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ORIGINAL ARTICLE

Iodized Salt: Assessment of Nutritional Status, Iodine Intake and Iodine Exposure

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KEYWORDS

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ABSTRACT: Food grade salt is the main carrier for iodine fortification to prevent iodine-deficiency disorders in iodine-deficient regions. Excessive and also too low iodine content in salt could cause diseases and human health risks. This study is aimed to investigate the iodine content of edible salts produced in Semnan province (Iran) and also the iodine intake and exposure were estimated in population. Iodine content of 75 salt samples from 25 different brands produced in Semnan province were measured using titration method. Urinary iodine was determined in 240 children (8-12 years old). Iodine intake and exposure was determined based on the defined variables. The results indicated that the mean iodine concentration of 32% iodized salt samples were not according to acceptable range (30-50 mg kg^{-1})set by Iranian National Standard Institute. The urinary iodine median was 161 µg L^{-1} and in 7.5% of studied population was more than 300 µg L^{-1}. The mean of daily iodine intake in all samples was 298.4 ± 79.6 µg per day. Obtained iodine exposure values demonstrated that the status of iodine intake in Semnan province was at optimal nutrition and no risk of iodine deficiency treat the population.

INTRODUCTION

Iodine is a necessary micronutrient for normal thyroid function and its deficiency caused by inadequate iodine content of diet especially in early stages of pregnancy and early childhood leads to delayed physical growth, mental retardation, auditory and motor disorders, cretinism, low IQ, decrease of fertility, miscarriage, and increased neonatal death risk [1-3]. Loss of learning ability by about 13.5 degrees of IQ level decrease has been caused by mild iodine deficiency in children[4]. Mild to moderate iodine deficiency leads to hypothyroidism and goiter in adults [1-4]. World Health Organization (WHO) showed that 2.2 billion people on 130 countries are at risk of iodine deficiency all over the world in 1990. [5, 6]. Therefore in 1994, prevention and control of iodine deficiency was started all over the world including Iran by introduction of salt iodization as a reliable method proposed by WHO, United Nations Children's Fund (UNISEF), and International Council for Control of Iodine Deficiency Disorders (ICCIDD) [2, 3]. Following the Universal Salt Iodization Program, although the number of countries with adequate iodine intake (in terms of urinary iodine concentration in school children) has increased from 67 to 112 countries, excessive iodine intake caused by iodized salt consumption has been reported in 10 countries [6, 10

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and 11]. The important point is that as iodine deficiency, the excessive iodine intake can disturb thyroid function by causing goiter, hypothyroidism, iodine-induced hyperthyroidism, papillary thyroid carcinoma, thyrotoxicosis, and autoimmune thyroiditis (autoimmune thyroid disorders) especially in sensitive groups such as fetuses, neonates, and the elderly [1, 2, 10, 12 and 13].

Iodized salt is table salt which mixed with a determined amount of the element iodine to prevent iodine deficiency. The iodization could performed by spraying of potassium iodate or potassium iodide solution on edible salt in salt production line. In fact, the iodization of salt may be simplest and most cost-effective practice to promote health in worldwide. WHO/UNISEF/ICCIDD report in 2001 showed that after 5-10 years of salt iodization program, excessive iodine intake has led to hyperthyroidism in sensitive groups [2]. In Sri Lank, high prevalence of iodine-induced hyperthyroidism and high concentration of urinary iodine especially in female adolescents was reported to be caused by excessive iodine intake as a result of lack of control on salt iodization [14]. So, it is important to control iodine nutritional status and keep at acceptable level [12]. According to Iranian National Standard |(No. 1195), the iodine content of salt should be equal to 45 ± 15 (30-50 mg kg^{-1}) [15]. Semnan province is one of the leading regions of salt production in Iran. The monitoring of iodine level in salt samples is not only necessary to assessment of iodine status but also for evaluating the health risk of iodine exposure in population [14]. The present study is aimed to investigate the iodine content of iodized salts samples and urinary iodine level in order to estimate the iodine intake and exposure status.

