Iodine Content of Branded Iodized Nigerian Table Salt: Ten Years After USI Certification

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ABSTRACT

The present study estimated iodine content of five common branded iodized salts in Nigerian markets to ascertain compliance with Universal Salt Iodization (USI) at retail level after ten years. The study also derived iodine formula for estimating iodine content in salt for easy nutrition applications. Qualitative detection of iodide ions in salts were by tetraoxosulphate (VI) acid, oxidation, and silver nitrate tests. Iodate ions in 20% iodized salt solution was by iodometric titration. An iodine formula for iodine content was derived from the average titer volume and titrimetric equations for iodate ions. According to the results, only oxidation method was able to detect iodide ions in all salt samples. The derived Iodine formula was $I_{2_{SALT}} = V_{Na2S2O3}\ X\ M_I$*, (where,* I_{2SALT} *is amount of iodine in ppm,* $V_{Na2S2O3}$ *is volume of thiosulphate and* M_I *is iodine factor =* $10.58333\frac{ppm}{ml}$*). Based on the derived iodine formula, the amount of iodine in the assessed branded salts ranged from 38.45 to 49.57 ppm with an average of 43.71 ppm. The present study revealed continuous compliance of 30 ppm iodine in Nigerian retail common salts. The derived iodine formula is simple, self-explanatory and useful for iodine estimates using iodometric titration in laboratories.*

Keywords: Branded iodized salts, iodine, iodine formula, iodometric titration,

INTRODUCTION

Iodine is an essential micronutrient that is not synthesized by human body but required by the thyroid gland to produce thyroid hormones, tetraiodothyronine (thyroxine, T4) and triiodothyronine (T3) for regulation of cell metabolism, that is, conversion of oxygen and calories to energy. Insufficient or lack of iodine in the human body causes series of diseases known as iodine deficiency disorder (IDD) and is the single cause of preventable mental retardation. Severe deficiencies of iodine cause cretinism, stillbirth and miscarriage and mild deficiency can significantly affect the learning ability of populations. Even a moderate deficiency, especially in pregnant women and infants, lowers their intelligence by 10 to 15 IQ points [1].

The research results of Marine and Kimball [2] for complete effectiveness of iodine as a goiter prophylactic and salt as vehicle of its consumption in USA stimulated and reinvigorate the successful formulation of iodized salts, globally. Since then, iodized salts have been the main mainstay of treating iodine deficiency, globally. Commonly used forms of iodine include potassium iodate, potassium iodide, sodium iodate, and sodium iodide. Each of these forms of iodine offers the body the needed T4 and T3 hormones by the thyroid gland. Salt producers are a key partner in combating IDD today. IDD has been recognized as a public health problem in Nigeria as far back as five decades [3, 4, 5]. The entire landscape of Nigeria predisposes the country to IDD because of its proximity to the equator and the long months of rainfall ranging from April to November, perhaps, resulted into high cations and anions in drinking water as linked to endemic goiter in Plateau State, Nigeria [6, 7]. Data from 1988 found total goiter rate (TGR) of 67% in endemic states, which dropped sharply to 10.6 % in 1998 and 0.0% in 2005 due to adoption of USI [8, 9].

In 1992, Standard Organization of Nigeria (SON) mandated that all food grade salt be iodized with 50 ppm potassium iodide at packaging stage, and revised with inclusion of 30 ppm at distributor and retail levels, and > 15 ppm iodine at household level [10, 11]. In 2002, an official multi-sectorial IDD-USI Task Force was established with the support of UNICEF Nigeria and it coordinates the multi-sectorial range of partner institutions to routinely monitor the market place through product registration, surveillance and inspection activities. In addition, consultation meetings and workshops, and public education and social marketing activities ensure communications among partners and sustain awareness. Also, in the same, 2002, the Nigerian government launched its National Food and Nutrition Policy, underscoring its determination to improve the well-being of its populace with set targets, which included reduction of micronutrient deficiencies by 50% by 2010, and 30% reduction in severe and moderate malnutrition among under-fives by 2010 [8].

Consequently, the Nigeria's Health Sector has made tangible progress and achieved significant successes in mitigating the large-scale losses of brain-power and productivity caused by IDD. Virtually all Nigeria's newborns were protected against the mental impairment arising from the absence of iodine, in adequate quantity, in the diet. Not only has Nigeria been 'put on the map' in the world, for achieving Universal Salt Iodization (USI), it became the benchmark for other nations needing to and aiming for the same feat [6, 12]. With this success, Nigeria was given a USI certificate and global recognition for USI compliance in 2007 [13].

