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Investigation of the effects of heat and light on iodine content of packaged and open salt brands collected from Jimma town

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ABSTRACT

Iodine deficiency is one of the most common micronutrient deficiencies in developing countries, which leads to iodine deficiency disorders (IDD). To combat iodine deficiency disorders, universal salt iodization is mandatory. However, iodized salt can lose its iodine due to environmental factors such as heat, light, moisture, and so on. Therefore, the aim of this study is to investigate the effects of heat and light on the iodine content of packaged and open salt brands available in Jimma town, Oromia, Ethiopia. An experimental study design was employed to determine the effects of heat and light on the iodine content of salts. A total of six salt samples were collected from retailers selected based on convenience sampling technique. Among six different salt brands, three were packaged salts, and the rest were non-packaged (open) salts. The iodine content of the salt samples was determined by the iodometric titration method, and the effects of heat and light on the concentration of iodine were also investigated. It has been revealed that heat and light decrease the iodine content of salt samples. The findings of this study provide valuable insights into the stability of iodized salt against heat and light. It is also helpful in identifying the right time at which salt should be added while cooking and the appropriate storage conditions for salt in households.

1. Introduction

Iodine is a crucial element that every person needs for optimal health and well-being since it supports healthy thyroid function, proper growth, and overall development [1]. The thyroid gland uses it to make the hormones triiodothyronine (T3) and thyroxin (T4), which control the body's physiological processes and metabolism [2]. Iodine can be found naturally in milk, spinach, vegetables, fruits, cereals, eggs, meat, and sea foods. Since the iodine in these sources is not bioavailable and has a lower concentration, it frequently falls short of meeting daily needs, especially for pregnant women [1].

Iodine intake guidelines from the WHO state that adults should consume 150 μg of iodine per day, while pregnant women should consume 200–250 μg. Therefore, the salt's iodine concentration at the point of production should be 20–40 mg per 1 kg of iodized salt in order to meet each person's daily requirement of 150 μg. The WHO calculated the recommended level using the assumptions of a 20% loss in iodine from the manufacturing site to the household, a 20% loss during cooking, and a 10 g average salt intake per person [2]. The actual availability of iodine in salt depends on its form of fortification and environmental factors such as heat, light, and

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moisture. Salts iodized with potassium iodide lose a significant quantity of iodine when exposed to sunlight, wind, and other environmental factors, but salts iodized with potassium iodate show minimal losses [2]. Even though it is to a different extent, exposure of any iodized salt to heat, light, and moisture decreases its iodine content, and individuals consuming such a type of salt are deprived of sufficient iodine in their diet.

Inadequate iodine consumption leads to a limited ability to synthesize thyroid hormones in the body, which causes iodine deficiency disorders (IDD) and hypothyroidism [2]. Lack of iodine impairs the production of thyroid hormones, which are necessary for healthy brain growth. Iodine deficiency in pregnant women is linked to a variety of birth problems, including miscarriages, stillbirths, congenital malformations, neurological cretinism, myxedematous cretinism, mental illnesses, dwarfism, hypothyroidism, psychomotor impairments, and more. Iodine deficiency in adults is linked to goiter, iodine-induced hyperthyroidism, hypothyroidism, reduced mental function, increased vulnerability to nuclear radiation, and other conditions [3–9].

Universal salt iodization is an effective and affordable way to prevent and treat iodine-deficient illnesses. The term "universal salt iodization" refers to the addition of iodine to all food-grade salts used for cooking purposes. 86% of the world's population has access to iodized salt because of the universal salt iodization approach [3]. Due to their good iodine availability and inexpensive cost, potassium iodate (KIO_3) and potassium iodide (KI) are iodine compounds used for salt fortification. During manufacture, these substances are added as either a dry solid or an aqueous solution. Due to its superior stability and oxidation resistance, potassium iodate is preferred to potassium iodide in tropical regions [1]. Different countries, including Ethiopia, have adopted a universal salt iodization strategy to avoid iodine deficiency disorders and maintain the well-being of their societies.

