Stability of iodine in iodized fresh and aged salt exposed to simulated market conditions

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Abstract

Background. *The salt iodization law of the Philippines required that iodized salt sold at retail not be exposed to direct sunlight, high temperature and relative humidity, and contamination with moisture and dust from the environment. However, because the majority of local consumers buy salt displayed in open heaps, it was suggested that iodized salt should be sold in the same manner for greater accessibility and availability.*

Objective. *We aimed to provide evidence on the stability of iodine in local aged and fresh salt iodized at 100 ppm iodine and exposed to various market and storage conditions.*

Methods. *Samples of salt in open heaps and repacked salt were exposed for 4 weeks, and salt packed in woven polypropylene bags was stored for 6 months. The iodine content of the salt was determined by the iodometric titration method, and the moisture content was determined by the oven-drying method.*

Results. *For all types of exposed salt, iodine levels were above 60 ppm after the end of the study (4 weeks). Within each salt type, losses were greater for open-heap salt than for repacked salt. The greatest drop in moisture content occurred in the first week for most types of salt and exposure combinations. Moisture content was linearly correlated with iodine content. Iodine levels in stored salt remained above 60 ppm even after 6 months.*

Conclusions. *Iodized salt is able to retain iodine above the recommended levels despite exposure to an open environment and use of ordinary packaging materials while being sold at retail and kept in storage.*

Key words: Iodine levels, iodized salt, open heap, repacked, salt iodization law

Introduction

Iodine deficiency remains a major health concern because of its devastating effects on the mental and psychomotor development of infants and young children [1]. The World Health Organization (WHO) estimated that 36.5% of school-aged children and 35.2% of the general population have insufficient iodine intake, which puts them at risk for iodine deficiency disorders [2].

The recommended long-term intervention for preventing and correcting iodine deficiency is universal salt iodization [3], which several countries have already enacted [2]. In the Philippines, the implementing rules and regulations of the salt iodization law enacted in 1995 mandate that salt for human consumption must have iodine levels of 70 to 150 ppm for bulk packing and 60 to 100 ppm for retail packing at the production site. Iodized salt sold at retail should contain 50 to 100 ppm iodine for bulk packing and 40 to 100 ppm iodine for retail packing [4]. In recent years, monitoring programs have been implemented nationwide to check that all salt available in the market is iodized. A national survey found an improvement in the rate of household utilization of iodized salt from only 25% in 1998 to 56% in 2003 [5].

The implementing rules and regulations of the law have been revised to exclude some of the limitations to the selling of iodized salt at retail [6]. The implementing rules and regulations previously required that iodized salt sold at retail not be exposed to direct sunlight, high temperature and relative humidity, and contamination with moisture and with dust from the environment [4]. Thus, iodized salt had to be repacked

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in polyethylene bags or bottles and sealed prior to selling. However, difficulties were encountered in selling iodized salt to the majority of consumers because of unavailability, inaccessibility, and high cost. Furthermore, the majority of consumers buy ordinary salt sold by *takal* (i.e., by volume) at public markets and village variety stores. In the *takal* retail system, salt is placed on a large basin made of plastic or wood, displayed in open heaps, measured with the use of cans of various sizes, and placed in polyethylene bags upon purchase.

This study aimed to provide evidence on the stability of iodine added to locally available aged salt and to fresh salt at 100 ppm and exposed to various market conditions at different time points. We hoped that the results of the study would encourage the selling of iodized salt through the *takal* retail system regardless of the age of the salt and help guide future policy on the selling of iodized salt.

Materials and methods

Materials

Two types of solar-dried, coarse, raw salt locally available in the Philippines were used for the study: fresh salt and aged salt. Fresh salt is raw salt stored for a month, whereas aged salt is raw salt stored for 5 months. Fresh salt has a higher moisture content than aged salt because of the shorter time it is allowed to dry prior to iodation. Both types of salt were packed in woven polypropylene sacks without polyethylene lining, stacked on a wooden palette, and stored in a storeroom.