Since USI certification in 2005 and the formal recognition of the efforts of the Nigerian government in 2007, financial support for the IDD program decreased on the part of the government and donors. The usual quarterly and annual monitoring of iodized salt at the factory, wholesale, retail and household levels became irregular and sporadic. Without the needed quality control and assurance by government regulatory agencies, manufacturers and marketers also became complacent and failed to comply with the mandatory iodization standard. An outcome of this situation was a significant decline in the household consumption of adequately iodized salt, from 98 percent in 2003 to 52 percent in 2008 [14].

In lieu of the above justification, the present study evaluated the iodine content of iodized salts available in Nigerian markets to ascertain continuous implementation of USI regulations at retail level, ten years after USI recognition.

MATERIALS AND METHODS

Chemicals and Reagents

Iodine antiseptic solution, 3% hydrogen peroxide (H_2O_2), white vinegar, laundry starch solution, nitric acid (HNO_3), silver nitrate solution ($AgNO_3$), ammonia solution (NH_3), saturate bromine water, sodium sulphite (Na_2SO_3), methyl orange, phenol solution, 2M tetraoxosulphate (VI) (H_2SO_4), 10% potassium iodide (KI), sodium thiosulphate solution ($Na_2S_2O_3$) and distilled water (H_2O). All reagents were of analytical grade and purchased from a registered Vendor in Nigeria while distilled water was prepared in Chemical Sciences Laboratory, Tai Solarin University of Education, Ijebu-Ode, Nigeria.

Salt Samples

Five branded iodized **s**alt samples were purchased at local markets from Ijebu-Ode with replications from Abeokuta and Ibadan, and inclusion of two imported samples purchased in a popular shopping mall, Shoprite, Ibadan. The branded salt samples names were appropriately relabeled. There were three replicates per city, making a total of nine replicates per a brand of iodized sample except the imported salts that had three replicates

Qualitative test for Iodine in salt

Three qualitative tests were employed for comparison and identification of most suitable

Concentrated tetraoxosulphate (VI) test: conc**.** H_2SO_4 was added to 1 g salt sample in a 1.5 ml Eppendorf tube and observed for color change.

Silver nitrate test: A gram of salt sample was dissolved in dil. H_2O in a clean 1.5 Eppendorf tube and few drops of dil. HNO_3 was added, followed by addition of few drops of $AgNO_3$ with observation of color change, after which, few drops of dil. was added followed by excess solution.

Oxidation test: A positive control test of starch solution was first prepared by diluting 2.5 ml starch with 120 ml dil. H_2O in a 250 ml plastic beaker and several drops of iodine antiseptic solution was added and mixed thoroughly and color change was observed. For test samples, 80 g of salt sample was dissolved in 200 ml of dil. H_2O made up to 250 ml and mixed thoroughly and 15 ml of vinegar was added to the salt solution followed by addition of 15 ml 3% H_2O_2 and 2.5 ml starch solution, the mixture was stirred and left for color change.

Quantitative determination of iodine in salt by iodometric titration

The procedure followed thiosulphate titrimetry of Manaar and Dunn [15] with modifications, iodate was first extracted, and free iodine was liberated and then quantified by standardized sodium thiosulphate titration.

Extraction of iodate ions: Twenty percent (20%) concentration of salt sample solution was prepared by dissolving 50 g salt sample in 200 ml double distilled water and made up to 250 ml in a conical flask and stirred very well till a clear solution was obtained**.** 50 ml of the 20% salt sample solution was titrated with 2M H_2SO_4 using methyl orange as indicator till a pink coloration appeared. Thereafter, bromine water was added drop wise to obtain a yellow solution, and left to stand for 5 min, after which 1% sodium sulphite solution was added drop wise until the solution turned pale yellow. Finally, phenol solution was added drop wise till a clear solution was obtained to remove any bromide ions.

Liberation of free iodine: 1 ml of 2M H_2SO_4 was added to the above solution to liberate iodine followed by 5ml 10% KI solution to solubilized the liberated iodine, the solution turned yellow to indicate presence of iodide ions. The resulting colored solution was kept in dark cupboard for 10 min to avoid oxidation before titration step.

Determination of iodine and derivation of iodine formula: The salt solution was removed from the dark cupboard after 10 min, and titrated with 0.005N sodiumthiosulphate and 2 ml of starch solution was added as an indicator near end point and titration with thiosulphate continued until the deep blue color formed disappeared and the solution became colourless. The volume of thiosulphate used is equivalent to the amount of iodine in salt according to the titration reaction equations and formula provided below (Eqns. 1, 2, 3, and 4).

