Aliments et nutriments

Assessment of iodine concentrations of cooking salt commercialized in some municipalities in eastern Algeria

Evaluation de la teneur en iode des marques de sel alimentaire commercialisées dans des communes de l'est Algérien

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Abstract ***Introduction.*** Iodine is a vital element for the thyroid hormones synthesis. Iodine deficiency disorders (IDD) are a major public health problem. In Algeria, iodine prophylaxis has been endowed by an executive decree imposing iodization of food salt. The assessment of the iodine content of cooking salt will contribute to updating the nutritional situation in the region. ***Objective***. The iodine content was evaluated in packed cooking salt, commercialized in twelve municipalities located in East of Algeria. ***Material and methods***. The samples number of 191 divided into 18 salt brands marked "iodized salt" were analyzed by iodometric titration. ***Results.*** Iodine content ≥ 15 ppm was noted in 80.7% of the collected salt samples, among which 57.6 % involved excess iodine (> 40 ppm). Iodine content < 15 ppm was observed in 16.7% of the samples displayed insufficient. The non appearance of iodine was perceived in 2.6% of cases, such as in AinFakroun and Meskiana samples which exposed the lowest average concentrations *($p<0,001$)*. The minimum and maximum iodine content ranged between 0 ppm and 93 ppm with a median of 46.4 ppm. ***Conclusion.*** An increase in the rate of iodized salt samples (≥ 15 ppm) is noted, but in an irregular way between regions. Five municipalities display low iodine contents in salt, thus exposing their populations to increased risk of iodine deficiency, in particular in Meskiana and AïnFakroun. Conversely, another risk that should not be overlooked concerns the overiodized salt. The urgency is to control the quality of salt iodization at all levels, and at the determination of the iodized balance of the populations.

Keywords: *Iodine, Deficiency, Salt, Iodometry, Titration*

Résumé ***Introduction.*** L'iode est un substrat indispensable à la synthèse des hormones thyroïdiennes. Les troubles dus à la carence iodée (TDCI) constituent un grand problème de santé publique. En Algérie, la prophylaxie iodée a été dotée par un décret exécutif obligeant l'iodisation du sel alimentaire. L'évaluation de la teneur en iode dans le sel empaqueté contribuera à l'actualisation de la situation nutritionnelle dans la région. ***Objectif.*** Evaluer la teneur en iode dans le sel alimentaire empaqueté, vendu dans le commerce dans douze communes situées à l'Est Algérien. ***Matériels et méthodes.*** Le nombre d'échantillons collectés était de 191 répartis en 18 marques de sel portant la mention "sel iodé". Ils étaient analysés par titrage iodométrique. ***Résultats.*** Une teneur en iode≥15ppm était retrouvée dans 80,7% des échantillons collectés dans les 12 communes, dont 57,6% contenaient de l'iode en excès (>40 ppm). Une teneur en iode<15ppm était notée dans 16,7% des échantillons qui étaient insuffisamment iodés. L'absence d'iode était constatée dans 2,6% des cas, localisée à AïnFakroun et Meskiana où les concentrations moyennes étaient les plus faibles ($p<0,001$). Les teneurs minimale et maximale en iode étaient respectivement de 1 ppm et 93 ppm avec une médiane de 46,4 ppm. ***Conclusion.*** Une augmentation du pourcentage de sel iodé (≥15ppm) est notée, mais de manière disparate entre les régions. Cinq communes ont les pourcentages les plus faibles en sel iodé, exposant ainsi leurs populations à un risque accru de carence en iode, en particulier à Meskiana et à AïnFakroun. Un pourcentage élevé de sel excessivement iodé pourrait constituer un autre risque à ne pas négliger. L'urgence est au contrôle de la qualité du sel iodé à tous les niveaux et à la détermination du bilan iodé des populations.

