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Comparative Assessment of Iodine Content of Commercial Table Salt Brands Available in Nigerian Market

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Abstract Iodine deficiency disorders (IDD) has been a major global public health problem threatening more than 2 billion people worldwide. Considering various human health implications associated with iodine deficiency, universal salt iodization programme has been recognized as one of the best methods of preventing iodine deficiency disorder and iodizing table salt is currently done in many countries. In this study, comparative assessment of iodine content of commercially available table salt brands in Nigerian market were investigated and iodine content were measured in ten table salt brands samples using iodometric titration. The iodine content ranged from 14.80 mg/kg – 16.90 mg/kg with mean value of 15.90 mg/kg for Sea salt; 24.30 mg/kg – 25.40 mg/kg with mean value of 24.60 mg/kg for Dangote salt (blue sachet); 22.10 mg/kg – 23.10 mg/kg with mean value of 22.40 mg/kg for Dangote salt (red sachet); 23.30 mg/kg – 24.30 mg/kg with mean value of 23.60 mg/kg for Mr Chef salt; 23.30 mg/kg – 24.30 mg/kg with mean value of 23.60 mg/kg for Annapurna; 26.80 mg/kg – 27.50 mg/kg with mean value of 27.20mg/kg for Uncle Palm salt; 23.30 mg/kg – 29.60 mg/kg with mean content of 26.40 mg/kg for Dangote (bag); 25.40 mg/kg – 26.50 mg/kg with mean value of 26.50 mg/kg for Royal salt; 36.80 mg/kg – 37.20 mg/kg with mean iodine content of 37.0 mg/kg for Abakaliki refined salt, and 30.07 mg/kg – 31.20 mg/kg with mean value of 31.00 mg/kg for Ikom refined salt. The mean iodine content measured in the Sea salt brand (15.70 mg/kg) was significantly $P < 0.01$ lower compared to those measured in other table salt brands. Although the iodine content of Abakaliki and Ikom refined salt exceed the recommended value, it is clear that only Sea salt brand falls below the World Health Organization (WHO) recommended value (20 – 30 mg/kg), while the remaining table salt samples are just within the range. The results obtained have revealed that 70 % of the table salt brands were adequately iodized while 30 % of the table salt brands were not adequately iodized and provided baseline data that can be used for potential identification of human health risks associated with inadequate and/or excess iodine content in table salt brands consumed in households in Nigeria.

Keywords: *iodine content, consumable salt, iodine disorder, iodine validation*

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1. Introduction

Iodine is one of the most essential trace elements or micronutrient required at all stages of human life; foetal development and early childhood being the most critical phases of requirement. It is required during the synthesis of thyroid hormone, which play a determining role in the process of the early growth and development of most organs, especially human brain during foetal and early post-natal life [1,2]. It is widely known that 60 % of iodine in the human body is stored in the thyroid gland. Iodine deficiency has important consequences for mental development, intellectual capacity and growth, particularly in children [3,4,5]. Most recent estimate states that globally over two billion people are adversely affected by iodine deficiency [6]. Iodine is essential for good health; it is an essential component of thyroid hormone, thyroxin and triiodothyronine which are important in regulation of the basal metabolic rate. Inadequate iodine leads to insufficient production of hormone resulting in adverse effect of many part of the body, especially the muscle, heart, lungs, kidney and brain development [7]. However, hypertension and hypothyroidism is a typical disorder of adult life that has been associated with iodine deficiency disorder. According to Kapil [1], it is known that the healthy human body contains 15 – 20 mg of iodine and iodine deficiency remains the main cause of preventable brain damage as well as mental retardation around the world.

During the 1990 World Summit for Children (WSC), an initiative of United Nations Children's Fund (UNICEF) held in September 1990 at the United Nation (UN) in New York, eliminating iodine deficiency was recognized as one of the most achievable of the goals set for the year 2000 [8,9,10]. It is widely known that iodine deficiency which occurs at different stages of life in a given population often leads to series of functional and developmental abnormalities such as Iodine Deficiency Disorders (IDD), abortion, stillbirth, congenital abnormalities, cretinism, goitre and impaired mental function [11,12,13,14]. Considering the various associated human health implications, compulsory iodization of table salt at 20 mg/kg to 60 mg/kg was introduced in 1995 and remarkable improvement in both process and impact indicator of iodine deficiency and endemic goitre have been reported over the years [11,14,15]. According to Zimmermann et al. [14], introduction of iodized salt to chronic iodine-deficiency disorders might transiently increase the proportion of thyroid disorders in the populations, but overall the small risks of iodine excess are far outweighed by the substantial risks of iodine deficiency. It has been reported that addition potassium iodide to table salt is considered the best method for providing iodine to iodine–deficient populations [16,17,18]. Over the years, universal salt iodization (USI) is the recommended strategy for fortification of food-grade salt with iodine for the prevention and control of iodine deficiency disorders [19,20].