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O \quad \text{(Eqn. 1)}$$

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6 \quad \text{(Eqn. 2)}$$

Overall titrimetric equation

$$IO_3^- + 5I^- + 6H^+ + 6S_2O_3^{2-} \rightarrow 6I^- + 3S_4O_6^{2-} \text{ - } \quad \text{(Eqn. 3)}$$

Salt KI H_2SO_4 $Na_2S_2O_3$ NaI $Na_2S_4O_6$

The amount of iodate (g) in salt is calculated using the formula:

$$\frac{C_1V_1}{C_2V_1} = \frac{n_1}{n_2} \quad \text{(Eqn. 4)}$$

……. and in 1g of 20% salt (50 g salt in 250 ml) is calculated as:

$$IO_3^-{}_{SALT} = \frac{C_{Na2S2O3}\ X\ nKIO_3\ X\ V_{Na2S2O3}\ X\ V_{SALT}(250\ ml)\ X\ MmKIO_3}{VKIO_3\ X\ n_{Na2S2O3}\ X\ M_{SALT}} \quad \text{(Eqn. 5)}$$

The amount of iodine in the iodate in ppm (mg/1000g salt) is estimated as:

$$I_{2\,salt} = \frac{Mm_{iodine}}{Mm_{Iodate}}\ X\ IO_3^-{}_{SALT}\ X\ 1000\ mg\ and\ 1000g_{SALT} \quad \text{(Eqn. 6)}$$

Combining Eqns. 5 and 6, where $MmKIO_3$ is also Mm_{iodate}:

$$I_{2_{SALT}} = \frac{Mm_{iodine}\ X\ C_{Na2S2O3}\ X\ nKIO_3\ X\ V_{Na2S2O3}\ X\ V_{SALT}\ X\ 1000\ mg\ X\ 1000g_{SALT}}{VKIO_3\ X\ n_{Na2S2O3}\ X\ M_{SALT}} \quad \text{(Eqn. 7)}$$

As known, all factors in Eqn. 7 are constant except, $V_{Na2S2O3}$ and if all constant factors are combined as single factor, named as Iodine factor, M_I, we have:

$$I_{2_{SALT}} = V_{Na2S2O3} \left[\frac{C_{Na2S2O3}\ X\ nKIO_3\ X\ MmI_{iodine}\ (X\ 1000\ mg)\ X\ V_{SALT}\ X\ X\ 1000g_{SALT}}{VKIO_3\ X\ n_{Na2S2O3}\ X\ M_{SALT}}\right] = V_{Na2S2O3}\ M_I \quad \text{(Eqn. 8)}$$

Where: I_{2SALT} is amount of iodine in salt (ppm), $V_{Na2S2O3}$ is average titer volume of $Na_2S_2O_3$ used up in titration (X ml, unknown), $C_{Na2S2O3}$ is the concentration of $Na_2S_2O_3$ (0.005 N, g/L= 0.005M, mol/L), *nKIO3* is moles of KIO_3 (1 mol), MmI_{iodine}, is the molar mass of Iodine (127 g mol^{--}), V_{SALT}, is volume of salt solution prepared (250 ml = 0.25 L), V_{KIO3} is volume of KIO_3 used for titration (50 ml), $n_{Na2S2O3}$, number of moles of $Na_2S_2O_3$ used up (6 mol), M_{SALT}, mass of salt used (50 g), *$MmKIO_3$* also as Mm_{iodate} is molar mass of iodate (214 g mol^{-1}).

Inputting values for all constant factor, then M_I is estimated as:

$$M_{I=}\left[\frac{0.005\frac{mol}{L}\ X\ 1mol\ X\ 127\frac{g}{mol}(1000\ mg)\ X\ 250\ ml\ (0.25\ L)\ X\ 1000g_{SALT}}{50\ ml\ X\ 6\ mol\ X\ 50g}\right] = 10.58333\ ppm/ml \quad \text{(Eqn. 9)}$$

Therefore:

$$I_{2_{SALT}} = V_{Na2S2O3}\ X\ M_{I=}\ V_{Na2S2O3}\ X\ 10.58333\ ppm/ml \qquad \text{(Eqn. 10)}$$

RESULTS AND DISCUSSION

Qualitative test for five assessed iodized salts consumed in Nigeria (2017)

