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Quality assessment of refined table salts and locally processed unrefined salts consumed in Nasarawa State (north-central Nigeria)

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Abstract

Background and objective: Table salt is an ideal vehicle for the delivery of micronutrients. This study assessed the quality of refined salts and locally processed salts in Awe and Keana local government areas, Nasarawa state, Nigeria.

Materials and methods: Forty-five samples were collected from local markets in Nasarawa state. Moisture content, water-insoluble matter, and acid-insoluble matter were determined according to the AOAC method. Sodium chloride and iodine contents were determined by titration. The concentration of calcium, potassium, magnesium, and sodium was determined by inductively coupled plasma-mass spectrometry (ICP-MS).

Results and conclusion: Moisture content of the refined and unrefined salts ranged from 0.060 to 0.133% and 0.599 to 2.574%, respectively. The moisture content and amounts of water-insoluble and acid-insoluble matters in the unrefined salts were higher than the refined salts. The concentration of sodium chloride in most of the unrefined salts did not meet the national minimum limit of 97%. The concentration of iodine, calcium, potassium, and magnesium in the refined salts was significantly higher than the unrefined samples. Iodine content in the refined and unrefined salts ranged from 22.22 to 40.20 mg/kg and below the detection limit of 6.35 mg/kg, respectively. None of the unrefined salts met the minimum iodine content of 30 mg/kg. We concluded that the locally processed salts available in Awe and Keana local markets were highly deficient in essential elements and were of poor quality for use as table salt.

Keywords: Essential elements, Iodine, Refined salt, Table salt, Unrefined salt

1. Introduction

Salt, usually referred to as "common salt," is a chemical compound of sodium chloride (NaCl). It is a crucial component of human, animal, and plant diets which is added to enhance the flavor as well as served as a preservative for many processed and fresh foods to inhibit the growth of spoilage and pathologic bacteria with a smaller proportion of sodium carbonate which is used to tenderize the food during cooking [1,2]. Table salt is a food additive and is an excellent carrier of various micronutrients [3]. Although, the main component of salt is NaCl, some impurities such as $MgSO_4$ and $CaSO_4$ may be present depending on the source of raw materials or the

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preparation methods [4].

Table salt is consumed daily and most people are accustomed to the taste of salt, so its consumption has increased despite numerous challenges. It contributes to the rising cases of hypertension, and cardiovascular and kidney diseases [5]. Regular consumption of edible salts replenishes the body's supply of the vital mineral ions that produce hydrochloric acid, which aids in digestion. In addition, it promotes potassium absorption, transports carbon dioxide in the blood, and maintains the body's acid-base balance [6].

The people suffering from chronic NaCl deficiency may experience major health issues including nausea, muscle cramping, loss of appetite, and weight loss. Excessive loss of NaCl from the body may cause vascular collapse, which could result in mortality. In comparison, hypertension as well as heart, liver, and kidney disorders may develop if too much sodium is delivered by salt or other meals [6]. The National Agency for Food, Drug Administration and Control (NAFDAC) adopted the specifications of the Standards Organization of Nigeria (SON) regarding the composition of salt, as outlined in their 1992 guideline. Accordingly, sodium chloride should not be lower than 97%, and the content of iodine, moisture, calcium, magnesium, water-insoluble matter, iron, copper, and lead should not exceed 40 mg/kg, 1%, 0.3%, 0.3%, 0.12%, 10 mg/kg, 2 mg/kg, and 2 mg/kg, respectively. Therefore, different types of salt are different based on their varying mineral composition [7].

Salts are composed of 90–95% pure NaCl [8]. Most salts are mined as rock salt or halite, or they are derived from seawater. Consumer salts used in the food industry are separated, refined, and crushed. Frequently, an anticaking agent is also used. Customers may buy table salt as sodium chloride with or without additional iodine. Iodine is required to make thyroid hormones like thyroxin and triiodothyronine. Thus, it is added to foods to avoid iodine deficiency [9]. Moreover, several sea salts that have been separated by solar or open pan approach are available in the market. The main ions in seawater are included to 56% chloride, 31% sodium, 4% magnesium, 8% sulfate, 1% calcium, and 1% potassium [10]. The flavor of sea salt might differ from other salts depending on where it is acquired. The salt's color and flavor may be influenced by the substances other than sodium chloride [11].