Mots clés : *Iode, Sel, Iodométrie, Titration, Algérie*

Introduction

Iodine is an essential substrate for the human body and a vital element for the synthesis of thyroid hormones. Iodine deficiency disorders (IDD) are a major public health problem in several countries, where they behave in the form of several pathologies, the most visible of which is goiter [1]. In 2020, 88% of the worldwide population used iodized salt, however, nearly 1 billion people still do not have access to it [2]. Iodized salt represents the most recommended vector of choice [3] since it contributes to reduce the prevalence of severe forms of iodine deficiency in vulnerable populations, especially pregnant women and children [4,5]. Algeria is not spared from IDD, despite Algerian legislation commanding iodization of salt [6]. The national prevalence of goiter (palpable and visible) was estimated in 1991 at 8% [7]. Health data in 2003 indicate that endemic goiter is rife in iodine deficiency areas, mainly in the Northern region of the country, from Tenes in the Ouarsenis Mountainsup to Skikda area and from Constantine until the Large and Small Kabylia [7]. Thyroid cancer is constantly increasing; it can be an indirect consequence of iodine deficiency, especially among women in the East and Southeast region (6,7/100 000 inhabitants in 2014 et 8,3/100 000 inhabitants in 2016) where it is the fourth most widespread type of cancer [8,9]. In Algeria, the United Nations Children's Fund (UNICEF) [10] carried out in 2013 a cluster survey on multiple indicators (MCIS 2012-2013), it has been mentioned that only about 67% of households consume enough iodized salt (≥15ppm). Recently, a prospective survey, conducted in Algiers on 276 pregnant women, has shown that 34% display deficiency in iodine [11]. The few available studies are often old and they do not provide a clear picture of the current nutritional situation.

The objective of this study was to assess according to the Algerian standard and the recommendations of the World Health Organization (WHO), the iodine content in packaged food salts, designated "iodized salt" and sold in twelve municipalities located in the East of Algeria.

Material and methods

Study design and sampling

The study focused on the analysis of iodine in commercially available packaged salt throughout 12 municipalities in eastern Algeria (**Table 1**). Samples were collected at the stores level, in order to have a closed packaged salt samples, with known opening date in the laboratory, as well as the expiration date, being problematic for household samples. Priority was offered to the stores most frequented by households, in the neighborhood of the housing estates and containing packaged salt on their shelves. Samples number of 191 were collected and divided into 18 brands produced by Algerian salt manufacturers (**Table 1**) distributed in the wilayas as follow: El Oued (11 brands), Biskra (3 brands), Constantine (2 brands), and Algiers (2 brands). The transport conditions remained unknown. The brands collected according to the municipality or region are grouped in table 1. Technical and material conditions limited the collection of a larger number of packaged salt samples, in particular in certain municipalities, such as: AïnBerda, El Hadjar et El Bouni. Sampling was carried out gradually, starting with city centers due to their strong commercial activity up to the peripheries with relatively weak activities. The salt packages of 1 kg were packed in polypropylene (PP) plastic bags. The collected batches were intact, labeled with the company contact details, the expiry date and the indication "iodized salt". All Samples were collected over the period from March to May 2018. The storage and warehousing conditions in the stores were not known.

Samples analysis

Analysis of the samples was carried out by iodometric titration [14,12]. The assessment of the iodine content was conducted according to Algerian standards (food salt must contain between 30 and 50 ppm of iodine which was supplied in the form of potassium iodate).

Recommendations established by WHO, UNICEF and the International Council for the Control of Iodine Deficiency Disorders (ICCIDD) [14,15] stipulate that "*the sustainable elimination of iodine deficiency disorders (IDD) requires that at least 90% of households use salt with an iodine content ≥ 15 ppm, without exceeding 40 ppm*".

Analysis method

Iodometric titration consisted in reducing potassium iodate (KIO_3) contained in food salt to molecular iodine (I_2) [14-16]. The amount of released iodine $I_2$was titrated with a sodium thiosulfate solution ($Na_2S_2O_3$). Practically, a mass Pe (g) of salt previously dried was dissolved in 100 mL of distilled water. One mL of acid H_2SO_4 (Cheminova, Germany) and 1 mL of KI solution (Merck, Germany) were added to obtained solution, the solution turned pale yellow, indicating formation of molecular iodine (I_2). Five minutes in dark was mandatory before titration with 0.002N $Na_2S_2O_3$solution (Panreac, Spain) in the presence of starch (Panreac, Spain). Each sample was analyzed in triplicate. The iodine concentration was determined by the following formula [12]:

Iodine content (ppm) = $0.002 (V_2-V_1) 21.16 \times 1000/P_e$

V_1 (mL): volume of titrant ($Na_2S_2O_3$) ; V_2 (mL): volume of blank solution.

When package was opened, salt was immediately put in desiccator for 24 hours. The iodine concentration was expressed in ppm.