MATERIALS AND METHODS

study area

This study was conducted in Semnan province of Iran which covers 97491 km2 constitutes about 5.9% of the whole country's area. The province is located at geographic coordinates of 5'14˚ 5 N and 15'55˚ 53 E. Semnan province is the main region of salt production in Iran supplying 60% of the country's salt consumption. It has 33 salt mines from which rock salt is extracted. Meanwhile, there are 31 salt processing units in the cities of Semnan, Garmsar, Sorkheh, and Eyvankey; some of them produce non-edible industrial salt and some others produce refined edible salt.

Sampling

Samples were collected from supermarkets and shops of Semnan city (Iran) in 2018. Totally, 75 one-kg salt package samples with 25 different brands (3 samples from each brand) were collected. The salt samples were transferred to laboratory and kept at the laboratory temperature (21ºC) until to analysis. Due to ethical considerations, the salt brand names have not been mentioned in the research and they are reported by numbers 1 to 25.

Iodine determination in salt

Iodine content of salt was measured according to standard method was adopted by Institute of Standards and Industrial Research of Iran (ISIRI 1195). At first, 65 mL of double distilled water was added to 12.5 g of salt and after mixing (1 min), 1 mL of sulfuric acid (2 N) and 5 mL of potassium iodide (10%) were added to the mixture. At the end, the flask content was titrated by sodium thiosulfate (0.02 N). The iodine content was calculated using following equation (1):

$$\text{Iodine content } (\gamma)\left(\frac{\text{mg}}{\text{kg}}\right) = \frac{(F \times V \times 0.1058)}{\text{w}} \times 1000 \qquad (1)$$

Where V is the volume of the used sodium thiosulfate (mL), W is the salt sample weight (g), and F is the correction factor of sodium sulfate solution.

Urine samples and iodine content determination

The study subjects were included school students of 8-11 years old that selected from elementary schools of six geographical regions in Semnan. In total 240 urine samples were collected from male and female (healthy children) by random cluster sampling. An informed consent letter was received from all the participants (240 people) or their parents and their information was kept private. Also based on initial questionnaire, the participants had no concurrent disease affecting urinary iodine. Urine sampling was done by 10 cc of 24-hour urine. The samples were kept in sterile polyester containers and they were put in ice packs and transferred to laboratory in the shortest time. The urinary iodine concentration (UIC) was determined based on acid digestion (ammonium sulfate) followed by colorimetric measurement of Sandel-Kolthoff reaction in 96-well plates. The absorbance was read at 405 nm[18].

Evaluation of iodine exposure

The daily iodine intake in terms of body weight (kg) per day was calculated as chronic daily intake (CDI) using following equation[19].

$$\mathrm{CDI} = \frac{(\mathrm{C}\times\mathrm{IR}\times\mathrm{EF}\times\mathrm{ED})}{(\mathrm{BW}\times\mathrm{AT})} \qquad (2)$$

CDI is chronic daily intake (mg kg^{-1}.day), C is concentration of salt iodine content (mg kg^{-1}), IR is daily salt consumption (mg/day), EF is the annual consumption times (day/year), ED is the number of years during which this substance is used (year),BW is body weight (kg), AT is obtained by multiplying ED with the number of days (days).

Statistical analysis

The results were reported as mean and standard deviation, and comparison of variances by Kolmogorov-Smirnov test was done for checking the data normality (P=0.0001). Due to non-normal distribution of urinary iodine, the urinary iodine was reported as median. All the statistical analyses were done by SPSS 18 at the significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Iodine content of edible salt

Table 1 presents the results of measuring the iodine content of the salt samples produced in Semnan province. The total mean of iodine content in salt samples was 41.77 mg kg^{-1}. The highest mean (64.80 mg kg^{-1}) was reported for sample 11 produced in Garmsar, and the lowest mean (15.87 mg kg^{-1}) was reported for sample 24 produced in Semnan. According to the Iranian national standard the acceptable range of iodine in edible salt is 30-50 mg kg^{-1}; [20, 21] in this regard the results showed that among the 25 salt samples the mean iodine content 17 samples (68% of brands) was at acceptable level, in 8 samples (20% of the brands) was upper than 50 mg kg^{-1} and in 5 samples (12%) was below the acceptable minimum level (30 mg kg^{-1}). Also the percentage of salt samples according to the concentration range of iodine (mg kg^{-1}) is shown in Figure 1.

