Salt Iodization in Thailand
and
Factors Affecting Quality of Iodized Salt

Institute of Nutrition, Mahidol University
Salaya, Nakhon Pathom

ISBN 978-974-11-0933-3

Salt Iodization in Thailand and Factors Affecting Quality of Iodized Salt

Visith Chavasit

Pattanee Winichagoon

Somsri Charoenkiatkul

Nipa Rojroongwasinkul

Kunchit Judprasong

Chantakan Thongplave

Institute of Nutrition, Mahidol University

Salaya, Nakhon Pathom, Thailand

Preface

Salt iodization has been used as the important intervention for nationwide combating of iodine deficiency disorder (IDD) in Thailand for the last two decades. Like in many developing countries, Thailand is facing the problem of quality of iodized salt, especially on iodine content. Appropriate quality control system must be established, however, situation analysis is firstly needed. Institute of Nutrition, Mahidol University, therefore, requested the support from UNICEF Thailand in 1999 for the studies on the techniques of iodine fortification of salt and factors affecting qualities of iodized salt. The result of this study was expected to be useful for provincial health officers, salt producers, both in Thailand and other developing countries in the region to develop and implement a suitable quality control system for iodized salt.

Acknowledgement

The kind assistance and support of the following persons are highly appreciated: (1) Staffs of the Provincial Health Offices in Mahasarakam, Petchaburi, Ratchaburi, Samut Songkram, Samut Sakorn, Pitsanulok, Chiang Mai, Chiang Rai, Nan, Lampang, Uthaithani, Udonthani, Sakon Nakhon, Nakhon Ratchasima. (2) Staffs of the Nutrition Division, Department of Health, Ministry of Public Health. (3) Prof. Kraisid Tontisirin, Director of Institute of Nutrition, Mahidol University. (4) Assoc. Prof. Bhinyo Panijpan, Assoc. Prof. Pintip Ruenwongsa, and their staffs, Department of Biochemistry, Faculty of Science, Mahidol University. (5) Karen Codling, UNICEF Area Office for Thailand. (6) Assist. Prof. Suvate Ningsanondh, Suranaree University. (7) Staffs of the Pimai Salt Company Limited. (8) Pimarn Pholnukulkit. (9) Kunyapak Khotham. (10) Directors of the high schools in districts of Borabue, Na Chuek, Wapeepratum, Muang, Payakapoompisai, Nadoon in Mahasarakam province. (11) Directors of the high schools in the districts of Wiang-sa and Pua in Nan province. And finally, salt producers in various provinces who kindly allowed the researchers to visit and collect all necessary data for the project.

Executive Summary

Quality assurance system is necessary for efficient monitoring and producing iodized salt. In order to develop appropriate quality assurance system, the information on fortification techniques, factors affecting the iodine content and degree of homogeneity are required. This research aimed to study the quality of iodized salt produced by using various iodization processes in Thailand and propose a quality assurance system. The survey indicated that there were 119 iodized salt producers in Thailand. Ninety percent of the producers were small-scale of the capacity lower than 50 tons per year. Fifty percent of the producers were in the northeast and thirty four percent were in the north, where the highest numbers were in Mahasarakam and Nan provinces, respectively.

There were two major categories of salt iodization process i.e. continuous and batch. The continuous process included (i) fully automated and computerized facility found only at the factory in Pimai district of Nakhon Ratchasima province, (ii) UNICEF conveyor model and its modifications found mostly used, and (iii) others. The batch process included (i) mechanical method which consisted of modified cement mixer of different designs, and (ii) manual method which consisted of the manual mixings of iodine solution and salt on different surfaces e.g. floor, trough, basin, or in bin.

By using iodometric titration analysis, it was found that the iodine content in most iodized salt were higher than 30 ppm however with wide ranges. Using multiple regression analysis, close supervision, correct ratio of iodine to salt, appropriate mixing period after fortification, optimum size of salt pile for mixing, good dispersion pattern of iodine solution and fine salt particle size significantly affected the iodine content in salt. Iodine solution in iodized salt stored in a large bin could migrate downward upon a long storage period. Degree of homogeneity of iodized salt in the UNICEF model was found to be significantly affected by additional mixing after fortification. The fully automated model in Pimai district resulted in a homogeneous iodized salts, however the iodine content was high, up to about 100 ppm.

The test kits used for quality control were MBI kit and I-kit. Both of them could be used only for qualitative control. Therefore, use of titration analysis was absolutely required for monitoring the quality of iodized salt. The study in Mahasarakam and Nan provinces indicated that it was feasible to use science laboratory of the local high school to perform the titration analysis for provincial health officers and salt producers. Record form and instruction manual were also developed and used in the monitoring process by provincial health officers at Mahasarakam province.

In summary, the following operations were needed in order to obtain a good quality iodized salt.