Table 1 shows tetraoxosulphate (VI) acid test produced a positive test for only a branded imported salt samples while all the local salts were negatives. On oxidation of iodine ions, the local salt samples produced faint black coloration in varying intensity while the imported samples produced purple color for confirmation of iodide ions (Table 2). For silver nitrate test, all the samples, both local and imported showed white precipitate for chloride ions rather than pale yellow precipitate for iodide ions and also their precipitates dissolved in excess ammonia, which is unexpected for iodide ions (Table 3). Among the qualitative tests employed for assessment of iodine content in the assessed branded iodized salts, oxidation with peroxide showed better potential for iodide ion determination than tetraoxosulphate (VI) acid and silver nitrate tests. Therefore, oxidation with peroxide could serve as a quick assay method for qualitative determination of presence of iodine in salts having showed varying color intensity with black for local salts and purple for imported salts. The positive result shown by tetraoxosulphate (VI) acid for only Diamond crystal, might be pointing toward the source of iodine used, for example USA used potassium iodide while Nigeria used potassium iodate [16]. The results obtained at present showed that silver nitrate test perhaps is insensitive at low iodide concentrations as found in the present assessed iodized salts.

Table 1: Tetraoxosulphate (VI) acid test for the five assessed iodized salts consumed in Nigeria (2017)

Test	Observation	Inference	Presence of Iodide
1. Dangote	Steamy white fumes	absent of I^-	Negative
2. Annarpurna	Steamy white fumes	absent of I^-	Negative
3. Mr. Chef	Steamy white fumes	absent of I^-	Negative
4. Diamond crystal	Steamy white fumes with purple vapor and faint red color solution	Presence of I^-	Positive
5. Sebree	Steamy white fumes	Presence of Cl^-, absent of I^-	Negative

Table 2: Oxidation test for the five assessed iodized salt consumed in Nigeria (2017)

Test	Observation	Inference	Presence of iodide ion
Dangote Solution + Vinegar + H_2O_2	Fairly clear solution		
Solution + starch	Faint black coloration	Presence of I^-	positive
Annapurna Solution + Vinegar + H_2O_2	Fairly clear solution		
Solution + starch	Faint black coloration	Presence of I^-	positive
Mr. Chef Solution + Vinegar + H_2O_2	Fairly clear solution		
Solution + starch	Faint black coloration	Presence of I^-	positive
Diamond Solution + Vinegar + H_2O_2	Fairly clear solution		
Solution + starch	Purple solution	Presence of I^-	positive
Sebree Solution + Vinegar + H_2O_2	Fairly clear solution		
Solution + starch	Dark-Purple solution	Presence of I^-	positive

Table 3: Silver nitrate qualitative test for five assessed iodized salts consumed in Nigeria (2017)

Test	Observation	Inference	Presence of I^-
1). Dangote + H_2O	Clear solution	Salt is soluble	
Solution + HNO_3	No color change		
Solution + $AgNO_3$	White precipitate is formed	Cl- is suspected	
Solution + few NH_3	Precipitate dissolved	Cl- suspected	
Solution + excess NH_3	Precipitate dissolved to give white clear solution	Cl- is present No iodide	Negative
2). Mr Chef + H_2O	Clear solution	Salt is soluble	
Solution + HNO_3	No color change		
Solution + $AgNO_3$	White precipitate is formed	Cl^- is suspected	
Solution + few NH_3	Precipitate dissolved	Cl^- suspected	
Solution + excess NH_3	Precipitate dissolved to give white clear solution	Cl^- is present No iodide	Negative
3). Annapurna + H_2O	Clear solution	Salt is soluble	
Solution + HNO_3	No color change		
Solution + $AgNO_3$	White precipitate is formed	Cl^- is suspected	
Solution + few NH_3	Precipitate dissolved	Cl^- suspected	
Solution + excess NH_3	Precipitate dissolved to give white clear solution	Cl^- is present No iodide	Negative
4). Diamond + H_2O	Clear solution	Salt is soluble	
Solution + HNO_3	No color change		
Solution + $AgNO_3$	White precipitate is formed	Cl^- is suspected	
Solution + few NH_3	Precipitate dissolved	Cl^- suspected	
Solution + excess NH_3	Precipitate dissolved to give white clear solution	Cl^- is present I^- is absent	Negative
5). Sebree + H_2O	Clear solution	Salt is soluble	
Solution + HNO_3	No color change		
Solution + $AgNO_3$	White precipitate is formed	Cl^- is suspected	
Solution + few NH_3	Precipitate dissolved	Cl^- suspected	
Solution + excess NH_3	Precipitate dissolved to give white clear solution	Cl^- is present No I^-	Negative

Table 4: Pearson Correlation among volume of thiosulphate used up, iodate and iodine content in iodized salt consumed in Nigeria (2017).

