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Salt Production and Availability of Iodized Salt in the Municipality of Sèmè-Kpodji in 2022

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Abstract

Background: Cooking salt is widely used to provide iodine to humans. In Benin, the production of salt is still artisanal. Our study focused on salt produced in Sèmè-Kpodji, a secondary site of local salt production in Benin, and on the availability of iodine in salt in this municipality.

Methods: The descriptive cross-sectional study included exhaustive salt producers and randomly selected households in Sèmè-Kpodji. Direct observation was made to describe salt production. In household, a standard questionnaire collected data about the physical characteristic of salt used. Iodine content was determined with the MBI kit and by the iodometric titration method.

Results: A total of 8 producers and 365 participants in the households were surveyed. Salt is produced by drying sea water on tarps for three and a half days. The process is done in eight (8) steps, the last of which is the iodization of the product and the packaging. By iodometric titration, the salt produced had an iodine content of 5.2ppm. The mean content of iodine in salt in household was: 87.5 ± 66.0ppm (2.6-396.1). Only 31.2% of cooking salt samples were adequately iodized (15-40ppm). High iodine concentrations have been observed in 62.2% of salt samples.

Conclusion: Salts consumed in households in Sèmè-Kpodji 'municipality were, for the most part, excessively iodized, whereas local production is artisanal and low in iodine. Iodization of the latter is mandatory before marketing. A monitoring of the salt iodization strategy should be maintained to avoid excessive iodine consumption which can cause hormonal disorders.

Keywords: Sea Salt; Production; Iodine; Household; Nutrient

Abbreviations: ID: Iodine Deficiency; IDD: Iodine Deficiency Disorders; WHO: World Health Organization; UNICEF: United Nations Children's Fund.

Introduction

Iodine is an essential trace mineral, vital for its functions in many physiological processes in the human body. Iodine deficiency (ID) and excessive iodine intake often coexisted within populations [1]. ID is a global public health problem, and its impact is more pronounced in low-income countries [2]. ID causes mental impairment around the world; inadequate thyroid hormone production also causes many other adverse effects on growth and development [3,4]. Many of these adverse outcomes, collectively referred to as iodine deficiency disorders (IDD), result from the effects of iodine deficiency on fetal brain development during early pregnancy [5]. Salt iodisation is the most effective strategy for addressing IDD globally and in Africa. This strategy was recommended by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) [6]. However, the success of the iodisation and fortification program is highly dependent on household coverage [3].

In most countries, the salt iodine levels were lower than the legislated standards and household access to iodised salt was also low. In Ethiopia, the pooled proportion of adequately iodized salt at the household level was 37% (95% CI: 28, 46%) [7]. Iodine levels in brands of salt on the markets of Accra, Ghana showed that only (2/11) samples were close to the Ghana Standard Authority's specification [8]. Furthermore, all samples analyzed did not meet the concentration levels indicated on their labels and no iodine was observed in the raw-pellet salt crystallized directly from sea water, in contrast to the long-held belief that it contains natural iodine.

In Benin, the universal salt iodization strategy was adopted in 1994, which includes the implementation of a regulation setting the iodine content of salt for production, import and consumption in households [9]. While the 2017 Benin Demographic and Health Survey indicated 89.6% coverage of iodized salt in households [10], our previous work showed very low iodization of the main local production (Djègbadji) [9], low availability of iodine in communal markets and in Dantokpa (Benin's largest market) [11], insufficient consumption of iodine based on median urinary iodine concentration in Zou region [12]. These results demonstrate some weaknesses in the implementation of the salt iodization strategy in Benin. The objective of this study was to investigate: i) salt production in Sèmè-Kpodji (a secondary site of local production) and ii) the iodine content of salts consumed in this municipality.

