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Iodine Concentration of Iodized Salts Consumed in Harper

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Abstract

This study determined concentrations of iodine, consistent with WHO iodine fortification standards, in commercial edible salts mostly consumed in Harper. The following hypothesis was put forward in the research study; H_1: the iodine content of the two brands of iodized salts is different from the WHO iodine fortification levels; H_0: the iodine content of the two brands of iodized salts is not different from the WHO iodine fortification levels. The hypothesis was tested in MS Excel 2010 and 2016 via the T-Test function giving p-value = 0.1476 and p-value = 0.0395 indicative of no significant difference in the iodine concentration of the salts compared with the lower limit of WHO standard 20 mg·Kg^{-1} and huge contrast in the iodine concentration of the salts compared with the upper limit of WHO standard 40 mg·Kg^{-1} respectively. The UV spectrophotometric method was used to analyze and measure the iodine concentration in the twelve (12) samples of two different brands bought from grocery stores in Harper city. Results indicated that all samples of the two (2) brands of iodized salts contained iodine of no significant difference relative to the lower limit of WHO standard but far below the upper limit of the WHO standard. The study therefore recommends monitoring of commercial iodized salts by appropriate authorities in Harper to ascertain the WHO iodization fortification standards before reaching consumers.

Keywords

Harper, Iodized Salt, Potassium Iodate, Potassium Iodide, Spectrophotometric, Thyroid Function

1. Introduction

Common salt is an edible chemical substance that serves usually as food additive in most delicacies and basically as food preservative; it is chemically referred to as a normal salt with a formula *NaCl*, sodium chloride, in its solid state (crystalline form).

The thermodynamic properties with numerical values of this compound (*NaCl*) at 1-bar pressure and 25˚C in the physical state (solid or crystalline) are thus: change in standard enthalpy of formation (ΔH°_{f} = −411.15 kJ·mol^{-1}), change in standard Gibb's free energy of formation (ΔG°_{f} = −384.14kJ·mol^{-1}), standard entropy (S° = 72.13 JK^{-1}·mol^{-1}), standard heat capacity at constant pressure (C°_{p} = 50 JK^{-1}·mol^{-1}). This physical property also attracts its wide use domestically [1]. For the salt to be appreciably soluble, the free energy, ΔG°, should be negative, where $\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$ [2]. Most of foods with the exception of those from the marine environment are devoid of significant amounts of iodine. Salts, including sea salt contain iodine naturally to trace [3]. Iodized salt is table salt mixed with a minute amount of various salts of the element iodine. Edible salt can be iodized by spraying it with a potassium iodate or potassium iodide solution. Fifty seven (57) grams of potassium iodate are required to iodize a ton of salt [4]. Iodized salt is salt that contains small amounts of sodium iodide or potassium iodide [5]. Four inorganic compounds are used as iodide sources, depending on the producer: potassium iodate, potassium iodide, sodium iodate, and sodium iodide. Any of these compounds supplies the body with its iodine required for the biosynthesis of thyroxine (*T*4) and triiodothyronine (*T*3) hormones by the thyroid gland. Animals also benefit from iodine supplements, and the hydrogen iodide derivative of ethylenediamine is the main supplement to livestock feed [6]. Thyroid hormones regulate many important biochemical reactions, including protein synthesis and enzymatic activity, and are critical determinants of metabolic activity. They are also required for proper skeletal and central nervous system development in fetuses and infants [7]. Thyroid function is primarily regulated by thyroid-stimulating hormone (*TSH*), also known as thyrotropin. It is secreted by the pituitary gland to control thyroid hormone production and secretion, thereby protecting the body from hypothyroidism and hyperthyroidism [7]. The use of potassium iodide and cuprous iodide for salt iodization was approved by the *Food and Drug Administration* [8]. The World Health Organization recommends the use of potassium iodate due to its greater stability, particularly in warm, damp, or tropical climates. Salt that is iodized with iodide may slowly lose its iodine content by exposure to excess air over long periods [9]. An opened package of table salt with iodide may rapidly lose its iodine content through the process of oxidation and iodine sublimation [10]. Additionally, iodine is an unstable product which sublimes slowly at room temperature. A hot and humid climate is a factor contributing to the impoverishment of food iodized salts [11]. The ingestion of iodine prevents iodine deficiency. Worldwide, iodine deficiency affects about two billion people and is the leading preventable cause of intellectual and developmental disabilities. At the World Summit for Children in 1990, a goal was set to eliminate iodine deficiency by 2000. At that time, 25% of households consumed iodized salt, a proportion that increased to 66% by 2006 [4]. A 2017 study found that the introduction of iodized salt in 1924 raised the IQ for the one-quarter of the population most deficient in iodine. The study also found "a large increase in thyroid-related deaths following the countrywide adoption of iodized salt, which affected mostly older individuals in localities with high prevalence of iodine deficiency" [12]. Salt producers are often, although not always, supportive of government initiatives to iodize edible salt supplies. Opposition to iodization comes from small salt producers who are concerned about the added expense, private makers of iodine pills, concerns about promoting salt intake, and unfounded rumours that iodization causes AIDS or other illnesses [4]. Median urinary iodine concentrations of 100 - 199 μg/L in children and adults, 150 - 249 μg/L in pregnant women and >100 μg/L in lactating women indicate iodine intakes are adequate [13]. Women who restrict their dietary salt intake also have lower urinary iodine concentrations and might be more likely to be iodine deficient than women who don't restrict salt intake [14]. A median urinary iodine concentration of 150 - 249 mcg/L indicates adequate iodine nutrition during pregnancy, while values less than 150 mcg/L are considered insufficient [13]. If a person's iodine intake falls below approximately 10 - 20 μg/day, hypothyroidism occurs [7]. The use of iodized salt is the most widely used strategy to control iodine deficiency. Iodine status is typically assessed using urinary iodine measurements. Urinary iodine reflects dietary iodine intake directly because people excrete more than 90% of dietary iodine in the urine [15]. To provide 150 μg daily requirement of iodine for each person, the salt iodine concentration at the point of production should be 20 - 40 mg per 1 kg of iodized salt [16].

