A New Process for Stabilizing Iodine in Iodized Salt

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Sodium carbonate was successfully tested as a stabilizer for iodine in iodized salt in factories at Tuticorin, Gandhidham and Kharagoda in India. The effect of storage and transportation on iodine stability was studied for 12 months. The new process enhanced the iodine stability, which was not affected by road or rail transportation. Storage at ambient temperatures did not affect the initial iodine concentration (30 ppm) even after one year. On the other hand, control-iodized salt without sodium carbonate showed poor iodine stability, the iodine loss was 30-50% in the first three months depending upon the salt type, pH, moisture, magnesium, calcium and insoluble that were present in salt. The new process did not alter the daily production of iodized salt in the factories. Sodium carbonate is a permitted food additive and is priced low. This process is cost-effective and very useful to manufacture stable iodized salt in order to combat iodine deficiency in India.

INTRODUCTION

Iodine deficiency disorders (IDD) are present throughout India. Out of 275 districts surveyed in different parts of the country, 235 have been found to be endemic for IDD with the extent and magnitude being greater than previously thought[1]. In fact, India is one of the major iodine deficient countries in the world. The simplest and cheapest method to overcome IDD is through iodized salt[2]. Common salt is manufactured in India by solar evaporation of sea water and inland brine. The annual production of common salt in the country in recent years had crossed 12 million metric tons. As on today there are more than 800 salt iodization plants with an annual capacity of producing 12 million metric tons of iodized salt. The country is self sufficient in salt production and iodization plants fabricated indigenously. But, the stability of iodine in iodized salt is not satisfactory[3-5]. The poor iodine stability may be due to various reasons. However, inadequate addition of potassium iodate (KIO_3) at the manufacturing stage, loss of iodine during storage as well as transportation and the quality of salt used for iodization are the major causes. Furthermore, common salt produced in India contains amounts of moisture and magnesium impurities that adversely influence the stability of iodine compound added to salt[3]. If some reducing agents are present in water used for iodization, and if the pH becomes acidic, part of KIO_3 is reduced to iodine and loss of iodine occurs in iodized salt. Although KIO_3 is used for salt iodization in India, iodine loss to the tune of 10-50% in the first 3 months has been reported in the country[3-6]. Similar losses have been observed in abroad also in KIO_3 added salt[7]. Earlier laboratory studies have shown the usefulness of sodium carbonate (Na_2CO_3), a permitted food additive[8], for its potential to enhance the stability of iodine in iodized salt[9].

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Therefore, the present study was undertaken in three factories to study the feasibility of using Na_2CO_3 for the large-scale manufacture of iodized salt.

MATERIALS AND METHODS

The new process was tested in the following salt factories in India where iodized salt is regularly manufactured: M/s. Sahayamatha Salterns Private Limited, Tuticorin (Factory 1); M/s. Chirai Salt Works, Gandhidham (Factory 2); and M/s. Hindustan Salt Limited, Public Sector Undertaking, Kharagoda (Factory 3). Edible grade common salt and food grade chemicals were used. Salt analysis[4] and iodine estimation[10] were done by standard methods. Iodized salt samples were selected randomly according to standard procedures laid down by the Bureau of Indian Standards[11] and replicate analyses of six were done for iodine estimations. Particulars of the salt and other details are given in Table 1.

(a) Factory 1

Iodized salt is usually produced in this factory by spraying an aqueous solution of KIO_3 (7.5 g/200 ml) over common salt (150 kg) in a ribbon blender. Same procedure was followed in the present study also. Both powder salt and crystal salts were used. Required quantities of KIO_3 and Na_2CO_3 were dissolved in water (Table 1) and sprayed on salt loaded in the ribbon blender and then mixed. After thorough mixing for 5 minutes, the iodized salt was discharged and tested for iodine content. It was then divided into 3 groups and packed, without any drying, in 50 kg high density polyethylene (HDPE) oven sac. One group was stored inside the room and the second group was kept outside the room, exposed to sunlight. The third group was transported by road to the National Institute of Nutrition (NIN), Hyderabad, India, where the salt bags were stored in the same conditions of storage as that of the factory.