Table 1. Iodine content of iodized salt samples (mg.kg^{-1}).

Salt Sample (Brand)	Salt production area	Min Mg kg^{-1}	Max Mg kg^{-1}	SD	Mean Mg kg^{-1}
1	Semnan	52.17728	65.77896	6.80	58.90
2	Semnan	43.62044	52.17941	4.83	46.60
3	Semnan	39.89703	46.85147	3.92	42.33
4	Eyvankey	34.93945	40.01496	2.86	36.71
5	Garmsar	50.62883	60.59366	5.62	54.10
6	Semnan	48.26574	53.14178	2.47	50.94
7	Semnan	44.94028	49.11047	2.11	47.23
8	Garmsar	35.88034	38.2911	1.22	45.52
9	Garmsar	61.51541	67.48668	3.03	47.61
10	Semnan	25.95118	27.00491	0.52	37.21
11	Garmsar	62.7588	67.08517	2.17	64.80

12	Garmsar	22.1511	31.08873	4.47	26.45
13	Garmsar	28.44819	43.49254	7.54	35.60
14	Garmsar	58.23927	61.96833	1.87	60.00
15	Garmsar	23.62831	38.28391	7.412	30.31
16	Garmsar	32.75525	37.22204	2.33	35.39
17	Garmsar	32.23433	42.68633	5.77	36.04
18	Garmsar	28.16912	50.20457	11.18	38.08
19	Garmsar	20.87394	31.86519	5.54	25.93
20	Garmsar	48.06085	50.62169	1.30	49.19
21	Garmsar	39.00349	45.86025	3.58	43.03
22	Semnan	33.6559	33.83147	0.08	33.75
23	Eyvankey	34.22004	39.49002	2.75	37.32
24	Semnan	15.86509	15.87551	0.01	15.87
25	Garmsar	40.73301	48.86191	4.23	45.49
Total					41.77

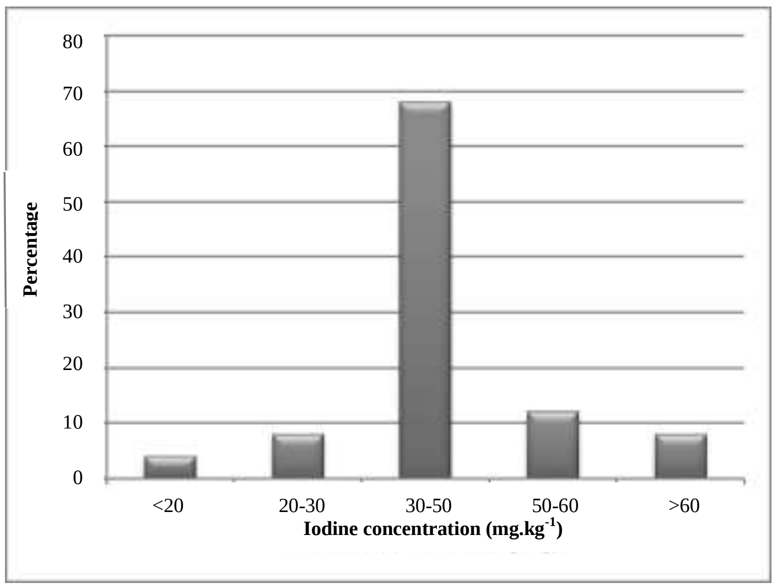

Figure 1. Percentage of salt samples considering iodine concentration range (mg kg^{-1})

