

PJN

ISSN 1680-5194

PAKISTAN JOURNAL OF
NUTRITION

ANSI*net*

308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
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Effect of Exposure and Storage Conditions on the Levels of Iodine in Selected Iodated and Non-iodated Salts in Ghana

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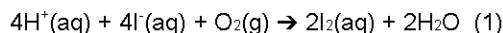
Abstract: Iodated salt is the best means of providing iodine to deficient populations, and it has been used successfully and safely over the past 70 years around the world. Since iodine readily sublimates at high temperatures, iodate is typically used due to its better resistance to oxidation. The actual availability of iodine from iodated salt at the consumer level can vary widely due to a number of factors, including the variability in the amount of iodine added during production, storage and meal preparation. The stability of iodine in typical salts available in the country's market were determined under different storage conditions such as in the fridge, cupboard, exposure to direct sunlight for several days to mimic how salts are usually stored. Iodine levels dropped slowly in most iodated salt ranging from less than 10% to 30% of the added iodine but dropped rapidly from less than 10% to 100% in the raw non iodated salts. The reason was that the latter did not have stabilizers. While there is a wide band of iodine intake levels that are safe to consume, it is important that adequate amounts are delivered to the consumer. Therefore it is critical to have an accurate estimate of the losses in iodine prior to consumption, so that the producers may compensate for the losses.

Key words: Salt, titration, iodine, loss, storage, sunlight

INTRODUCTION

Salt is a clear brittle mineral that has been used to flavour and preserve food since ancient time (The World Book Encyclopedia, 2003). The principal function of salt is to regulate the osmotic pressure and the movement of fluid to and from the cell. Most salts leave the human body through sweat. It is also excreted through urine to maintain the body temperature at appropriate levels. Today, common salt as a seasoning for food is expected to meet dietary requirement that include iodine. The principal source of iodine is seawater (mean value of 58 µg/l); it also ranges between 0.01 to 70 µg/l in surface and ground waters respectively depending on geographical position, local geology and soils (Fuge, 1987). The total dissolved salts in sea water contain less than 2 µg of iodine per gram of salt. However, when sea water evaporates, much of the iodine either remains in solution or is lost by evaporation. Seafood is also one rich source of the element (Istwan and Benton, 1997). Iodine is an element that is critical for normal function of the thyroid gland, which is a key regulator of the body's basic metabolic rate. Iodine is a micronutrient, meaning we require only small amounts of it (Rosenfeld, 2000). For example, adults need about 150 micrograms of iodine in the form of iodide ion per day. However, an insufficient supply of iodide via diet causes the non-cancerous enlargement of the thyroid gland known as

goiter (Sinadinovic *et al.*, 1991). Prolonged lack of iodide can lead to loss of thyroid function and the birth defect known as cretinism, which has been recognized since the Middle Ages (iodide ion, in the form of potassium iodide, may be added to table salt to produce "iodized salt" in order to easily provide the population with a sufficient dietary supply of this essential nutrient. One difficulty with this is that iodide ion is easily oxidized to iodine by atmospheric oxygen" (Wright, 2007). The chemical equation below shows the oxidation of iodide to iodine:



Nearly one-third of the earth's population live in areas of iodine deficiency. Ghana is one of the major salt producers in West Africa. Current production is about 200,000 tons of which 100,000 tons are exported in crude form (Egbuta, 2001). In many rural areas, where iodine deficiency is most severe, the populations are largely dependent on subsistence foods. Their diet is typically based on one or two cereals, tubers or pulses as the staple food. If the household has any livestock, it may also consume some dairy products. It is this dietary and economic context that must be considered while choosing a vehicle for iodine to reach such populations. Its consequences, the iodine deficiency disorders,

include irreversible mental retardation, goitre, reproductive failure, increased child mortality and socio-economic compromise (Kruger, 1971).