Table 1
Details of materials used in the factories for the production of iodized salt

Particulars	Factory 1	Factory 2	Factory 3
Process	Batch	Cont.	Cont.
Salt (MT)	0.15	4.5	5
KIO_3 (g)	7.5	225	250
Na_2CO_3 (g)	30	900	1000
Water (l)	0.2	9	6.25
Salt	P/C	P/C	C
Iodine (ppm)	30	30	30
KIO_3 (ppm)	50	50	50
Na_2CO_3 (ppm)	200	200	200

Cont.: Continuous; MT: Metric Ton; P: Powder; C: Crystal; ppm: parts per million.

Iodine testing of iodized salt was done in the factory laboratory (FL), salt department laboratory (SDL) and NIN every fortnight for three months to study the iodine stability. The stability studies were carried out further for a period of one year at NIN. The maximum as well as minimum temperatures, relative humidity and the rainfall data during the study period at NIN were recorded.

(b) Factory 2

The routine procedure followed in this factory is to spray a solution of KIO_3 in water (225 g/9 l) over 4.5 metric tons of common salt to produce iodized salt by a continuous process. Therefore, a mixture of KIO_3 and Na_2CO_3 in water (Table 1) was used to iodize salt by the same process. Control-iodized salt without Na_2CO_3 was also produced. The salts were tested for iodine content by replicate analyses of six and packed, without drying, in 50 kg HDPE oven sac and transported by rail to NIN and there the effect of transportation as well as iodine stability were studied for one year by storing salts at ambient temperatures.

Table 2
Composition of salt used in the factories for the production of iodized salt

Contents (%)	Factory 1 P	Factory 1 C	Factory 2 P	Factory 2 C	Factory 3 C
NaCl	98.9	98.6	97.9	97.6	98.2
Moisture	2.00	3.00	3.50	6.00	1.80
$MgCl_2$	0.34	0.40	0.60	0.70	0.80
$CaSO_4$	0.35	0.40	0.65	0.80	0.57
Insoluble	0.41	0.60	0.90	0.90	0.43
pH:					
Raw salt	7.7	7.5	6.0	6.2	7.9
*Iodized salt**	8.6	8.3	8.5	8.0	8.7

P: Powder salt; C: Crystal salt;
*New process

(c) Factory 3

Crystal salt was used for iodization. Potassium iodate (250 g) and Na_2CO_3 (1000 g) were dissolved in water (6.25 l) and used to iodize 5 metric tons of salt (Table 1) by spray mixing process in a continuous production plant. Control iodized salt was prepared in the same way but without Na_2CO_3. Iodine content and its distribution were tested immediately after the production of iodized salt. The salts, without drying, packed in 50 kg HDPE oven sac were transported to NIN by railways. All the test parameters mentioned in the factories 1 and 2 were studied here.

RESULTS

(a) Factory 1

The quality of common salt used for iodization was good. Moisture and impurities were low in the salt (Table 2). The pH of the common salt increased to 8.5 after the addition of Na_2CO_3. The initial iodine content of the iodized salt was 30 parts per million (ppm) in both powder and crystal salts. The inter-laboratory testing showed no loss of iodine in the first 3 months (Table 3). When the salt bags were received at NIN by roadways after a week of iodization there was no loss of iodine. The storage study showed excellent results for the iodized salt produced by the new process. Sodium carbonate added iodized salt retained the initial iodine content (30 ppm) even after one year of storage at ambient temperatures (Table 4). But, the control-iodized salt without Na_2CO_3 showed poor stability of iodine; the iodine loss was 30% by 3 months, 35% by 6 months, 38% by 9 months and 41% by 12 months. The iodine loss was more in the crystal salt (Table 4). The changes in temperature, rainfall and humidity during the storage period at NIN (Table 5) did not affect iodine stability in the iodized salt containing Na_2CO_3 (Table 4).