For instance, the legislation announced by the Ethiopian Council of Ministers in February 2011 stated that every salt used for human consumption must be iodized, and any iodized salt used for human consumption must abide by the iodized salt standards established by the relevant authority. However, research conducted on the iodine content of salts used in Ethiopian households revealed that the majority of the salts have a lower level of iodine than the standard limit. Some of the reasons for the low iodine concentration of salt consumed by Ethiopian households include improper storage, poor handling, and purchasing non-iodized salt [10]. Some researchers have presented their evaluation of the impact of salt storage conditions on salts used in Ethiopian households. For instance, a prior survey found that the existence of adequately iodized salt in households was positively correlated with avoiding exposing iodized salt to sunlight, storing the salt in a dry or cool environment, and having good knowledge about iodized salt [11]. A related study revealed a positive link between the availability of adequately iodized salt and the use of covered salt and dry storage of salt [12]. Additionally, inappropriate packaging and high-temperature heating of salt with low iodine content are associated [13]. However, these studies did not experimentally assess the effect of the above-mentioned environmental factors; their findings are solely based on the data collected from respondents in the form of a survey. Therefore, the present study is aimed at investigating the effects of heat and light on iodine content of packaged and open salt brands available in Jimma town, Oromia, Ethiopia, using the iodometric titration method.

2. Materials and methods

2.1. Reagents and chemicals

The reagents and chemicals used in this study include Sodium thiosulfate ($Na_2S_2O_3.5H_2O$), Potassium iodate (KIO_3), Potassium iodide (KI), Potassium dichromate ($K_2Cr_2O_7$), Sulfuric acid (H_2SO_4), starch, and distilled water.

2.2. Equipments

Equipments used for this study included volumetric flasks, a burette, a burette stand, Round flat flasks, a measuring cylinder, aluminum foil, beakers, droppers, a hot plate, and an electronic balance.

2.3. Sample collection

A convenience sampling technique was used for sample collection. Three open salt brands (Afdera, Amole, and Bale) and three packaged salt brands (Berta, NM, and Sara) were purchased from retailer shops in Jimma town. The salt samples were checked for proper sealing and storage conditions before buying, as there are chances of iodine loss by oxidation from exposure to air or moisture.

Table 1
Iodine content in various salt samples.

Types of salt samples	Salt sample's brand name	Average volume of $Na_2S_2O_3$ consumed (mL)	Iodine content (mg/Kg)
Open	Afdera	1.65	17.506 ± 0.21
	Amole	1.10	11.671 ± 0.04
	Bale	1.30	13.793 ± 0.15
Packaged	Berta	1.85	19.629 ± 0.23
	NM	2.25	23.873 ± 0.35
	Sara	4.05	42.971 ± 0.24

The results are the average of triplicate measurements ± standard deviation.

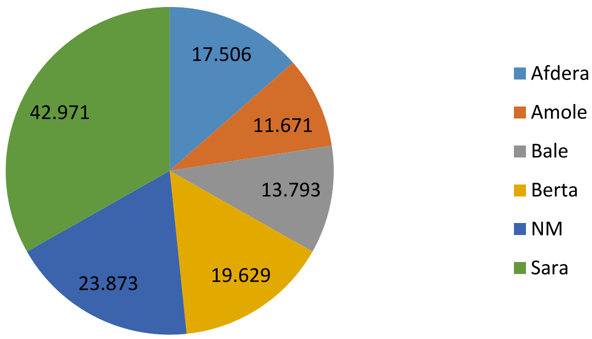

Fig. 1. Iodine content in various salt samples using a pie chart.

All salt samples were brought to the Jimma University Chemistry Laboratory and kept in a dark and dry area until analysis.

2.4. Determination of iodine concentration using iodometric titration

The iodine content of salt samples was determined by the iodometric titration method following standard procedures [4]. Briefly, 10 g of salt was put in a flask and dissolved in 50 mL of distilled water. Then, 5 mL of 10% (m/v) KI and 1 mL of 1 M H_2SO_4 solutions were added, and the flask was immediately closed using aluminum foil. The mixture was well shaken, and its color turned yellow, which indicates the formation of molecular iodine. Then, the mixture was titrated against a standardized $Na_2S_2O_3$ solution (0.005 N) until the yellow color changed to pale. In the meantime, 3 drops of starch indicator solution were added, resulting in a change of color to dark blue-black, which indicates the formation of the iodine-starch complex. The titration was continued until the dark blue-black color changed to colorless at the endpoint. The titration process was repeated three times, and an average value was determined for the volume of $Na_2S_2O_3$ consumed. Finally, the concentration of iodine (mg/Kg or ppm) in the salt samples was calculated using the following formula:

$$Concentration\ of\ iodine\left(\frac{mg}{Kg}\right)=\frac{VxNx0.001x1000x21.22}{M}$$

where V is the average volume of $Na_2S_2O_3$ in milliliters, N is the normality of $Na_2S_2O_3$ which is 0.005 equivalent per liter, M is mass of the salt sample which is 0.01 kg or 10 g, *0.001* is the conversion factor to convert milliliters of $Na_2S_2O_3$ into liters, *1000* is the conversion factor to convert a gram of iodine into a milligram, *21.22* is equivalent weight of iodine in grams per equivalent.