Awe and Keana local government areas (LGAs) of Nasarawa State are enriched with salt deposits. The inhabitants earn their living from mining and processing the salts from the salt mines in these regions. In the past, salt was produced by boiling brine in exposed pans, through which the water was evaporated, and salt crystals were left. Today, it is vacuum-evaporated in large containers to create white salt [12]. However, the traditional methods are used currently in the Awe and Keana salt mines, which provides a source of income for the individuals. The aim of this study was to compare the quality of commercially available refined table salts with that of locally processed unrefined salts in the Awe and Keana local government areas of Nasarawa State.

2. Materials and methods

2.1. Geography of the region

The Awe brine field, which is enriched with salt deposits is located in the Awe LGAs of Nasarawa State (Figure 1). It is one of the brine fields that make up the Benue brine field, which is situated in the Benue trough. The Awe brine field covers a region of roughly 12 km^2, located between latitudes 8° 05′ N and 8° 07′ N, and longitudes 9° 05′ E and 9° 10′ E. The region experiences a temperature range from 26 °C to 32 °C in a day, a mean annual rainfall of 1248 mm, and a relative humidity of 60-80% [13]. The terrain is mild, with elevations ranging from 100 to 145 m. According to Obaje et al. [14], the Awe brine field is defined by the geological formations of Ezeaku, Keana, saliferous Awe, and Asu River. The sedimentary strata overlay the Precambrian-age Basement complex [14].

Keana salt village is in Keana LGA (Figure 1) of Nasarawa state. The settlement is 67 km from the state capital, Lafia, and its coordinates are 8° 8' 0" North and 8° 48' 0" East. The Keana salt mining business goes back to the 12th century when the discovery of salt drew human habitation to the region [15]. The Keana Formation was also traced to Old Awe town. It is made up of grey, coarse-grained, pebbly sandstone beds. The formation is heavily fractured with orthogonal joint sets and brines are found to originate from these fractures. This likely links the Keana Formation to the Awe Formation.

