International Journal of NaturalandEngineeringSciences
E-ISSN: 2146-0086 16(2): 60-68, 2022
Research Article

ASSESSMENT OF IODINE CONTENT AND ITS EXPOSURE IN COMMERCIALLY AVAILABLE IODIZED SALTS IN WOLDIA TOWN, ETHIOPIA

Bantie Yasabu Mekonnen[1,a*], Beshir Legas Muhammed[1], Shiferaw Dessie Mekonnen[1], Asnakew Amare Tadesse[1]

[1]*Department of Chemistry, Woldia University, Woldia, Ethiopia*

**Corresponding author:*
Email: bantieyas09@gmail.com

(Received 28th March 2022; Accepted 28th July 2022)

a: ORCID: 0000-0002-3336-1625

ABSTRACT. The amount of iodine necessary for our body can be achieved by the consumption of iodized salt. This study aimed to determine the iodine content and its exposure to the commercially available iodized salt product in the supermarkets of Woldia town, Ethiopia. The study was conducted by collecting five different salt products from the supermarket and the iodine content was determined by both iodometric and UV-Vis spectrophotometric methods. The iodine content of salt samples measured with the UV-Vis Spectrophotometric and Iodometric titration method were found to be in the ranges of 11.33±2.588 to 31.73±1.726 ppm. From all salt products 60% (brand 2, brand 3, and brand 5) were adequately iodated (15-45 ppm) while 40% (brand 1 and brand 4) were under the standard limit (<15 ppm). The iodine exposure at low level of consumption during cooking ranged from 68.03±15.62 to 190.35±12.69 µg/day while 90.61±25.36 to 253.8±16.92 µg/day for medium consumption, 113.43±31.97 to 162.15±12.21 µg/day for moderate high salt consumption and 135.92±38.04 to 194.82±14.86 µg/day for high salt consumption. In this study, UV-Vis Spectrophotometer was successful applied for iodine analysis in salt sample.

Keywords: *Risk assessment, Iodometric titration, UV-Vis Spectroscopy*

INTRODUCTION

Iodine is a trace element present in the human body in very low quantities (10-15 mg) [1]. The only known role of iodine in the human body is to constitute an essential element in the synthesis of the thyroid hormones: Thyroxin and Triiodothyronine (T3) [2, 3]. Inadequate iodine intake by the human body causes the insufficient synthesis of thyroid hormones, resulting in hypothyroidism and Iodine Deficiency Disorders (IDD) [4]. It can cause goiter and abnormal enlargement of the thyroid gland [5, 6].

The safe dietary intake of iodine as recommended by the World Health Organization (WHO) is 100 µg day−1 for infants and 150 µg day−1 for adults [7, 8]. The report showed that 38 million children are born every year at risk of brain damage because of iodine deficiency [3]. For the elimination of iodine deficiency, WHO recommended the Universal Salt Iodization program [9]. Adequate intake of iodine can be achieved by the consumption of iodized salt [5, 8]. Iodization of salt is done by the addition of iodate to salt samples due to its good stability and bioavailability [10, 11].

In Ethiopia, though iodine is found naturally in topsoil areas, in most areas of the country, especially in the highlands, the upper layer of the soil has been removed by factors such as deforestation, erosion, and flooding. And thus, food crops lack iodine content, which in turn results in the dietary deficiency of iodine [3, 7]. In Ethiopia households using adequately iodized salt is only 15%; this indicates that the largest segment of the population is at risk of iodine deficiencies [3]. Despite efforts to eliminate iodine deficiency, Ethiopia is still among the high-risk iodine-deficient Countries in East Africa [7]. According to a national micro-nutrient survey (MNS, 2016) 48% of school-aged children and 52% of reproductive-aged women had mean urinary iodine concentration below the cutoff, [8] and the study conducted in Hawassa town Ethiopia point out that all salt samples tested for iodine had iodine concentration below the recommended level [9]. Another study was done in Dessie and Kombolcha Towns, South Wollo, Ethiopia showed that 31.2% of the households used inadequately iodized salt and the calculated iodine content was less than the World Health Organization recommendation level (≥15 ppm) at the household [10].

Salt handling practice, lower monthly per-capital income, poor socioeconomic status, unavailability of the salt, lack of awareness about the risk of IDD, using unpackaged salt, exposing salt to sunlight, expensiveness, and lack of knowledge about iodized salt are among the factors associated with the absence of adequately iodized salt at home [11,12,13,14,15,16].