2.5. Investigation of the effect of heat on iodine content of salts

The effect of heat was studied to examine the effect of cooking temperature on iodine levels. 10 g of salt samples were dissolved in 50 mL of distilled water in a flask and boiled for 30 min in order to mimic the actual cooking temperature. The solution was cooled to room temperature, and its iodine concentration was determined by the iodometric titration method following the procedures described under Section 2.4. The iodine concentrations of the salt samples determined after boiling were compared to their original concentrations, which were determined before boiling.

2.6. Investigation of the effect of light and dark storage conditions on iodine content of salts

To study the effect of light on iodine content, two samples with the highest iodine content were selected among the studied samples. One sample was selected from open salt brands, and the other was selected from packaged salt brands. Each sample was divided into two parts and transferred to a closed plastic bottle (for studying the effect of light) and an amber bottle (for studying the effect of dark). The sample in the amber bottle was kept in the dark, and the sample in the plastic bottle was kept in the light at room temperature for 3 weeks by covering the bottles with aluminum foil. After 3 weeks, the iodine content of both samples of each salt was determined by the iodometric titration method using the same procedures as described under Section 2.4. The percentage loss of iodine for samples stored in dark and light was calculated and compared to each other.

Table 2
Percent loss of iodine level by heat.

Salt brand	Average volume of $Na_2S_2O_3$ consumed (mL)	Iodine content before boiling (mg/Kg)	Iodine content after boiling (mg/Kg)	Net loss of iodine (mg/kg)	Net loss of iodine (%)
Afdera	1.35	17.506 ± 0.21	14.324 ± 0.23	3.182	18.176
NM	1.23	23.873 ± 0.35	13.050 ± 0.32	10.823	45.335
Sara	2.45	42.971 ± 0.24	25.995 ± 0.21	16.976	39.505

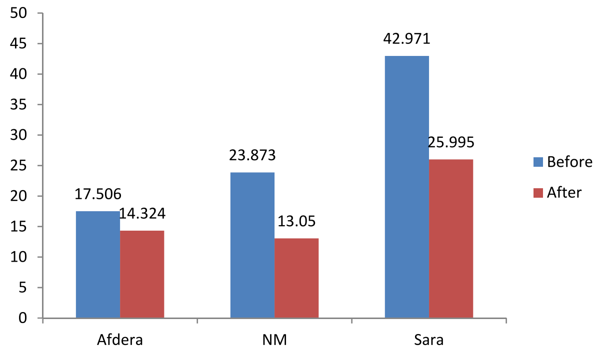

Fig. 2. Iodine content of salt samples before and after heating using a bar graph.

3. Results

3.1. The iodine content of the collected salt samples

The initial concentration of iodine (mg/Kg) determined by iodometric titration of the salt samples has been depicted in Table 1.

As can be seen from Table 1, the iodometric titration results showed that the iodine content of the studied salt samples was found within the range of 11.671 ± 0.04 to 42.971 ± 0.24 mg/kg. The packaged salt brands (Sara, NM, and Berta) were found to have higher concentrations of iodine than the open salt brands (Afdera, Amole, and Bale). This may be due to the loss of iodine by oxidation when exposed to air in open salt brands, while this effect is not possible for packaged salt brands. Among the studied salt samples, Sara and Amole were found to have the highest and lowest iodine content, respectively, as presented in Table 1 and Fig. 1.

3.2. Effect of heat on the iodine content of the salt samples

As described in Table 2, heating until boiling temperature could cause 18.176–45.335% loss of iodine, depending on the type of salt brand.

Although the iodine concentration loss was varied and dependent on the type of salt brand, there was a significant loss of iodine content by heat in all salt samples studied, as described in Table 2 and Fig. 2. Therefore, it is advisable to add salt at the last few minutes of cooking or after cooking to minimize this loss. It is also suggested to avoid storing salt in a hot area.

