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Research Article

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Assessment of Iodine Depletion in Food Grade Salt under Households' Storage Conditions

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ABSTRACT

Iodine is an essential element for human body and represents a fundamental part of thyroid hormones. Salt iodization is an effective and sustainable strategy to prevent and control iodine deficiency for populations. Effectiveness of iodization programs depends on iodine content conservation until consumption. Overall objective of the study was to assess this micronutrient depletion in salt under Senegalese households' storage conditions. These were identified through a survey over 122 households. Comparative study of iodine loss was carried out between raw salt iodized in laboratory at 40 ppm and commercially available salt at 49.1 ppm. Samples were stored in PET and glass jars with covers as well as in PP bags. Each packaging type was divided into two batches in order to evaluate possible iodine migration: salt was homogenised (batch 1) or not (batch 2) before iodine concentration determination by iodiometric titration during six weeks. Micronutrient losses were more important for PP bags, between 16.0% and 30.5%. Largest decreases in iodine content were associated with raw salt compared to commercial salt. A migration phenomenon of iodine within containers was observed. Despite observed depletion over the six weeks period, iodine levels remained adequate in accordance with food grade salt requirements.

Keywords: Iodine; Depletion; Migration; Food grade salt; Titrimetry.

INTRODUCTION

Iodine is an essential trace element in human diet to ensure good health and regulate physical growth and development [1]. A healthy human body contains 15-20 mg of iodine, of which 70-80% is stored in thyroid gland [2]. It is required for synthesis of thyroid hormones which are the only compounds containing this micronutrient that possess biological activity [3,4]. These hormones, Triiodothyronine (T3) and Thyroxine (T4), are necessary for protein metabolism and promote nitrogen retention, glycogenolysis, and intestinal absorption of glucose and galactose, as well as for lipolysis and uptake of glucose by adipocytes [5]. Deficient daily dietary iodine intake is responsible for a range of abnormalities, termed "Iodine Deficiency Disorders" (IDD) whose consequences must be curable. IDD cause goitre, hypothyroidism, mental retardation (cretinism), intellectual disability, psychomotor defects, hearing and speech impairment, anaemia, spontaneous abortions, stillbirths and reduced fertility [6,7]. Another IDD occurs during pregnancy, as hormones produced by thyroid gland are responsible for ensuring normal development of fetal brain and nervous system before birth [8]. Most people need an additional source of iodine as it is found in relatively small amounts in diet. Natural dietary iodine sources are milk, vegetables, fruits, cereals, eggs, meat, spinach and sea foods but in low concentrations and not in bioavailable form [9]. Iodization is process of fortifying salt for human consumption with iodine and an effective strategy to increase its intake at the population level [10]. Salt iodization is a public health issue. In order to eliminate IDD, about 70% of world's population currently consumes iodized salt [11,12]. However, it has been estimated that globally 1.88 billion people still have insufficient iodine intake [13]. According to World Health Organization (WHO), daily intake of iodine should be 90 µg for preschool children (0-5 years), 120 µg for schoolchildren (6-12 years), 150 µg for adolescents (above 12 years) and adults, 250 µg for pregnant and lactating women [5]. United Nations Children’s Fund (UNICEF) specifies that adequately iodised salt must contain more than 15 ppm of iodine. Besides UNICEF, countries worldwide have established national standards for daily iodine uptake. Senegalese regulation authority locally known as “Association Sénégalaise de Normalisation” requires an iodine content between 30 and 50 ppm for commercialised salt [14]. Senegalese government is working to strengthen salt iodization through the “Cellule de Lutte contre la Malnutrition (CLM)” which is supported by international programs (UNICEF, World Food Program-WFP, Micronutrient Initiative-MI, Global Alliance for Improved Nutrition- GAIN-, etc.) [15]. Iodate is added to salt as a source of iodine to prevent IDD in many countries [16]. Our recent study dealing with evaluation of iodine content in table salts collected from Senegalese households revealed that adequately iodized salt is not sufficiently consumed [17]. Faced with this observation, we wondered about iodine loss and migration from food grade salt under households’ storage conditions. These parameters were evaluated in the present work.

Experimental Section

A survey of 122 households in Dakar area was conducted to identify conditions under which salt is stored after purchase. A comparative study of iodine loss was carried out between raw salt iodized in laboratory according to food grade salt regulations and commercially available iodized salt, reproducing storage conditions encountered in households.

Sampling

Raw salt was collected from "Lac Rose" also known as Retba Lake (Sangalkam rural community, Dakar region, 14°50'N-17°20'W). It is located 30 km north of Dakar along great Senegalese coast and represents one of the main salt production areas in Senegal [15,18]. Food grade fine salt with a 49.1 parts per million (ppm) iodine levels was taken from trade.

