

Iodine content of non iodized salts and iodized salts obtained from the retail markets worldwide

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Iodine determination, by a very sensitive colorimetric and automatic method, is realized in natural sea and rock salts from France, 12 samples and 81 samples from 21 countries worldwide. This study confirms the very low level of iodine <0.71 mg I/kg in natural salts, whatever the procedure of preparation, artisanal or industrial. The control of iodine content in « iodized salts » is realized at the retail point in salts from France, 144 samples and 48 samples from 24 countries worldwide. The nature: KIO_3 , KI, NaI and the content: 7.65 - 100 mg I/kg of the iodized salt added are depending on each country's legislation. Only in France, sodium iodide is used for salt iodization; the mean value found at 3 months after iodization process is about 12-25% lower than the value found at the production level: 10.5 and 9.0 mg I/kg for fine and raw salts versus 11.9 mg I/kg.

1 INTRODUCTION

It is well known, among the scientific and medical community that natural salts (sea salt and rock salt) are poor in iodine, a very important trace element necessary for the biosynthesis of thyroid hormones. But as sea water contains notable amounts of iodine as an iodide form around $40 \mu\text{g/l}$, consumers think that sea salt contains also iodine. In fact according to the procedure of preparation, sea salt is poor in iodine. It is also claimed that sea salt is good for health particularly the one extracted by artisanal procedure like in Guerande area in France [1]. This salt is rich in mineral and trace elements but with specifications only for some ions like Ca^{2+} , Mg^{2+} , Zn^{2+} and nothing about iodine. As an important fraction of French and European consumers generally favour natural products about industrial ones it is notheworthy to inform them that sea salt is poor in iodine.

One of the aims of this work is to confirm, by an extremely sensitive method of iodine determination, the very low iodine level in natural salts whatever the procedure, artisanal or industrial.

The relationship between iodine deficiency, goiter and cretinism was discovered in 1813. Since the pionnering work of the French scientist, Boussingault, in Colombia in 1831 [2], dealing with the use of natural iodized water and/or salt to prevent the goiter, iodine has been used for the

treatment of goiter. In fact, the salt iodized with sodium iodide was used only on a large scale in USA since 1924 and proved its effectiveness in preventing goiter [3]. At about the same time iodized salt was introduced in Switzerland where goiter and cretinism occurred very frequently [4]. As the benefits of iodine supplementation appeared convincing, salt iodization became mandatory in this country [5]. Salt iodization was recommended in different industrial continents (America and Europa) but not mandatory like in France and special legislation was adopted by each country. Monitoring of salt iodization is usually done only at the point of production, through a combination of internal quality assurance measures and external inspection in order to follow legislation criteria. Monitoring at intermediate distribution sites: whole sale and retail level, are usually not done in industrial countries.

These monitorings at production and distribution points, as well as at the household level are now necessary to follow universal salt iodization (USI) programmes recommended by WHO/UNICEF in developing countries.

The other aim of this study is to check the iodine content of commercial « iodized salt » from France and different countries worldwide for human consumption at the retail point using the same sensitive method.

2. MATERIAL AND METHODS

2.1. Material :

Salt is produced 1/ from natural evaporation by sun and wind, of sea water (sea salt) 2/ from natural evaporation of underground or saline like brine (solar salt) 3/ from thermal evaporation of brine from solution of rock salt (vacuum salt). This salt is refined, dried and powdered to fine or raw particles before packaging. Salt was purchased in markets or in the site of production, particularly in Africa and in retail stores worldwide. On markets, salt is available either packaged in bulk jute sacks (18,50 or 100 kg like Sine Saloum Salt, SSS, Senegal) or not packaged such as rock salt like in Morocco [6] or with different forms according to the vessel where brine is evaporated like in Niger [7]. On retail stores the salt is packaged in bag made of polypropylene or retail pack box (125, 250, 500, 1000 g). Labelling notice includes legally mandated informations such as purity of salt, presence of ingredients like anticaking agents and in the case of iodized salts the nature of the salt : potassium iodate (KIO₃) or iodide (KI), or sodium iodide (NaI) the amount of iodine in mg/kg or part per million (ppm) and date of iodization.

2.2. Methods :

1 g of salt sample was dissolved in 10 ml of water. For natural salts, poor in iodine, this solution was directly analysed by flow analysis in an entirely automatic Autoanalyzer Technicon Type 2. Iodine present as iodide or iodate in the sample was transformed first by an acidic digestion into iodate.