Salt iodation

Both types of raw salt were iodized in a ribbon blender-type salt iodination machine. A 33.7-g portion of food-grade potassium iodate (KIO_3) was dissolved in 200 mL of distilled water and sprayed onto 200 kg of salt to produce an iodine level of approximately 100 ppm. The solution was manually sprayed onto the raw salt with a pressurized plastic sprayer. Initial spraying was done before the salt was mixed. The rest of the solution was sprayed onto the salt while the ribbon blender was in continuous rotation. No other food additives, such as anticaking agents, stabilizers, or emulsifiers, were added.

On-the-spot determination of the iodine content of the salt randomly collected during the iodation process by the iodometric titration method revealed that homogeneity was achieved in both kinds of iodized raw salt.

Exposure and storage

Thirty-three kilograms of salt to be exposed in an open heap was placed in a plastic basin, and another batch was packed in low-density polyethylene bags of 0.00085 gauge thickness at 200 g per pack. Both batches were exposed in a shaded, open area with galvanized iron roofing and no walls. The salt was exposed for 4 weeks; the aged salt was exposed in November and December, and the fresh salt was exposed in June and July. The mean weekly temperature in the exposure area ranged from 26.8º to 28.0ºC during the exposure of aged salt and from 27.5º to 30.9ºC during the exposure of fresh salt. Between week 0 and week 4, the relative humidity ranged from 66.0% to 83.0% during the exposure of aged salt and from 62.5% to 82.6% during the exposure of fresh salt (**fig. 1**).

Salt to be kept in storage was placed in woven polypropylene sacks without polyethylene lining at 50 kg per sack and transported to a storeroom after iodation. The sack was placed on a plastic palette and stored in a

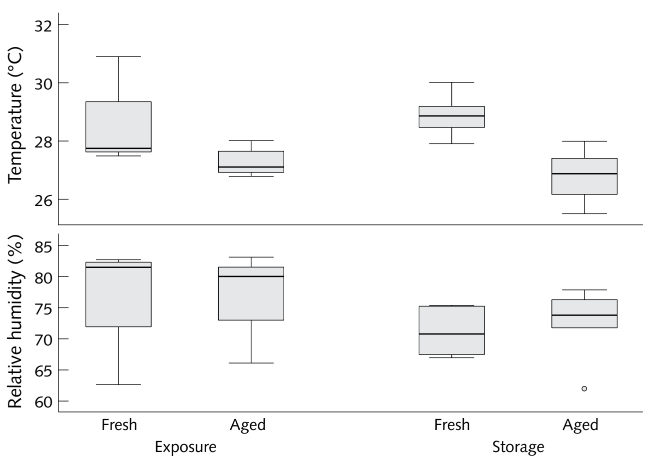

FIG. 1. Mean temperature and relative humidity in the exposure and storage areas

room made of wood and concrete without ventilation for 6 months. The storage period was from November to April for the aged salt and from June to November for the fresh salt. The temperature in the storeroom ranged from 25.5° to 28.0°C during the storage of aged salt and from 27.9° to 30.0°C during the storage of fresh salt. The relative humidity in the storage room ranged from 61.8% to 77.8% during the storage of iodized aged salt and from 67.0% to 75.3% during the storage of fresh salt (**fig. 1**). The difference between the exposure and storage conditions of aged and fresh salt was due to the unavailability of newly harvested salt in November, the rainy season.

Sampling

One-hundred-gram samples each of aged and fresh salt exposed in an open heap and stored in woven polypropylene sacks were obtained. Separate samples were collected from the top, middle, and bottom portions of the open heap and sack. These samples were mixed to make a composite sample. From this composite sample, 100 g was collected and submitted for analysis. Repacked salt samples were randomly collected as packed.

Samples of both aged and fresh salt were collected immediately after iodation (designated as week 0) and at weeks 1, 2, 3, and 4 of exposure. Samples of stored salt were collected once a month for 6 months for both aged and fresh salt.

Content analysis

The chemical characteristics of both types of raw salt were determined prior to iodation. Samples of raw and iodized salt were submitted to the Laboratory Services Division of the Bureau of Food and Drugs of the Department of Health for analysis of moisture, sodium chloride, and water-insoluble contaminants. The iodine content of the iodized salt samples was measured by the iodometric titration method [7], and moisture content was determined gravimetrically.