A similar study investigated the evaluated iodine concentration in 1450 samples of iodized salt from 70 brands produced in 30 provinces in Iran[20]. They found that in 49% of the salt samples the iodine content was at the optimal standard level. In addition they reported the mean iodine concentration in salt samples produced in Semnan province was 36.26 ± 97.96 mg kg^{-1} in which 78% of samples had acceptable level iodine concentration and in 22% of samples was not acceptable [20]. A similar study investigated the iodine content and purity of 40 salt samples supplied in Kermanshah province, and they found that 72.5% of samples were at optimal and 12.5% of them were above the standard level[22]. The study investigated the iodine content of edible salts in Qom city, and they found that the iodine content in 91% of the refined salts, was at the optimal range (30-50 mg kg^{-1}), and in 2% of the samples, were more than 50 mg kg^{-1} [17]. In research the iodine content of table salt in central highland of Ethiopia reported in 60.38% of samples were in allowable standard limit (15-40 ppm); in 38.33% were over the acceptable limit; and in 0.83%, it was lower than standard level also the mean iodine content of studied samples was 45.29 + 14.47 ppm[23]. Hawas study performed a cross-sectional study with multistage sampling to investigate the household (HH) consumption of iodized salt in Asella in Ethiopia. The HH iodized salt consumption was 62.9%. This study suggested that 76.8% of households add salt to foods at the end of cooking or just after that. As a matter of fact some demographic indexes such as education level, income level, and people's knowledge about iodine deficiency and its effects on health are so effective in the way of adding salt to the food[24]. Furthermore, different studies indicated that there is an allowable level of iodine concentration in most of the iodized salt samples. However the factors such as the condition and storage duration of are effective on sustainability of iodine in salt[20]. In the case of non-observance of the above mentioned factors, iodine concentration of salt will be decreased even in the salt samples containing adequate amounts of iodine. Therefore, investigation of household consumption of iodized salt and proper use of that besides continuous assessment of iodine content of salt is one of the important actions to be taken for promotion of health in societies.

Urinary iodine concentration (UIC)

One of the indicators used for evaluating iodine intake status is measuring the UIC because more than 90% of the iodine content of foods is excreted in urine. So, it reflects the changes in iodine intake [3, 20]. WHO, UNICEF, and ICCIDD reported that in children, the UIC of 100-199 $\mu g.L^{-1}$ indicates an adequate iodine intake; below 99 $\mu g\ L^{-1}$ indicates inadequate iodine intake; ranging in 200-299 $\mu g\ L^{-1}$ indicate above-adequate iodine intake; and above 300 $\mu g\ L^{-1}$ indicates excessive iodine intake [8, 20]. The results of determining UIC for 240 students of 8-12 years old in Semnan are presented in Table 2. The median of obtained UIC was 158 $\mu g\ L^{-1}$. According to WHO/UNICEF/ICCIDD standard, in 56.6% of the subjects, the UIC was in the standard range (100-199 $\mu g\ L^{-1}$); in 24.3% was lower than 99 $\mu g\ L^{-1}$, and in 7.5% of cases, was above 300 $\mu g\ L^{-1}$ that suggests a high iodine intake which may be accompanied by health risks.

Table 2. Urinary iodine concentration in student of 8-12 years old.

Number of Sample	Mean	Median	Minimum	Maximum	<20 $\mu g\ L^{-1}$ %	20-49 $\mu g\ L^{-1}$ %	50-99 $\mu g\ L^{-1}$ %	100-199 $\mu g\ L^{-1}$ %	200-299 $\mu g\ L^{-1}$ %	>300 $\mu g\ L^{-1}$ %
240	158	161	19	393	4	6.2	16.7	56.6	12.6	7.5