Then after reduction to iodide, iodide was monitored by the colorimetric method of Sandell and Kolthoff [8]. For iodized salts, rich in iodine, appropriate dilutions (1/10 to 1/100) in water were done before analysis, according to the expected iodine level in the salt indicated by producer.

3. RESULTS AND DISCUSSION

3.1. Iodine in natural salts from France

Iodization in France being not mandatory, about 50% of salt consumed is not iodized. The market is shared by two producers : CSMSE or « Compagnie des Salins du Midi et des Salines de l'Est » and SCB « Salines Cerebos de Bayonne » who is part of Solvay Industry. Table 1 shows that all the samples of salt analyzed from CSMSE (sea salt, La Baleine, or vacuum salt, Salinor) and SCB (solar salt, Cerebos) are poor in iodine (< 0,48 mg I/kg). The salt originating from small scale producers (Guerande, Ile de Ré, Portovecchio) contains also low levels of iodine (< 0,57 mg I/kg) even if one of them claims on the label « rich in iodine ».

3.2. Iodine in iodized salts from France

For human consumption in France, table salt iodization is not mandatory but authorized according to « arrêté interministériel » 28/02/1952. This salt must be prepared by adding 10 to 15 mg of NaI/kg salt i.e 8.5 to 12.7 mg I/kg salt. Packaging of this salt must be done in box of 1 kg maximum and labelling must indicate : producer's name and address, iodized salt nature and content and iodization date : year and trimester (1 tri 99 for

Table 1
Iodine content of natural salts from France

Brand	Producer	City	I mg /kg salt*
Cerebos	S C B	Paris	0.25 (4)
La Baleine	CSMSE	Aigues-Mortes	0.21 (1)
Salinor	CSMSE	Varangeville	0.28 (1)
Armor	CSMSE	Batz-sur-mer	0.48 (1)
Fleur de Sel	Coop.Saunier	Ile de Ré	0.22 (1)
Sel de Mer	Coop.	Portovecchio	0.40 (1)
Le Guerandais	SARL Le Guerandais	Pradel	0.57 (2)
Sel	Salines d'Einvile	Einvile	0.28 (1)

* mean value and number of samples analyzed in brackets

example). France is the only country to utilize NaI. Table 2 summarizes results of iodine content of iodized salts produced by CSMSE and SCB, Solvay ranked according to the time elapsed between iodization process and analysis. The values found in 106 samples of fine salt and in 38 samples of raw salt are expressed as mean value and extreme values. This table shows that iodine content of both salt decreases with time, fact already known [9,10,11], but more rapidly in raw salt. Our results on salts at retail level (time of iodization less than 3 months) are always lower than the value found at the site of production level: 10.5 and 9.0 mg I/kg for fine and raw salt respectively versus 11.9 ± 5.4 mg I/kg. For animal consumption in France, salt as a salt block to be leaped could be iodinated according to « arrêté interministériel » 28/11/1973.

Iodine at a maximum level of 40 ppm must be added as CaIO_3 or /and KI, NaI. Iodine is also very important for preventing IDD in animals. Iodized salt is also utilized in some other countries like in U S A [12]. We were able to analyse such samples.

3.3. Iodine in natural salts from different worldwide countries.

Table 3 summarizes results of iodine determination in 81 natural salts samples collected across 21 different countries. All these salts are poor in iodine (< 0.71 mg I/kg) except 19 samples from Niger where values vary from 1.42 to 6.50 mg I/kg. This appreciable iodine amount is due to the preparation procedure: direct evaporation of ground or underground brine by sun (50°C). In this country, famous salt camel caravaning like

Table 2

Iodine content of « iodized salts » produced in France by CSMSE and SCB, Solvay according to the size (fine or raw) and to the time in months elapsed between iodization process and analysis