(1) Know the correct proportion of the ingredients i.e. potassium iodate and water for preparing iodine solution, and salt.

(2) Use appropriate methods in measuring amount of each ingredient.

(3) Maintain fortification equipment in good condition e.g. nozzle, motor, mixing blade, conveyor.

(4) Set up the proper system for controlling the amount of iodine solution to be sprayed on salt e.g. using timer, volumetric measurement.

(5) Additional mixing after iodine fortification was needed in all models of fortification machine and techniques.

(6) Keep iodized salt in a sealed package e.g. polypropylene, polyethylene bags.

(7) Sampling for quality analysis should be from at least 3 different points (>100 g/point) per production batch.

(8) Titration method was needed for the quality assurance system of iodized salt.

(9) It was feasible to use science laboratory at local high school to perform titration analysis for local health officers and iodized salt producers.

(10) Results from titration analysis from local high school could be timely used for monitoring quality of iodized salt at production site.

Table of Contents

Salt iodization in Thailand and factors affecting quality of iodized salt

Background

Salt iodization in Thailand began in 1965 but was promoted only in the highly endemic areas in the north (1). In 1994, the Food and Drug Administration (FDA) issued a government notification to specify the minimum iodine content of iodized salt to be 30 ppm (2). This standard was based on the 5 g of salt consumed/day by Thai population, in order to meet the requirement of 150 μg/day (Thai RDI) (3, 4). The Nutrition Division, Ministry of Public Health has supported salt producers by providing free potassium iodate to salt producers.

Iodization of salt has been done by one large-scale factory and several small scale ones, particularly those at the community level (1). Iodine content and homogeneity of iodine in salt were speculated to be affected by iodization process, particle size and moisture content of salt. The prevention program for iodine deficiency disorder can be ineffective if the level of iodine is not within the standard. On the other hand, there have been reports on the possible effect of iodine-induced thyrotoxicosis in population which were living in low iodine environment and high iodine (e.g. iodized salt) was rapidly introduced (5-9).

Several surveys reported the wide variation of iodine in iodized salt available in the market (10-12). This occurred despite of the government efforts to monitor iodine content of iodized salt. Moreover, monitoring of quality of iodized salt is mostly done using test kit, which is only a semi quantitative measurement. While the titration technique which is the most reliable method recommended is seldom used. Besides, the reliability of the available test kits has not been validated with users in the field.

This study focused on how different iodization methods used by various scales of production may affect the quality of iodized salt. Iodine test kit developed in Thailand was also evaluated, especially when it was used by iodized salt producers.

The feasibility to use science laboratory of local high schools as quality control laboratory for iodized salt producers and health officers by using titration method was also tested.

General objective

To study the quality of iodized salt produced by using various iodization processes in Thailand and propose the quality assurance system.

Specific objectives

(1) To survey the salt iodization processes used in Thailand.

(2) To study the iodine content of iodized salt produced by different iodization processes and scales of production.

(3) To study the homogeneity of iodine in salts produced by different iodization processes.

(4) To study factors affecting iodine content and homogeneity of iodized salt.

(5) To evaluate iodine test kits used in Thailand (MBI kit and I-kit).

(6) To test for the feasibility to use science laboratory of local high schools in performing titration test for quality control of iodized salt produced locally.

Materials and Methods

This study consisted of three phases. Phase I was a survey of iodized salt producers in Thailand. This was performed to define the sampling frame. Phase II was a field visit of production sites and producers of the selected samples. Information and salt samples from various iodization methods were collected. Phase III was the design of the quality control system for local health officers and iodized salt producers.

Phase I: Survey of iodized salt producers in Thailand

The data on iodized salt producers were collected and analyzed during August to October 1997. Lists of names and addresses of iodized salt producers in Thailand were obtained from Nutrition Division, Department of Health, Ministry of Public Health (MOPH). A questionnaire was sent to each provincial public health office (34 provinces according to the Nutrition Division original list) to verify the active iodized salt producers and to obtain any further updated information about producers in the areas. The questionnaire included type of raw salt, iodization method, production capacity and existing quality control procedure. The results of this phase were used as a basis for selecting samples for Phase II.

Phase II: Survey of iodized salt producers by various iodization methods

(a) *Sampling of iodized salt producers*

From the Phase I survey, 214 iodized salt producers were identified. However, only 119 producers were confirmed to be in operation as of the time of the survey. During September 1997 to March 1998, a cross sectional survey was used to collect samples of different types of salt iodized by various iodization methods and production scales. Since there were very few large capacity (over 100 tons per month) producers, all of them were included in the sample. From the small-scale producers, having the capacity of less than100 tons per month, half of the samples from each iodization method were taken. Due to the limitations in resource and time, a purposive sampling was therefore used to obtain the samples.