3.3. Effect of light and dark storage conditions on iodine content of the salt samples

Results displayed in Table 3 indicate that the percentage loss of iodine for the Sara salt sample decreased from 36.543% in light to 24.691% in dark, while the percentage loss of iodine for the Afdera salt sample decreased from 19.998% in light to 7.877% in dark. Salt samples stored in a dark place showed a lower percentage loss of iodine than those stored in a light place. Although the loss of iodine was observed in both light and dark storage conditions, the effect was more pronounced for the samples stored in light place. This result shows that the best storage condition for salt in a household is in a dark area.

3.4. Comparison of the level of iodine in salts with WHO and Ethiopian standards

As it can be seen in Table 4, among the studied salt samples ($n = 6$), 16.7% ($n = 1$) was insufficiently iodized, 66.7% ($n = 4$) were adequately iodized, and 16.7% ($n = 1$) was over-iodized according to the WHO recommended level of iodization. The majority of salt brands collected from Jimma contained an adequate amount of iodine (15–40 ppm). In Ethiopia, an iodization level of 36–48 ppm is an adequate level for human consumption, according to the Quality and Standard Authority of Ethiopia (QSAE) [14]. According to QSAE's recommended level of iodization, all of the studied salt brands did not contain an adequate level of iodine except the Sara salt

Table 3
Percentage loss of iodine level of salt stored in light and dark places.

Storage condition	Salt brand	Average volume of $Na_2S_2O_3$ consumed (mL)	Initial iodine content (mg/kg)	Iodine content (mg/kg)	Net loss of iodine (mg/kg)	Net loss of iodine (%)
Light	Afdera	1.32	17.506	14.005	3.501	19.998
	Sara	2.57	42.971	27.268	15.703	36.543
Dark	Afdera	1.52	17.506	16.127	1.379	7.877
	Sara	3.05	42.971	32.361	10.610	24.691

Table 4
Comparison of the level of iodine with the WHO standard.

Level of iodization according to WHO	Number of salt brands	Percentage (%)
Non-iodized (<5 ppm)	0	0
Insufficiently iodized (5–14.9 ppm)	1	16.7
Adequately iodized (15–40 ppm)	4	66.7
Over iodized (>40 ppm)	1	16.7

brand. This may be due to improper iodization at the production level and/or long exposure to heat, sunlight, moisture, and so on.

4. Discussions

This study provides insight into the effects of heat and light on the iodine content of salt samples. It also helps to determine the ideal time to add salt when cooking and the ideal storage conditions for salt in homes. The results of this investigation demonstrated that iodine content decreases more when salt is exposed to heat and light than when salt is stored in a dark environment.

When salt is exposed to heat and light, iodizing chemicals such as potassium iodate and potassium iodide break down into free forms of iodine, which may be the possible reason for this loss. Elemental iodine readily sublimes and diffuses away quickly into the atmosphere. Moisture naturally present in salt or absorbed from the air by hygroscopic impurities like magnesium chloride that are present in salt can convert potassium iodide into elemental iodine. The iodizing agents present in salt breaks down through a reaction that takes place in the dampness. Elevated temperatures accelerate the processes that create elemental iodine and speed up the evaporation of iodine, as is the case with the majority of chemical reactions [15]. Similar to heat, sunlight exposure seems to speed up the degradation of the iodizing compounds in salt. The loss of iodine from salt when it is exposed to sunlight is thought to be caused by a photochemical reaction [16]. However, little definite information is available concerning the mechanism or the dynamics of the change, and further research is still needed in this regard. A good vapor barrier (packaging material), which prevents moisture from penetrating and iodine from evaporating, significantly improves the stability of iodine in samples of iodized salt, as shown in the previous research. Since increased storage time increases the loss of iodine, the time needed for distribution, sale, and consumption should also be minimized to ensure effective use of the added iodine [15].