	Time in months	mg I/kg salt	
		mean value	extreme values
Fine salt	<3	10.5 (8)	4.6-19.1
	3	8.0 (36)	3.2-14.9
	6	7.5 (20)	1.0-17.3
	9	7.9 (21)	4.4-12.5
	12	7.0 (9)	4.6-10.7
	15	8.6 (2)	6.9-10.3
	18	4.8 (3)	3.2-6.4
	24	5.8 (2)	4.4-7.1
	27	6.7 (2)	6.3-7.1
	30	4.2 (1)	
	33	7.3 (1)	
	55	3.1 (1)	
Raw salt	<3	9.0 (1)	
	3	7.4 (6)	4.8-8.8
	6	6.8 (8)	2.2-9.3
	9	5.6 (3)	0.8-8.8
	12	7.0 (4)	4.8-8.3
	15	4.9 (5)	1.0-10.7
	18	4.8 (3)	2.7-6.4
	21	7.9 (2)	6.2-9.6
	24	2.8 (3)	1.2-4.8
	27	12.0 (1)	
	51	4.3 (1)	
	81	8.8 (1)	

Mean value determined by an idiometric method in control laboratory of CSMSE (Mr Teissèdre) at the site of production was 11.94 ± 5.4 mg I/kg salt for a 6 months period.

Table 3
Iodine content of natural salts from different worldwide countries

Countries	Brand	Producer	City	I mg/kg salt
EUROPA				
Denmark	Fint salt	Dansk salt	Mariager	0.45 (1)
Germany	Romu	Muller	Hamburg	0.17 (3)
	Mira	Muller	Hamburg	0.10 (1)
Italy	Sale marino	ISI	Saviano	0.13 (1)
	Sale marino	CIS	Milano	0.14 (1)
	Candor	Monop.Stati	-	0.32 (1)
	Sicilia	Italkali	Reggio	0.50 (1)
Netherlands	Salina salt	-	Hengelo	0.09 (1)
	Sanal zout	-	Hengelo	0.37 (1)
	Tafel zout	Boekelos	Hengelo	0.46 (1)
Portugal	Sopursal	Vatel	Faro	0.21 (1)
Spain	Sal marina	Dietisa	Barcelona	0.23 (1)
	Number One	Nieto	Carthagene	0.18 (2)
	Sel Vivo	-	Murcia	0.70 (1)
	Saxa	Gen.aliment.	Madrid	0.16 (1)
Turkey	Billur Tuz	Borrova Yoht	Izmir	0.33 (1)
United Kingdom	Cerebos	Cerebos	Middlewich	0.19 (2)
	Good Look	-	-	0.31 (1)
AFRICA				
Algeria	-	-	-	0.30 (1)
Djibouti	Rock salt	-	Assal Lake	0.52 (1)
Cameroon	Sea salt	Siselca	Douala	0.05 (1)
Madagascar	Sea salt	CSM	Antsiranama	0.24 (1)
Mali	Mine salt	-	Taoudenit	0.17 (4)
Mauritania	Mine salt	-	Idjill	0.55 (1)
Morocco	Sel Ora	Salimar	Casablanca	0.10 (2)
	Selux	SCS	Casablanca	0.14 (2)
	Sea salt	SCS	Sidi Brahim	0.10 (1)
	Rock salt	-	Tenghourt	0.50 (4)
	Rock salt	-	Ifri-n-tissant	0.54 (4)
	-	-	Bilma	3.14 (5)
Niger	-	-	Dallol Foga	1.42 (3)
	-	-	Teguida-n-Tessoun	3.43 (9)
	-	-	Tafadek	1.54 (1)
	-	-	Tidekelt	6.50 (1)
	Sea salt	SSS	Kaolack	0.09 (3)
Senegal	Mine salt	-	Chott El Djerid	0.71 (1)
Tunisia	Sea salt	-	Sfax	0.24 (1)
	Sea salt	-	Sousse	0.21 (1)
	Solar salt	Cotusal	Tunis	0.30 (1)
AMERICA				
Bolivia	Mine salt	-	Uyuni	0.24 (5)
Chile	Mine salt	-	Manicunga	0.50 (1)
MIDDLE EAST AREA				
Israel	Ahava	Kibbutz mitzpe	Dead Sea	0.28 (1)