	$Na_2S_2O_3$	Iodate	Iodine
$Na_2S_2O_3$	1	0.999	1
		<.0001	<.0001
Iodate		1	0.999
			<.0001
Iodine			1

Quantitative test and derivation of iodine formula

Potassium iodide test for iodide ions showed positive test with yellow coloration in both the local and imported branded salt samples. Also, addition of starch to produce starch-iodine complex showed positive blue coloration, which turned colorless on titration with thiosulphate ions. Table 4 shows that volume of sodium thiosulphate used up in titration, amount of iodate and iodine in salt are well correlated with one another with high values of R^2 at very high significant levels. Therefore, the present result supports the theory of Manaar and Dunn [15] that volume of thiosulphate used up corresponds to the amount of iodine in the salt and also corroborates well with derived equations (Eqns. 8 to 10). The equation 10, $I_{2_{SALT}} = V_{Na2S2O3}\ X\ M_{I=}\ \ V_{Na2S2O3}\ X\ 10.58333\ ppm/ml$, derived corroborates well with Manaar and Dunn [15] conversion Table for iodine and also the formula used by Fardousi [17]. Some factors used in Fardousi formula, such as 6 for atom of iodine are confusing and derivatization of Manaar and Dunn's Table [15] was not known. The present derived equation 10 is clear, simple, well understood from its chemical equations, robust and useful for direct estimation of iodine from volume of thiosulphate used up in any titrimetric method in salts.

The results obtained at present showed that the iodometry method is sensitive, robust and still remains a useful method for quantifying iodine in salts. Iodometric titration was referred to as the "gold standard" analytical method recommended for factory quality assurance and quality control and research studies [18]. Titrimetric method of iodine can achieve 0.1% absolute accuracy with a relative standard deviation (RSD) of just 0.2%, showing high precision for the measurement [18, 19]. In addition, the SE and CV obtained at the present employed thiosulphate titration (Table 5) is comparable to that of ICP-MS [20], showing its competitive efficiency to estimate iodine in salts as successful established in decade years [21]. It was also reported to have a precision between 2 to 5%. However, its use is limited to the laboratory for it is not practical for many small fortification facilities and field use in salt surveys [18, 22]. Analytical tool such as the inductive coupled plasma mass spectrometry (ICP-MS) is more widely acceptable and apply for easy use, convenience, time saving and mobility [20, 23] and a UV-Spectroscopic method is recently developed [24].

Iodine content of assessed five branded iodized salt consumed in Nigeria (2017)

Based on Eqn. 10 as estimated results shown in Fig. 1, Sebree iodized salt had the highest level of iodate and iodine and Dangote iodized salt had the least among the assessed iodized salts. Similar results were previously reported for Dangote and Mr. Chef iodized salts [25]. The results revealed higher level of iodine in imported salt over local salts. According to Table 5, the standard deviation (SD) and error (SE) are very minimal, taking a proportion of about 1.0 and 0.5%, indicating good precision that tends towards accuracy and as previously mentioned comparable to values obtained using ICP-MS [20]. The present amount of iodine detected by volumetric thiosulphate titration in the five assessed iodized salts commonly consumed in Nigeria are well above 30 ppm stipulated for retail salts by USI regulation. We could say "there is 100% adequacy" of iodine in retail salt in Nigeria. Therefore, regulation of iodized salt is still effective in Nigeria after ten years of recognition by USI.

Similar studies showed compliance across the globe [17, 26]. Also, studies showed effective salt iodization programs that cover the iodine requirements of all population groups, including pregnant and lactating women, infants and toddler [27, 28, 29]. Nevertheless, some parts of some regions still show non-compliance in level of iodine in iodized salt at retail level resulting in high level of IDD in their communities, for example Asia [30, 31] so also in rural and urban of Jalisco, Mexico [32]. Limited availability and use was also discovered in Volta region of Ghana and Laelay Maychew District in Northern Ethiopia [33, 34, 35]. Similar reports in USA claimed inadequacy in about 53% of assessed iodized salt in 2008 and Saudi Arabia [20]. In addition, estimated daily intake was reported to be underestimated if food groups were taken into consideration in addition with consumed iodized salt [36, 37].

Table 5: Precision measures for volume of thiosulphate used up, iodate and Iodine content of iodized salt consumed in Nigeria (2017).