Even though Ethiopia follows the universal salt legislation to increase the content of iodine in edible salt, to the best of our knowledge there is a lack of evidence on the level of the iodine content of commercially available salt samples. Therefore, this study was amid to determine the iodine content of different salt brand samples available in Woldia town, Ethiopia.

MATERIAL AND METHODS

Chemicals and apparatus

The material and instruments used in this experiment were an electronic balance, test tube, UV- Vis spectrophotometer (Lambda 35 Perkin Elmer), pH meter, filter paper, different sizes of beakers, volumetric flask, quartz cuvette, and burette.The chemicals and reagents used in this study were of analytical grade and available in Woldia University, chemistry department including distilled water, 10% KI, H_2SO_4 (1 M), KIO_3 (1 M), 1% starch, $Na_2S_2O_3$ (0.1 N), methylene blue dye (0.1 M) and sodium acetate (1 M).

Sample collection

A total of five different brands of most commonly sold commercial edible iodized salts were selected and purchased from supermarkets around Woldia town. The selected salt samples were kept unopened in the sealed plastic bags in the dark until used for analysis. The concentrations of iodine in each brand were determined by using the Iodometric titration and Spectroscopic method.

Quantitative determination of iodate by iodometric titration

The iodine content of iodized salt samples was determined by the iodometric titration method by using the following procedures [18]. About 10 grams of each salt sample were weighed and dissolved in distilled water in a 250 ml conical flask, 1 ml of 2 N Sulfuric acid and 5 ml of 10% potassium iodide were added into the salt solution. Then the solution turned yellow and was kept in the dark for ten minutes. After ten minutes, the salt solution was titrated with sodium thiosulphate and immediately stopped when the solution turned light yellow. Afterward, a few drops of 1% starch solution were added and turned the solution deep purple and continued titration until the purple color was disappeared and at this point, the volume of sodium thiosulphate was recorded. The iodine content can be calculated as follow.

$$\text{Iodine (ppm)} = \frac{\text{volume of } Na_2S_2SO_3 \text{ (ml) x N of } Na_2S_2SO_3 \text{ x1000}}{\text{Salt sample weight (g)}}$$

Eqn.1

Quantitative determination of iodate by Uv- vis spectrophotometer

An aliquot of standardized solution of iodate containing 0.25 to 6 ml was transferred into a series of 25 ml volumetric flasks. 1 ml of KI and 1 ml of H_2SO_4 (1 M) were added to each flask. The mixed solution was gently shaken until it turned to yellow color. At this stage, 3 ml of methylene blue dye solution was added followed by 2 ml of sodium acetate (1 M). The reaction mixture was then shaken for 2 min. Finally, it was diluted with distilled water to the mark of a 25ml volumetric flask. After 5 min, the absorbance of all solutions was recorded at 665.6 nm against water as a reagent blank [19, 20].

Risk assessment of iodine exposure

According to WHO estimations, The average salt intake per capita of the population at medium salt consumption was assumed to 10 g/day and they considered four levels of salt consumption at low, medium, moderately high, and high salt intake [21, 22, 23]. As shown in table 1 low and moderate-high intakes were calculated by adding ± 25 % of the medium salt consumption (10 g/day) and high-level consumption can be obtained by adding 50 % of the medium salt consumption [12, 17].

Table 1. Salt consumption levels and corresponding salt intake

Consumption level	**Salt intake (g/day)**
Low	7.5
Medium	10
Moderate high	12.5
High	15

Data Analysis

Experimental data were analyzed using Origin 8 software and Microsoft Office Excel 2007. The mean value of Iodate levels was compared using F-test, which was obtained by iodometric titration and UV-Vis spectroscopic method in all iodized salt samples. The level of iodate was determined with iodometric titration as well as UV-Vis spectroscopic method and compared using one-way ANOVA with Pearson's correlation coefficient (p= 0.05). All analyses were performed in triplicate and data are expressed as mean ± SD (n=3).

RESULTS AND DISCUSSION

Quantitative determination by Iodometric titration

Among salt samples measured by iodometric titration, the largest iodine content was found in Brand 3 (31.73±1.726) and the lowest iodine was shown in Brand1 (11.33±2.588). It can be seen that the iodine content distribution of the salt sample in this study area lacks homogeneity. This was due to the difference in concentration of iodine added during the iodization process, instability of iodine in salt, exposure to high temperature, impurity, moisture, and transportation from production to consumers [8].

