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Assessment of the iodine level of table salt from Senegalese households

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ABSTRACT

Senegal is affected by a relatively high prevalence of iodine deficiency disorders, which compromises its social and economic development. To address this situation, the Universal Salt Iodization strategy was adopted by the Senegalese Government. The monitoring of salt iodine status is crucial to the success of such a program. Therefore, this study aimed to evaluate the iodine concentration of table salt from Senegalese households. A total of 1575 samples collected in urban and rural areas were analyzed using the iodometric method. The powdered salt samples showed higher mean iodine content (18.99 ppm) and lower percentage of non-compliance (58.4%) than the other salt types (p = 0.02). Most of the samples collected from urban area were found with iodine content between 15 and 39.9 ppm, whereas, in rural areas, the situation was significantly different (p = 0.01). Iodine levels of most samples were lower than 5 ppm in the rural producing area or varied between 5 to 14.9 ppm in the rural non-producing area. A percentage of 37.3% of adequately iodized salt samples was obtained at a national scale with a significant disparity between urban and rural areas. Therefore, improvements in quality control procedures in tandem with the iodization process are necessary and an information, education and communication strategy should be adopted.

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1. Introduction

Iodine is a key component of thyroid hormones which are required throughout life for normal growth, neurological development, and metabolism [1]. Iodine deficiency has many adverse effects due to inadequate production of thyroid hormones and termed iodine deficiency disorders (IDD). Degrees of severity of these disorders vary from thyroid gland enlargement (goiter) to severe physical and mental retardation known as cretinism [2]. For instance, maternal iodine deficiency during pregnancy can result in maternal and fetal hypothyroidism, as well as miscarriage, preterm birth, and neurological impairments in the offspring [3,4]. Iodine deficiency is the most common cause of preventable mental impairment worldwide. Body iodine requirements vary according to age, sex, and physiological state. Recommended Daily Allowances (RDA) for iodine intake are 150 µg in adults, 220-250 µg in pregnant women, and 250-290 µg in breastfeeding women [5,6]. According to the World Health Organization, two billion individuals worldwide, including 285 million school-age children, have insufficient iodine intake, with those in South Asia and sub-Saharan Africa particularly affected [7]. To prevent iodine deficiency, several strategies have been adopted, among which the Universal Salt Iodization (USI) is considered the most effective long-term public health intervention for achieving optimal iodine nutrition. Effective salt iodization is a prerequisite for the sustainable elimination of IDD. In Senegal, direct and indirect evidence of continued endemic goiter and iodine deficiency lead to the introduction of mandatory iodization of table salt at an iodine concentration of 80-100 ppm at the production stage [8]. As in other African countries, the regulations require potassium iodate to be used for this purpose. However, excessive iodine intake can cause thyrotoxicosis, hypertension, gastric cancer, obesity, or osteoporosis [9].

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Table 1. Recovery, repeatability and intermediate precision of the iodometric titration method.

Iodine level (ppm)	Recovery (%)	Intraday precision (RSD %) *	Interday precision (RSD %)	Relative bias (RSD %)
12	100.2	1.7	2.2	+0.2
24	98.6	1.1	1.1	-1.4
36	98.1	0.7	0.7	-1.9

* RSD: Relative standard deviation.

Table 2. Results of the external quality evaluation.

EQA sample code	Result (ppm)	Acceptable range (ppm) *	Coefficient of variation (%)
EQA-1	7.05	4.05 - 7.75	4.01
EQA-2	14.08	11.85 - 17.15	1.90
EQA-3	23.44	22.10 - 27.70	1.23
EQA-4	33.77	35.90 - 42.48	1.11
EQA-5	41.56	43.56 - 48.64	0.59
EQA-6	59.42	61.75 - 66.65	2.12

* Set by accredited laboratory.

All these considerations highlight the need of adequate salt iodization. Therefore, this work aimed to evaluate the iodine concentration of table salt collected from Senegalese households. The outcomes may give valuable advice about the decision-making process and the appropriateness of Universal Salt Iodization.

2. Experimental

2.1. Sampling

The salt samples were collected as part of a survey on the use of iodized salt by Senegalese households. This survey was carried out on the whole country which was divided into three areas (Urban, Rural producing (salt) area, Rural nonproducing (salt) area).