Variable	***Mean***	***SD***	***SE±***	***CV***	***Range***	***Min***	***Max***	***N***
Annapurna								
Vol. $Na_2S_2O_3$, mL	3.83	0.05	0.02	1.35	0.1	3.8	3.9	6
Iodate, ppm	68.67	1.03	0.42	1.5	2	68	70	6
Iodine, ppm	40.57	0.55	0.22	1.35	1.06	40.22	41.27	6
Dangote								
Vol. $Na_2S_2O_3$, mL	3.65	0.05	0.02	1.5	0.1	3.6	3.7	6
Iodate, ppm	65.9	0.11	0.04	0.17	0.2	65.8	66	6
Iodine, ppm	38.63	0.58	0.24	1.5	1.06	38.1	39.16	6
Mr Chef								
Vol. $Na_2S_2O_3$, mL	3.77	0.05	0.02	1.37	0.1	3.7	3.8	6
Iodate, ppm	67.33	1.03	0.42	1.53	2	66	68	6
Iodine, ppm	39.86	0.55	0.22	1.37	1.06	39.16	40.22	6
Diamond								
Vol. $Na_2S_2O_3$, mL	4.63	0.05	0.02	1.11	0.1	4.6	4.7	6
Iodate, ppm	82.67	1.03	0.42	1.25	2	82	84	6
Iodine, ppm	49.04	0.55	0.22	1.11	1.06	48.68	49.74	6
Sebree								
Vol. $Na_2S_2O_3$, mL	4.7	0	0	0	0	4.7	4.7	6
Iodate, ppm	84	0	0	0	0	84	84	6
Iodine, ppm	49.74	0	0	0	0	49.74	49.74	6

SD, Standard deviation; SE, Standard error; CV, Coefficient of variation

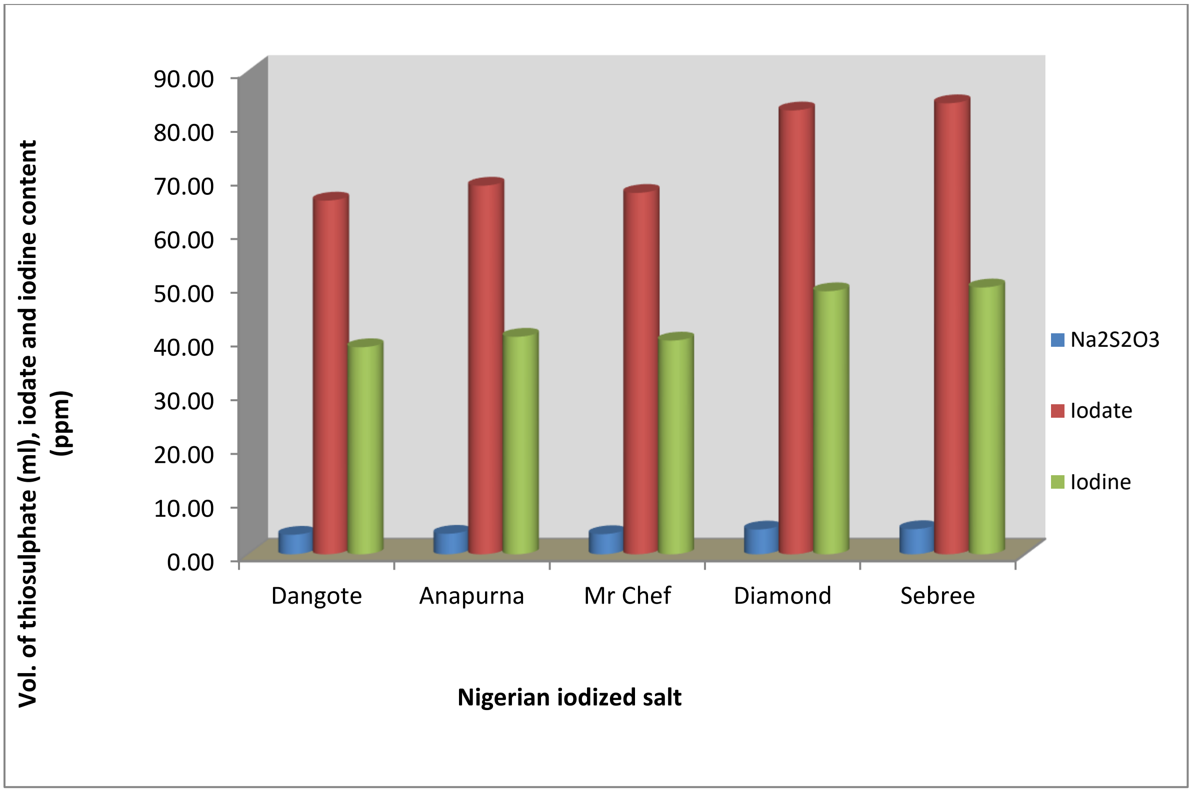

Figure 1: **Mean volume of thiosulphate, amount of iodate and iodine content in five assessed branded iodized salt consumed in Nigeria (2017).**