Uv-Vis spectrophotometric method

Optimization of parameters

To examine the optimum conditions needed to leach methylene blue dye, optimization of different parameters were done, and optimized parameter used in this work were presented in table 2. By using the optimized condition the concentration of iodine in the form of iodate was calculated through the calibrated equation (y=0.01208x +0.70742).

Table 2. Optimized parameters

Optimized parameters	**Values**
Sulfuric acid	1 ml(1N)
Potassium iodate	0.25 to 6 ml(1 M)
Potassium iodide	1 ml
Methylene blue dye	3 ml(0.1M)
Time	5 min
pH	4
Sodium acetate	2ml (1M)

Table 3. Average Iodine content of different commercial iodized salt in Woldia

Type of iodized salt samples	**The mean concentration of Iodate (ppm)**		
	Iodometric Titration	UV-Vis Spectroscopy	P-Value
Brand 1	11.33±2.588	13.39±0.79	0.0585
Brand2	22.63±0.994	22.63±1.58	0.372
Brand 3	31.73±1.726	29.71±0.56	0.065
Brand 4	12.10±0.907	13.78±0.57	0.181
Brand 5	16.22±0.912	15.02±0.62	0.204

brand 1: mosobo, brand 2: best, brand 3: desta, brand 4: wolf, band 5: raye

Table 4. *Iodine content status*

Iodine status	**Uv-Vis spectrophotometric method**		**Iodometric titration method**	
	Number of brands	Proportion (%)	Number of brands	Proportion (%)
Non-iodated (< 5 ppm)	0	0	0	0
Insufficiently iodated (5-14 ppm)	2	40	2	40
Adequately iodated (15 – 45 ppm)	3	60	3	60
Over-iodated (> 45 ppm)	0	0	0	0

Based on World Health Organization recommendation, quality and adequacy used in the household has been classified based on their iodine content in salt sample (ppm=mg iodine per kg of salt): non-iodated (<5), under standard limit (<15 ppm) level, allowable standard limit from 15–40 ppm; and over the standard limit (>40 ppm) [8]. Data given in Table 4 showed that 40% (brand 1 and brand 4) were under standard limit, 60% (brand 2, brand 3, and brand 5) were adequately iodized and in this study none of the salt samples were non-iodinated and over iodinated.

Risk assessment of iodine exposure

The probable exposure level and corresponding status of iodine from each product were assessed according to WHO, ICCIDD, UNICEF, Recommended iodine levels in salt, and guidelines [23]. The organization set the following intake status; Severe deficiency (< 30 µg/day), moderate deficiency (30-74 µg/day), Mild deficiency (5 – 149 µg/day), Optimal nutrition (150 – 299 µg/day), Above requirement (300 – 449 µg/day) and Excessive (>449 µg/day) [22, 23].

Table 5. Iodine exposure assessment with and without considering cooking losses

Band name	**Iodine content**	**Exposure ± SD**			
		Low	Medium	Moderate high	High
Considering cooking loss					
Brand 1	11.33±2.588	68.03±15.62	90.61±25.36	113.43±31.97	135.92±38.04
Brand 2	22.63±0.994	131.12±7.30	174.82±9.74	218.53±12.18	262.24±14.618
Brand 3	31.73±1.726	190.35±12.69	253.8±16.92	317.25±21.15	380.70±25.38
Brand 4	12.10±0.907	71.91±7.32	95.88±9.76	119.85±12.21	143.82±14.65
Brand 5	16.22±0.912	97.29 ±7.32	129.72±9.76	162.15±12.21	194.82±14.86
Without considering the cooking loss					
Brand 1	11.33±2.588	84.95±23.77	113.26±31.70	141.58±39.62	169.89±47.45
Brand 2	22.63±0.994	163.89±9.13	218.53±12.18	273.16±15.22	327.79±18.27
Brand 3	31.73±1.726	237.93 ±15.86	317.25±21.15	396.56±26.44	475.87±31.72
Brand 4	12.10±0.907	89.88±9.15	119.85±12.21	149.81±15.26	179.72±18.31
Brand 5	16.22±0.912	121.61±9.16	162.15±12.21	202.68±15.26	243.20±18.31

According to the data presented in Table 5, at low salt consumption level with and without considering cooking loss 70% of the units can cause moderate and mild deficiency (30-150 µg/day) and only 30% belongs to the optimal nutrition range. Among medium salt consumption from all salt products, 60% cause mild deficiency while 40% belong to moderate nutrition. Among moderate high salt consumption, only 20 % of the unit shows iodine exposure above requirement, while the rest 40 % categorized under mild deficiency and 40% cause optimal nutrition. At a high level, salt consumption from all salt products with considering the cooking loss only 20% can cause excessive intake of iodine. From all sets of data, only one of the 5% without considering cooking loss can lead to cause excessive intake of iodine.