In recent years, in an effort to introduce iodine regularly into the daily diet, several foods have been considered as possible vehicles. These include salt, bread, sweets, milk, sugar and water. Among these salt has become the most commonly accepted owing to the fact that it is one of the few commodities that come close to being universally consumed by almost all sections of a community irrespective of economic level. It is consumed at approximately the same level throughout the year in a given region by all persons. Thus, a micronutrient like iodine when introduced through salt will be administered to each individual at a uniform dosage throughout the year.

Iodate is typically used in tropical climates, due to its better resistance to oxidation. Despite the superior oxidation resistance of iodate, iodated salt tends to lose its iodine content over time (Diosady *et al.*, 1998) and it is therefore important that simple, effective tests be developed for the determination of iodine content of these salts. Iodised salt is common salt containing small quantities of an iodide as a supplement to the diet. Usually, the iodine concentration in salt is fixed between 30-100 µg of iodine in one gram of salt. Salt consumption ranges from 5-20 g/day (Ekepechi, 1987). The actual availability of iodine from iodized salt at the consumer level can vary widely due to a number of factors, including the variability in the amount of iodine added during production, its uneven distribution within the batches or bags produced due to poor mixing and due to losses in distribution and retail; during storage and meal preparation. While there is a wide range of iodine intake levels that are safe to consume, it is important that adequate amounts are delivered to the consumer, while minimizing the costs of iodization. Therefore it is critical to have an accurate estimate of the losses in iodine prior to consumption, so that the producers may compensate for the losses by the addition of excess iodine during production.

For these reasons, manufacturers add small amounts of iodine in the form of potassium iodide to the salts they produce. Iodized salt is the best means of providing iodine to deficient communities. The high solubility of the potassium iodide enables its dispersion by atomized sprays on very dry crystals. However, potassium iodide in salt is not very stable and can easily be lost by oxidation to iodine if the salt is subjected to conditions such as moisture in the salt, heat, humid and excessively aerated environments (Hem, 1992). Hence the determination of the levels of iodine in both iodated and non-iodated (traditional) salts from manufacturing, distribution, retail and household levels has become necessary for adequate supply of iodine to consumers for an effective prevention and elimination of the iodine-

deficiency disorders and also to ensure that salt produced meets specific requirements.

The purpose of the present research was to determine the range and timing of the iodine losses that may be expected from both the iodated and the non-iodated salts under typical storage conditions. The main strategy for the achievement of the objective of preventing iodine deficiency disorders will be the fortification of all "food grade" consumed by all people and also improving the iodine status of animals which will improve animal reproduction, milk and meat yield and increase the iodine content in these foods. The objective is to investigate the effect of selected storage conditions and length of period of storage on the iodine levels in selected iodated and non-iodated salt.

MATERIALS AND METHODS

Sample collection: Commonly used iodated salts were obtained from their production sites as well as from the supermarket. The samples obtained from the factory were sampled into a High Density Polyethylene Bags (HDPE) with production and expiring dates as well as the iodine concentration clearly stated. Some raw non-iodated salts were also sampled from two (2) major salt producing centres in the country; Daboya in the northern region where terrestrial salt was obtained and Ada in the south where sea salt is produced. These samples were taken at the site at the time of harvesting. The samples were collected into plastic containers and labelled.

Sample preparation: The iodine values were obtained by analysis immediately on return to the laboratory at Department of Applied Chemistry, Navrongo Campus after the samples were collected. The period of sampling and sample preparation were calculated and the number of days for exposure started from the day the samples were collected. Initial levels could not be obtained as this could not be done immediately on site. Samples were then divided into equal portions and exposed to different storage conditions which included refrigeration, storage in laboratory cupboards and exposure to direct sunlight. This was to mimic conditions under which salts are usually stored at home for use. The iodine content of the salt samples was then analysed using Iodometric titration, as described by De Maeyer *et al.* (1979).