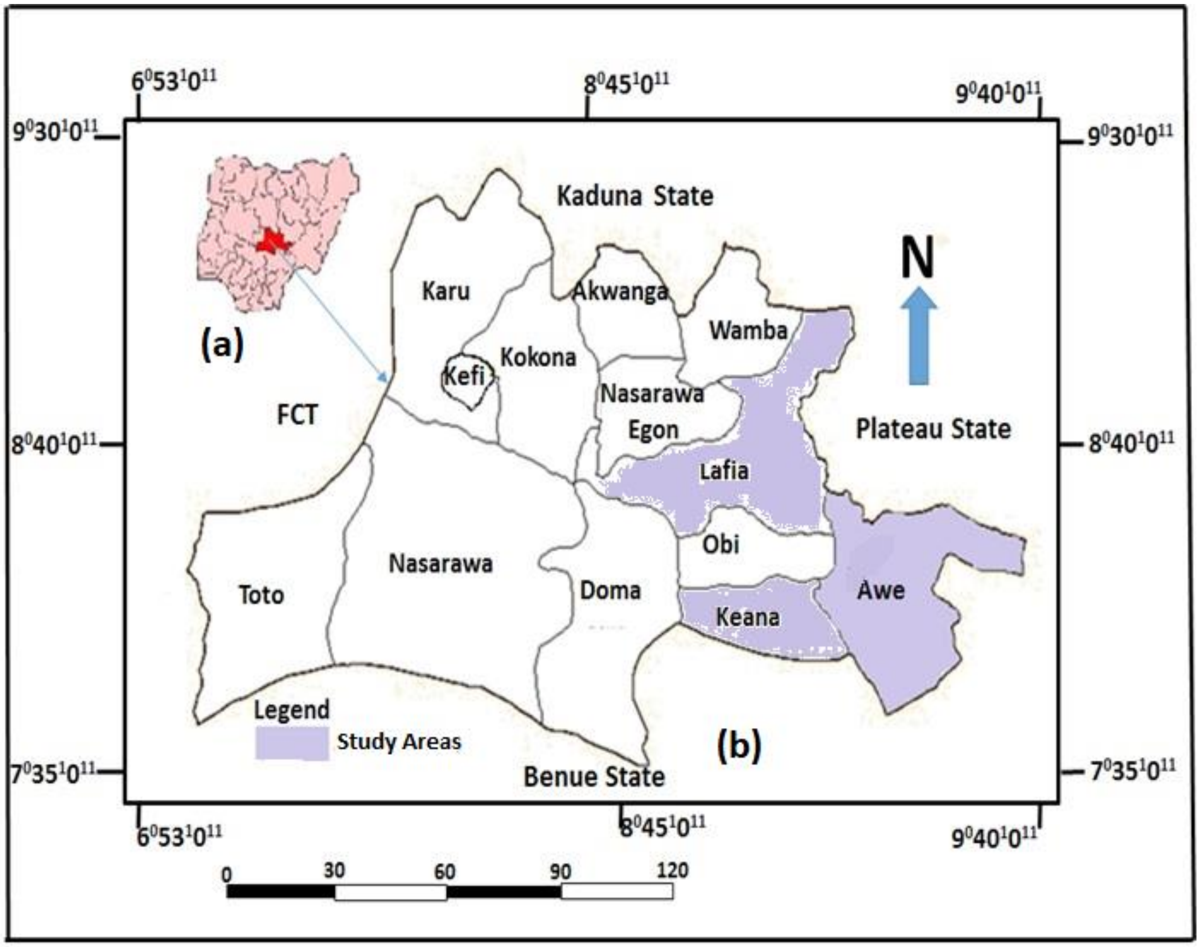

Figure 1- Map of Nigeria; a) Nasarawa State, and b) Lafia, Awe and Keana local government areas

2.2. Sample collection

Forty-five salt samples were collected from fifteen different sources. Three samples from each source were collected. Only three brands of refined salts (Dangote, Mr Chef, and Royal Salt) were found in Awe, Keana and Lafia market. Thus, nine refined salts were collected from the three brands (three different batches of each brand were analyzed). Three unbranded industrial salt samples (usually sold openly on wheelbarrows or plastic containers) were collected from three different vendors in Lafia markets (MK1). Thirty unrefined locally processed salt samples were collected from ten different salt production sites at Awe salt mine (Angwan Kaw, Angwan Kaw2, Angwan Marina, Angwan Marke, Angwan Pada, Angwan Rogo, Angwan Waje, Angwan Sarkin Gishiri, Bakin Abu, Gangaren Bitrus). Then, three unrefined locally processed salt samples were collected from the salt production site at Keana salt mine. The samples were collected using well-sterilized plastic containers. In practice, 100 g of salts were collected from five miners at each location and blended to create a composite sample. Three samples were collected at each location, with an interval of one week to ensure complete exhaustion of the raw materials used during the salt production by the miners. The GPS coordinates of the sampling points collected using Google Map in Samsung Galaxy A12 are presented in Table 1. The samples were coded, as shown in Table 1.

Table 1- Coded samples and coordinates of the sampling areas

Sample Name	Sample code	Latitude	Longitude
Refined Salt Samples			
Dangote salt	RFS1	8.490902	8.526751
Mr. Chef salt	RFS2	8.490750	8.526400
Royal salt	RFS3	8.490644	8.526169
Unrefined Salt Samples			
Awe LGA			
Angwan Kaw	Ad1	8.099603	9.132200
Angwan Akaw 2	Ad2	8.100493	9.133509
Angwan Marke	Ad3	8.103415	9.134109
Angwan Mirna	Ad4	8.100246	9.130885
Angwan pada	Ad5	8.101844	9.129910
Angwan Sarkin Gishiri	Ad6	8.100923	9.130584
Angwan Rogo	Ad7	8.102539	9.134354
Angwan Waje	Ad8	8.102350	9.133940
Bakin Abu	Ad9	8.101177	9.128481
Gangaren Bitrus	Ad10	8.100756	9.129710
Keana LGA			
Keana salt village	Ak1	8.137173	8.793428
Lafia Main Market			
Market salt	Mk1	8.490325	8.526851

2.3. Sample preparation

Each sample was air-dried for 24 h at room temperature, crushed, and sieved through a number 20 mesh. The required portions were weighed and stored in labeled plastic bottles.

