<0.001
SD	4.10 ± 0.10	0.02 ± 0.01	0.39 ± 0.01	<0.001
SE	4.40 ± 0.20	0.48 ± 0.02	0.34 ± 0.01	<0.001
SF	5.45 ± 0.10	ND	0.03 ± 0.01	<0.001
SG	7.40 ± 0.10	ND	0.07 ± 0.01	<0.001
TBS, 2014	5.0	00	0.5	
WHO, 2018	45.0	0.1	1.0	

Table 4
Concentration of ammonia, copper, iron, and manganese in salt.

Sample	Ammonia (mg/Kg) ± SD, (n = 3)	Copper (mg/Kg) ± SD, (n = 3)	Iron (mg/Kg) ± SD, (n = 3)	Manganese (mg/Kg) ± SD, (n = 3)
SA	0.5 ± 0.1	2.0 ± 0.2	1.8 ± 0.1	1.8 ± 0.1
SB	0.5 ± 0.1	2.0 ± 0.2	1.0 ± 0.1	1.0 ± 0.1
SC	0.5 ± 0.1	1.0 ± 0.1	0.5 ± 0.1	0.5 ± 0.1
SD	0.5 ± 0.1	1.0 ± 0.1	0.5 ± 0.1	0.5 ± 0.1
SE	0.5 ± 0.1	1.0 ± 0.1	0.5 ± 0.1	0.5 ± 0.1
SF	0.6 ± 0.2	0.9 ± 0.1	0.9 ± 0.1	0.9 ± 0.1
SG	0.5 ± 0.1	1.0 ± 0.1	0.9 ± 0.1	0.9 ± 0.1
p value	p > 0.001	p < 0.001	p < 0.001	p < 0.001
TBS, 2014	1.0	2.0	5.0	1.0
WHO, 2018	1.0	0.1	1.0	1.0

Only one sample of SG showed an iodine level within TBS limits; the rest had a lower iodine content than recommended by TBS [12]. reported that of the 19 common salts tested in the Tanzanian market, only two, 79.95 mg/kg Super Salt and, 76.67 mg/kg Kipepeo met the accepted iodine levels [64]. recommends salt-iodine amount should be 50–60 mg/kg at the production and 20–30 mg/kg at retail shops for household consumption [20]. study conducted in Sri Lanka on commercial salts revealed that all six salt products have iodine above the accepted level (15–30 mg/kg) [19]. report that sufficiently iodized salt exposure among the households in North Ethiopia was 51 (17.5 %).

About 42 (14.38 %) had 15 mg/kg to 80 mg/kg, 9 (3.08 %) had >80 mg/kg, 188 (64.4 %) had 1.1 mg/kg to 14.9 mg/kg, and 53 (18.2 %) had no iodine in the salt (0 mg/kg). Only 26 (8.9 %) of the households had used iodized salt properly.

Generally, commercial salts have higher iodine levels compared to local salts, which agrees with the present study. The amount of iodine in salt from the studied villages was influenced by regulatory measures, processing methods [17,19,20], and the natural variability of source mineral deposits present, clearly observed in commercial-branded and local salt [2,65,66]. Variability in iodine content of commercial-branded, SA (Kaysalt), and SB (Néel Premium) depends on the method used to fortify salt with iodine [9,67], transportation and distribution [34], and quality control measures during salt production [12], affecting the final iodine content. Proper handling and storage maintain the intended iodine levels in the salt [2,20]. Exposure to moisture and sunlight affects iodine stability in salt degradation over time [21,67], as observed in local salts that were in an open state and not packed. The natural iodine content of the raw salt source may result in some salt deposits naturally containing more iodine than others [68] experienced in the studied villages.