RESULTS AND DISCUSSION

Salt samples analysed at the beginning showed high levels of iodine with some values closer to the reported values indicated on the labels while others varied widely. Generally, the values were comparable to the recommended iodization levels of 40-50 ppm as given by the WHO (1994). Iodine levels Salts of Apn and X2 samples determined at the beginning of the experiment gave initial iodine concentration of 44.4 ppm. Figure 1

Table 1: Iodine content of freshly opened salts (ppm)

Source of salt	Label	Determined
Abg.	45	39.1
Apn	45	44.4
Pbs	*50	42.3
xu	*30	44.4
Sea	-	13.8
Terrestrial	-	11.6

*Minimum iodine concentration

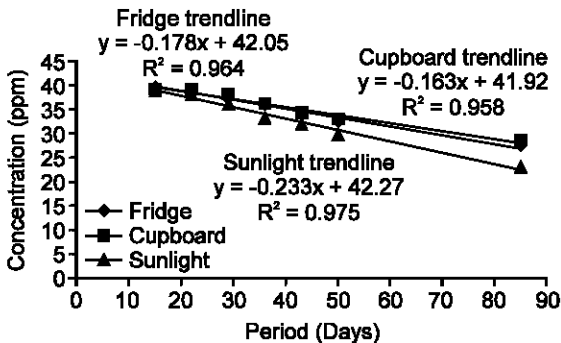


Fig. 1: Iodine levels in Abg iodated salt under three different storage conditions

shows a scatter diagram of the results which indicates that iodine levels present in the sample from the sampling period to the time of analysis ranged from 45.9 to 47.9 ppm for Apn and 46.2 to 47.9 ppm for x2. Samples of Pbs reported an initial concentration of 42.3 ppm but the iodine content present ranged from 44.0 to 45.9 ppm while Abg iodated salt gave an initial concentration of 39.1 ppm but the iodine present ranged from 41.9 to 42.3 ppm using the y-intercept.

It was observed that, the iodine levels determined in the various samples vary from that given on the labels. Levels of iodine on the labels were different for the various manufacturers. While the labels had the highest value is greater than 50 ppm and the minimum being 30 ppm. These values are within the WHO recommendation of iodization. There were no available data for the raw salts as they had no labels as such iodine levels determined at the start of the experiment were used as the amount present at the time of sampling.

The first iodine value obtained from the analysis for Apn salt was very close to that of the value on the label while those of Abg and Pbs were quite different from that on the labels. The iodine level for x2 salt was close to 45 ppm as that of Apn and Abg but the label value indicated only the minimum. However, concentrations determined for the periods were regressed with the time the salt was stored. This was to indicate the maximum available iodine concentration for each salt which must be comparable with the values on the labels or better. If this is true, regressions for the terrestrial and sea salts should yield similar results. The sea salt which is non-

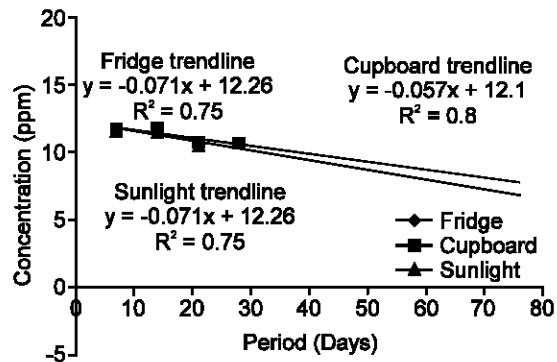


Fig. 2: Iodine levels in terrestrial salt under different storage conditions

iodated has less iodine than the iodated salts which must be the case but comparatively higher than the terrestrial salt.

All the salts after the exposure decreased in iodine concentration. This is in line with other workers who found similar results. For example, Chauhan *et al.* (1992) showed with data obtained after comparing iodine stability over 300 days in common salt iodized with iodate, packed in 5 kg solid High Density Polyethylene (HDPE) that iodine concentrations decreased between 9-10% of the added iodine within the first month after which values remained practically constant.

The decrease in iodine content varied with storage conditions and percentage lost also varied with the individual samples (Fig. 2). Samples of Abg salt showed highest losses with a decrease of about 40% during the period of storage than samples of the Pbs which gave a decrease of about 35%. Salts of Apn and x2 showed relatively little losses during the period. Samples of raw salt from the sea recorded an initial iodine content of 13.8 ppm while salts from the terrestrial environment gave a concentration of 11.6 ppm. Both samples practically lost all the iodine after four (4) weeks of exposure and storage.