Results

There were slight differences in the humidity and temperature ranges between the two exposure and storage environments, closely reflecting the real situation, in that fresh salt is available only in the warmer summer months.

Purity of raw salt

Purity analysis of the raw salts showed that fresh salt had higher moisture and lower sodium chloride contents but also a lower content of contaminants than aged salt (**table 1**).

Iodine content and losses in exposed salt

The iodine content of all salt groups was above 60 ppm after 4 weeks of exposure to an open environment (**fig. 2**). The figure shows the iodine content at various time points for the four exposed salt groups: aged open-heap, aged repacked, fresh open-heap, and fresh repacked. At all time points, within each salt type (aged or fresh), the percentage losses of iodine were greater from open-heap than from repacked salt. At week 4, the losses of iodine were 1.8 times greater from aged open-heap salt than from aged repacked salt. Also at week 4, the losses of iodine were 2.7 times greater from fresh open-heap salt than from fresh repacked salt. The greatest percentage reduction in iodine content was seen in fresh open-heap salt, and the least reduction was seen in aged repacked salt.

The initial moisture content of fresh salt was clearly higher than that of aged salt (**fig. 2**). This difference persisted at all time points. Most of the moisture losses occurred during the first week, except for the aged repacked group, which displayed the least variability in moisture content with time. Regression analysis showed that moisture content and iodine content were linearly correlated (coefficient = 3.79 ppm; 95% confidence interval, 2.35 to 5.22; $p < .001$). Thus, the higher iodine loss incurred by the fresh open-heap salt could be attributed to its higher moisture content (**fig. 3**).

Iodine content and moisture in salt stored in woven polypropylene sacks

The amount of iodine present after 6 months of storage was above 60 ppm, regardless of the type of salt (**fig. 4**). Most of the losses in iodine content from both types of salt occurred in the first month. Losses were greater for fresh salt (12% vs. 35% at month 1, and 19% vs. 37% at month 6).

The moisture loss from fresh salt (49.4%) and aged salt (49.8%) was almost equal after 6 months of storage, but a higher initial moisture content kept the fresh salt more moist throughout the storage period, except briefly in the second month (**fig. 4**).

TABLE 1. Chemical characteristics of the iodized raw salt

Characteristic (%)	Aged salt	Fresh salt	Standard[a]
Moisture, coarse	8.12	12.4	≤ 8.0
Sodium chloride, dry	91.49	85.9	≥ 97.0
Calcium and magnesium (expressed as calcium)	2.12	0.55	≤ 2.00

a. Source: Department of Health. Revised Implementing Rules and Regulations of Republic Act No. 8172 [6].