Results in Table 3 indicate that most samples meet the regulatory standards set by TBS and WHO for nitrate and sulphate content, with the exception of phosphate. The concentration range was nitrate (3.30–4.40 mg/kg, 5.45–7.40 mg/kg), sulphate (0.31–0.42 mg/kg, 0.03–0.07 mg/kg) for local and commercially branded salt, respectively. Phosphate was not detected in commercially branded salt; for local salt, the amount ranged from 0.02 mg/kg to 0.17 mg/kg. There were significant differences observed between the salt nitrate, phosphate, and sulphate contents of the five villages ($p < 0.001$). Results in Table 3 and 4 suggest variations in nitrate, phosphate, sulphate, ammonia, copper, iron, and manganese concentrations in local and commercially branded salt samples, suggesting potential differences in production methods [13], sourcing [2], and quality control measures [20,21]. Disparities in mineral content between commercial and local salt have implications for observed nutritional adequacy in Mangwanjuki (sample SB), Chibumagwa (sample SD), and Chali Igongo (sample SE) villages, affecting areas where salt is a primary source of these minerals. The consistency of some cations and anions concentrations across different sources of salt observed indicates uniformity in mineral composition [2,9,65] and quality assurance practices in commercially branded salts.

According to Table 4, the ammonia content was consistent across all samples, with values ranging from 0.5 mg/kg to 0.6 mg/kg falling within the range recommended (1.0 mg/kg) and found to be not significant statistically ($p > 0.001$). Copper concentrations ranged from 0.9 mg/kg to 2.0 mg/kg across the samples, with samples SA and SB displaying the highest values. Iron levels were between 0.5 mg/kg and 1.8 mg/kg, within the TBS (5.0 mg/kg) and WHO (0.1 mg/kg) limits. Manganese concentrations ranged from 0.5 mg/kg to 1.8 mg/kg within regulatory standards (1.0 mg/kg). The concentrations were statistically significant ($p < 0.001$) for copper, iron, and manganese.

Table 5
Household socioeconomic characteristics.

Socioeconomic status	Category	Villages				
		Nkonkilangi	Mangwanjuki	Unyanga	Chibumagwa	Kinyambwa
Education	Informal	13 (08.0 %)	09 (9.4 %)	11 (20.4 %)	24 (22.6 %)	23 (45.1 %)
	Primary	74 (45.4 %)	27 (28.1 %)	08 (14.8 %)	41 (38.7 %)	17 (33.3 %)
	Secondary	51 (31.3 %)	31 (32.3 %)	22 (40.7 %)	33 (31.1 %)	07 (13.7 %)
	Tertiary	25 (15.3 %)	29 (30.2 %)	13 (24.1 %)	08 (07.6 %)	04 (7.8 %)
		163 (100 %)	96 (100 %)	54 (100 %)	106 (100 %)	51(100 %)
Income	Low	88 (54.0 %)	27 (28.1 %)	29 (53.7 %)	33 (31.1 %)	15 (29.4 %)
	Middle	63 (38.6 %)	52 (54.2 %)	21 (38.9 %)	46 (43.4 %)	27 (52.9 %)
	High	12 (07.4 %)	17 (17.7 %)	04 (7.4 %)	27 (25.5 %)	09 (17.7 %)
		163(100 %)	96 (100 %)	54 (100 %)	106 (100 %)	51 (100 %)
Occupation	Peasant	103 (63.2 %)	57 (59.4 %)	34 (61.8 %)	45 (42.4 %)	27 (53.0 %)
	Business	23 (14.1 %)	18 (18.8 %)	11 (20 %)	39 (36.8 %)	12 (23.5 %)
	Employee	37 (22.7 %)	21 (21.8 %)	10 (18.2 %)	22 (20.8 %)	12 (23.5 %)
		163(100 %)	96 (100 %)	54 (100 %)	106 (100 %)	51 (100 %)