Figure 2 show scatter diagrams of the effect of storage conditions on the iodine levels. The graphs revealed the decrease in iodine concentration with the time and type of storage. The losses were proportional with the length of storage. All storage conditions also showed changes in iodine concentration. The greatest decrease was seen for samples that were exposed to direct sunlight while those stored in the cupboard lost least iodine. Hence, the decreasing trend of iodine in the three storage conditions was Sunlight > Fridge > Cupboard.

The scatter diagrams show high correlation and the regression line passes through almost all the points. This suggests that lost of iodine is a direct function of time. This means that, the longer the period of storage irrespective of the type of storage the more iodine is lost.

Table 2: Summary of percentage loss of iodine under the various storage conditions in the iodated salts

Salts	Label value	Fridge	% loss	Cupboard	% loss	Sunlight	% loss
Abg	45	42.1	-6.4	41.9	-6.8	42.3	-6
Apn	45	47.8	6.2	45.9	2	47.6	5.8

Table 3: Summary of iodine concentrations (ppm) in the various salts

Source of salt	Fridge		Cupboard		Sunlight	
	Mean	Range	Mean	Range	Mean	Range
Abg	34.9	27.5-39.1	35.4	28.6-39.1	32.9	23.3-39.1
Apn	41.6	33.9-44.4	40.8	34.9-44.4	40.3	31.7-44.4
Pbs	38.5	30.7-42.3	39.8	34.9-42.3	36.9	27.5-42.3
x2	41.6	33.9-44.4	41.4	34.9-44.4	39.0	31.7-44.4
Sea salt	12.3	10.6-13.8	12.2	10.6-13.8	12.4	10.6-12.7
Terrestrial salt	11.3	10.6-11.6	11.1	10.6-11.6	11.3	10.6-11.6

The value on the y-intercept suggests the values at the time of iodization for the iodated salts. These values were compared with the values on the labels as obtained in Table 1.

The salts from sea and terrestrial did not have initial or labelled iodine values since they were obtained directly from their natural sources. The apparent iodine values obtained from the regression using the y-intercept ranged from 12 to 16 ppm.

From this table values for the Abg salt were very close less than 2% to the value of iodine on the label while that of Apn was about 6.2% different which is acceptable. Since Pbs and x2 salts did not give actual estimated values, it was difficult to compare. Similarly, if the magnitude of error is within 10% as per calculation it is possible to obtain maximum iodine values for the sea and terrestrial salts at the time of deposition. Therefore, these values of the sea and terrestrial salt are 15 to 16 ppm and 12 ppm respectively.

The concentration of the iodine content remaining in Apn salt revealed a loss of 9.46%-23.65% for samples stored in the fridge after of 85 days, while samples that were stored in the cupboard lost from 9.46%-21.40% within the same period and from 11.94%-28.60% for samples that were exposed to the sun. Percentage lost for all the samples are detailed in Appendix 1.

Appendix 1: Table of levels of iodine (ppm) remaining in x2 salt under different storage conditions

Period	Fridge	Cupboard	Sunlight
15	44.4	44.4	44.4
22	44.4	44.4	42.3
29	43.4	43.4	41.3
36	43.4	41.3	39.1
43	41.3	41.3	38.1
50	40.2	40.2	36.0
85	33.9	34.9	31.7

The decrease indicates that, in addition to iodine losses, other factors may account for the low levels of iodine in iodated salts purchased by consumers. A case study in Shandong province demonstrated that the iodine content of iodated decreased progressively from 75% in the

fortification plant, to 49% in warehouses, to 8% in the local market and finally to 7.6% in households (Noguera *et al.*, 1986).