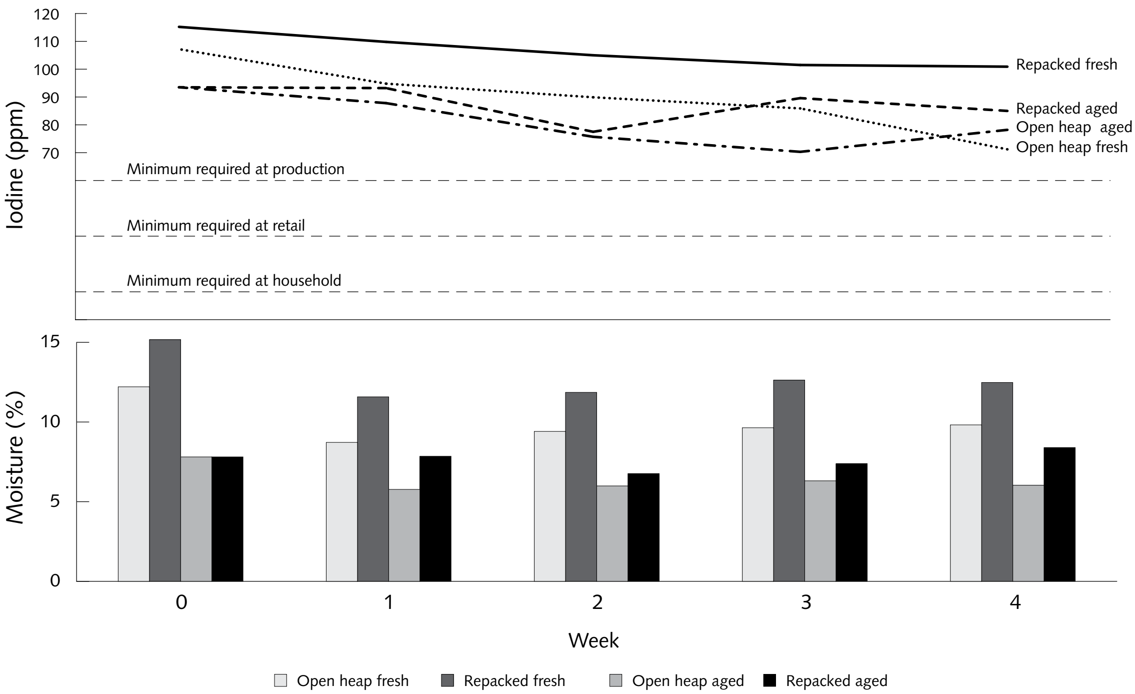

FIG. 2. Iodine and moisture contents of iodized aged and fresh salt exposed in an open heap and repacked from 0 to 4 weeks

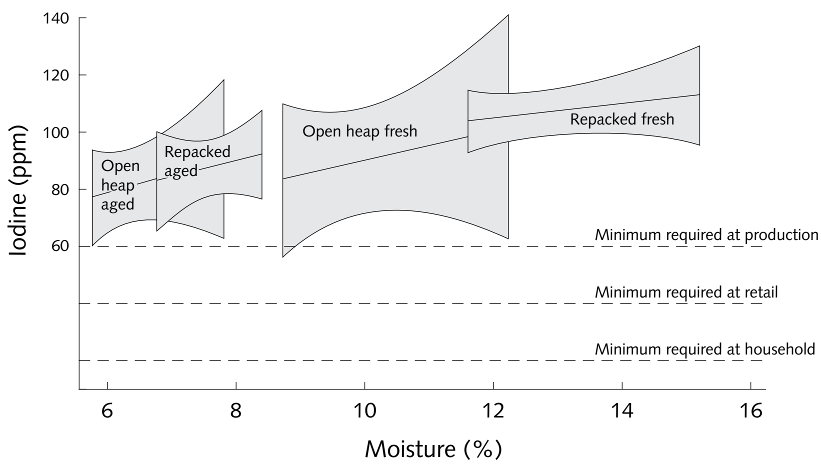

FIG. 3. Association of iodine content with moisture content of iodized aged and fresh salt exposed in an open heap and repacked

Discussion

A higher iodine reduction rate was observed in fresh salt under both exposure and storage conditions. However, the retained iodine in both fresh and aged salt after 4 weeks of exposure in open heaps or as repacked salt was above the prescribed level of iodine for retail sale (50 to 100 ppm for bulk packing and 40 to 100 ppm for repacked salt). Similarly, the retained iodine in both types of iodized salt packed in woven polypropylene sacks was above the prescribed level of iodine for retail sale (70 to 150 ppm) after 6 months of storage. This was in spite of the use of raw salt with high moisture content for iodation and the unstable conditions to which the iodized salt was subjected.

All salt samples lost iodine over 4 weeks of exposure in an open heap or repacked in low-density polyethylene bags; the loss ranged from less than 1% to 25% for aged salt and from 5% to 34% for fresh salt. Iodine loss was also observed in the stored salt over the 6-month