The WHO report revealed that salt consumption in Africa content is lower than in the rest of the world [22]. Eastern and Southern Africa ranks lowest in salt consumption and many countries in eastern Africa including Ethiopia consume salt less than the fortification level [25]. According to a national community-based survey of 2007, Ethiopia is known for its mountainous topography and at risk of IDD [26]. Even though there is no available information about the iodine status of the current study area, the average iodine intake from other sources other than table salt is expected to be lower than the estimated value due to different factors. People in Woldia cannot regularly consume seafood and marine fish. In addition to this, the mountainous nature of its topography can lower the iodine content of soil [26]. Due to those factors, the average iodine intake per capita in Woldia can be lower than the estimated value. Therefore, the mild and moderate deficiency consumption levels were considered to resemble closely the possible average salt intake per capita in Woldia.

It can be seen from Table 5 that in case of low level of consumption by considering cooking loss only brand 3 attained Optimal nutrition of iodine status, the rest of salt brands attained blow optimal nutrition (< 150 µg/day). And this can cause risks of adverse health effects such as fibrocystic breast changes and goiter due to iodine exposure in deficient amounts [28]. At a high level of consumption, only brands 3 can also cause adverse health effects of IIH and autoimmune thyroid diseases due to iodine exposure in excessive amounts [17]. People who in taking brand 1 and brand 4 in all levels of consumption (low, medium, moderate-high and high) man not get the recommended amount of iodine (> 150 µg/day). Therefore, special attention should be given to monitoring salt iodization programs and quality assurance measures at the stages of production, storage, and transportation to get the recommended amount.

Comparison of iodometric and Spectrophotometric methods

As shown in Fig. 1, the mean value of iodine determined by using iodometric titration and UV-Vis spectroscopy in each salt sample did not show a significant difference at $p = 0.05$ (Table 3). As shown in Table 3, the iodate contents obtained by Iodometric titration and UV-Vis spectroscopic method were in the range of 11.33–33.85 ppm and 12.6−30.27 ppm, respectively. When we separately compared for the mean value of iodine content between the five salt samples using iodometric titration and UV-Vis spectroscopy, there were a significant difference ($F_{(5, 12)} = 92.83$, $p \leq 0.001$) and ($F_{(5, 12)} = 307.79$, $p \leq 0.001$), respectively, at $\alpha = 0.05$. This result shows that UV-Vis spectrophotometer can validly replace the iodometric titration. There was a similar report which shows the validity of UV-Vis spectrophotometer for the determination of iodine content in table salt [8, 19, 28]. B. Narayana et al. evaluate the statistical analysis of the results by using F- and t-tests and the result showed there was no significant difference between the accuracy and precision of the two methods [19]. And they conclude UV-Vis spectrophotometer successfully applied to the determination of iodate in table salt samples and seawater.