2.4. Physicochemical analysis

2.4.1. Moisture content

A 10 g portion of the salt sample was weighed using a pre-dried and pre-weighed watch glass. It was heated at 150-200 °C for 2 h, then cooled in a desiccator and weighed until two successive weighing agreed within 0.05 g. The flask was frequently shaken to ensure that the sample dried uniformly. Equation 1 was used to calculate the percentage of moisture [16]:

$$\text{Moisture (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \qquad \text{Equation 1}$$

Where W_1 is the initial mass of the sample, and W_2 is the final mass of the sample.

2.4.2. Water-insoluble matter

A 10 g of sample was weighed into a 250 ml beaker, and 200 ml distilled water was added at room temperature. The mixture was left for 30 min with regular stirring. Then, it was filtered through a weighted Gooch crucible containing asbestos material and dried at 110 °C. The residue was transferred to a Gooch crucible using 50 ml distilled water until a few drops of $AgNO_3$ solution produced only mild opalescence in 10 ml of filtrate. The crucible and its content were dried at 110 °C. The weight of the Gooch crucible and its contents were recorded as water-insoluble matter, and the result was given as percent on a water-free basis [16].

2.4.3. Acid-insoluble matter

A 10 g of sample was treated with 200 ml HCl, and the solution was heated at 101 °C for 2-3 min. Then, it was left for 30 min with regular stirring. It was filtered through a Gooch crucible and dried at 110 °C. The residue was washed followed by drying at 110 °C, cooling, and weighing. The result was expressed in percentage [16].

2.4.4. Sodium chloride

A 30 g portion of the sample was weighed into a 100 ml volumetric flask. The sample was diluted with distilled water and neutralized with 15 ml of 0.1 N sodium hydroxide solution, using phenolphthalein as indicator. The final solution was transferred to a 250 ml volumetric flask, made up to volume, agitated, and filtered. An aliquot of the solution was titrated with 0.1 N $AgNO_3$ solution. About 1 ml of aqueous potassium chromate solution (5%) was used as indicator for titration. The amount of $AgNO_3$ solution necessary to generate a reddish-brown endpoint color was recorded. A blank titration was performed using the same amount of distilled water as the sample aliquot [17].

1000 ml of AgNO3 solution (1 N) = 1 g mole of sodium chloride = 58.45 g

$$\text{NaCl}(\%) = \frac{58.45(V_2 - V_3)N \times V}{10 \times V_1 \times W} \quad \text{Equation 2}$$

Where, V (m) is the volume made up, V_1 (ml) is the volume taken for titration, V_2 (ml) is the volume of $AgNO_3$ solution required for the sample titration, V_3 (ml) is the volume of $AgNO_3$ required for the blank titration, N is normality of $AgNO_3$ solution, and W is weight (g) of the sample.

2.5. Elemental analysis

2.5.1. Iodine

A 10 g portion of the sample was weighed into a 50 ml volumetric flask, and the flask was made up with distilled water. The solution was shaken vigorously, and treated with 1 ml of concentrated sulfuric acid and 5 ml of 10% potassium iodide. The flask was kept in darkness for 10 min. The solution was then treated with a small amount of starch solution, which turned the solution dark blue (nearly black). The final solution was titrated with a 0.005 N solution of sodium thiosulfate. To determine the iodine content of the sample, the volume of sodium thiosulfate solution required to titrate the sample was multiplied by 10.58, yielding the iodine concentration in mg/kg.

2.5.2. Other minerals

The collected samples were analyzed for different quality parameters, including trace elements. Exactly 0.5 g of each sample was digested using 5 ml of concentrated HNO_3 and 2 ml of concentrated $HClO_4$. After digestion, the sample was diluted to 50 ml with deionized water. Then, 1 ml of aliquot was diluted to 10 ml with deionized water in a volumetric flask. Concentration of the elements in the samples were measured in triplicate using inductively coupled plasma-mass spectrometry (Elan600 Spectrometer, Perkin Elmer, Canada), and the results presented as mg/kg.