Iodine deficiency has multiple adverse effects on growth and development, and is the most common cause of preventable intellectual disability in the world [17]. Historically, iodine deficiency was endemic in mountainous regions of the United States and Mexico, and in the so called "goiter belt" around the Great Lakes [18]. Currently, about 88% of household worldwide use iodized salt, but iodine insufficiency is still prevalent in certain regions, particularly Southeast Asia, sub-Saharan Africa, and Eastern Europe [19]. In South Africa, direct and indirect evidence of continued endemic goiter and iodine deficiency led, in 1995, to the introduction of mandatory iodization of table salt at an iodine concentration of 40 - 60 ppm. Salt iodization had previously been voluntary. As in other African countries, the regulations require potassium iodate to be used for this purpose. After the introduction of mandatory iodization, increased iodine concentrations were reported in retailed salt and the iodine status of primary-school children improved [20]. However, there continued to be shortcomings in the accuracy of salt iodization. There was considerable variation in the iodine content of retailed salt, and evidence of endemic goiter and iodine deficiency persisted in some areas [21].

A relevant question required by this study was put forward as; what is the proportion of iodine content in the different brands of iodized salts relative to WHO iodine fortification levels? Hence the hypothesis was H_1: the iodine content of the two brands of iodized salts is different from the WHO iodine fortification levels; H_0: the iodine content of the two brands of iodized salts is not different from the WHO iodine fortification levels. Liberia consumes iodized salt of different brands; in this study location, Harper, two major brands of iodized salts are usually consumed which include the "bridgeway" and "toboggi" (**Figure 3**), major source of iodine among others, as such this research paper was required to determine the iodine content in each brand consistent with global or WHO standards to meet dietary need of consumers in Harper.

2. Materials and Method

2.1. Description of Study Area

Latitude 4.3782 and longitude −7.71081
4.3782˚N 7.7108˚W
4˚22'41.5"N 7˚42.649'W

Figure 1. Harper, Liberia Geographic coordinates.

Figure 2. Satellite map of study area.

2.2. Sample Site and Sample Collection

Specific brands of iodized salt, noting the expiration date, frequently consumed were bought from recognized grocery stores in Harper, a coastal city, as indicated in **Figure 1** and **Figure 2**.