Salt iodization which has been implemented at large scale in many countries is among the most cost effective and sustainable interventions to counter iodine deficiency and its disorders. The compound used for iodization determines the stability of iodine after processing [21] and basically, potassium iodate (KIO_3) and potassium iodide (KI) are usually utilized during iodization process. Potassium iodate (KIO_3) is more stable under adverse climate conditions compared to potassium iodide (KI). It is also less soluble than iodine and less likely to oxidize from the bag. The iodate breaks down more rapidly in the human body and effectively delivers iodine to thyroid gland for synthesis of thyroid hormone [2,22]. The high solubility of potassium iodide enables dispersion by atomized spray on the dry crystal [21]. Although potassium iodide (KI) in salt is not very stable because it can be easily lost by oxidation to iodine and there are various factors that affect iodized salt. Some of these factors include high moisture, humidity or excessive aerated environment, exposure to sunlight, exposure to heat, acidic reaction in the salt, presence of impurities and damped packaging materials. Salt iodization has been mandatory since 1993 and Nigeria is among the countries that have succeeded in achieving and sustaining high levels of salt iodization coverage from < 40 percent in 1993 to 95 percent or higher (from 1998 to 2004). The national iodization and eradication of iodine deficiency disorders has been made possible through the joint effort of Federal Ministry of Health and National Agency for Food and Drugs Administration and Control (NAFDAC) [23]. Nigeria was certified for sustained universal salt iodization (USI) compliance level of 95 % to 98 % in 2005 [24,25]. Although important progress in reducing iodine deficiency and its disorders has been made in the past two decades [11], there is a dire need for routine external quality control monitoring surveys on the salt production processes in order to ensure compliance with regulations and to check if the salt is iodized at the required level.

There are different methods used to measure iodine in salt [26,27,28,29] and some of these methods include ion-pair high pressure liquid chromatography, rapid test kits, potentiometric method, spectrophotometric method, inductively coupled plasma mass spectrometry and iodometric titration. Iodometric titration is the most widely used method to determine quantities of iodine in salt samples because of its accuracy, precision, ease of operation and cost effectiveness [27-32]. This method is recommended at various levels of a distribution system and also recommended for quality control testing. Quantitative iodine measurements in salt are typically done in laboratories situated at salt iodization plants for internal quality control and external quality control as well as national monitoring surveys are often carried out in governmental laboratories, academic or research institutions [29]. Therefore, this research study is aimed at evaluating the iodine content of commercially available iodized salt consumed in every household in Nigeria and estimate the level of compliance with set standards as well as the percentage of table salt brands that are adequately iodized.

2. Materials and Methods

2.1. Materials

The chemicals and reagents used for the iodometric titration analyses were of analytical grade. The chemicals/ reagents used were: 0.005 M sodium thiosulphate ($Na_2S_2O_3.5H_2O$), stored in a dark bottle; 2 M tetraoxosulphate (vi) acid, (H_2SO_4); 10 % Potassium iodide, stored in a dark bottle; 1 % starch solution and boiled deionized water, stored in an airtight container.

Ten (10) different commercially available table salt brands used in this study were obtained in Nigerian markets. The different brands of table salt sampled were: Sea salt, Blue – sachet Dangote iodized salt, Red – sachet Dangote iodized salt, Mr Chef iodized salt (sachet), Annapurna iodized salt, Uncle Palm iodized salt (sachet), Dangote Salt (bag), Royal Salt (bag), Refined Salt (Abakaliki) and Refined Salt (Ikom).