Variation of thiosulphate volume, iodate and iodine among salt samples

Table 6 provides the estimates of ANOVA based on general linear model and the results show highly significant difference among the five iodized salt for titer volume of thiosulphate used up in iodometric titration, estimated amount of iodate and iodine content of the assessed salts. The results showed a marked variation in iodine content among the branded iodized salt used across Nigeria. The non-significant variation among the replicates is an indication of high precision in the process of titrimetric method used. Significant variation in iodine content among iodized salt is no news and has been reported for decades and also variation was established with storage and processing and over time.

Table 6: Summary estimates of ANOVA for titer volume of thiosulphate, iodate and iodine content among the five assessed iodized salts consumed in Nigeria (2017)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
	Titer Volume of $Na_2S_2O_3$				
Salt	4	6.17	1.54	625	***
Rep	5	0.0057	0.0011	0.46	ns
R-Square	**CV**	**RMSE**	**Mean**		
0.99	1.21	0.05	4.12		
	Amount of Iodate				
Salt	4	1879.2	469.80	627.18	***
Rep	5	1.079	0.22	0.29	ns
R-Square	**CV**	**RMSE**	**Mean**		
0.99	1.17	0.87	73.71		
	Amount of Iodine				
Salt	4	691.17	172.54	625.36	***
Rep	5	0.63	0.13	0.46	ns
R-Square	**CV**	**RMSE**	**Mean**		
0.99	1.21	0.52	43.57		

***, significant at p<0.0001; ns, not significant at p<0.05

CONCLUSIONS

The results obtained at present corroborate sensitivity of iodometry method and its relevance in laboratory for determination of iodine content of salts. The iodine formula derived ($I_{2_{SALT}} = V_{Na2S2O3}\ X\ M_{I=}\ \ V_{Na2S2O3}\ X\ 10.58333\ ppm/ml$) is robust and applicable in quantifying iodine in any salt type in laboratories. The amount obtained also showed that the importer and Nigerian manufacturing companies are cooperating well with Nigerian government in ensuring that the Nigerian populace, especially the children and pregnant women, have adequate access to iodized salts as at 2017, ten years after recognition as USI compliant. Though, there is further need for monitoring and evaluation.

REFERENCES

1. United Nations International Children's Emergency Fund (UNICEF). The American Thyroid Association Symposium. USA. October **2007**.

2. Kenneth J. C., Journal of Nutrition, 135 (4), (2005) 675, https://doi.org/10.1093/jn/135.4.675

3. Ekpechi, O. L., Brit, J. Nutr. 21 (3), (1967) 537
4.
5. Ekpechi, O. L., in Hetzel B. S., Dunn J. T, and Stanbury J. B., eds. *The Prevention and Control of Iodine Deficiency Disorders*, P. 291 *Elsevier*, UK, 1987.

6. WHO/UNICEF/ICCIDD, Review of findings from 7-country study in Africa on levels of salt iodization in relation to iodine deficiency disorders, including iodine induced hyperthyroidism. P. 39, World Health Organization, Geneva. 1997.

7. Egbuta, J., Onyezil, F., and Vanormelingen, K., Public Health Nutrition 6(2), 2003, 169

8. Das, S. C., Isichei, U. P., Egbuta, J. O., and Banwo, A. I., Tropical and Geographical Medicine**,** 41 (1989) 346.

9. UNICEF-Nigeria. Universal Salt Iodization in Nigeria - Processes, successes and lessons, P. 25. UNICEF-Nigeria, Abuja. 2005.

10. World Health Organization (WHO). WHO Global Database on Iodine Deficiency-Nigeria. 2007. Access 20th Dec. 2017. http://www.who.int/nutrition/publications/micronutrients/iodine_deficiency/9241592001/en/

11. Nigeria Industrial Standards (NIS). Agriculture and Food Technology-Law Nigeria. **1992**

12. Nigeria Industrial Standards (NIS). Agriculture and Food Technology-Law Nigeria. **1994**

13. United Nations International Children's Emergency Fund (UNICEF). UNICEF/Micronutrient Deficiency, Damage Assessment Report for Nigeria, 2004. UNICEF, UK,

14. Intellectual Development Disorders (IDD). IDD Newsletter, 32 (**2009)**

15. Intellectual Development Disorders (IDD). *IDD Newsletter*. 37 (**2010)**.

16. Mannar M. G. V., and Dunn, J. T. ICCIDD/MI/UNICEF/WHO

publication, P. 133. Netherland. 1995.