Table 3
Iodine stability in iodized salt produced in Factory 1: First 3 months data

Centre	Percentage Iodine[a] Powder Stored inside	Powder Stored outside	Crystal Stored inside	Crystal Stored outside
NIN				
Initial[b]	100	100	100	100
3 months	99.7	100.1	100.1	99.6
FL				
Initial[b]	100	100	100	100
3 months	99.9	99.3	99.8	100
SDL				
Initial[b]	100	100	100	100
3 months	99.9	99.5	99.9	99.3

a: Analysis of 6 replicates; b: 30 ppm iodine
NIN: National Institute of Nutrition
FL: Factory Laboratory
SDL: Salt Department Laboratory

Table 4
Effect of sodium carbonate (Na_2CO_3) on iodine Stability in iodized salt produced in factories

Factory and salt	Percentage Iodine[a]		
	Initial[b]	6 months	12 months
Factory 1			
(i) Powder:			
+ Na_2CO_3	100.0	99.4	99.7
- Na_2CO_3	100.0	70.9	65.3
(ii) Crystal:			
+ Na_2CO_3	100.0	100.0	100.0
- Na_2CO_3	100.0	58.3	52.5
Factory 2			
(i) Powder:			
+ Na_2CO_3	100.0	99.8	99.8
- Na_2CO_3	100.0	65.0	58.2
(ii) Crystal:			
+ Na_2CO_3	100.0	100.0	99.9
- Na_2CO_3	100.0	47.6	40.0
Factory 3			
Crystal:			
+ Na_2CO_3	100.0	99.8	99.9
- Na_2CO_3	100.0	50.3	50.2

A: Analysis of six replicates; b: 30 ppm iodine

(b) Factory 2

The crystal salt used was soft and had more moisture (Table 2). The pH of the iodized salt was 8.5 as compared to the pH of the common salt. The initial iodine concentration was 30 ppm for both control-iodized salt and Na_2CO_3 added iodized salt. When the salt bags were received at NIN after one month of iodization, there was no loss of iodine in the Na_2CO_3 added iodized salt. No loss of iodine was observed till one year of storage at ambient temperatures at NIN. But, the control-iodized salt lost 40% of the initial iodine by 3 months, 44% by 6 months, 49% by 9 months and 51% by one year. The crystal salt lost more iodine (Table 4).

(c) Factory 3

The crystal salt used in this factory was 'Baragara' type and was very hard. Moisture and impurities were reasonably low, but magnesium chloride was high. The pH of the raw salt was 7.9 and it increased to 8.7 after the addition of Na_2CO_3 (Table 2). The initial iodine concentration was 30 ppm. When salt was received at NIN after one month of iodization it was observed that the rail transportation did not affect the initial iodine content. Storage at room temperatures did not alter the iodine content in the Na_2CO_3 added iodized salt during the one year period. But, the control-iodized salt lost 50% of the initial iodine by 3 months and no further loss was observed thereafter (Table 4).

DISCUSSION

The stability of iodine in iodized salt is very important for two reasons. First, it is very necessary to ensure that iodized salt carries the actual amount of iodine stipulated by the authority; individuals and people for whom

Table 5
Average values of temperature (^{O}C), relative humidity (%) and rain fall (mm)

Parameter	Season		
	Summer[a]	Rainy[b]	Winter[c]
Temp.			
Maximum	40	32	26
Minimum	23	20	10
Humidity	18	90	49
Rain fall	43	477	Traces

a: February, March, April, May
b: June, July, August, September
c: October, November, December, January

iodized salt is intended as IDD preventive must receive the effective quantity in their daily intake of salt, and not something else. Secondly, regulations governing the sale of iodized salt must be framed in fairness to manufacture under statutory obligations to provide iodized salt of a certain standard.

Five principal groups of physical or environmental factors determine whether or not iodine will be lost from iodized salt. These are: (1) moisture content of the salt and humidity of the atmosphere; (2) light, heat, excessive currents of air, and weather conditions generally; (3) impurities in the mother-liquor crystallized with the sodium chloride of the salt; (4) factors pertaining to acidity or alkalinity of the salt; and (5) the iodine compound used for iodization[12].