2.2. Analytical Procedure

Salt iodometric titration was carried out by the standard procedure and guidelines of the Association of Official Analytical Chemist [33]. Ten grams (10 g) of salt was dissolved in 50 ml of distilled water. During the analysis, 1 ml of 0.5 M H_2SO_4 acid and 5 ml of 10% Potassium Iodide was added in sequence with the help of a laboratory pipette. After keeping the solution in dark for 10 minutes, it was titrated against 0.005 N Sodium Thiosulphate. Two (2) ml of starch solution was added when the solution became pale yellow. Titration was continued till the solution became colourless. Iodine content in salt was estimated by extrapolation after measurement of the titre value.

The iodine content of iodized salt determination follows a two-step reaction mechanism as described by De Meayer et al. [34]:

Reaction I: The liberation of free iodine from the Salt.

It consists of addition of tetraoxosulphate (vi) acid (H_2SO_4) to liberate free iodine from the iodate in the salt sample. The addition of excess potassium iodide (KI) helps to solubilize the free iodine which is quite insoluble in pure water under normal condition.

$$KIO_3 + 5KI + 3H_2SO_4 \rightarrow 3K_2SO_4 + 3I_2 + 3H_2O.$$

Ionic equation.

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O.$$

Reaction II: Titration of free iodine with sodium thiosulphate solution.

Free iodine is consumed by sodium thiosulphate in the titration step. The amount of thiosulphate used is proportional to the amount of iodine liberated from the salt.

$$2Na_2S_2O_3 + I_2 \rightarrow 2NaI + Na_2S_4O_6.$$

The titration was achieved with constant stirring using the magnetic stirrer. The iodine content was extrapolated from the Codex standard chart, based on the titre value [35,36].

3. Results and Discussion

World Health Organization has mandated that commercial salt should have an average of 50 ppm of iodine [9] and in order to ensure that commercially available table salt brands in Nigerian market have the required level of iodine, an assay has been developed in order to monitor iodine contents of different salt samples. The iodine content of the different salt brands available in the Nigerian market is presented in Table 1. The iodine content ranged from 14.80 mg/kg – 16.9 mg/kg with mean value of 15.90 mg/kg for Sea salt; 24.30 mg/kg – 25.40 mg/kg with mean value of 24.6 mg/kg for Dangote salt (blue sachet); 22.10 mg/kg – 23.10 mg/kg with mean value of 22.40 mg/kg for Dangote salt (red sachet); 23.30 mg/kg – 24.30 mg/kg with mean value of 23.60 mg/kg for Mr Chef salt; 23.30 mg/kg – 24.30 mg/kg with mean value of 23.60 mg/kg for Annapurna; 26.80 mg/kg – 27.50 mg/kg with mean value of 27.20 mg/kg for Uncle Palm salt; 23.30 mg/kg – 29.60 mg/kg with mean content of 26.40 mg/kg for Dangote (bag); 25.40 mg/kg – 26.50 mg/kg with mean value of 26.50 mg/kg for Royal salt; 36.80 mg/kg – 37.20 mg/kg with mean iodine content of 37.00 mg/kg for Abakaliki refined salt, and 30.07 mg/kg – 31.20 mg/kg with mean value of 31.00 mg/kg for Ikom refined salt.