Material and Methods

Study Area

The study took place in the municipality of Sèmé-Kpodji located in Ouémé region in the intertropical zone. Sèmé-Kpodji has an area of 250 km^2, included at the last census (RGPH4-2013), a population of 222701 inhabitants, of which 109594 men and 113107 women [13]. These inhabitants are spread over six (6) districts (Agblangandan, Ekpè, Aholouyèmè, Djèrègbé, Tohouè, Sèmè-Kpodji) subdivided into 55 villages and city neighborhoods and comprise 49,490 households. In a recent year, a joint sea salt production activity has been developed in Sèmè-Kpodji, mainly managed by a women's group.

Study population and sampling

The cross-sectional and descriptive study was conducted from January to July 2022. The study population consisted of salt producers and individuals living in households in the municipality of Sèmé-Kpodji. For producers, any subject over 18 years of age who was encountered at the local production site during the investigation period and who consented to the study was included. In households, participants over the age of 18 who have been resident in the municipality for at least 6 months, who have consented to the study, are able to respond to the questionnaire and who have enough for the collection of salt during the visit of the collection team, were selected.

Sample: The sample size of households was calculated using the SCHWARTZ formula n= $\varepsilon\alpha^2$ x p x(1-p)/ i^2 with p = 38.9 corresponding to the proportion of households with adequately iodized salt in a recent national survey in 2014 [14]; $\varepsilon\alpha^2$ = 1,96 corresponding to the accepted risk of error and the accuracy i = 0.05. Thus, the calculated size thus gives 365.

Sampling: We exhaustively recruited all salt producers found at the Sèmè-Kpodji production site. At the household level, a 3-degree sampling technique was used. We have thoroughly recruited all the salt producers found at the Sèmé-Kpodji production site. At the household level, a 3-degree sampling technique was used. At the first stage, two (2) out of six (6) districts in the municipality of Sèmè-Kpodji were randomly selected. At the second level, 30% of the villages or neighborhoods of the selected districts were randomly selected. In the third degree, the number of households to be surveyed was calculated pro rata to the total size of households per neighborhood. Households were selected using a sampling step. Only one adult per household was interviewed.

Data collection

Two questionnaires were used to collect the data. The first one administered to salt producers contains socio-demographic information, practices of salt production by observing the production chain: the salt production materials, the stages, the duration of salt formation, and the iodization of the salt; the characteristics of the salt produced.

The second questionnaire administered to the participants in households, recorded in addition to socio-demographic information; the characteristics of the salt samples collected, namely: color, presence of physical impurities, grain size, type of salt, place of supply, method of preservation at purchase and in households; the salt consumption practices during cooking (yes, no). About 100 g of salt was taken from the production site, while 30 g of salt was taken from households.

Samples analysis

Analyses were performed in the Laboratory of Analytical Chemistry and Drug Analysis in Faculty of Health Sciences of Cotonou. MBI Kits were for qualitative test and iodometric titration for quantitative test.

Iodine analysis by MBI-Kits International: The reagents used consisted of two 10 mL test solution ampoules, each containing potassium iodide (KI), starch, sulfuric acid and one test solution ampoule. Iodine was analysed according to the manufacturer's recommendations (D. Chandrasekhar, Chennai, 600017 Tamilnadu, India). A color scale was provided for visual comparison and estimation of the iodine content of the salt.

Iodine content by iodometric titration: The principle is as follows: in the presence of sulfuric acid (H_2SO_4) and potassium

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iodide (KI), the iodate ions (IO_3) contained in the salt are reduced to iodine (9,15). The released iodine is then titrated with sodium thiosulfate in the presence of starch as an indicator. The volume of sodium thiosulfate used is proportional to the amount of iodine released by the salt. The equation for the reaction is:

$$5KI + KIO_3 + 3H_2SO_4 \rightarrow 3I_2 + 3H_2O + 3K_2SO_4$$

The reagents used were:

1. Sodium thiosulfate solution 0.005 N ($Na_2S_2O_3$: Scharlau, Spain).
2. Concentrated sulfuric acid solution 2N (H_2SO_4: Sigma Aldrich, Germany).
3. Potassium iodide solution 10% (KI: Scharlau, Spain);
4. Soluble starch (Scharlau, Spain);
5. Sodium chloride (NaCl: Analar, England).