MATERIALS AND METHODS

Raw salt was ground before iodization to 40 ppm using potassium iodate (KIO_3) through drip method then dried in a desiccator containing freshly activated silica gel. KIO_3 is commonly used for salt iodization in developing countries and considered as most stable chemical form for tropical climates [19,20]. This level was taken as an average value since commercial salt should contain between 30 and 50 ppm iodine [14]. During study, samples were stored in plastic and glass jars with covers as well as in plastic bags in laboratory where average temperature is 25°C. Each packaging type was divided into two batches in order to assess possible iodine migration: salt was homogenised (batch 1) or not (batch 2) before taking analytical sample. Iodine depletion monitoring was carried out over six weeks with a control interval of fifteen days. Iodine content in samples was determined by titrimetric method which is conventional technique for its estimation in iodized salt. In this approach, iodate in salt reacts with added iodide. Generated I2 can then be titrated with sodium thiosulphate solution and thus iodine in food grade salt can be quantified [16,21,22]. We also have previously verified these methods validity parameters. Briefly, salt (10 g) was dissolved in water (50 mL). Solution was kept for 10 minutes in the dark after addition of 1 M sulphuric acid (1 mL), 5% potassium iodide (5 mL) and 1% starch indicator (5 to 10 drops) solutions. Resulting yellow/brown mixture was titrated with 2.5 mM sodium thiosulphate solution until discoloration [23]. Each assay was done in triplicate. Chemicals and reagents of analytical grade, double distilled water as well as class A burettes and pipets were used during our investigations.

RESULTS AND DISCUSSION

Within households, we identified the use of plastic and glass jars as well as plastic bags in polypropylene (PP) as shown in Table 1. PP represents packaging in which iodized salt is marketed. Plastic jars originally contained Nesquik® chocolate powder and are made of recyclable polyethylene (PET). Amount of salt purchased for consumption in households varied from 125 g to 2 kg. After purchase, the shelf life was usually no longer than one month (Table 2).

Table 1: Distribution of iodized salt storage containers in households

Container	Households number	Percentage (%)
Plastic (PET) jars	60	49.19
Glass jars	30	24.59
Plastic (PP) bags	32	26.23
Total	122	100

Table 2: Distribution of purchased amount and shelf life of iodized salt

Purchased amount	Shelf life	Households number	Percentage (%)
125 g	Less than a week	6	4.92
125 - 250 g	One week	52	42.6
250 g	One to two weeks	61	50
1 - 2 kg	One month	3	2.46
Total		122	100

Iodine content variation of both salt samples initially at 40 and 49.1 ppm over the six weeks period is shown in Table 3.

Table 3: Variation in iodine levels

Mean ± SD (ppm)										
		PET jar	**PET jar***	**Δ iodine loss (%)**	**Glass jar**	**Glass jar***	**Δ iodine loss (%)**	**PP bag**	**PP bag***	**Δ iodine loss (%)**
Raw salt (initially iodized at 40 ppm)	t: 2 weeks	36.9 ± 0.33	35.5 ± 0.00	-	40.0 ± 2.64	34.8 ± 0.33	-	40.2 ± 1.31	30.6 ± 0.99	-
	t: 4 weeks	36.2 ± 1.32	35.0 ± 0.66	-	39.3 ± 1.98	34.3 ± 0.33	-	40.0 ± 0.00	28.7 ± 0.99	-
	t: 6 weeks	34.6 ± 0.66	34.1 ± 1.32	-	37.6 ± 0.33	34.6 ± 0.66	-	33.6 ± 0.66	27.8 ± 0.98	-
	Iodine loss (%)	13.5	15	1.3	6	14	7.5	16	31	14.5
Commercial salt	t: 2 weeks	44.9 ± 0.65	43.7 ± 0.99	-	44.4 ± 2.64	44.9 ± 0.66	-	44.2 ± 0.33	44.9 ± 0.66	-

(initially at 49.1 ppm)	t: 4 weeks	44.2 ± 0.33	43.0 ± 1.99	-	43.5 ± 1.32	43.0 ± 1.99	-	40.7 ± 1.31	40.0 ± 0.99	-
	t: 6 weeks	41.4 ± 2.31	39.3 ± 0.66	-	39.3 ± 1.98	40.0 ± 2.31	-	36.9 ± 3.97	37.9 ± 3.30	-
	Iodine loss (%)	15.7	20	4.3	20	19	1.5	24.8	23	2
Δ iodine loss (%)		2.2	5.2	-	14	5	-	8.8	7.7	-