Table 1. Number of salt samples per municipality

Department Chief town	Municipality	Stores visited	Population [13]	Salt brands by municipality (or by region)
Eastern Highlands	**6 municipalities**	**95**	**587731**	**(16)**
Oum El Bouaghi (OEB)	OEB	13	80357	3
	AïnFakroun	16	55282	4
	Meskiana	18	28315	8
	AïnBeïda	20	118662	6
Khenchela	Khenchela	13	108580	6
Tébessa	Tébessa	15	196535	3
Northeast	**6 municipalities**	**96**	**440598**	**(7)**
Guelma	Guelma	13	120846	5
El Taref	El Taref	22	25595	3
Annaba	Annaba	45	257358	5
	AïnBerda	5	20611	2
	El Hadjar	5	37364	2
	El Bouni (Town)	6	27950	3

Statistical analysis

Results were statistically processed using Excel software. Qualitative variables were expressed as percentage (%) and represented by mean concentration and standard deviation (SD). Data comparison was performed by Student *t*-test and analysis of variance (Anova). The significance level α was 5% (0.05) for statistical processing.

Results

Table 2 presents the iodine content of cooking salt collected in each municipality and region. The analyzes were carried out under room temperature. According to Algerian standards [6], 36.1% of salt samples contained excess iodine, *i.e.* more than 50 ppm, whereas 39.9% were correctly iodized (30-50 ppm). The rest of the samples did not comply with Algerian standards that was their iodization was either insufficient (less than 30 ppm) for 21.4% of samples, or completely absent for 2.6%.

According to the WHO/UNICEF/ICCIDD standards, (standards being less restrictive) [14,15], 57.6% of samples contained excess iodine, (more than 40 ppm), 23.1% were adequately iodized (15 to 40 ppm), 16.7% were insufficiently iodized (less than 15ppm), the absence of iodine was recorded in 2.6% of cases. Student t-test analysis for the four packaged salt produced by the wilayas (collected in the study area) showed that there was a significant difference in the average iodine concentrations, between El Oued (19.8±22.6 ppm) and Algiers (49±14.3 ppm; p<0.001), Constantine (53.6±17.4 ppm; p<0.001) and Biskra (49.7±22.7 ppm; p<0.001).

Fig. 1 represents the distribution of the salt samples percentage with a municipality iodine content ≥ 15 ppm (C-8, **Table2**) with respect to number of inhabitants. A correlation was found in the Eastern Highlands (**Fig.1**), with the linear correlation coefficient R^2=0.77 according to the equation: $y=4\times10^{-4}x+28.976$.

Discussion

The objective of this study was to assess the iodine content of the commercially available packaged salts, marked "iodized salt". The municipalities of Annaba, AïnBerda, El-Hadjar, El-Bouni, Guelma and El-Taref are located in the Northeast of Algeria, relatively close to the coast, while the other municipalities are located in the interior of the country in the East Highlands.

Table 2. Iodine content of analyzed food salt samples

Municipality	Iodine content								
	C-1	Executive decree N°90-40			OMS/UNICEF/ICCIDD				Concentration
		C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9
	= 0 ppm	≠ 0 et <30 ppm	≥ 30 et ≤ 50 ppm	> 50 ppm	≠ 0 et < 15 ppm	≥ 15 et ≤ 40 ppm	> 40 ppm	≥ 15 ppm	Average ± SD
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(ppm)
Highlands East	**5.3**	**31.6**	**45.3**	**17.8**	**31.6**	**24.3**	**38.8**	**63.1**	**32±28.8**
OEB	0	15.4	84.6	0	15.4	53.9	30.7	84.6	31.1±17.8
Aïn Fakroun	12.5	43.7	43.8	0	43.7	0	43.8	43.8	13.5±22.3
Meskiana	16.6	55.4	28	0	55.4	28	0	28	5.7±12.3
Aïn Beïda	0	40	20	40	20	40	40	80	48.8±26.2
Khenchela	0	23.1	7.9	69	23.1	23.1	53.8	76.9	45.1±29.0
Tébessa	0	0	33.4	66.6	0	0	100	100	56.8±13.5
Northeast	**0**	**11.4**	**34.5**	**54.1**	**2.1**	**21.9**	**76**	**97.9**	**48.7±15.1**
Guelma	0	15.4	0	84.6	0	15.4	84.6	100	49.3±20.9
El Taref	0	0	9.1	90.9	0	4.5	95.5	100	54.6±12.9
Annaba	0	15.5	9	75.5	4.4	20	75.6	95.6	47.1±15.6
AïnBerda	0	0	20	80	0	20	80	100	50.2±20.4
El Hadjar	0	0	100	0	0	100	0	100	36.0±2.8
El Bouni (Touwn)	0	0	16.7	83.3	0	16.7	83.3	100	48.0±10.0