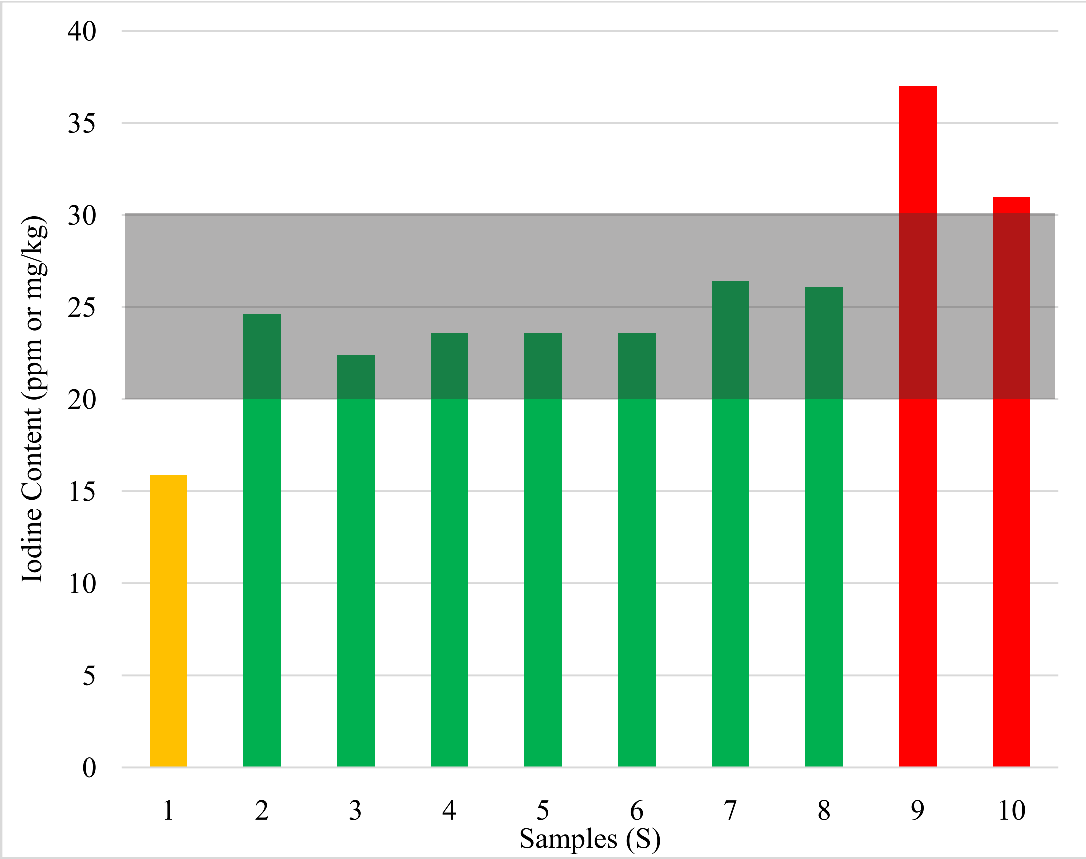
From the results of iodine validation presented in Table 2, Sea salt had the lowest mean iodine content of 15.90 mg/kg ± 1.05 mg/kg while Abakaliki refined salt had the highest mean iodine content of 37.00 mg/kg ± 2.07 mg/kg. The recommended minimum iodine validation requirement in table salt ranged from 20 mg/kg – 30 mg/kg at the retailed shop in order to achieve at least 15 mg/kg in the household dietary consumption [23,30,37]. Comparing the results of the iodine contents determined in the present study, only raw sea salt had a mean iodine content of 15.19 mg/kg less than permissible iodine limit of 20 mg/kg – 30 mg/kg recommended by World Health Organization (WHO) [38]. However, the general low values of the iodine content below the minimum requirement of 50 mg/kg – 60 mg/kg at the production packaging stage may be attributed to poor stability of iodine in salt due to moisture content of the salt, humidity of the atmosphere, bad packaging, impurities in the salt, alkalinity and acidity of the salt and the form in which the iodine is present [31,39].

Table 1. Iodine Content of Different Salt Brands (mg/kg)

S/N	SALT TYPE	First Sampling (mg/kg)	Second Sampling (mg/kg)	Third Sampling (mg/kg)	Mean (X) (mg/kg)	Standard Deviation (mg/kg)	Range (mg/kg)
1.	Sea Salt	14.80	16.90	15.90	15.90	1.05	14.80 – 16.90
2	Dangote (Blue sachet)	25.40	24.30	24.30	24.60	0.64	24.30 – 25.40
3	Dangote (Red sachet)	23.10	22.10	22.20	22.40	0.56	22.10 - 23.10
4	Mr Chef	23.30	24.30	23.30	23.60	0.58	23.30 – 24.30
5	Annapurna	24.30	23.30	23.30	23.60	0.58	23.30 – 24.30
6	Uncle Palm	27.50	26.50	27.50	27.20	0.58	26.50 – 27.50
7	Dangote (measured)	23.30	29.60	26.50	26.40	3.15	23.30 – 29.60
8	Royal Salt	25.40	26.50	26.50	26.10	0.64	25.40 – 26.50
9	Refined salt (Abakaliki)	36.80	37.20	37.00	37.00	0.20	36.80 – 37.20
10	Refined salt (Ikom)	31.20	30.07	31.70	31.00	0.87	30.07 – 31.20

Table 2. Coefficient of Variation and Operating Control Range (OCR) in (mg/kg)