3. Results and discussion

3.1. Physicochemical characteristics

3.1.1. Moisture content

The moisture content of the analyzed salt samples is shown in Table 2. Moisture of the refined salt samples ranged from 0.060% ±0.018 to 0.133% ±0.049, while it was in the range of 0.599% ±0.213 to 2.574% ±0.993 in the unrefined salt samples. It was observed that the moisture contents of the unrefined samples were higher than those of the refined salts. It could be attributed to the exposure to humidity, absence of anticaking agent, and unprofessional packaging of the unrefined salts [18]. Furthermore, the moisture content of all refined salts was below the NAFDAC limit of 1%. In comparison, the moisture content of most of the unrefined salts was above the NAFDAC regulatory limit [7]. It leads to short-term shelf life, lump formation, and poor stability of iodine in the unrefined salts [19, 20]. The moisture content of refined salts in this study are below the values of 0.417%, 0.609%, and 0.649% reported by Usman and Filli [21] for Dangote, Royal, and Mr Chef salts, respectively.

Table 2- Physicochemical characteristics of the salt samples

S/N	Sample ID	Sample Name	Moisture (%)	Water insoluble matter (%)	Acid insoluble matter (%)	Sodium chloride (%)
	Refined salt samples					
1	RFS1	Dangote	0.060±0.018	0.444±0.002	0.089±0.003	99.160±1.045
2	RFS2	Mr Chef	0.084±0.0280	1.163±0.005	0.141±0.044	98.313±2.538
3	RFS3	Royal salt	0.133±0.049	0.629±0.053	0.113±0.005	98.737±4.142
Mean			0.092±0.032	0.745±0.020	0.114±0.017	98.737±2.241
Range			0.060-0.133	0.444-1.163	0.089-0.141	98.313-99.160
	Unrefined salt samples					
1	Ad1		0.948±0.338	4.151±0.019	0.575±0.006	97.889±1.376
2	Ad2		0.599±0.213	10.190±0.045	1.092±0.002	92.380±0.225
3	Ad3		1.551±0.526	6.516±0.028	0.664±0.103	92.803±5.897
4	Ad4		1.625±0.530	9.298±0.041	1.103±0.007	94.499±0.375
5	Ad5		2.574±0.993	4.358±0.019	0.467±0.001	96.194±1.087
6	Ad6		1.432±0.489	1.314±0.005	0.932±0.202	95.770±2.325
7	Ad7		1.792±0.599	4.868±0.021	1.013±0.003	90.685±3.175
8	Ad8		0.907±0.308	7.723±0.042	0.976±0.000	91.532±2.754
9	Ad9		1.613±0.502	3.913±0.017	1.021±0.319	98.737±4.663
10	Ad10		1.024±0.325	6.516±0.031	0.372±0.001	99.160±4.255
11	Ak1		0.708±0.225	8.814±0.048	1.011±0.000	94.922±6.869
12	Mk1		1.094±0.367	8.023±0.035	0.867±0.003	93.227±2.750
Mean			1.322±0.451	6.307±0.0293	0.675±0.054	94.817±2.979
Range			0.599-2.574	1.314-10.190	0.372-1.103	90.685-99.160
(NAFDAC, 2019)			1.0 max.	0.1 max.	0.1 max.	97 min.

3.1.2. Water insoluble matter

Water insoluble matter are substances that cannot dissolve in water such as cellulose and lignin. Its amount in salt determines the stability of iodine in the salt [19]. The amount of water insoluble matter in the refined and unrefined salts ranged from 0.444 to 1.163%, and 1.314 to 10.190%, respectively (Table 2). These levels were above the NAFDAC threshold of 0.1% for both refined and unrefined salts [7]. On the other hand, amount of water insoluble matters in the unrefined salts were higher than the refined salts. It might be due to the exposure of the unrefined salts to dust, sand, and ash particles from the production equipment and unskilled handling during the packaging process [21]. Usman and Filli [21], Abrar et al. [22], and Kirabira et al. [23] similarly reported a high level of water insoluble matter (> 0.1%) in Mr. Chef, unrefined rock salt deposits, and solar evaporated salts, respectively.