Six bags, two hundred (200 g) grams, each of "Bridgeway" and "Tobbogi" brands of iodized salts (**Figure 3**) served as samples under study. The samples were separated in different holders, protected from tearing and taken to the laboratory. In the laboratory these sample were marked for easy identification according to brand name as follows; BIS1, BIS2, BIS3, BIS4, BIS5, and BIS6 for "Bridgeway" iodized salt, also TIS1, TIS2, TIS3, TIS4, TIS5, and TIS6 for "Tobbogi" iodized salt. Hence a total of twelve samples for the two brands of iodized salt were analyzed in this research study.

2.3. Chemicals and Equipment

Reagents used in the analysis are potassium iodate (KIO_3), sodium hydroxide

($NaOH$), sodium chloride ($NaCl$), sodium thiosulphate ($Na_2S_2O_3 \cdot 5H_2O$), potassium iodide (KI) and acids. All reagents used were of analytical reagent grade; distilled water was also used throughout in the analysis of the samples. Measurements were carried out using Nano UV-Spectrophotometer (**Figure 4**).

2.4. Preparation of Standard Solutions

The following solutions were used in the spectrophotometric procedures:

Solution 1:

0.214 g of the primary standard potassium iodate (dried in an oven to 110˚C) was made up to 100 mL in a volumetric flask in order to obtain a 0.0100 mol·L^{-1} solution. This solution was diluted in order to obtain a final standard iodate solution of 1.000×10^{-5} mol·L^{-1} to be used in the calibration curve.

Solution 2:

5.00 g of sodium chloride were made up to a volume of 50 mL.

Solution 3:

3.32 g of potassium were made up to a volume of 10 mL, including 1 mL of 0.1 mol·L^{-1} sodium hydroxide.

Solution 4:

11.4 g of phosphoric acid (85%) were made up to a volume of 100 mL to obtain a 1.0 mol·L^{-1} solution.

Figure 3. Iodized Salts Samples used.

Figure 4. Nano UV-Spectrophotometer (microdigital).

Solution 5 (Blank 1 solution):

2.0 mL of solution 2 plus 1.0 mL solution 4 were made up to a volume of 10 mL in a volumetric flask.

Solution 6A (Sample solution):

About 1 g of the salt was made up to a volume of 25 mL, for checking homogeneity of the product.

Solution 6B (Sample solution):

About 100 g of the salt were made up to 500 mL for analyzing the average iodate content, and comparing of methods.

Solution 7 (Blank 2 solution):

5 mL of solution 6A or 6B plus 1.0 mL solution 4 were made to a volume of 10 mL in a volumetric flask.

2.5. Method/Procedure (Determination of Iodine Content in Salt)

Spectrophotometric method was employed for analysis of the samples in this research study.

The spectrophotometric method based on the chemical oxidation of iodide to iodate, formation of iodine to iodide complexes and measurement of absorbance of the complexes in near ultraviolet (λ = 288, 352 nm) is well-known among the photometric methods for the determination of iodide [22].

Procedure 1 (Calibration curve):

4 mLof the standard iodate solution (1.000×10^{-5} mol·L^{-1}) were pipetted into 10 mL volumetric flask with 1 mL of solution 3, 2.0 mL of solution 2 and finally 1 mL of phosphoric acid. The volumes were made up and the absorbance at 352 nm versus the blank solution 5 were measured

Procedure 2 (Sample analysis):

5 mL of solution 6A and 6B and 1 mL solution 4 were made up to 10 mL. Absorbance at 352 nm versus blank 2 (solution 7) containing the same salt solution were measured.

C is the concentration of potassium iodate or iodine in mg·Kg^{-1} of salt and was calculated by the following formula:

$$C = \frac{1000AWV_1V_3}{b\varepsilon V_2 m} \quad (1)$$

where A is the absorbance at 352 nm wavelength with corresponding molar absorptivity ε, W is the mole of potassium iodate, 214.0 g or the mole of iodine, 126.9 g, b is the light path, 1cm; m in grams is the sample of salt weighed out and made up to a V_1, mL volumetric flask (solutions 6A and 6B) V_2 is the volume of 5 mL pipetted into the V_3 volumetric flask (10 mL) in order to prepare the working solution.