In a study by Ref. [69] on metal contaminants Tehran in edible salts, Pb (1.59 ± 0.90), Cd (0.91 ± 0.32), Zn (6.02 ± 2.54), Fe (17.8 ± 6.11), Cu (1.24 ± 0.90), and Al (5.82 ± 0.61) mg/Kg in salts were Pb (0.86 ± 0.52), Cd (0.65 ± 0.34), Zn (6.5 ± 4.86), Fe (15.3 ± 5.95), Cu (1.21 ± 0.79), and Al (5.60 ± 0.75) mg/Kg in table salts [8]. study on the mineral composition showed that the composition of copper (Cu) in Mozia and Persian blue salt was 41.63 ± 4.18 mg/kg and 50.61 ± 6.19 mg/kg, respectively. Iron (Fe) 1.44 ± 0.26 mg/kg had the highest manganese (Mn) content with 5.15 ± 0.62 mg/kg while Maldon salt had the lowest with 0.82 ± 0.04 mg/kg. Comparing these results, there are consistent mineral content differences between commercial and local salts. Non-compliance with mineral content requirements in salt has significant health implications, including nutritional deficiencies [70], increased health risks [20], population health burdens [28], and vulnerability to certain demographic groups [35]. Inadequate mineral intake leads to osteoporosis [32], cardiovascular diseases [34], and muscle cramps [16], and legal and regulatory consequences for manufacturers and producers, such as recalls and fines [9], undermine consumer confidence in food products' safety and quality [2], leading to skepticism about fortification programs [68]. According to Ref. [43], addressing non-compliance requires targeted interventions, improved production practices, enhanced monitoring, and public education campaigns; therefore, collaboration between government agencies, industry stakeholders, and public health organizations is essential to ensuring compliance.

The socioeconomic characteristics of households in Nkonkilangi, Mangwanjuki, Unyanga, Chibumagwa, and Kinyambwa villages are presented in Table 5, categorized as education level, income, and occupation.

The highest percentage of households with informal education was found in Chibumagwa 24 (22.6 %), followed by Kinyambwa 23 (45.1 %). Nkonkilangi village has the highest percentage of households with primary and secondary education, at 74 (45.4 %) and 51 (31.3 %), respectively.

Tertiary education is least prevalent across all villages, with the highest percentage of 29 (30.2 %) in Mangwanjuki village. As for income levels, Nkonkilangi has the highest percentage of households with low income at 88 (54.0 %), followed by Chibumagwa at 33 (31.1 %). This suggests a significant proportion of households in these villages face financial challenges. Mangwanjuki and Kinyambwa have the highest percentages of households with middle income: 52 (54.2 %) and 27 (52.9 %), respectively. Chibumagwa and Mangwanjuki have the highest percentages of households with high income: 27 (25.5 %) and 17 (17.7 %), respectively. The majority of households across all villages were peasants, with percentages ranging from 45 (42.4 %) to 103 (63.2 %). Chibumagwa has the highest number of households doing business, at 39 (36.8 %), followed by Kinyambwa at 12 (23.5 %). Households engaged in employment ranged from 10 (18.2 %) to 12 (23.5 %) across villages. Variation in education levels across villages, with some showing higher proportions of informal and primary education shown in Table 5, is likely to affect choice of salt due to a lack of knowledge on salt quality [2]. The majority of households across all villages fall into the low- and middle-income categories. Low- and middle-income households are more sensitive to prices, opting for cheaper options, which could include locally produced salt, which is more affordable compared to branded salt [44]. In many rural areas, locally produced salt might be more readily available than branded salt in purchase decisions, especially when transportation costs are factored in Refs. [37,43]. According to the interview, locally produced salt was perceived as more natural and authentic by some consumers. This perception could influence their choice, as they value traditional methods and are more concerned about additives in commercial products. On the other hand, middle-income households, in particular, were more aware of the nutritional content of salt and its health implications. This awareness led them to choose branded salt that is iodized for their family health. Low- and middle-income households considered value for money as branded salt was more expensive and opted to use local salt.