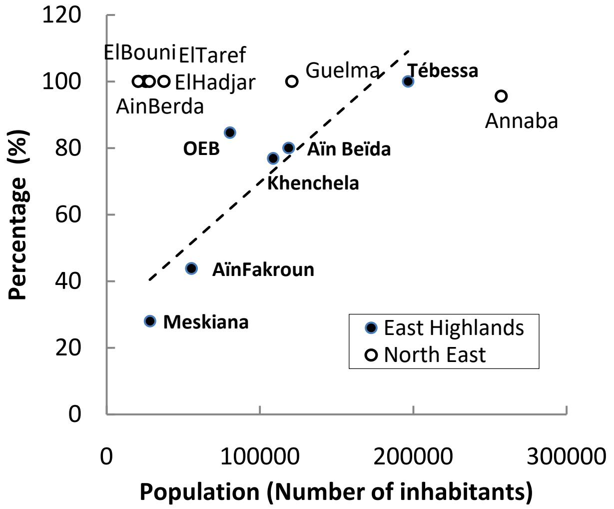

Fig.1. Salt samples with an iodine content ≥15 ppm

In all of the 191 visited stores, the salt packages were placed in a dry place protected from bad weather. The price of packaged salt was reasonable, the kilogram was sold between 0.24 and 0.27 USD (official exchange rate). However, seafood (supposed to contain iodine) was so expensive even in coastal regions. As examples, the sardine price fluctuated between 3.72 and 5.58 USD; the shrimp between 16.62 and 22.07 USD. A study was carried out in 2005 by the Food and Agriculture Organization of the United Nations (FAO) on the Algerian nutritional profile [7], concluded that fish was less consumed due to irregular supply and high cost (except sardines). According to these findings and because of high prices of iodine containing foods, iodized salt would therefore be the choice vector for iodine prophylaxis, since it provides a daily and regular ration of iodine [3,17,18] at a lower price. According to Zou *et al.*, [17], there is a relationship between the iodine amount in the ingested salt and the urinary iodine concentration. Hence, any insufficient salt iodization could represent a risk for vulnerable populations to develop IDD [1,3-5,10,17]. The standard deviation values showed that the mean iodine concentrations (C-9, Table 2**;** p<0,001, Anova) were variable and dispersed.