3. Results and Discussion

Tables 1-3 are indicative of spectrophotometric analysis results of the twelve samples (n = 12) of two different brands (**Figure 3**) used in this study; "tobbogi"

Table 1. Iodine content in "tobbogi" iodized salt samples.

Sample identification n = 6	Wavelength (nm)	Absorbance	Concentration (ppm)
TIS1	352	0.41620	22
TIS2	352	0.41620	22
TIS3	352	0.41620	22
TIS4	352	0.41620	22
TIS5	352	0.41620	22
TIS6	352	0.41620	22

Table 2. Iodine content in bridgeway' iodized salt samples.

Sample identification n = 6	Wavelength (nm)	Absorbance	Concentration (ppm)
BIS1	352	0.22034	26
BIS2	352	0.22034	26
BIS3	352	0.22034	26
BIS4	352	0.22034	26
BIS5	352	0.22034	26
BIS6	352	0.22034	26

Table 3. Summary of Spectrophotometric analysis results of iodine concentration in salt samples.

Sample identification	No. of samples (n)	Wavelength (nm)	Absorbance	Concentration (ppm)
TIS	06	352	0.41620	22
BIS	06	352	0.22034	26

P value = 0.1476; P value = 0.0395.

iodized salt (TIS) 50% of the samples (n = 6) and "bridgeway" iodized salt (BIS) 50% of the total number of samples (n = 6) bought from recognized shops in Harper.

The results showed that all twelve samples of the two brands of edible iodized salt have iodine concentration that is between the iodine fortification levels of 20 - 40 mg·Kg^{-1} in accordance with WHO standard. Data from Table 1 and Table 2 indicated 22 ppm and 26 ppm iodine concentration of "Tobbogi" and "bridgeway" iodized salt (Figure 3) samples respectively, hence there were no statistically significant difference between these concentrations and the recommended lower limit of iodine fortification level of 20 mg·Kg^{-1} (P = 0.1476) (14.76%) in accordance with T-Test; however these results further expressed that there was statistically significant difference in the iodine concentrations of both brands of iodized salts in question and the recommended upper limit of iodine fortification of 40 mg·Kg^{-1} (P = 0.0395) (3.95%) with respect to T-Test. This therefore implies the iodine concentrations of the two brands of edible iodized salt as reported were far below the value of the upper limit of WHO iodine fortification required value.

An opened package of table salt with iodide may rapidly lose its iodine content through the process of oxidation and iodine sublimation [10], as such based on the iodine content in the two brands of salts under study, there is a likelihood of reduction in their iodine content which might be due to poor handling via exposure to sunlight by consumers in Harper. Additionally it was also expressed that iodine is an unstable product which sublime slowly at room temperature. A hot and humid climate is a factor contributing to the impoverishment of food iodized salts [11]. Hence all of these conditions will lower the minimum dietary intake of iodine as required by consumers in Harper and such will leave the consumers susceptible to pathogenic conditions and this is in accordance with the statement as which indicated that, if a person's iodine intake falls below approximately 10 - 20 µg/day, hypothyroidism occurs [7]. Also iodine deficiency has multiple adverse effects on growth and development, and is the most common cause of preventable intellectual disability in the world [17].

4. Conclusion

All twelve samples of the two brands, "bridgeway" and "Tobbogi", commercial edible iodized salt products contained iodine concentrations in forms of iodate and iodide. These products have iodine concentrations between the lower and upper limits (20 - 40 mg·Kg^{-1}) of WHO iodine fortification levels. This implies that the iodine concentration of the products is slightly above the lower limit (20 mg·Kg^{-1}) and far below the upper limit (40 mg·Kg^{-1}) of WHO iodine fortification levels; subsequently there is need for monitoring of these products by the Liberian bureau of standard in collaboration with health authorities in order to ascertain normal iodine concentrations of edible iodized salts consistent with WHO standard in routine manner before reaching consumers in Harper for especially health reasons. Therefore, the determination of iodine concentrations in edible iodized salts in Harper for compliance with the recommended iodine fortification level is of primordial importance.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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