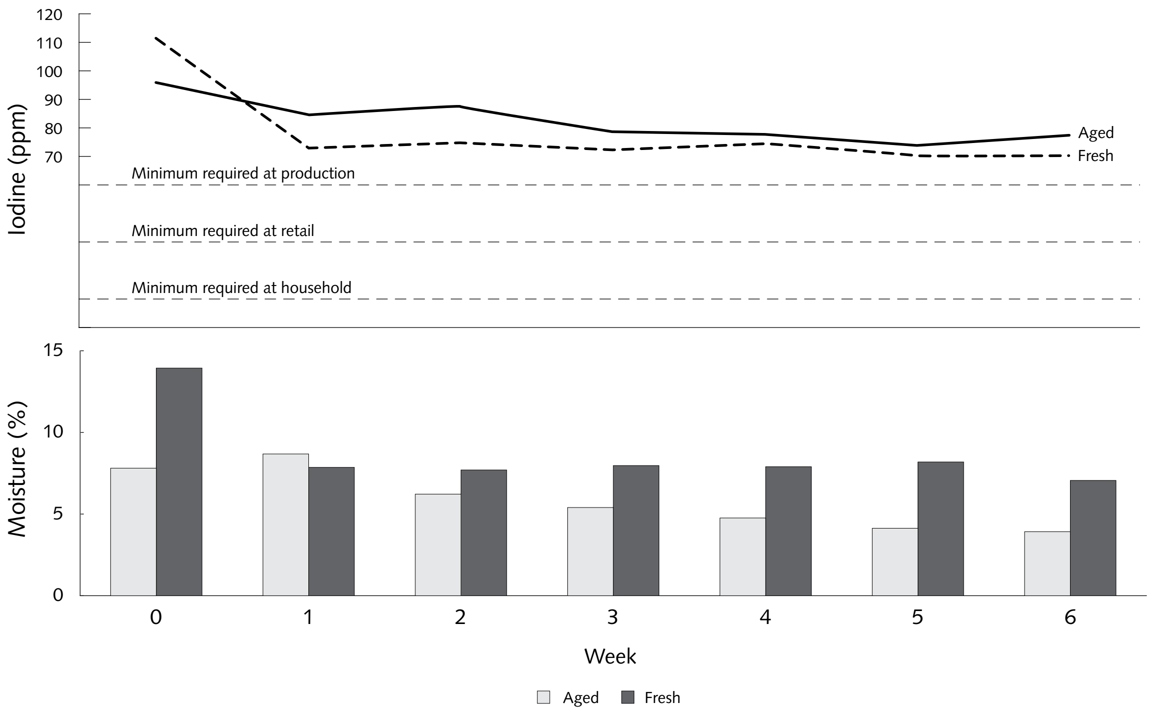

FIG. 4. Iodine and moisture contents of iodized aged and fresh salt kept in woven polypropylene sacks and stored for 6 months

storage period, ranging from 9% to 24% for aged salt and from 33% to 49% for fresh salt. The iodine reduction rate was higher in fresh salt than in aged salt after 4 weeks of exposure and 1 month of storage.

The rate of iodine loss was influenced by the age of the raw salt at iodization and by the exposure and storage conditions. From weeks 0 to 4, the iodine content of salt exposed in an open heap gradually decreased. Exposure in an open heap resulted in the evaporation of a significant amount of dissolved iodine. These exposure conditions add to the instability of the iodine in salt.

Iodine loss was greater in fresh repacked salt than in aged repacked salt after 4 weeks of exposure, despite the use of the same type of packaging material. This result was probably due to the high moisture content, which results in diffusion of dissolved iodine in and out of the packaging material from weeks 0 to 1. Although a moisture barrier was used to prevent the evaporation of iodine, losses were still incurred because the bags were not vacuum and heat sealed and the gauge of the plastic bag used was less than the required 0.03-mm gauge [8].

The losses from repacked iodized salt of both salt types, however, were still minimal compared with the loss of iodine from iodized salt exposed in an open heap. The use of ordinary low-density polyethylene bags commonly found in the market during exposure minimized the loss of iodine in both types of iodized salt. Although the thickness of the plastic used was below the minimum gauge for repacking iodized salt, the packaging material still prevented the movement of iodine into and out of the bag. A study by Diosady et al. in 1998 [9] had similar results. In their study, two samples of raw salt from the Philippines were iodized at 50 ppm iodine with potassium iodate and exposed to various controlled conditions. Iodized salt stored in low-density polyethylene bags lost about 37% to 42% of added iodine at 100% relative humidity and 40°C after 12 months. The retained iodine was still sufficient to meet the daily iodine requirements even after a year of exposure to high humidity and temperature. It is therefore recommended that iodized salt be repacked in ordinary polyethylene bags to minimize not only iodine loss but also packaging costs. Thus, iodized salt could be made more widely available and accessible to a majority of consumers at an affordable price.