The sample size was determined using the formula [10]:

$$n = z^2 \times p(q) \div d^2 \quad (1)$$

where n is the sample size to be determined, z is the z-score (reliability coefficient) of 1.96 at 95% confidence level, p is the national coverage (48%) [11] of household iodized salt, d is the margin of error at 5% (0.05), and q is 1-p. Because of the involvement of cluster sample in the sampling method, a "design effect" of 3 was considered in the sample size calculation.

A two-stage sampling method conceived by the National Agency for Statistics and Demography was used. It consists, in the first stage, to select 41 census districts (primary sampling units) using the Probability Proportional to Size (PPS) method in each of the three areas. In the second step, 12 households were selected using computer-generated random numbers from the list of households of the primary sampling units. A small amount of salt sample (approximately 50 g) was obtained from each participating household and put in a polyethylene packaging with a self-adhesive closure. Samples were identified using a bar code conceived using a sampling unit and household number. They were then transported to the laboratory in a dedicated container and stored at room temperature. Twenty-three (23) salt samples with insufficient amount were not considered for analysis.

2.2. Chemicals and reagents

Chemicals and reagents (Sodium thiosulfate, sulfuric acid, potassium iodide, potassium iodate, and starch) of analytical grade were purchased from local suppliers. Double distilled water as well as class A burettes and pipets were also used during this study.

2.3. Iodine quantification

Depending on the form of iodine (iodate or iodide), different salt iodine testing methods are needed to monitor the fortification process. Because salt fortification is usually done with potassium iodate (KIO_3) which is recommended mainly for salt by international organizations, analyses were done using the iodometric titration method. It is the most frequently used method to determine the amount of iodine in salt because of its accuracy, relatively easy to use, and incurs low cost [12]. In this method, first, the iodine content of salt is determined by liberating iodine from a salt sample, then by the titration of iodine with sodium thiosulfate using starch as an external indicator. A 10 g salt sample was introduced in a 250 mL conical flask containing 50 mL of double distilled water. Known volumes of 1 M sulfuric acid (1 mL), 5 % potassium iodide (5 mL) solutions were added to the mixture. The flask was kept in obscurity for 10 minutes before adding a 1 % starch indicator (5 to 10 drops). The mixture was then titrated with a 2.5 mM sodium thiosulfate solution until color disappearance [13-15].

2.4. Quality assurance

Intraday and interday precisions expressed as relative standard deviation (% RSD) and accuracy (% of recovery) of the method were assessed by testing salt samples doped at three concentrations of iodine (12, 24 and 36 ppm) using the method described by Gueye *et al.* [13].

The quality assurance implied participation in the external quality assurance (EQA) program organized by the Global Alliance for Improved Nutrition (GAIN) and the United Nations Children's Fund (UNICEF). Salt samples with unknown (for authors) iodine concentration were supplied and analyzed using the method described above. The evaluation of the EQA results was done by the GAIN-Accredited Laboratory.

All experiments were performed in triplicate (sampling was done thrice) and the data expressed as mean±standard deviation. Statistical analyzes were performed using Excel and Epi Info 7.2.2.1. A 0.05 p value was considered significant.

3. Results

Recoveries, intraday and interday precisions of the iodometric titration method are presented in Table 1. Relative standard deviations (RSD) of intraday and interday precision ranged from 0.7 to 1.7% and 0.7 to 2.2%, respectively. The average recoveries of iodine were 100.2, 98.6, and 98.1% at 12, 24, 36 ppm, respectively. Therefore, the iodometric titration method showed good trueness and repeatability as evidenced by EQA results shown in Table 2.

A total of 1575 salt samples were collected in the targeted households which were divided into three types: urban, rural producing (Rural 1), and nonproducing (Rural 2) salt. The number of analyzed and nonanalyzed samples according to the household type is shown in Table 3. Out of the 1575 salt samples, 23 were not analyzed (14 urban and 9 rural nonproducing samples) regarding their insufficient salt amount.

Table 3. Distribution of analyzed and nonanalyzed samples according the household type.