Analyzes were carried out according to the procedure described by Dearth-Wesley et al. [16]. These tests were repeated five times for each sample, and for the control sample of salt (iodized salt sample at 40ppm, provided by the Directorate of Food and Applied Nutrition of Benin). The iodine content of salt is determined by the following formula expressed in mg kg-1 or ppm: iodine concentration (ppm) = volume of $Na_2S_2O_3$ poured (mL) × 21.15 × normality of $Na_2S_2O_3$ ×1000 solution/mass of sample of titrated salt (g). WHO and UNICEF standard were used to assess the iodine content of household salts: 90% of households salt with an iodine content of ≥15ppm (6) and iodine content comprised 20-60 ppm in salt at production stage.

Statistical analysis

Data digitized with Kobo Collect version 2020 software (Kobo Inc, Cambridge MA, US) were analyzed in STATA 16.0 software (Stata Corp, College Station, TX, USA). Iodine concentration was expressed in parts per million (ppm = mg/kg salt). Categorical variables were expressed as percentages. Quantitative variables were presented as mean and standard deviation, qualitative variables as frequency and percentage.

Results

A total of 365 subjects aged ≥18 years and 08 salt producers in the municipality of Sèmè-Kpodji were surveyed. We choose to present the results of the producer survey and the household survey separately.

Salt production in Sèmè-Kpodji

Socio-demographic characteristics of producers: The average age of salt producers was 50.5 ± 19.3 years with extremes ranging from 18 to 68 years. The majority (6/8) were 40 years of age or older, women (6/8), and educated (5/8).

Salt production process: Salt production is common to all salt producers in Sèmè-Kpodji. The process described by the 8 producers surveyed is summarized in Figure 1. The duration for salt production by drying on the tarps is 12 hours. All the producers stated that they added iodine to the salt produced. The average amount added was 1.17g of iodine per 24 kg of salt or 48.75mg of iodine per 1kg of salt.

The iodine used is supplied by the Directorate of Food and Applied Nutrition of Benin. The iodine solution is prepared by adding 725ml of distilled water or rainwater to 24g of Potassium Iodide (containing 14.2g of iodine). Then, 240ml of distilled water is added to 60ml of the concentrated solution obtained (containing 1.1 g of iodine). Finally, this solution is mixed with 24kg of salt.

Iodine content of the salt produced: The iodine content of the sample measured by titrimetric assay was 5.2ppm. The preliminary rapid test assay (kit-MBI) revealed the absence of iodine in the sample of the salt produced.

Survey results in households

Socio-demographic characteristics of participants, surveyed in households, physical characteristics of the salt collected and use: The mean age of participants was 36.3 ± 12.9 years ranging from 18 to 82 years. The average household size was 5 people ranging from 1 to 30 people. Women were in the majority. The predominant level of education was secondary education, and most of the subjects surveyed were engaged in non-administrative activity. The salt samples collected were white (84.3%) and 12.3% contained physical impurities. Only 1.6% of participants said that they obtained "iodized labeled" salt. Salts collected were mostly fine-sized, packaged in a container closed on purchase, and stored in closed plastic jars within the household (table 1). With respect to the use of salt, 90.4% of the respondents said they added salt during cooking.

Iodine content by MBI kit and iodometric titration methods: Table 2 presents the iodine content of household cooking salts by district. Using the Kit-MBI, 323 (88.5%) of the salt samples contained iodine, of which 209 (57.3%) had more than 15 ppm iodine. By iodometric titration, 31.2% of cooking salt samples were adequately iodized. The mean concentration was 87.5 ± 66.0 ppm (2.6-396.1). High iodine concentrations have been observed in 62.2% of salt samples.

Discussion

We described the production of salt in the municipality of Sèmé-Kpodji and assessed the iodine content of the salts consumed by household. Reference analytical method [16] was used to quantify iodine in samples and direct observation to describe local production.