A survey conducted by the authors among salt retailers in selected public markets and *sari-sari* stores showed that 94.2% of salt retailers selling salt by the *takal* retail system stored salt for less than 1 month; the majority of these retailers (73.1%) were able to sell all their salt within 1 week (Maramag, Solon, et al., 1998, unpublished report). On the basis of the percentage losses incurred after 4 weeks of exposure in an open heap and as repacked, salt iodized with 100 ppm of iodine retained an iodine level above that recommended for retail sale. If our results were extrapolated to an iodization level of 60 ppm, which is the common practice of local salt manufacturers, the retained iodine in the salt would still meet the recommended iodine for retail sales. A similar study by Chauhan et al. in 1992 [10] utilizing Indian salt iodized with potassium iodate and kept either in high-density polyethylene bags or in open heaps also showed minimal losses of iodine (9% to 10%) for the first 15 to 20 days. Thus, retail selling of iodized salt in open heaps or repacked in plastic bags is feasible.

Fresh salt packed in woven polypropylene sacks showed a more drastic reduction (35% loss) in iodine content than aged salt (12%) after 1 month of storage. This was probably due to the higher moisture content of the fresh salt, which affected the stability of dissolved iodine in the sack. Although the stored salt was not exposed to an open environment, woven polypropylene sacks have gaps through which moisture together with iodine could escape. Iodine loss might have occurred by the leaching of iodine-saturated brine through these gaps. However, in the succeeding months, the iodine content of both types of iodized salt remained almost constant. Prolonged storage dried the salt, resulting in a more stable iodine content.

The raw aged and fresh salts used in the study were of poor quality. Both types of raw salt have visible impurities and moisture contents above the standard for unrefined salt for iodization. Further, the percentage sodium chloride content was below the standard. Pollutants in the seawater from which salt is produced and the crude technology used during production might have affected the purity of the raw salt. Nevertheless, despite the poor salt quality, the retained iodine in both types of salt was persistently above the recommended levels. It is likely that the stability of iodine was not drastically affected by impurities in the salt used in our study.

We therefore recommend that no restrictions be placed on the manner in which iodized salt is sold at the retail level. The Department of Health has issued a circular permitting the selling of iodized salt by the *takal* retail system [11]. However, the circular permits iodized salt to be sold by *takal* only in sealed polyethylene sacks that are opened at the time of purchase and does not permit iodized salt to be exposed in an open heap.

Our study shows that iodized salt may be sold by the most common method—the open-heap system—without compromising the quality of iodized salt. Allowing iodized salt to be sold repacked in ordinary plastic bags is also feasible. Both retailing methods would help reduce packaging costs and make iodized salt more available and accessible to local consumers. Nevertheless, to ensure adequate amounts of iodine at the retail level, monitoring of compliance to the prescribed quality by producers and distributors of iodized salt will still be necessary.

A limitation of the present study is that the iodized salt samples were exposed to different environmental conditions. The aged salt was exposed in November and December, a rainy season in the Philippines, whereas the fresh salt was exposed in May and June, the summer season. This difference was due to the unavailability of fresh salt during the rainy months. Thus, although this difference in seasons of exposure makes the two salt types less comparable, the results are more realistic and closer to actual practice.

Conclusions

The current standards are adequate to meet the standards required by law. Our results further show that there may be room for a stepwise reduction in iodization standards. We found that iodized salt with high moisture content was able to retain iodine above the recommended levels in spite of exposure to an open environment and use of ordinary packaging materials while in retail conditions and in storage. Both the sale of iodized salt in open heaps and the use of cheaper materials for repacking and storing iodized salt should be considered to decrease production costs. The use of cheaper packaging material other than the plastic bags and woven polypropylene sacks we used in our study, however, warrants further testing.

Acknowledgments

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