17. Aburto, N. J., Abudou, M., Candeias, V., and Wu, T. WHO eLibrary of Evidence for Nutrition Actions (eLENA). P. 151, WHO, Geneva. **2014**.

18. Fardousi, M. B. Sc. Dissertation, East West University, Bangladesh. **2012**.

19. Myers, N. M., Strydom, E. E., Sweet, J., Sweet, C., Spohrer, R., Dhansay, M. A., Lieberman, M. Nanobiomedicine 3, (**2016)**, 5.

20. Stratton, S. W. Circ. Bur. Stand., 40, (**1912)**, 1.

21. Dasgupta, P. K., Liu, Y., and Dyke, J. V. Environ. Sci. Technol., 42(4), **2008**, 1315.

22. Drobnik, M., and Latour, T. Rocz. Panstw. Zakl. Hig. Polish 49 (2), **1998**, 169.

23. Yusufali, R., Garrett, G. S., and Locatelli-Rossi, L. Recommendations for iodine content measurement methods in salt iodization programs, p2798. IUNS 20th International Congress of Nutrition, Granada, Spain, **2013**.

24. Spohrer, R., Knowles, J., Jallier, V., Ndiaye, B., Indorf, C., Guinot, P., and Kupka, R. Ann. N.Y. Acad. Sci. 1357, **(2015)** 43.

25. Garcia-Arrona, R., Arranz, M., Bordagaray, A., and Millán, E. Journal of Laboratory Chemical Education, 5(2), (**2017)**, 26

26. Ombugus, W. M., and Matthew, M. O. International Journal of Scientific and Research Publications, 5 (11), (**2015)**, 454.

27. Rajabi, R. M. Sc. Thesis, P. 78. An-Najab National University, Nabitus, Palestine **2016**

28. Yusuf. H. K. M., Rahman, A. K. M., Chowdhury, F. P., Mohiduzzaman, M., Banu, C. P., Sattar, M. A. and Islam, M. N. Asia Pac. J. Clin. Nutr., 17 (4), (**2008)**, 620.

29. Wu, T., Liu, G. J., Li, P., and Clar, C. Iodized salt for preventing iodine deficiency disorders (Review). Cochrane Database of Systematic Reviews Issue 3. 2002, p22 Art. No.: CD003204. The Cochrane Collaboration. John Wiley & Sons Ltd. **2009**.

30. Zhang, H., Lv, S. Mu, Z., Li, W., Zhang, X. Wang, Y., and Shannon, R. British Journal of Nutrition, 114, (**2015)**, 126.

31. Ahmad, N., Panthari, M., Gupta, A., and Chandra, P. *International*

Journal of Health Sciences & Research 2(9), (**2012)**, 25.

32. Pandav, C. S., Yadav, K., Srivastava, R., Pandav, R., and Karmarkar, M. G. Indian J. Med. Res., 138, (**2013)**, 418.

33. Guajardo, A. Honors Theses, P. 47. College of Saint Benedict and St. John's University. Jalisco, Mexico. **2015**. http://digitalcommons.csbsju.edu/honors_theses/99.

34. Gidey, B., Alemu, K., Atnafu, A., Kifle, M., and Tefera, Y. J. Nutr. Health Sci. 2(1), (**2015)** 103.

35. Nicholas, A. S., Appiah, K. P., Ahiabor, S. Y., Asalu, A. G., Takramah, K. W., and Kweku, M. Central African Journal of Public Health. 2 (1), (**2016)**.

36. Tweneboa, M. M. Ph. Dissertation, P. 68. University of Ghana, Ghana, **2015,**

37. Haldimann, M., Alt, A., Blanc, A., and Blondeau, K. Journal of Food Composition and Analysis, 18, (**2005)** 461.

38. Watutantrige-Fernando, S., Barollo, S., Bertazza, L., Sensi, F., Cavedon, E., Censi S., Veronese, N., Ceccato, F., Vianello, F., Boscaro, M., Nacamulli, D., Camozzi, V., and Mian, C. J. Nutrition Health Food Sci., 5(1), **(2017)**, 1.