Table 4
Iodine content of « iodized salts » from different countries worldwide

Countries	Brand	Producer	City	I mg/kg salt	iodized salt
				Found	Legal
EUROPA					
Austria	Fein salt	Salinen Austria	Bad Ischl	10.6 (1)	7. 65 KI
	Tafel salt	Salinen Austria	Bad Ischl	6.6 (1)	
Finland	Suola	Pirrka	Helsinki	16.8(1)	18.75 KI
Germany	Meersalz	Salz handel	Munchen	9.5 (1)	14. 9 KIO3
	Sel Jod haltig	Salz handel	Munchen	13.7(1)	
	Jodsalz	-	Bad Reichenhall	14.8(1)	
Greece	HPA Kalas	-	Missolonghi	44.0 (1)	36.7 KI
Hungary	Asztali	Horvath	Rozi	15.6(1)	15.0 KIO3
Netherlands	Nezo	-	Hengelo	9.7(1)	19.1 KI
	KNL	-	Hengelo	14.0(1)	
Spain	Leda	Salinera esp.	Murcia	15.0(1)	44.1. KI
Switzerland	Sel table	Soc.Salin. Vaud	Beix	10.5(3)	11.0 KI
	Sel table	Schweitzerhalle	Basel	11.7(3)	
Turkey	BillurTuz	-	Izmir	36.5(1)	50-70 KI
United Kingdom	Cerebos	Cerebos	Middlewich	10.5(1)	15-26 KI
Yugoslavia	Sol	Sodaso	Tuzla	4.7(2)	7.65 KI
AFRICA					
Algeria	-	-	Oran	8.1(1)	30-50 KIO3
Cameroon	-	-	-	44.1(1)	100 KIO3
Egypt	Cook Salt	Tagel Melouk	6 October	33.0 (1)	50-80 KIO3
Kenya	-	-	-	21.3(1)	25.8 KI
Morocco	Pigeon	Nutrisys	Essaouira	34.8(1)	80.0 KIO3
	Selux	SCS	Casablanca	49.0(1)	
	La Colombe	Math mezguit	Taza	75.6(1)	
Tunisia	Solar salt	Cotusal	Tunis	7.7 (1)	10-15 KIO3
ASIA					
Indonesia	Cap Kam	UD.Jaya	Agun Abadi	30.3(1)	30-80 KIO3
	Cap Kude	UD Somat	Surabaya	25.7(1)	
Thailand	-	Thai Company	Bangkok	46.5(1)	100 KIO3
Vietnam	Muoi iot	Muoi Phong	Ninh Hoi	43.2(1)	50 KIO3
AMERICA					
Argentina	Dos Anclas	Salinas del Bebe	Buenos Aires	17.2(2)	19.6 KIO3
	La Loberia	Comodoro	Rivadavia	14.5(1)	
Brazil	Garca	Salinas Perynas	Rio de Janeiro	10.6(1)	8.9-17.8 KIO3
	Sal cisne	Salinas Pontada	Rio de Janeiro	21.7(2)	
Canada	Sifto	Domtar.inc.	Mississauga	64.6(1)	77 KI
USA	Sysco		St Clair	21.4(1)	77 KI
	Sterling	Int. Salt CO	Clarks summit	36.9(2)	
	Morton	Morton CO	Chicago	37.8(1)	
	Diamond	Diamond CO	St Clair	52.7(3)	
	Stop Shop	-	Boston	56.7(1)	

« azalai » yet occurs. Salt samples from Africa and South America are generally collected and sold in bulk [13]. One special brand of « blind iodized salt » in France is seaweed salt containing 5% of *Laminaria digitata*, Algosel. As *Laminaria* is a brown seaweed with a high iodine content, this salt has an « outlaw » iodine level : 508 mg I /kg. There is now specific regulation in France for edible seaweeds in particular for iodine level (see paper of Marchal et al. in this symposium about algae for naturally iodized salt).

3.4. Iodine in iodized salts from different countries worldwide.

Table 4 summarizes the results of iodine determination in 48 « iodized salt » samples collected across 24 countries worldwide. Current iodization levels according to specific country legislation vary from 20 to 100 ppm of KI or KIO₃. As the iodine content depends on the nature of the salt (KI : 76,5% ; KIO₃ : 59, 5%) the iodine levels, found and legal, are expressed in mg I/kg. The selection of an appropriate iodine level in salt for a given population depends on numerous factors : per capita salt consumption per day (5-15g), iodine deficiency degree, packaging type, transit losses due to heat and humidity, iodine salt stability (14). Seven countries only : Algeria, Brazil, Egypt, Indonesia, Tunisia, Turkey and United Kingdom give two extreme values for legal iodine content. In general, values found are close (+30%) to the level expected, except in some countries with lower values like Spain, USA, but because few samples were examined, these results are to be analyzed cautiously. The iodization date is very rarely notified except producers like SCS, Morocco, thus we have no idea of the elapsing time since the iodization process.

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