3.1.3. Acid insoluble matter

Acid insoluble matter refers to the amount of impurities in the salt that are unable to dissolve in acid [16]. Table 2 shows the levels of acid insoluble matter in the refined and unrefined salts. Accordingly, the levels in the refined salts were than those in the unrefined salts. It was included to 0.089% ±0.003 to 0.141% ±0.044, and 0.372% ±0.001 to 1.104% ±0.017 in the refined and unrefined salts, respectively. Only the refined sample of RFS1 (Dangote) showed the level within the NAFDAC maximum permissible limit of 0.1% (i.e., 0.089% ±0.003) [7], and all of the other refined and unrefined salts had the acid insoluble matter above the NAFDAC threshold [7]. Interestingly, the levels in the refined salts were slightly higher than the threshold, while those of the unrefined salts were significantly higher than the NAFDAC threshold. It might be attributed to the ionic impurities especially in the unrefined samples [24], or might be related to dust, sand, and ash which settled on the salts during packaging and manufacturing processes [21].

3.1.4. Sodium chloride

Sodium chloride (NaCl) regulates the water content in the body, but higher intake may cause health problems including high blood pressure [25]. Table 2 shows that there were considerable differences in the NaCl content of the refined and unrefined salt samples. The average NaCl content of the refined salts was higher than that of the unrefined salts. The NaCl contents of the refined salts were more than 98%, and RFS1 (Dangote) showed the highest NaCl content of 99.16%. All of the refined salts had NaCl content above the minimum value of 97%, as determined by NAFDAC [7]. NaCl content of the unrefined salts ranged from 90.685% ±3.175 to 99.160% ±4.255. It was observed that only three (i.e., Ad1, Ad9, and Ad10) out of twelve unrefined salts met the NAFDAC minimum requirement of 97% [7]. It could be due to the poor manufacturing techniques [24]. Usman and Filli [21], and Attique et al. [26] reported a similar NaCl content of > 98% for selected refined salts in Nigeria and Pakistan, respectively. NaCl content of 95.22% was reported in the rock salt sample from Assale, Ethiopia [27].

3.2. Minerals

Normal functioning of the human body requires trace quantities of essential elements. However, these elements may become toxic if consumed in excess concentrations [28]. The level of essential elements was determined in the refined and unrefined salt samples and result are presented in Table 3.

3.2.1. Iodine

Iodine is an essential micronutrient that is not synthesized by the human body but is required by the thyroid gland to produce thyroid hormones including tetraiodothyronine (thyroxine, T4) and triiodo-thyronine (T3). These hormones regulate the cell metabolism [29].

Table 3 showed that iodine levels were significantly higher in the refined salt samples than the unrefined salts. The iodine levels varied from 22.22 ±0.53 to 40.20 ±2.1 mg/kg, and below than limit to 6.35 ±0.06 mg/kg in the refined and unrefined salt samples, respectively. Iodine levels in the household edible salts were within the NAFDAC permitted range (15-30 mg/kg) [7]. However, only RFS2 (Mr Chef) (with the highest iodine level of 40.20 ±2.1 mg/kg) had iodine level that met NAFDAC requirement of 30-50 mg/kg [7]. The high iodine level in the refined salts was due to the iodization of the salts during the production process [21]. The result of this study on iodine level for the refined salts is in agreement with the reports on refined salts by Usoro et al. [30], and Usman and Filli [21]. All the unrefined salts had iodine levels far below the NAFDAC minimum requirement for edible salt [7]. It may be attributed to the poor iodine stability in the unrefined salts due to the high water insoluble matter [31], high moisture content, poor packaging and storage conditions, and high levels of impurities in the salt [19]. Ekott and Etukudo [32] reported that low iodine levels are often the result of inadequate iodization machinery. The low iodine levels in the unrefined salts suggest that they may not be suitable for use as table salts. Table salt is one of the major sources of iodine to the body, and insufficient or lack of iodine in the human body causes mental retardation and a range iodine deficiency disorder [5]. Severe deficiencies of iodine cause cretinism, stillbirth, and miscarriage, and mild deficiency can significantly affect the learning ability of individuals [33]. Even a moderate deficiency, especially in pregnant women and infants, lowers their intelligence by 10 to 15 IQ points [34]. However, these unrefined salts are consumed by low-income residents in Awe and Keana, and are also sold in neighboring towns and villages.