S/N	SALT TYPE	MEAN (X). (mg/kg)	STANDARD DEVIATION (SD) (mg/kg)	COEFFICIENT OF VARIATION (% CV)	OPERATIONL CONTROL RANGE. (OPR) (mg/kg) L_{lower} - U_{upper}
1.	Sea Salt	15.90	1.05	6.60	13.80 – 18.00
2.	Dangote (Blue Sachet)	24.60	0.64	2.60	23.32 – 25.68
3	Dangote (Red Sachet)	22.40	0.56	2.50	23.28 – 23.52
4	Mr Chef	23.60	0.58	2.46	22.44 – 24.73
5	Annapurna	23.60	0.58	2.46	22.44 – 24.73
6	Uncle Palm	23.60	0.58	2.13	26.04 – 28.36
7	Dangote (measured)	26.40	3.15	11.39	20.01 – 32.70
8	Royal Salt	26.10	0.64	2.45	25.12 – 27.38
9	Refined Salt (Abakaliki)	37.00	0.20	0.54	36.60 – 37.40
10	Refined Salt (Ikom)	31.00	0.86	2.87	29.22 – 32.80



S_1 – Sea salt, S_2 – blue sachet Dangote, S_3 - blue sachet Dangote, S_4 – Mr Chef, S_5 – Annapurna, S_6 – Uncle Palm, S_7 – Dangote (measured) salt, S_8 – Royal Salt, S_9 – Refined salt (Abakaliki) and S_{10} - Refined salt (Ikom).

Figure 1. Iodine content (mg/kg)

The graphical representation of the iodine content measured in different commercially available table salt brand samples in this present study is presented in Figure 1. The shaded region shows the WHO permissible range for iodine content at the retail shops and household. From the results, 70 % of the table salt brands were adequately iodized while 30 % of the table salt brands were not adequately iodized. The results showed that S_1 – Sea salt (yellow peak) had low iodine content compared to S_2 to S_8 (green peaks) which showed an array of salt samples that have met the requirement of the World Health Organization (WHO) for salt iodization requirement of iodine contents (20 mg/kg – 30 mg/kg).

Low iodine content measured in S_1 – Sea salt (yellow peak) brand found in Nigerian market is posing a potential human health concern. The measured low iodine content in S_1 – Sea salt (yellow peak) could be attributed to conditions of packaging and storage as well as other factors such as humidity and temperature which might have influenced the final iodine ingredient of the salt. In a study by Abubakar [23], salt–iodine content at the production packaging stage must be within 50 – 60 mg/kg and 20 – 30 mg/kg at the retail shops and/or iodized table salt for household dietary consumption. It is known that adequate iodine intake is essential for thyroid function and as such low iodine content in table salt could pose serious human health implications. Finding from a related study (Amrita Thyroid Survey) carried out in South India have shown that iodine deficiency was significantly higher in subjects with new and known hypertension and this relation merits further evaluation [40].

In this present study, salt samples S_9 and S_{10} (Figure 1) revealed that the mean value for the iodine contents had exceeded the recommended specified concentration for salt iodine contents at the consumption level [37]. It is known that excessive iodine intake could also contribute to thyroid disorders such as development of goitre, subclinical or overt hypothyroidism, and increased auto immune thyroiditis, etc. [41,42,43]. Therefore, a constant monitoring survey of iodine status is essential to maintain the right level of iodization among the population [40]. In a related study, it has been reported that even a cautious iodization of salt accompanied by a moderate increase in the incidence rate of overt hypothyroidism and primarily in young and middle-aged subjects with previous moderate iodine deficiency [42]. The results of this present research support the suggestion that more than 2.2 billion people (> 30 % of the world population) who live in areas with iodine deficiency are estimated to be at risk of iodine deficiency and its associated human health complications [30,44].

4. Conclusions

Iodine content in different brands of commercially available table salt were monitored in this present study and the results showed that some brands of commercially available table salt products in Nigerian market have not met the requirement for total salt iodization. However, for some of the commercial brands, the difference in the iodine content from the specified iodine content by the regulatory agencies has not been significant at the 95 % confidence level by the t-test. In order to combat the problem of iodine deficiency disorders [11], the World Health Organization (WHO) recommended iodization at 50 mg/kg – 60 mg/kg at the point of production and 20 mg/kg – 30 mg/kg iodine content at consumption point [23]. Although salt iodization has remained the long-term strategy adopted by several countries around the world, more future research work should focus on the factors affecting the stability of iodine. It is important to routinely monitor the iodine that is added to salt in order to avoid iodine intakes that are periodically above the recommended levels which causes hypothyroidism and goitre, although the consequences are less devastating than those of iodine deficiency. Therefore, in order to maintain the achievement of Universal Salt Iodization (USI) programme in Nigeria, the Federal Government through relevant government agencies such as the Federal Ministry of Health, National Agency for Food and Drugs Administration and Control (NAFDAC) and the Standard Organization of Nigeria (SON) should monitor the production of commercial salt at the factory level to ensure compliance with the total salt iodization.