According to the Algerian standard, absence of iodine was only found in 12.6% and 16.6% of Meskiana and Aïn Fakroun samples, respectively (C-1, Table 2). Iodine content <30 ppm is considered as offense and salt is insufficiently iodized. The most affected municipalities were Meskiana, AïnFakroum, AïnBeïda, Khenchela, Guelma, Annaba and Oum-El-Bouaghi (OEB) (C-2, Table 2). The lack of iodine may be due to bad iodization during the manufacturing process or to defective conservation and storage conditions [19]. Even if the iodate is more stable than the iodine, the amount of dissipated iodate depends on the environment, packaging material, salt quality and storage time [19,20]. A survey on production chain and quality of salt iodization seemed mandatory. Beyond 30 ppm, salt samples are adequately iodized, but by exceeding the limit value of 50 ppm, they will be considered as excessively iodized. In the both cases, salt serves as the normal carrier of iodine, however excess iodine could be a major contributor to serious diseases, such as hyperthyroidism or iodine-induced hypothyroidism or autoimmune thyroiditis, especially for susceptible people [4,21,22]. The rate of iodized salt for samples of El-Hadjar and Oum El-Bouaghi municipalities was important (column C-3 , Table 2). This could partially cover the iodine demand. On the other hand, the inadequately iodized salt (C-3, Table 2) in many other municipalities would increase the IDD risk. According to Azizi *et al*.,. [23], an optimized and regular iodine salt supplementation in Iran for five years (1996-2001) ranging between 33.0±10.2 and 32.7±10.1ppm significantly reduced the total goiter rate by 74.2%. Compliance with the national legislation required in certain countries brought satisfactory results [17,18,23,24]. It is thus imperative to adjust the iodine doses in the salt to Algerian standards. The percentage of excessively iodized salt was high (C-4, Table 2) compared to adequately iodized salt (C-3, Table 2), especially in the Northeast municipalities, (C-9, Table 2; *p<0,001*, Anova), thus creating a disturbed situation. The cause of this iodine overload was the poor monitoring of salt iodization [4, 21]. In Algeria, in spite a national program to fight iodine deficiency [10], epidemiological surveillance of dysthyroidism induced by excess iodine was not available. This led us to consider other experiences in the world, where the legislation on salt iodization was close to that of Algeria. For example, Brazilian population was exposed for 5 years (1998-2003) to a legislation requiring salt iodization of 40 to 100 ppm iodine [22], permitting disorders disappearance related to iodine deficiency. Unfortunately, 17.6% among 829 persons taken as sample were diagnosed having chronic autoimmune thyroiditis with a very high urinary iodine content (greater than 300 µg/L), for an average iodine concentration in salt of 35.5±6.61 ppm [22]. In 1996, Côte d'Ivoire launched a salt iodization program in a way that the required iodine content was between 30 and 50 ppm. The 2002 inspection held in Abidjan revealed that 45% of the salt samples were over-iodized, with an average concentration of 52.74±32.56 ppm, thus increasing the hyperthyroidism risk, especially in coastal areas due to the iodine seafood abundance [18]. In Pakistan [25], the requested iodine content was 25 to 50 ppm. The survey carried out on a sample of 150 patients with goiter and hyperthyroidism indicated that multinodular goiter was the most frequent (72%), and has evolved in many cases into hyperthyroidism. It was also revealed that iodine excess was not the unique trigger for hyperthyroid-dism, but other risk factors may interfere, namely: gender, pregnancy and personal or family hyperthy-roidism history [25]. With the disorders noted in the examples mentioned above [18,22,25], it would be hazardous to disregard this risk, especially when some iodine concentrations in our study (C-9, Table 2) especially in the municipalities of El-Taref and Tebessa were close or higher than those mentioned in precariously cited reports, such as that of Abidjan (52.74±32.56 ppm) [18]. Further studies showed that the benefits of correcting iodine deficiency far out weigh the risks of iodine supplementation [26,27]. Indeed, hyperthyroidism mainly arose in vulnerable persons, especially after too rapid and excessive iodine intake. The incidence was generally low and the disease returned spontaneously to the initial state after 1 to 10 years of supplementation and it could be avoided by adjusting iodine intake [27]. Therefore, numerous reports [2,26,27] admit that salt iodization is the safest and easiest way to get rid of iodine deficiency and, hence, IDD diseases. Salt overloaded with iodine can lead to side effects, but not as important as IDD. The success of the salt iodization program relies on strengthening the quality control of salt at all levels, from producer to consumer [2,14,18,19,21,25-27].