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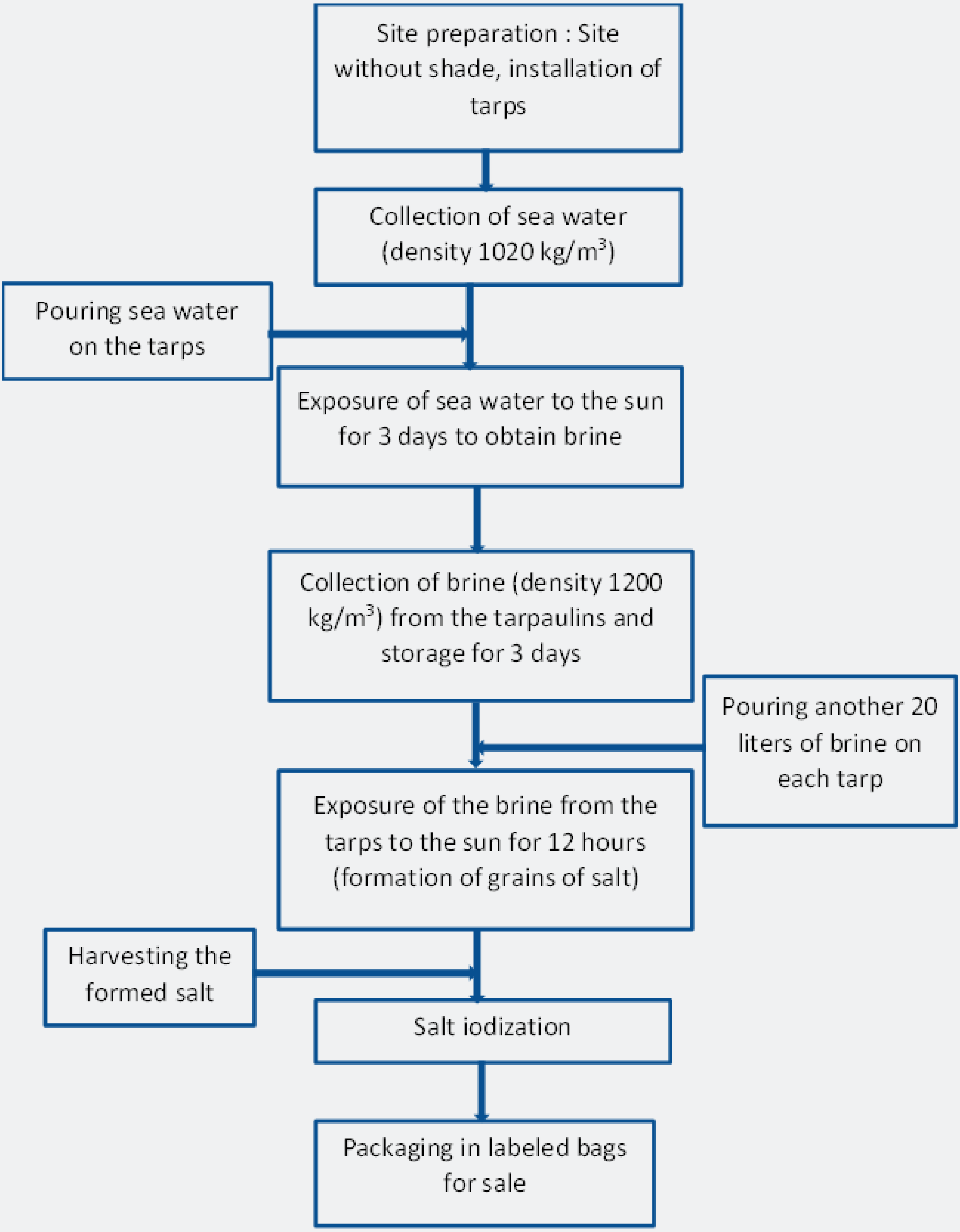