References

[1] Kapil, U., “Health Consequences of Iodine Deficiency,” *Sultan Qaboos University Medical Journal,* 7 (3). 267-272, 2007.

[2] Ahad, F., and S. A. Ganie, “Iodine, Iodine metabolism and Iodine deficiency disorders revisited,” *Indian Journal of Endocrinology and Metabolism,* 14 (1). 13-17, 2010.

[3] Zimmermann, M. B., and M. Andersson, “Assessment of iodine nutrition in populations: past, present, and future,” *Nutrition Reviews,* 70 (10). 553-570, 2012.

[4] Steen, R. G., *Human Intelligence and Medical Illness: Assessing the Flynn Effect*, New York: Springer 2009.

[5] Allen, L., and WHO, *Guidelines on Food Fortification with Micronutrients*: World Health Organization, 2006.

[6] Benoist, B. d., E. McLean, M. Andersson, and L. Rogers, “Iodine Deficiency in 2007: Global Progress since 2003,” *Food and Nutrition Bulletin,* 29 (3). 195-202, 2008.

[7] Kenji, G. M., K. K. Nyirenda, and G. C. Kabwe, “Iodine levels in edible salt sold in Malawi, Kenya and Zambia,” *African Journal of Food, Agriculture, Nutrition and Development,* 3 (2). 2003.

[8] Feinstein, A. S., and P. Uvin, *The Hunger Report 1993*: Gordon & Breach Publishing Group, 1994.

[9] Bellamy, C., and UNICEF, *The State of the World's Children 2002*: UNICEF, 2002.

[10] Annan, K. A., and UNICEF, *We the Children: Meeting the Promises of the World Summit for Children*: United Nations Children's Fund (UNICEF), 2001.

[11] WHO, *Indicators for assessing iodine deficiency disorders and their control programmes: Report of a Joint WHO/UNICEF/ICCIDD Consultation, 3-5 November 1992*, World Health Organization, 1992.

[12] Medeiros-Neto, G., “Iodine Deficiency Disorders,” *Thyroid,* 1 (1). 73-82, 1990.

[13] Hetzel, B., “Iodine Deficiency Disorders,” *The Lancet,* 331 (8599). 1386-1387, 1988.

[14] Zimmermann, M. B., P. L. Jooste, and C. S. Pandav, “Iodine-deficiency disorders,” *The Lancet,* 372 (9645). 1251-1262, 2008.

[15] Jooste, P. L., M. J. Weight, and C. J. Lombard, “Iodine concentration in household salt in South Africa,” *Bulletin of The World Health Organization,* 79 (6). 534-540, 2001.

[16] Elias, A. J., *A Collection of Interesting General Chemistry Experiments*: Sangam Books, 2002.

[17] Gislason, S., *Intelligence and Learning*: Environmed Research Inc, 2016.

[18] Johnston, M. V., H. P. Adams, and A. Fatemi, *Neurobiology of Disease*: Oxford University Press, 2016.

[19] Imam, S. K., and S. I. Ahmad, *Thyroid Disorders: Basic Science and Clinical Practice*: Springer International Publishing, 2016.

[20] Pearce, E. N., *Iodine Deficiency Disorders and Their Elimination*: Springer International Publishing, 2017.

[21] Mannar, M. V., and J. T. Dunn, "Salt iodization for the elimination of iodine deficiency," International Council for the Control of Iodine Deficiency Disorders The Netherlands, 1995.

[22] WHO, *Vitamin and Mineral Requirements in Human Nutrition*: World Health Organization, 2004.

[23] Adejo, G. O., and M. Enemali, “100% Salt Iodization in Nigeria: the Lopsided Figure,” *Transnational Journal of Science and Technology,* 3 85-91, 2013.

[24] Lantum, N., "Food and Nutrition Security." pp. 22-24.