Salt is an effective way to distribute iodine to populations because it does not expire and is consumed at roughly estimable levels. While other foodstuffs can be iodized, salt has also the advantage of being widely consumed and inexpensive [24]. However, iodine content in iodized salt may evolved depending on various parameters such as impurities, acidity/alkalinity at production, time after purchase from factory, storage conditions during retail sale as well as in households, packaging nature, humidity (moisture content), temperature, light and cooking (heating) [2,20,25,26]. Our recent study over 1575 table salt samples collected from Senegalese households showed that only 37.3% were adequately iodized [17]. Likewise, evaluation of iodine content in 50 salt samples sold by some retailers in Abidjan (Ivory Coast) had also revealed that 20 of them (40%) were below the quality criteria limit (30 ppm). It should also be noted that 21 of these samples (42%) were above the upper limit (50 ppm) [27]. Just as iodine deficiency, too high intake is also associated with adverse effects on human body. Excessive iodine intake may increase blood glucose level and blood pressure, developing risk of hypertension and diabetes [28]. It also causes other disorders, including hyperthyroidism and autoimmune thyroid disease [29]. Among 327 cooking salt samples collected from households in two Beninese goitre-endemic areas, only 54.74% were correctly iodized [30]. Testing of iodine content in 178 salt samples from all Moroccan regions households revealed that only 4.5% were in conformity with regulations with a 17.8 ppm median concentration [31]. These results highlight that countries fortification program does not reach the target that stipules households' access to iodized salt should be more than 90% [24]. Present study evaluated iodine loss in food grade salt. Households surveyed mainly used PET jars (49.19%) and in comparable proportions glass jars or PP bags (24.59-26.23%) for salt storage. Frequency of such packaging use must vary depending on area since in a study over household salts in two goitre-endemic areas of Benin, PET bags and plastic bottles were used for storage at 44.04% and 41.59% respectively. In these areas, shelf life of cooking salt in home could also be more than three months [30]. PET and glass jars as well as PP bags were used as packaging for our study and locally identified storage period of up to one month but more frequently between one and two weeks for iodized salt purchased from households allowed us to determine experiments duration. Iodine depletion was monitored for six weeks after which it was variable between iodized raw salt and commercial salt but also depending on different packaging used and whether or not the sample was homogenised before testing.

In PET and glass pots, decrease in iodine content varied respectively in the ranges [13.5%-20.0%] and [6.00%-20.0%]. However, for PP bags, losses observed were between 16.0% and 30.5%. These latter were more important because PP bags are less airtight than the two used pots types. Exposure to air facilitates iodine loss [30].

For a starting sample in two identical containers whether or not there was homogenisation, difference in iodine loss was in the range [1.30%-2.00%] for raw salt in PET jars as well as for commercial salt in glass jars and PP bags. This value reached 4.30%, 7.50% and 14.5% respectively for commercial salt in PET jars and raw salt in glass jars and PP bags. The variation did not follow a trend but the largest decreases in iodine content were associated with raw salt. This difference could be related to the fact that raw salt contains hygroscopic impurities such as sulfates ($MgSO_4$, $CaSO_4$), chlorides ($MgCl_2$, $CaCl_2$, KCl) and soil impurities. Indeed, based on quality of food grade salt production requirements, there are several chemical and physical purifying methods in order to fulfill them. Salt purification technologies include brine washing, evaporation also called recrystallization and chemical addition [32,33]. To reduce iodine loss during storage, iodized salt should be as pure as possible. This confirms other author's findings whose variation in iodine content was greater for raw salt that had not undergone any treatment (washing, refining, grinding, etc.) than for fine salt; even if their raw salt sample had different grain sizes compared to ours which had been previously ground. Greatest added value of our study was evaluation of salt homogenisation influence before dosing. Difference in loss was variable between the two starting salt samples, when there was no homogenisation before testing: 2.20%, 8.80% and 14.0% for PET jars, PP bags and glass jars. On the other hand, the magnitude of this variation was smaller in the case of homogenisation, where it was between 5.00% and 7.70%. This implies that there was a migration phenomenon of iodine within containers in which the micronutrient distribution was not homogeneous.

Present study is complementary to the work of Seid Ali et al. who studied impact of three other packaging bags types on iodine loss: High Density Polyethylene (HDPE), TRIPLEX made up of a PET layer, HDPE and a metallized film as well as DUPLEX which is PET and HDPE reinforced with black. At the end of their investigation, no impact of the plastic based packaging used on iodine content decrease was found.

CONCLUSION

Despite observed losses over the six weeks period, iodine levels remained adequate in accordance with recommendations of Senegalese regulation authority. However, it is preferable to store food salt in glass or polyethylene containers with covers, rather than in polypropylene bags, in order to minimize the micronutrient losses. It is also necessary to mix or shake cooking and table salts before use to ensure homogeneity and adequate iodine content in portion added to foodstuffs. Complementary study in various Senegal regions could be interesting in order to possibly identify other packaging's used for storage or longer shelf life's for iodized salt in households. It would also be interesting to evaluate iodine behaviour, in particular migration phenomenon, as a function of iodized salt particle size and temperature. A long-term study could also provide an idea of a cut-off date between salt iodization date and the one at which iodine content would no longer be compliant.

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