Figure 1 : Salt production process in Sèmè Kpodji

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Table 1: Socio-demographic characteristics of participants and physical aspects and conservation of the salts collected (N=365)

	Effectif (n)	Percentage (%)
Age (years)		
18-39	235	64.4
≥ 40	130	35.6
Sex		
Men	56	15.3
Women	309	84.6
Occupation		
Administrative (public servant)	20	5.5
Student	45	12.4
Non administrative (farmer, breeder, craftsman, driver, etc.)	273	75
Jobless	26	7.1
Instruction level		
No Schooling	119	32.7
Primary	79	21.7
Secondary	132	35.9
University	35	9.6
Color		
White	308	84.3
Soiled	38	10.5
Yellow	18	5.1
Granulometry		
Fine	293	80.3
Mean	68	18.6
Great	4	1.1
Physical impurities		
Yes	45	12.3
No	320	87.6
Type of salt		
Labeled & iodized	6	1.6
Don't know	359	98.4
Place of supply		
Market	150	41
Local production site	5	1.4
Retailers	210	57.6
Conditioning on purchase		
Closed container	243	66.6
Opened Container	113	30.9
Opened Container and exposed to light	9	2.5
Storage in the household		
Closed glass jar	17	4.6
Closed plastic jar	247	67.7
Jar not closed	22	6
Plastic bags	73	20
Other closed containers	6	1.6

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Table 2: Iodine content of salt collected in household, Sèmè-Kpodji, 2022 (N=365)

Iodine Content (ppm)	Kit MBI		Titration	
	n	%	n	%
0	22	6	0	0
< 15	80	21.9	24	6.5
≥15	263	72	341	93.4
Total	365	100	365	100
15-40			114	31.2

Salt production was artisanal and based on seawater. This technique is different from that reported in Djègbadji (Ouidah), the largest local salt production site in Benin [9,17]. Of the techniques production of salt identified in Benin, solar distillatory had better performances compare to a batch crystallizer and to a traditional salt cooked system solar [18]. In many countries nearly all salt used for human consumption is raw solar salt, which is produced by the multistage evaporation of sea water in large outdoor ponds. The salt is scraped from the final stage ponds and stacked for later use [19]. It may then be iodized and sold directly by the producer or sent for further processing. The iodization step is a strong recommendation [20] since the iodine content of the salt is almost zero at the production stage regardless of the technique used as demonstrated in this study (5.2ppm).

Of the salt samples collected from households (n=365), only 31.2% are adequately iodized. These results are less to the national coverage of iodized salt in household (38.9%) obtained in Benin in 2014 [14], but closer to that found in Ethiopia (32%) in 2020 [7]. However, a recent review of literature from 10 countries assessing household coverage of iodized salt revealed greatly disparities between country and by residence type and socio-economic status. National household coverage of adequately iodized salt varied from 6.2% in Niger to 97.0% in Uganda [3].

The large proportion (62%) of households with excessively iodized salt is a worrying result when we know the negative effects of excessive iodine consumption on health [21]. Similar results can be observed in several countries following the implementation of iodination strategies [1,22]. Moreover, other dietary sources of iodine may be available to populations such as drinking water [23,24], which is not the case in Benin. Monitoring of iodine intakes should be an ongoing activity, as well as raising awareness of best practices for iodine conservation and use that were not fully satisfactory in this study.

The joint production of salt did not allow us to observe different production techniques and collect several samples at the production site for comparison. Our study does not cover all the districts of the municipality but is based on a random survey which validates our results.

Conclusion

From the results of this study, it appears that the production of salt in the municipality of Sèmè-Kpodji is artisanal. It is done by exposing the sea brine to the sun and the salt produced needs to be iodinated since it has almost zero iodine content at production. In addition, the salt consumed by households in the municipality of Sèmé-Kpodji is iodized. Nevertheless, the excessive iodine levels found in more than half of the salt samples analyzed call for better monitoring of the iodization strategy of the salt in Benin, considering regional disparities, to avoid excessive or low consumption of iodine among the population.

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