Zimmermann studied UIC as an indicator of iodine intake in 117 countries. Their findings suggested that 29.8% (246 million people) of the children of 6-12 years old had an inadequate iodine intake; 78 million people of this population lived in Southeast Asian countries and 57 million children lived in African countries. Iodine intake was reported adequate in 32 countries (100-199 $\mu g\ L^{-1}$), inadequate in 71 countries (below 100 $\mu g.L^{-1}$), above adequate in 36 countries (200-299 $\mu g\ L^{-1}$), and excessive in 11 countries (above 300 $\mu g\ L^{-1}$). Iran was recognized as one of the countries with above adequate iodine intake and it was reported that more than 90% of Iranians can access iodized salt [8]. In Iran, after the initiation of iodine fortification (in 1989), iodine monitoring studies were accomplished considering the prevalence of goiter, thyroid function, and UIC determination in students. The results of these studies suggested that the mean UIC (15.7 $\mu g\ L^{-1}$) and goiter prevalence (68%) all over the country (1989) respectively reached up to 145 $\mu g\ L^{-1}$ and 5.7% in 2007 [6].

The Mirmiran study in 2002, studied 1350 students of 8-10 years old in Semnan province. They found that the median of UIC in the studied population was 35 µg/dl, while this value was more than 10 µg/dl in 89% of cases. The total prevalence of goiter in the province was 49% with the respective values of 52% and 45% in girls and boys. It suggested that 7 years after the establishment of salt iodine fortification program, Semnan is considered as an endemic province in terms of goiter [25]. In another study in 2002, Mirmiran investigated the students of 7-10 years old in Semnan province concerning goiter prevalence and UIC. The UIC was measured in one-tenth of the urine samples. The total prevalence of goiter in the students was reported as 17% (with the respectively values of 7.17% and 3.16% for girls and boys), and the median of UIC in the studies population was 7.13 µg/dl; in 2.73% of the samples, it was more than 10 µg/dl. Also the UIC values of below 5 µg/dl were reported in 8.10% of subjects. None of the subjects reported a UIC value of less than 2 µg dl^{-1} [25]. According to the UIC findings in this study and comparing them with the studies performed in the province in the years 1996 and 2001, Semnan is considered as one of the regions without iodine deficiency. As a research consistent with the present study, Asadi Karam studied 201 male and female students of 6-18 years old in Rafsanjan, and they found that in 68.1% of the students, UIC was above 100 µg L^{-1}; also, normal function of thyroid hormones was reported in 94% of students [26]. In the study of Rostami studied 500 female students of 9-16 years from three different educational programs in two districts of Uromia. They reported the students' mean UIC as 146.3 µg L^{-1}; a UIC value of above 100 µg.L^{-1} was reported for 75.5% of students [27]. In the study of Delshad investigated goiter prevalence and UIC of 17 years after salt iodization program in Tehran province by studying 1200 elementary school students of 8-10 years old. They found that the total frequency of goiter was 2.3% and the mean UIC was 94.1 µg L^{-1}; also, they reported a below 50 µg L^{-1} UIC in 20.8% of population. In addition 54.9% of Iranian families used refined salt and 62.5% of the salts used by households had iodine content of less than 15 γ [6].

Iodine daily exposure

As deficiency of daily iodine intake decreases thyroid hormone synthesis and causes iodine deficiency disorders, exposure to more than 1100 µg L^{-1} per day (the tolerance daily iodine intake) leads to increased activity of thyroid stimulating hormones (TSH) and loss of normal thyroid function occurred in the form of iodine-induced hypothyroidism (IIH) and increased risk of thyroid cancer [8, 14]. Therefore, it is so necessary to determine the iodine concentration of the produced iodized salts in order to observe the standard iodine exposure regarding the iodine intake and iodine status. According to Table 3, the daily iodine exposure of 150-299 µg L^{-1} indicates a favorable iodine status, and the values of above 300 µg L^{-1} per day are more than the necessary iodine intake and they can increase the risk of thyroid disorders [14].

Table 3. Iodine exposure levels and the corresponding iodine status [13]

Exposure level (µg/day)	Iodine status
<30	Severe deficiency
30 – 74	Moderate deficiency
75 – 149	Mild deficiency
150 – 299	Optimal nutrition
300 – 449	Above requirement

Figure 2 presents the results of the mean daily iodine exposure obtained from salt consumption estimation and calculated CDI (mg kg^{-1}.day) of iodine in salt samples. The results show that the total mean of CDI for the 25 salt samples produced in Semnan was 298.4 ± 79.6 µg kg^{-1} (body weight) per day. The maximum and minimum values of daily exposure obtained for the studied salt brands are respectively 462.9 and 113.4 µg.kg^{-1}.