Table 3- Concentration (mg/kg) of essential elements

	Iodine	Ca	K	Mg	Na
Sample ID			Refined Salt Samples		
RFS1	22.22±0.53^{f}	3.43±0.48^{b}	1.71±0.10^{b}	3.54 ± 0.16^{e}	383,878.30 ± 5,808.20^{g}
RFS2	40.20±2.10^{g}	4.79±0.01^{c}	3.75±0.35^{d}	4.37 ± 0.39^{f}	342,463.90 ± 36.80^{d}
RFS3	25.39± 3.32^{f}	4.61±0.73^{c}	2.99±0.16^{c}	2.68 ± 0.17^{d}	380,268.40 ± 261.40^{g}
Mean	29.27±1.98	4.28±0.40	2.82±0.21	3.53 ± 0.24	368,870.20±2035.47
Range	22.22–40.20	3.43–4.79	1.71–3.75	2.68 - 4.37	342,463.90–383,878.30
			Unrefined Salt Samples		
AD1	BDL	ND	ND	0.48 ± 0.04^{a}	364,927.20± 5,579.10^{ef}
AD2	6.35±0.06^{de}	ND	ND	1.14 ± 0.14^{bc}	325,207.70± 6,102.90^{bc}
AD3	2.12±0.08^{a}	ND	ND	0.55 ± 0.02^{ab}	338,635.80 ± 112.40^{cd}
AD4	4.23±0.01^{b}	0.03±0.04^{a}	ND	0.31 ± 0.38^{a}	325,722.30± 5,091.00^{bc}
AD5	3.17±0.13^{ab}	0.04±0.00^{a}	0.06±0.00^{a}	0.20 ± 0.02^{a}	303,095.40 ± 3,590.8^{a}
AD6	2.12±0.00^{a}	ND	0.11±0.16^{a}	0.59 ± 0.04^{ab}	374,391.20± 7,566.10^{fg}
AD7	4.23±0.57^{b}	0.39±0.02^{a}	0.09±0.04^{a}	0.49 ± 0.02^{a}	320,032.40 ± 688.70^{b}
AD8	2.12±0.04^{a}	ND	ND	0.25 ± 0.01^{a}	337,939.80± 2,093.00^{cd}
AD9	5.29±1.05^{bc}	ND	ND	0.49 ± 0.04^{a}	360,634.70 ± 282.60^{ef}
AD10	2.12±0.00^{a}	0.06±0.00^{a}	0.06±0.00^{a}	0.08 ± 0.01^{a}	352,448.50± 4,277.90^{de}
AK1	5.29±0.04^{bc}	0.06±0.01^{a}	5.23±0.46^{c}	1.38 ± 0.12^{c}	364,715.70 ± 28.30^{ef}
MK1	2.12±0.22^{a}	0.17±0.01^{a}	1.32±0.06^{b}	0.08 ± 0.00^{a}	322,715.70 ± 3,889.20^{b}
Mean	3.27±0.18	0.06±0.00	0.58±0.08	0.53 ± 0.08	314,229.53±3275.17
Range	BDL–6.35	ND–0.17	ND–5.23	0.08 – 1.38	303,095.40–374,391.20
NAFDAC [7]	30 min.	3000 max.		3000 max.	
F		133.91	228.50	147.95	81.51
P		<0.001	<0.001	<0.001	<0.001

*The means with different superscript letters are significantly different in the columns (P < 0.05).
****** ND = not detected, BDL= below detection limit

3.2.2. Calcium

Calcium (Ca) is an important mineral that plays a vital role in the human body including bone and teeth formation, as well as regulation of nerve and muscle function [35]. Ca levels in the refined and unrefined salts ranged from 3.43 to 4.79 mg/kg, and not detected to 0.17 mg/kg, respectively (Table 3). The refined salts showed significantly higher Ca levels than all the unrefined salts. It might be due to the probable use of Ca salts (such as calcium aluminosilicate, calcium carbonate, calcium silicate, etc.) as anticaking agent during the processing of the refined salt. However, Ca levels in both the refined and unrefined salts were not above the NAFDAC recommended maximum level of 3000 mg/kg [7]. It was in agreement with the report by Muhammad and Filli [24] for Ca levels in refined and unrefined salts in Nigeria. Ca was not detected in five out of twelve unrefined salts, and there was no significant difference in the level of Ca detected in seven of the unrefined salts. Deficiency in Ca can lead to dental problems in both children and adults, while excess Ca can negatively affect cardiac activity and results in respiratory and cardiac failure [36].