It is indicated in Table 5 that peasants dominated in all villages, forming the majority of households with the highest percentages. While price, quality, accessibility, and convenience are important factors for all groups, the specific priorities and considerations of peasants, businessmen, and employees led them to make different choices when it comes to local salt versus commercial salt. Businessmen prioritized convenience and time-saving options, opting for branded salt available in shops due to its accessibility and the convenience of purchasing multiple items in one location. Businessmen trusted branded salt more due to standardized production processes and quality control measures, leading them to choose it over local salt, which also associated branded products with their lifestyle and status. Employees with stable incomes prioritized health and nutrition by choosing branded salt, which is often seen as a

Table 6
Household consumption of commercially-branded and local salt.

Village	Local salt %	Commercial salt %	Total households	p - value
Nkonkilangi	110 (67.9 %)	53 (32.1 %)	163	<0.001
Mangwanjuki	16 (17.2 %)	80 (82.8 %)	96	<0.001
Unyanga	15 (26.7 %)	39 (73.3 %)	54	<0.001
Chibumagwa	67 (63.0 %)	39 (37.0 %)	106	<0.001
Chali Igongo	38 (74.6 %)	12 (25.4 %)	51	<0.001
	234 (49.88 %)	236 (50.12 %)	470	

healthier option for themselves and their families. In addition, employees have brand loyalty, preferring to stick to familiar brands that they trust and choosing branded salt because they have positive associations with the brand from previous experiences. These variations in salt consumption patterns were influenced by availability, affordability, cultural practices, and perceptions of salt quality. These consumption patterns can be used to design targeted interventions aimed at promoting the consumption of adequately iodized salt within these communities.

Table 6 shows household consumption of commercial-branded and local salt in different sources and villages, in which out of 470 households surveyed, 234 (49.88 %) consumed local and 236 (50.12 %) consumed commercial-branded salt, with varying prevalence of the types of salts across villages that were significantly different ($p < 0.001$) across different villages. Mangwanjuki village recorded the highest preference for commercial-branded salt (80 (82.8 %), whereas Chali Igongo village predominantly consumes local salt (38 (74.6 %). Other villages exhibited a mix of varying preferences for both commercial-branded and local salt. Results suggest varying preferences for salt consumption across different villages, with some showing a clear preference for local salt while others overwhelmingly prefer commercial salt. The observed variations likely result from a combination of these factors, reflecting the complex interplay of cultural, economic, geographic, and social influences on dietary choices within each village. Different villages had distinct cultural preferences regarding food, including the type of salt used in cooking and seasoning, stemming from historical practices and beliefs about the health benefits of certain types of salt. Economic considerations, such as the affordability and availability of commercial-branded versus local salt, influenced consumption patterns. Commercial-branded salt was more easily accessible in urban areas such as Mangwanjuki and Unyanga villages, leading to higher consumption rates. Access to markets and salt distribution varied between villages, impacting the availability of different types of salt. Villages with better access to markets had a wider variety of salt options, including commercial-branded and local varieties, leading to more balanced consumption patterns. Risks associated with different types of salt raised concerns about additives in commercial-branded salt, while others opted for commercial-branded salt based on perceived quality and safety standards. Villages located near salt production sites had easier access to local salt, while those farther away relied more heavily on commercially-produced varieties.

4. Conclusions

The study revealed a significant difference in the composition of minerals in commercially branded versus locally sourced salts from Bahi, Iramba, Manyoni, and Singida urban districts in Tanzania. Local salts often had higher concentrations of essential minerals compared to branded salts, yet iodine content was inconsistent and sometimes below recommended levels. These findings call the need for improved regulation and standardization of salt production to ensure consistent mineral intake and prevent deficiencies, particularly of iodine, which is important for thyroid health. The limitations of the study include a relatively small sample size and a limited geographic focus, which may not fully capture the variability in mineral content across different regions. In addition, did not account for potential seasonal variations in mineral content. Future research should broaden the sampling area, and consider seasonal effects. This study calls the need for standardized regulations to ensure consistent edible salt quality and consumer awareness for health benefits.

Data availability statement

The data will be made available upon request.

Additional information

Questionnaire survey for households in the studied villages.

CRediT authorship contribution statement

Jackson Henry Katonge: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author declares that have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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