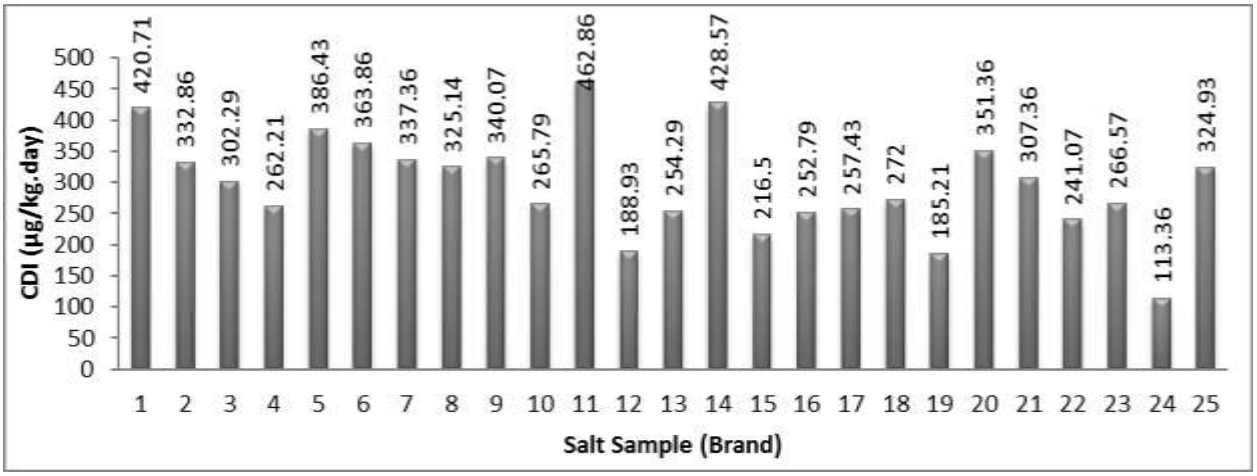

Figure 2. Chronic daily intake (mg kg^{-1}.day) of iodine in salt samples

A study in Sri Lanka showed that all the studied salt samples had a mean iodine content of above the suggested fortification level (15-30 µg kg^{1}). The value of daily iodine exposure was equal to 244.4-432.2 µg kg^{-1}(body weight) for people with low salt consumption, 407.4-720.4 µg kg^{-1} (body weight) for people with medium salt consumption, and 488.8-864.4 µg kg^{-1}(body weight) for people with high salt consumption. In the group of people using salt after cooking, these values were higher [14]. So, there is a direct relationship between salt consumption pattern, and adding the salt to food after cooking causes a higher iodine intake and exposure. In this base the estimation of salt consumption was considered as one of the study limitations. Regarding the values of iodine exposure reported for the salt samples produced in Semnan province, iodine intake is at an optimal nutritional status that is in agreement with the results of UIC reported for the students of Semnan province.

CONCLUSIONS

The exposure to iodine via salt consumption in peoples is evaluable by continuous monitoring of iodine fortification status in edible salt and also UIC. The present study demonstrated that the iodine content of the majority of salt samples produced in Semnan province were according to national standard acceptable range. The median urinary iodine concentrations of student in studied region were at optimal nutrition of iodine exposure level. Taken together iodine intake from iodized salt was in agreement with the criteria that regard to prevent iodine deficiency. Further researches are urgent to demonstrate the pattern of salt consumption in population and the efficiency of industrial iodization of salt.

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ETHICAL CONSIDRATION

The study project had approved by the research ethics committee of Semnan University of Medical Sciences (approval ID: IR.SEMUMS.REC.1397.290).

Conflicts of interest

All authors have declared that they do not have any conflict of interest for publishing this research.

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