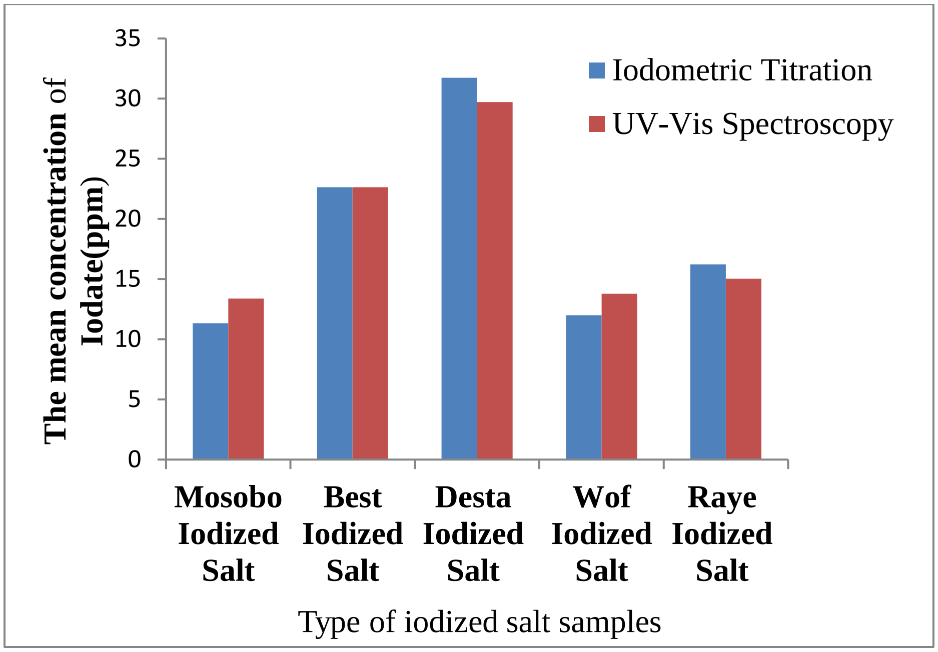

Fig.1. *Comparison of iodine content using iodometric titration method and UV-Vis spectrophotometric method*

CONCLUSION

In the present study, all commercial iodized salt products that were collected from supermarkets contained iodine in the form of iodate. The quantitative determination of iodine by iodometric titration and UV-Vis spectrophotometric method showed that not all salt products meet the recommended level. Therefore, there would a proper salt iodization program to avoid iodine deficiency and to achieve the recommended iodine status in the area. The results obtained by the UV-Vis spectrophotometric method are in good agreement with those obtained by the conventional iodometric method, thus validating the method. Based on the risk assessment, the iodine consumption in the study area may cause deficient exposure to iodine. This indicates the health sector and authorities may give concern on production and quality of iodized salt at the recommended level.

Acknowledgement. The authors thank the Chemistry Department of Woldia University for allowing us to use the laboratory facility and Mr. Desiew Mekuanint for his endless support during laboratory work.

REFERENCES

[1] Delange, F. (1993):Requirements of iodine in humans. Iodine deficiency in Europe. Springer. 3: 5-15.

[2] Ferede, A. (2018): Evaluation of quantity and access of iodized salt using titration method in Arsi zone, Oromiya, Ethiopia in 2018: A Community based cross sectional study. Journal of Nutrition and Human Health 2(2): 11-16.

[3] Zahidi, A., Zahidi, M., Taoufik, J.(2016): Assessment of iodine concentration in dietary salt at household level in Morocco. BMC Public Health 16(1): 1-6.

[4] Kulkarni, P.S,, Dhar, S.D., Kulkarni, S.D. (2018). A rapid assessment method for determination of iodate in table salt samples. Journal of Analytical Science and Technology 4(1): 1-6

[5] Al-Dakheel, M.H., Haridi. H.K., Al-Bashir, B.M., Al-Shangiti, A.M., Al-Shehri, S.N., Hussein. I. (2018): Assessment of household use of iodized salt and adequacy of salt iodization: a cross-sectional National Study in Saudi Arabia. Nutrition Journal 17(1): 1-7.

[6] Haddad, L., Achadi, E., Bendech , M.A., Ahuja, A., Bhatia, K., Bhutta, Z. (2015): The Global Nutrition Report 2015: actions and accountability to accelerate the world's progress on nutrition. The Journal of Nutrition 145(4): 663-671.

[7] Dinka, A.W., Kebebe, T., Nega, G.(2021): Iodine level of salt and associated factors at household level in Gidami District, Oromia Region, Ethiopia: a cross-sectional study. Nutrition and Dietary Supplements 13: 9-16.

[8] Bediye, M., Berihe, G.(2015): Iodometric titration and spectrophotometric method for the determination of iodine in salt samples commercially available in Bahir Dar. North Western Ethiopia. Chemical and Material Research 7(4): 59-66.

[9] Girma, M., Loha, E., Bogale, A, Teyikie, N., Abuye, C., Stoecker, B.J. (2012): Iodine deficiency in primary school children and knowledge of iodine deficiency and iodized salt among caretakers in Hawassa Town: Southern Ethiopia. Ethiopian Journal of Health Development 26(1): 30-35.

[10] Mekonnen, T.C., Eshete, S., Wasihun, Y., Arefaynie, M., Cherie, N. (2018): Availability of adequately iodized salt at household level in Dessie and Combolcha Towns, South Wollo, Ethiopia. BMC Public Health 18(1): 1-9.

[11] Buxton, C., Baguune, B.(2012): Knowledge and practices of people in Bia District, Ghana, with regard to iodine deficiency disorders and intake of iodized salt. Archives of Public Health 70(1): 1-9.