Household type	Population households	Population	Sample size	Number of analyzed samples	Number of non-analyzed samples
Urban	640	815793	538	524	14
Rural 1	652	9232	554	554	0
Rural 2	652	712656	483	474	9
All types	1944	1537681	1575	1552	23

Table 4. Sample size, means of iodine concentrations, and percentages of non-conformity of powdered and coarse household salt.

Type of salt	Sample size	Mean iodine content (ppm)	Range (ppm)	Non-conformity (%)
Powdered	315	18.99±14.11	1.52-194.84	58.4
Coarse/small	197	10.69±8.92	1.81-86.28	75.6
Coarse/medium	820	10.86±7.79	0.78-176.19	76.9
Coarse/large	220	8.02±6.85	0.00-55.46	83.6

Table 5. Relative distribution (%) of samples according to iodine content and household type.

Household type	< 5 ppm	5 - 14.9 ppm	15 - 39.9 ppm	≥ 40 ppm
Urban	10.4	36.3	48.3	5.0
Rural 1	52.3	36.8	8.6	2.3
Rural 2	27.6	53.3	16.5	2.6
All types	18.7	44.2	33.3	3.8

Table 6. Means of iodine content (ppm) and percentages (%) of non-conformity of household salt samples from Africa.

Country	Mean iodine content (ppm)	Percentages of adequately iodized salt (%)	Number of samples	Reference
Senegal	11.92	37	1552	Our study
Ivory Coast	52.74	77	400	[23]
Niger	9.46	15	222	[24]
Benin	33.80	86	327	[25]
Ghana	-	24	450	[19]
South Africa	27.00	62	2043	[18]

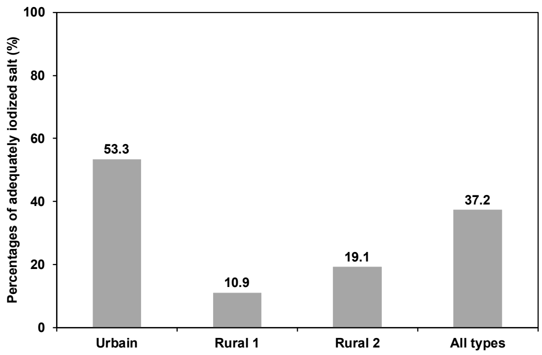

Figure 1. Percentages of adequately iodized salt samples according the household type.

Overall, the iodine content of the samples varied between 0 and 194.84 ppm. The table 4 shows the means of iodine content and the percentages of non-compliant samples according salt granulometry. Powdered salt samples showed higher mean iodine content (18.99 ppm) and lower percentage of non-compliance (58.4%) than the other types of table salt (p = 0.02). As it can be seen from the data in Table 4, an increase in salt particle size results in a decrease in the mean iodine content.

The distribution of salt samples according to their iodine content and the household type is summarized in Table 5. The majority of samples collected from urban areas were found with iodine content between 15 and 39.9 ppm, whereas in rural areas the situation was significantly different (p = 0.01). Iodine levels of most samples were lower than 5 ppm in rural producing areas or varied between 5 to 14.9 ppm in rural nonproducing areas with a significant value between rural areas (p = 0.008). Thus, salt samples from these two areas were frequently found with inadequately iodine levels as shown by Figure 1.

A percentage of 37.2% of adequately iodized salt samples was obtained at a national scale with a significant disparity between urban (53.3%) and rural areas (10.9 and 19.1% for rural producing and rural nonproducing, respectively). The mean iodine level found in table salt from Senegalese households was lower than that found in some West African countries (Table 6).