Since coarse crystalline salt is generally used for salt iodization in India, the risk of iodine loss is high due to high moisture content (to the extent of being damp to touch) and high magnesium content (upto 1%). In spite of using KIO_3 for salt iodization, about 25% of iodine loss in the first 3 months are reported[3-7]. Iodized salts with alkaline pH retain iodine than those having neutral or acidic pH. A wide variety of chemical additives such as calcium carbonate, magnesium carbonate, calcium oxide and sodium thiosulphate are mentioned in literature to overcome the iodine loss in iodized salt[12].

Earlier laboratory studies have shown the usefulness of Na_2CO_3 for iodine stabilization in iodized salt[9]. When KI or KIO_3 was used in solar salt, pan salt and vacuum salt at 20 ppm iodine level, the sodium carbonate added salt retained the initial iodine content till 12 months; control-iodized salt without sodium carbonate lost about 30% iodine by 3 months and about 50% by 12 months[9]. The present study proved the application of sodium carbonate at factory level for the production of stable iodized salt.

Moisture content and the quality of common salt used were different in the three factories (Table 2). Batch mixing was followed in Factory 1 while continuous process was followed in the other two factories. The volume of water used for dissolving KIO_3 was different (3-4%) in the three factories (Table 1). Iodine loss was more in the control-iodized salt (without Na_2CO_3) depending upon the moisture content. The loss was about 50% when the moisture was less than 2%, increased proportionately with high moisture, and reached a maximum of 60% when the moisture was 6% in the salt (Tables 2 and 4). Nevertheless, the addition of Na_2CO_3 neutalised the moisture effect and increased the stability of iodine in both powder salt and crystal salt (Table 4). The addition of Na_2CO_3 at 200 ppm level enhanced the pH to 8.5 from the initial pH and at this alkaline condition the stability of iodine was improved. Sodium carbonate has affinity for water and so it might have an effect of stabilization by trapping water in the form of *carbonate-hydrate* outside the salt crystal.

Long distance (2,000 km) transportation by road or rail did not affect the iodine stability of iodized salt produced by the new process containing sodium carbonate. The overall behaviour of the stability of iodine in the iodized salt produced by the new process and control-iodized salt are depicted in Figure 1.

Sodium carbonate is a permitted food additive for its use as *acidity regulator* and *anticaking agent*; it is allowed upto 20 g/kg in the final product[8]. However, its usage in the present study was 0.2 g/kg of iodized salt. At this level the daily intake of sodium carbonate through iodized salt will be about 2 mg only. Thus, the total daily intake arising from its use in salt does not present any problem to the health. Sodium carbonate is easily available in the country and its price is low. The cost of its addition to salt is approximately 5 Paise in Indian currency per kg of iodized salt.

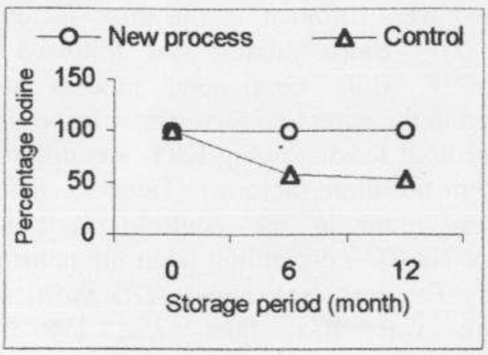

Figure 1. Iodine stability in iodized salt

Based on excellent iodine stability on storage and transportation, it is recommended that for iodized salt produced by the new process the iodine concentration at production point can be fixed at 20 ppm instead of the current level of 30 ppm in India. The new process is economical and cost effective as the amount of iodine imported for iodization of salt can be reduced by 30% in the country. Thus, the factory studies in India have proved the utility of sodium carbonate as a useful stabilizer for iodine in iodized salt. Stable iodized salt is the need of the hour to protect the population from the ill effects of IDD.

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