The WHO/UNICEF/ICCIDD standards [14,15] were selected to enable comparison with international data, especially the UNICEF survey [10] carried out in 2012 using test kits. This analytical technique tends to overestimate the iodine content compared to iodometry method [19]. Nevertheless, this approach will allow us to assess the salt iodization quality over these six years, which will make it possible to suggest measures to eliminate sustainably IDD. According to the UNICEF survey [10], in 67% of Algerian house-holds, the salt contained ≥15ppm of iodine, unfor-tunately the percentages of adequately and excessively iodized salt were not mentioned, thus leading us to use only the minimum iodine content (≥15ppm) of WHO/UNICEF/ICCIDD [14,15]. In the present study, 80.7% (C-8, Table 2) of the salt samples contained at least 15 ppm of iodine, thus revealed an increase compared to the UNICEF survey records [10]. This rate (80.7%) seemed acceptable because it was higher than the world average value. Indeed, according to WHO data, 70% of households worldwide have access to iodized salt (≥15ppm) [14,24]. Nevertheless, it was not sufficient to achieve the WHO/UNICEF/ICCIDD objectives [14,15] to permanently eliminate IDD, because the percentage of adequately iodized salt (15-40 ppm), determined by iodometric titration represented only 23.1% of this rate (80.7%). On the regional side, the UNICEF investigation [10] indicated that the percentage of consumed iodized salt (≥15ppm) was 70.9% in the Eastern Highlands and 62.3%, in the Northeast region. In the current study, the iodized salt rates (≥15ppm) in the Eastern Highlands and in the Northeast were respectively 63.1% and 97.9% (C-8, Table 2), indicating discrepancy between these two regions by 34.8%. In other words, an improvement of iodized salt quality in the Northeast (48.7±15.1 ppm) against a decline in the Eastern Highlands (32±28.8 ppm). Actually, the difference in average iodine contents was highly significant (C-9, Table 2; *p=0.007*, Student *t*-test). In the Eastern Highlands, the percentage (63.1%) of iodized salt (≥15ppm) was lower than the world average (70%), thus exposing the region to consume salt with insufficient or no iodization. In this case, the risk of IDD recrudescence would depend on the iodized salt quality [17,23,24]. The municipalities with less than 90% of sufficiently iodized salt samples (≥15ppm) were five, the lowest of which being Meskiana (43.8%) and AïnFakroun (28%). In fact, recent studies have shown that even a low to moderate iodine deficiency during pregnancy could reduce the child's intelligence quotient [4,5]. Regarding the percentage of over-iodized salt (C-7, Table 2), it was relatively important in certain municipalities. For the Northeast region, the majority of the salt samples (97.9%) contained iodized salt (≥15ppm), with a relatively large percentage (76%) of excessively iodized salt samples (> 40ppm). The latter deserves increased vigilance because of possible dysthyroidism [4,18,21,22]. The highest percentages of sufficiently iodized salt samples (≥15 ppm) were in the chief towns (wilayas), and the average iodine concentration of the chief towns (49.4±18.8 ppm) was higher than that of the other municipalities (28.2±26.6 ppm) (*p*<0.001). This indicated that the average iodine contents depended upon the municipality status. In the Eastern Highlands, the least populated municipalities had the minimum iodized salt. According to the UNICEF report, disparity between regions was due to residence areas, and wealth indices. In fact, in 2012, iodized salt coverage (≥15ppm) in households in the richest quintile was 27.7% higher than in households in the poorest quintile [10]. The same observation was noted in the study of Tran *et al*., [29], based on 11 low- and middle-income countries, with weak impact of socio-economic indicators. In Algeria, the number of a municipality population was an important factor involved in the determination of the status and the classification of a municipality [13]. The laboratory equipmentis, often located in the main towns (municipalities), were generally more or less far from peripheral communities [30]. For the both studied regions, poverty was mainly located in the Eastern Highlands due to the geographical and/or economic situation or by the weakness of the local means of supervision and management. In many cases, the disadvantaged municipalities were weakly populated [30]. The lowest iodized salt samples were collected in the municipalities of Meskiana and AïnFakroun, comprising 10 packaged salt brands, among which, only one presented a iodine content ≥15ppm. it is worth knowing that among the twenty-four fraud control laboratories covering the national territory, only one was located in the sampling area, specifically in the municipality of Annaba in the north-east [31]. According to Tran *et al*., [29], countries with low percentages of iodized salt (≥15 ppm) had underdeveloped salt industries which depended mainly on small producers, and had weak government inspection and enforcement systems. Tran *et al*. [29] recommended, for the durability of salt adequate iodization, renewed efforts of governments, together with bilateral and multilateral agencies and civil society. Therefore, several studies should be undertaken to boost more effective control of product compliance, and strengthen mobilization campaigns, and strategic communications [2,14,15,18,27-29].

Conclusion

In this study, the proportion of salt samples with sufficient iodine content is within the world acceptable level. Five municipalities have the lowest percentages of iodized salt, thus exposing their populations to an increased risk of iodine deficiency, in particular in Meskiana and AïnFakroun. The comparison with the 2012 UNICEF survey reveals an increase in the percentage of iodized salt in the North-East, against a decline in the East Highlands, which would have a consequence on the quality of the salt sold. The iodometric titration made it possible to note that the objectives recommended by the WHO (>90%) for the sustainable elimination of IDD are not met, due to the low percentage of adequately iodized salt (15-40ppm). Excessively iodized salt (>40ppm) is the most important percentage, it could be harmful. In the East Highlands, there is a relatively large number of salt brands against a low percentage of iodized salt (≥15ppm). Therefore, the urgency is to match the iodine content in salt to national standards. Simultaneously, studies should be initiated to determine the iodized balance of populations.

Conflict of interests

The authors state that they have no conflict of interests.

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