Similar experiments carried out by other researchers utilizing various analytical methods, such as iodometric titration, iodide combination electrodes, spectrophotometric methods, and induction-coupled plasma-mass spectrometry, provide support for the findings of the current study. For instance, iodometric titration was used to assess the iodine's tolerance to heat, light, and humidity in iodized salt. The findings showed that the ideal storage conditions for iodized salt were room temperature, complete darkness, and non-humidity [17]. In another study, an iodide combination electrode was used to measure the iodine level of salt at 50 and 100 °C. This study found that as temperature rises, the average iodine loss increases, with the maximum loss occurring at 100 °C [2]. Using the spectrophotometric technique, the iodine concentration of salt samples was evaluated after being cooked in an oven, boiling, or heated in water, as well as after being exposed to light or dark storage conditions. The study showed that up to 68% of iodine was lost during heating in a water solution, whereas dry heat led to a loss of 26%. Iodine loss was greater in the presence of light than in the absence of light (its concentration fell from 48.2 mg/kg to 23.6 mg/kg in the dark and to 22.2 mg/kg in the presence of light) [18]. Induction-coupled plasma-mass spectrometry was also utilized to investigate how much iodine was lost from salt when it was subjected to humidity, sunlight, and short-term heating (dry and in solution). When stored in high humidity, iodine is greatly lost, although light or dry heat has little effect [19]. Assessment of the effect of heat on the iodine content of salt was conducted using iodometric titration. The tests revealed that all items contained an appropriate level of iodine prior to cooking. However, it was shown that salts lost a large amount of their iodine concentration when they were fried (11.75–29.04%) [20]. Iodometric titration was again used in another study to measure the iodine concentration of samples of iodized salt that had been heated incrementally to 350 °C. The study's findings show that when exposed to high temperatures, samples of iodized salt lose iodine content gradually but minimally, with a maximum loss of 18.5% at 350 °C [21].

Based on the findings of the present study, we recommend households to add salt at the last few minutes of cooking or after cooking and store salt in a dark and cool area in order to minimize the loss of iodine. We also recommend further studies regarding the exact mechanism by which heat and light cause the loss of iodine from salt.

5. Conclusion

The results of this investigation showed that salt's iodine concentration is dramatically reduced by heat and light. The degradation of iodizing substances like potassium iodate and potassium iodide into the free form of iodine is thought to be accelerated by heat and light, which is one of the potential causes of iodine loss. In order to reduce the loss of iodine, it has been advised to add salt in the final few minutes or just after cooking, and to store salt in a place shielded from heat and light. It has also been suggested that raising awareness of the ideal salt storage conditions for society and setting up a suitable monitoring system at various levels (during production, distribution, and consumption) be done. The exact mechanism (the detailed chemical processes) by which heat and light promote iodine loss also needs further study.

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Author contribution statement

Ebisa Mirete Deresa: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper. Daniel Muluneh Befkadu: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data. Milkessa Geletu Hamda: Analyzed and interpreted the data; Wrote the paper.

Data availability statement

Data included in article/supp. Material/referenced in article.

Declaration of competing interest

We declare that we have no competing interests that could have appeared to influence the work reported in this manuscript.

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References

[1] E.J. Ekott, U.I. Etukudo, Iodine stability in commercial salt brands in Nigeria, Int. J. Eng. Tech. Res. (IJETR) 7 (3) (2017) 2454–4698. https://media.neliti.com/media/publications/265054-iodine-stability-in-commercial-salt-bran-39efc873.pdf.

[2] M. Vithanage, I. Herath, S.S. Achinthya, T. Bandara, L. Weerasundara, S.S. Mayakaduwa, Y. Jayawardhana, P. Kumarathilaka, Iodine in commercial edible iodized salts and assessment of iodine exposure in Sri Lanka, Arch. Publ. Health 74 (1) (2016), https://doi.org/10.1186/s13690-016-0133-0.

[3] A. Zahidi, M. Zahidi, J. Taoufik, Assessment of iodine concentration in dietary salt at household level in Morocco, BMC Publ. Health 16 (1) (2016), https://doi.org/10.1186/s12889-016-3108-8.

[4] M. Rahanur Alam, M. Dey, Md Kobirul Islam, S. Reza, S. Mamun, A. Zaher, Determination of iodine content of commercially available table salts at the retailer level in selected areas of Bangladesh, European J. Nutrition & Food Safety (2020) 284–288, https://doi.org/10.9734/ejnfs/2019/v11i430177.

[5] M. Winder, Z. Kosztyła, A. Boral, P. Kocełak, J. Chudek, The impact of iodine concentration disorders on health and cancer, Nutrients 14 (11) (2022) 2209, https://doi.org/10.3390/nu14112209.

[6] M.B. Zimmermann, M. Andersson, Global endocrinology: global perspectives in endocrinology: coverage of iodized salt programs and iodine status in 2020, Eur. J. Endocrinol. 185 (1) (2021) 13–21, https://doi.org/10.1530/eje-21-0171.