3.2.3. Potassium

In trace quantities, potassium (K) plays a crucial role in regulating acid-base balance, fluid balance, muscle contraction, and nerve conduction [35]. However, high levels of K in the bloodstream can lead to a condition called hyperkalemia [37]. Table 3 indicates that the K levels in the refined salts were higher than the unrefined salts (with the exception of the salt sample AK1 from Keana). This could be ascribed to the use of potassium iodide in the fortification of table salt during processing. The K levels ranged from 1.71 to 3.75 mg/kg, and ND to 5.232 mg/kg in the refined and unrefined salt samples, respectively. There was a significant difference between the K levels in the refined salts and unrefined salt samples from Awe. K was not detected in six unrefined salts from Awe, and very low K levels were obtained in the remaining four unrefined salt samples from Awe. The unrefined salt from Keana (AK1) showed the highest K level among all the salt samples. It might be attributed to the geography of the area the salt sample was obtained from. Tan et al. [38] similarly reported low K levels in table salt.

3.2.4. Magnesium

Magnesium (Mg) plays an important role in the human body since it activates many enzymes involved in energy metabolism, DNA synthesis, and protein metabolism [35]. Mg has a calming effect, and improve the neural function of the elderly [39].

NAFDAC recommends a maximum level of 3000 mg/kg for (Mg) in table salt [7]. The refined salt samples had higher Mg levels than the unrefined salt samples. It suggests the possible use of mg salt (e.g., magnesium oxide, magnesium carbonate, etc.) as an anticlumping agent during the processing of refined salts. Mg levels ranged from 2.68 ±0.17 to 4.37 ±0.39 mg/kg, and 0.079 ±0.003 to 1.38 ±0.08 mg/kg for the refined and unrefined salt samples, respectively (Table 3). Thus, Mg levels in all the analyzed salt samples were within the NAFDAC permissible limit [7]. Similar findings were reported by Muhammad and Filli [24], and Siulapwa and Mwambungu [37] for refined and unrefined salts. High concentration of Mg in food is mostly associated with mild diarrhea and rarely causes hypotension or muscular weakness [40]. The kidneys have a mechanism for eliminating excess Mg from the body through urine, which limits its toxicity in the human body [41].

3.2.5. Sodium

Sodium (Na) is an indispensable nutrient, and its appropriate amount in the body is critical for the proper cellular functions. It is essential for regulation of osmotic pressure, distribution of body fluids, normal pH, and most metabolic processes [35]. The average Na level in the refined salts exceeds that of the unrefined salts (Table 3). Lugendo and Bugumba [42] reported the Na levels ranging from 155,984-388,040 mg/kg for the unrefined salts extracted from Bahi wetlands in Central Tanzania. However, Wangila et al. [43] reported lower Na levels in indigenous reed commercial salts, ranging from 18,913.6 to 23,855.1 mg/kg. Nwaka and Gregory [44] also reported Na levels of 38,405.0 ±2,200.12 and 36,883.33 ±2,630.38 mg/kg in the refined iodized and locally processed salts, respectively, consumed in Ebonyi state, Nigeria.

4. Conclusion

This study analyzed the physicochemical parameters of the refined table salts and locally processed unrefined salts found in Awe and Keana, Nasarawa State. Results showed that the levels of moisture and impurities were higher in the unrefined salts than the refined salts. All the investigated refined salts have moisture content within the NAFDAC regulatory threshold. Most of the unrefined salts had NaCl content lower than the NAFDAC minimum requirement of 97%. Iodine, calcium, potassium, and magnesium contents were significantly higher in the refined salts compared to the unrefined salts. Iodine contents of all the unrefined salts were below the NAFDAC requirement. We concluded that the locally processed unrefined salts at Awe and Keana salt mines were deficient in essential elements and needed strict monitoring. Thus, good manufacturing and processing techniques are required to improve their quality as table salt.

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6. Conflict of Interest

The authors declare that they have no competing interests.

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