4. Discussion

Universal Salt Iodization is the recommended intervention for preventing and correcting iodine deficiency and resulting disorders. For countries with high iodine deficiency like Senegal, 90% coverage of adequately salt is recommended by the WHO for eradication of iodine deficiency disorders [3]. For the achievement of this goal, the implementation of a monitoring iodized salt program is a key factor. In Senegal, the "Cellule de Lutte Contre la Malnutrition", a governmental service, is responsible for the salt iodization program. This study is intended to evaluate the iodine concentration of table salt collected from Senegalese households and were conducted in three areas (urban, rural producing, and rural nonproducing). Such stratification was done to evaluate the impact of household type on the quality of iodized salt since several studies revealed a number of differences (income, education, size, etc.) between rural and urban areas [16]. The amount of salt collected was not sufficient for the 23 samples that were not considered in this study. Powdered salt samples showed higher mean iodine content (18.99 ppm) and consequently lower percentage of non-compliance (58.4%) than the other types of table salt. In addition, the mean iodine content decreases when the salt particle size increases. Similar results were reported in South Africa where the mean iodine concentration in fine salt was 31 ppm, whereas the corresponding values in coarse salt were significantly lower at only 20 ppm [17]. In Ghana, adequate iodine of more than 15 ppm was found in 92.3% of all the fine salt (packed iodized salt) tested, while only 1.7 and 7.9% of coarse and granular salt contained adequate iodine, respectively [18]. The iodization process seems to be generally less effective in coarse salt than in fine salt, possibly because of differences in particle size, impurities, or iodization methods [19]. As a better homogeneity is obtained with fine salt, the ideal would be to grind coarse salt before the iodization process. Moreover, care should be taken that the iodization process and the mixing and drying of coarse salt are performed as effectively as with fine salt.

The majority of the samples collected from urban areas were found with iodine content between 15.0 and 39.9 ppm. In the rural producing area, the iodine levels of most samples were lower than 5.0 ppm and varied between 5.0 to 14.9 ppm in the rural non-producing area. A percentage of 37.3% of adequately iodized salt samples was obtained at national scale with a significant disparity between urban (53.3%) and rural areas (10.9 and 19.1% for rural producing and rural non-producing respectively). Differences in household income, particle size of salt, and level of education of the corresponding areas could be explanatory factors since in Senegal, education level and household income are often higher in urban area than in the rural one [16]. Some authors found a positive association between iodized salt use and level of education, and that populations with formal education were more likely to use iodized salt than those with no education [20]. A study conducted in South Africa showed that more households in the low socioeconomic category used coarse salt than households in higher socioeconomic categories. It also showed that the mean iodine content of salt in the former households was lower than that in the latter [17]. Findings of this study were different than those of Aku Sarah *et al.* [18] in Ghana where households in urban areas are 64% less likely to use iodized salt than those in rural areas. In Morocco, Zahidi *et al.* reported no significant difference in iodine concentration between urban and rural areas [21]. However, in Democratic Republic of Congo and Pakistan, the results reported by Kitwa *et al.* and Bhutta *et al.*, respectively, revealed differences between rural areas and urban area with higher percentages of compliance in this latter [22,23]. Iodized salts from Senegalese households showed lower level of compliance with the recommended WHO/UNICEF/ICCIDD level (15 ppm) than that from households of some sub-Saharan countries except Niger and Ghana [17,18,24-26]. In the case of Senegal, the study was conducted at a national scale and results reflect the situation at the national level whereas in other countries studies were realized at a local scale as evidenced by the sampling size. Kibambe *et al.* [27] reported a significant heterogeneity of the salt iodine content from one country to another or from one site to another in the same country. Percentages of adequately iodized salts were also lower than those found in Democratic Republic of Congo (44.8%), Palestine (70%), and Lesotho (81.8%) [22,28,29]. In Morocco, Zahidi *et al.* reported 4.5% of adequately iodized salts which was lower than that found in this current work [21]. All in all, the results of this study show that the goal of at least 90% of households consuming adequately iodized salt is far from being achieved. These results also can explain the persistence of iodine deficiency and endemic goiter in landlocked areas of the country such as Kedougou, Goudiry and Bakel [30].

5. Conclusion

The percentages of adequately iodized salt samples from Senegalese households found in this study are relatively low. The situation is particularly worrying in rural producing salt areas and suggests that improvements in the internal and external quality control procedures in tandem with the iodization process are clearly necessary. In addition, an information, education and communication strategy should be adopted with a view to improving knowledge related to iodine deficiency disorders among consumers and salt producers. A thorough understanding of the public health issues related to iodized salt can be expected to strengthen the commitment of salt producers to marketing salt that is iodized in accordance with the law. In addition, the results of this study point to the need to assess the iodine status of the population, particularly in rural areas, to take effective measures to prevent iodine deficiency disorders if necessary.

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Disclosure statement

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