[12] Morley, J.E., Argiles, J.M., Evans, W.J., Bhasin, S., Cella, D., Deutz, N.E. (2010): Nutritional recommendations for the management of sarcopenia. Journal of the American Medical Directors association 11(6): 391-396.

[13] Kumar, D., Gupta, A., Lal, P., Sachdeva, A., Verma, G., Thakur, R. (2019): Household coverage with adequately iodized salt in an endemic district of North India and their common practices affecting iodine content of salt. EAS Journal of Nutrition and Food Sciences 1(4): 81-86.

[14] Desta, A.A., Kulkarni, U., Abraha, K., Worku, S., Sahle, B.W. (2019): Iodine level concentration, coverage of adequately iodized salt consumption and factors affecting proper iodized salt utilization among households in North Ethiopia: a community based cross sectional study. BMC Nutrition 5(1): 1-10

[15] Anteneh, Z.A., Engidayehu, M., Abeje, G. (2017): Iodine content of dietary salt at household level and associated factors using Iodometric titration methods in Dera District, Northwest Ethiopia. BMC Nutrition 3(1): 1-7.

[16] Kumma, W.P., Haji, Y., Abdurahmen, J., Mehretie, A.Y. (2018): Factors affecting the presence of adequately iodized salt at home in Wolaita, Southern Ethiopia: community based study. International Journal of Food Science 3: 1-9.

[17] Vithanage, M., Herath, I., Achinthya, S., Bandara, T., Weerasundara, L., Mayakaduwa, S. (2016): Iodine in commercial edible iodized salts and assessment of iodine exposure in Sri Lanka. Archives of Public Health 74(1): 1-7.

[18] Alam, M.R., Dey, M., Islam, M.K., Reza, S., Mamun, S., Zaher, A. (2019): Determination of iodine content of commercially available table salts at the retailer level in selected areas of Bangladesh. European Journal of Nutrition & Food Safety 15:284-288.

[19] Gadducci, A., Guerrieri, M., Genazzani, A. (2012): Benign breast diseases, contraception and hormone replacement therapy. Minerva Ginecologica 64(1): 67-74.

[20] Narayana, B., Pasha, C., Cherian, T., Mathew, M. (2006): Spectrophotometric method for the determination of iodate using methylene blue as a chromogenic reagent. Bulletin of the Chemical Society of Ethiopia 20(1): 143-147.

[21] Mizehoun-Adissoda, C., Agueh, V., Yemoa, A., Segla, B., Alihonou, F, Jossè, R.G. (2018): Validation of the use of spectrophotometer (WYD iodine checker) for the determination of iodine in food salt. African Journal of Food Science 12(2): 15-20.

[22] WHO (2007): Assessment of iodine deficiency disorders and monitoring their elimination: a guide for programme managers. 3rd ed. World Health Organization. https://apps.who.int/iris/handle/10665/43781.

[23] WHO/ICCIDD. (1996): Recommended iodine levels in salt and guidelines for monitoring their adequacy and effectiveness. World Health Organization. https://apps.who.int/iris/handle/10665/63322.

[24] Shawel, D., Hagos, S., Lachat, C.K., Kimanya, M.E., Kolsteren, P. (2010): Post-production losses in iodine concentration of salt hamper the control of iodine deficiency disorders: a case study in northern Ethiopia. Journal of Health, Population, and Nutrition. 28(3): 238.

[25] Abuye, C., Berhane, Y. (2007): The goitre rate, its association with reproductive failure, and the knowledge of iodine deficiency disorders (IDD) among women in Ethiopia: cross-section community based study. BMC Public Health 7(1): 1-7.

[26] Asfaw, A., Belachew, T.(2020): Magnitude of iodine deficiency disorder and associated factors in Dawro zone, Southwest Ethiopia; the hidden hunger: a cross-sectional study. BMC Nutrition. 6:1-10.

[27] Weke, K., Adamu, B., Girmay, A.,Yohannes, T., Alemnesh, Z., Abuye, C. (2014): Iodine deficiency disorders (IDD) in burie and womberma districts, west gojjam, ethiopia. African Journal of Food, Agriculture, Nutrition and Development. 14(4): 9167-9180.

[28] Fallah, S.H., Khalilpour, A., Amouei, A., Rezapour, M., Tabarinia, H. (2020): Stability of dine in iodized salt against heat, light and humidity. International Journal of Health and Life Sciences 6(1): 209-219.