The linear equations provided on the graphs indicate the magnitude of the losses. The gradient for the various conditions may be used to describe the nature of the losses with the highest value depicting a greater loss and the least value depicting a better storage condition. Table 3 summarizes the iodine concentrations under the various storage conditions. The mean values determined explain the levels of iodine under the various

storage conditions. The highest value of 35.4 ppm for samples of Abg salt stored in the cupboard means that cupboard conditions are best storage conditions as only little losses occurred within the period of storage while the minimum value of 32.9 ppm obtained for samples that were exposed to the sun shows that higher portions of iodine are lost when the salt are subjected to high temperatures and heat. This smaller loss compared to the fridge and cupboard suggests that other factors could be responsible. This could be explained using the presence of stabilizers. However, salts from the sea and terrestrial environments lost practically all its iodine at constant rates. This means that, raw non-iodated will reduce in iodine content no matter the type of storage with time revealing the absence of stabilizers in these salts.

A comprehensive review of the literature by Kelly (1953) concluded that the stability of iodine in salt is determined by (i) the moisture content of the salt and the humidity of the atmosphere (ii) light, (iii) heat (iv) alkalinity or acidity (v) the form in which the iodine is present. He concluded that the iodine content will remain relatively constant if the salt is packed dry with an impervious lining, and kept dry, cool and away from light.

Inherent variation between the rates of iodine loss from all the salts reflects changes in storage conditions. The gradual loss of the iodine from the samples stored in the fridge can be attributed to the presence of less air circulation and moisture in the salts. The pH of the condensed moisture on the salt very much influences

the stability of the iodine due to the ability of iodine to dissolve in water at a slow rate (Venkatesh Mannar, 1987).

Samples stored in the cupboard showed slight decreases in the variation of iodine during the period of storage suggesting that losses do not occur readily when salt samples are stored in cool, dry and dark places away from direct sunlight due to the absence of heat and moisture as well as less air.

Salts that were exposed to direct sunlight at temperatures of about 37°C-41°C lost greater portions of the added iodine. Similar losses were seen in the raw salts as well. This result can be attributed to the exposed nature of the reaction vessel and the presence of heat at such high temperatures causing elemental iodine to readily sublime which is then lost to the atmosphere due to the high volatility of the element. The effect of temperature on the iodine levels suggest that heat affects the rate of iodine losses as rapid decreases were registered at higher temperatures. Cooking loss could be a major reason for high Iodine Deficiency Disorders. Preliminary unpublished data from the Institute of Nutrition and Food Hygiene of China showed that the loss of iodine during conventional Chinese cooking ranges from 50% to 70%. Ranganathan and Narasinga (1986) found that coarse salt iodized with iodate at "normal" room temperature and humidity showed iodine losses of 20% after 12 months, while samples stabilized with calcium carbonate lost no iodine over an 18- month period. In a later study analyses of five types of Indian salt (including powder and crystal) iodized with iodate showed losses of 28-51% after 3 months, 35-52% after 6 months and up to 66% after 12 months.

Further suggesting may be due to the presence of stabilizing agents in the iodated salts which are absent in the raw salts. These are usually added in the form of anti-caking agents, to prevent adjacent grains cementing together to form a hard solid mass. Commonly used agents are potassium or sodium Ferro cyanide in the range 5-15 ppm and free flowing agents to provide the crystals with a mechanical coating that acts as a lubricant and absorbs any water vapour within the package after sealing. Commonly used free flowing agents are magnesium carbonate, calcium silicate, sodium silico-aluminate and tricalcium phosphate, at a level of 1-2%.

Conclusion: Iodine losses over the period ranged from 10% to 100%.The loss of iodine in all the salts especially, the iodated salts confirmed that the actual iodine available vary from the point of production to when it is consumed. Length and choice of storage greatly affects the iodine levels in salts be it iodated or non-iodated. Among the three selected storage conditions, effect of sunlight in particular showed highest losses as

a result of the high volatility of iodine as temperature increases the rate at which iodine sublimates. Moisture plays a critical role in the stability of iodine. In particular, when salt is stored at a temperature characteristic of storage and distribution conditions such as that of the refrigerator, moisture is absorbed by the salt which dissolves the iodine slowly. A cool and well ventilated storage system reduces the amount of iodine lost.

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