[7] H.-R. Kim, Y.H. Jung, C.W. Choi, H.R. Chung, M.-J. Kang, B. Kim, Il. Thyroid dysfunction in preterm infants born before 32 gestational weeks, BMC Pediatr. 19 (2019) 1–8.

[8] Z. Abebe, E. Gebeye, A. Tariku, Poor dietary diversity, wealth status and use of un-iodized salt are associated with goiter among school children: a cross-sectional study in Ethiopia, BMC Publ. Health 17 (1) (2017) 1–11, https://doi.org/10.1186/s12889-016-3914-z.

[9] F.J.K. Toloza, H. Motahari, S. Maraka, Consequences of severe iodine deficiency in pregnancy: evidence in humans, Front. Endocrinol. 11 (2020) 409, https://doi.org/10.3389/fendo.2020.00409.

[10] Z.A. Anteneh, M. Engidayehu, G. Abeje, Iodine content of dietary salt at household level and associated factors using iodometric titration methods in Dera District, Northwest Ethiopia, BMC Nutrition 3 (1) (2017), https://doi.org/10.1186/s40795-017-0203-x.

[11] G.F. Obssie, K. Ketema, Y. Tekalegn, Availability of adequately iodized dietary salt and associated factors in a town of Southeast Ethiopia: a community-based cross-sectional survey, Journal of Nutrition and Metabolism 2020 (2020) 1–7, https://doi.org/10.1155/2020/1357192.

[12] T. Mersha, T. Derso, M. Jemal, S. Kedir, B. Mohammed, Determination of the iodine content of salt at the household level and its predictors in Bahirdar Town, Northwest Ethiopia, Pan African Medical Journal 41 (2022), https://doi.org/10.11604/pamj.2022.41.260.17910.

[13] T. Keno, C. Ahrens, J. Lauvai, H. Kurabachew, H.K. Biesalski, V. Scherbaum, Iodine status in pregnant women and school children of the Aira District in Ethiopia, NFS Journal 7 (2017) 1–7, https://doi.org/10.1016/j.nfs.2017.03.001.

[14] H. Gerensea, A. Yohannse, B. Baymot, H. Atsbha, Knowledge, attitude and practice (KAP) towards iodized salt utilization in Hawelti Kebelle, Axum, Tigray, Ethiopia, 2015, Edorium J Nutr Diet 2 (2016) 1–8, https://doi.org/10.5348/N09-2016-3-OA-1.

[15] L.L. Diosady, J.O. Alberti, M.G.V. Mannar, S. FitzGerald, Stability of iodine in iodized salt used for correction of iodine-deficiency disorders. II, Food Nutr. Bull. 19 (3) (1998) 240–250, https://doi.org/10.1177/156482659801900306.

[16] Johnson, A.; Herrington, B., Factors influencing the loss of iodine from iodized salt. https://naldc.nal.usda.gov/download/IND43967398/PDF..

[17] S.H. Fallah, A. Khalilpour, A. Amouei, M. Rezapour, H. Tabarinia, Stability of iodine in iodized salt against heat, light and humidity, International Journal of Health and Life Sciences 6 (1) (2020), https://doi.org/10.5812/ijhls.100098.

[18] A. Sawalha, M. Sawalha, R. Rajabi, Determination of iodine level in consumer table salt from production to consumption: a cross-sectional study in Occupied Palestinian Territory, Lancet 393 (2019) S45, https://doi.org/10.1016/s0140-6736(19)30631-2.

[19] P.K. Dasgupta, Y. Liu, J.V. Dyke, Iodine nutrition: iodine content of iodized salt in the United States, Environ. Sci. Technol. 42 (4) (2008) 1315–1323, https://doi.org/10.1021/es0719071.

[20] M.R. Nath, G.C. Barmon, T.S. Monir, M.S. Mia, S.C. Paul, S. Bhowmik, Assessment of iodine content in the commercial edible salt of Bangladesh, Journal of Nanomedicine Research 8 (1) (2020) 7–9, https://doi.org/10.15406/jnmr.2020.08.00201.

[21] A. Bhatnagar, N.S. Maharda, V.K. Ambardar, D.N. Dham, M. Magdum, R. Sankar, Iodine loss from iodised salt on heating, Indian J. Pediatr. 64 (6) (1997) 883–885, https://doi.org/10.1007/bf02725517.