[25] R., Y., and T. Matlhafuna, “Universal salt iodization in Africa – the road to overcoming the last hurdles. Micronutrient initiative, 1-8.,” *Micronutrient Initiative* 1-8, 2005.

[26] Preedy, V. R., G. N. Burrow, and R. R. Watson, *Comprehensive Handbook of Iodine: Nutritional, Biochemical, Pathological and Therapeutic Aspects*: Elsevier Science, 2009.

[27] WHO, *Elimination of Iodine Deficiency Disorders: A Manual for Health Workers*, Regional Office for the Eastern Mediterranean: World Health Organization (WHO), 2008.

[28] Khazan, M., F. Azizi, and M. Hedayati, “A Review on Iodine Determination Methods in Salt and Biological Samples,” *Scimetr,* 1 (1). e14092, 2013.

[29] Jooste, P. L., and E. Strydom, “Methods for determination of iodine in urine and salt,” *Best Practice & Research Clinical Endocrinology & Metabolism,* 24 (1). 77-88, 2010.

[30] Diosady, L., J. Alberti, M. V. Mannar, and S. FitzGerald, “Stability of iodine in iodized salt used for correction of iodine-deficiency disorders. II,” *Food and Nutrition Bulletin,* 19 (3). 240-250, 1998.

[31] Wisnu, C., “Determination of iodine species content in iodized salt and foodstuff during cooking,” *International food research journal,* 15 (3). 325-330, 2008.

[32] Sharma, N., A. K. Pillai, N. Pathak, A. Jain, and K. K. Verma, “Liquid-phase microextraction and fibre-optics-based cuvetteless CCD-array micro-spectrophotometry for trace analysis,” *Analytica Chimica Acta,* 648 (2). 183-193, 2009.

[33] Horwitz, W., *Official methods of Analysis of the AOAC International*, The University of Wisconsin - Madison: The Association, 2000.

[34] Maeyer, E., F. Lowenstein, and C. Thilly, *The Control of Endemic Goitre*, Geneva: World Health Organization, 1979.

[35] Commission, C. A., “Codex standard for food grade salt,” *CX STAN,* 150 1-7, 1985.

[36] Commission, C. A., “Codex Standard: standard for food grade salt. CX STAN 150-Amend 3-2006. Codex Alimentarius Commission, Joint FAO,” *WHO Food Standard Program, Rome*, 2006.

[37] WHO, *Recommended iodine levels in salt and guidelines for monitoring their adequacy and effectiveness. WHO/NUT/96.13. WHO/UNICEF/ICCIDD.* , World Health Organization, Geneva, 1996.

[38] WHO, *Recommended iodine levels in salt and guidelines for monitoring their adequacy and effectiveness*, World Health Organization, 1996.

[39] Biber, F. Z., P. Ünak, and F. Yurt, “Stability of Iodine Content in Iodized Salt,” *Isotopes in Environmental and Health Studies,* 38 (2). 87-93, 2002.

[40] Menon, V. U., G. Chellan, K. R. Sundaram, S. Murthy, H. Kumar, A. G. Unnikrishnan, and R. V. Jayakumar, “Iodine status and its correlations with age, blood pressure, and thyroid volume in South Indian women above 35 years of age (Amrita Thyroid Survey),” *Indian Journal of Endocrinology and Metabolism,* 15 (4). 309-315, 2011.

[41] Bülow Pedersen, I., P. Laurberg, N. Knudsen, T. Jørgensen, H. Perrild, L. Ovesen, and L. B. Rasmussen, “A population study of the association between thyroid autoantibodies in serum and abnormalities in thyroid function and structure,” *Clinical Endocrinology,* 62 (6). 713-720, 2005.

[42] Bülow Pedersen , I., P. Laurberg, N. Knudsen, T. Jørgensen, H. Perrild, L. Ovesen, and L. B. Rasmussen, “An Increased Incidence of Overt Hypothyroidism after Iodine Fortification of Salt in

Denmark: A Prospective Population Study," *The Journal of Clinical Endocrinology & Metabolism,* 92 (8). 3122-3127, 2007.

[43] Premawardhana, L. D. K. E., and J. H. Lazarus, "Management of thyroid disorders," *Postgraduate Medical Journal,* 82 (971). 552-558, 2006.

[44] WHO, *Assessment of iodine deficiency disorders and monitoring their elimination: a guide for programme managers*, World Health Organization, Geneva, 2007.