Totally, 58 producers in 15 provinces were visited. Among the 13 large-scale producers, data were obtained from only 10 producers. Two of them did not produce iodized salt at the time of the study, and one was closed for repairs. Five small-scale producers provided incomplete or unreliable data and were dropped from analysis. Therefore, 10 large-scale producers and 43 small-scale producers were included in the study. Table 1 shows the sample size by iodization methods recruited and used in the final analysis.

Table 1 Iodized salt producers visited classified by type of salt, iodization methods and production capacity

Production Capacity (tons/mo)	Sea salt				Rock salt			
	Conveyor	Cement mixer	Chamber/ basin	Other	Conveyor	Cement mixer	Chamber/ basin	Other
>700	1	-	-	-	1	-	-	-
500-700	3	-	-	-	-	-	-	-
100-499	3	1	-	-	-	-	1	-
<100	1	8	2	1	1	8	18	4

(b) *Factory visit, data and sample collections*

A questionnaire including both close- and open-ended questions were used to interview iodized salt producers. Each stage of iodization process was carefully observed and recorded. Data included type and storage of raw salt, equipment used in the production process, dimension and feature of the equipment, preparation of KIO_3 solution, iodization and mixing techniques and time lapse before pack.

The number of sample collected was based on nature of iodization method and operation duration. There are two major categories of salt iodization process: continuous and batch. In the ***continuous process***, iodization was done by continually feeding salt on the conveyor such as belt or screw conveyor. Iodine solution was sprayed onto the salt as it passed the nozzle. The salt iodized was moved to a mixing chamber before packing was done. Unlike the continuous process, in the ***batch process***, iodization was done as discrete batches. Batch process may be done by a mechanical method such as modified cement mixer (using electricity to operate the machine); or a manual method by simply mixing salt and iodine solution in a large container or on the floor.

For the continuous large-scale producer with a long operation duration i.e. PM factory in Nakhon Ratchasima province, the Statistical Quality Control (SQC) method was used, and the sample was taken every hour for 5 hours. Additional samples (three samples) were also collected of the iodized salt prior to entering the drier. For continuous process in factories other than PM, salt samples from at least three batches of production were collected from each production site. Similar strategy was also used for batch process, but samples were collected from only one to two batches. When there was no production at the time of the visit, or only one batch was made for the day of visit, samples of salt from the sealed packages were obtained. In addition, potassium iodate solution (iodine solution) was sampled from each producer to determine its concentration. Iodine to salt ratio could be calculated.

(c) Laboratory determinations

All determination, except those of test kits, was done in duplicate. The average values were reported and used for data analysis.

(c.1) Titration method for iodine content

Iodometric titration method was used as a standard method recommended by ICCIDD/MI/PAMM (39) for determination of iodine when potassium iodate (KIO_3) is used as a fortificant. Iodine in iodized salt was first liberated as free iodine. Free iodine was then titrated with thiosulfate to the end point of titration. The amount of thiosulfate used is proportional to free iodine, hence, iodine content of salt.

(c.2) Moisture content determination

Moisture content was measured by using an infrared moisture determination (AD-4714A by A&D Co., LTD., Japan). Approximately 2-3 g of salt was weighed. For fine grain salt, salt sample was heated at 120 ^{0}C for 15 min. For coarse grain salt, the heat at 115 ^{0}C was used for 20 min. The moisture content of the sample salt was automatically read as percent moisture.

(c.3) Measurement of particle size

The particle size was determined by weighing 40 g of salt, with precision to the nearest 0.01 g. The salt sample was put on sieve size 18 meshes. After shaking and tapping the sieve for 4 min, the sample was weighed. The difference in weights before and after sieving was calculated as percentage of salt that passed through the sieve. The higher percentage of salt sieved through indicated the smaller particle size.

(c.4) Iodine content by test kit

Two types of test kits were used in this study, the MBI kit from India (13) and I-kit developed by the Faculty of Science, Mahidol University, Thailand (14). The same salt sample was determined for iodine content by titration method, MBI kit and I-kit. Test of all samples by MBI kit was performed by a scientist who has observed how to use the kit, but has not done the test before. Another skilled technician/scientist, who was involved in the development of the I-kit, was the reader of the I-kit. A sub-sample of salt samples was also given to iodized salt producer to read iodine content by I-kit. Since I-kit has been introduced shortly prior to this study, some producers had seen and used the kit before. None was well trained prior to the study.

Altogether, 331 samples were tested using titration method and MBI kit. Out of these, 324 samples were tested by skilled technician using I-kit and 141 was tested using I-kit by iodized salt producers. And 136 samples were tested on all three methods (titration, I-kit, and MBI kit) and I-kit done by both skilled technician and iodized salt producers.

(d) Data processing

DBASE III^{+} program was used for data entry for all coded variables. Selected variables on production process which were open-ended questions were encoded as scores and entered in the DBASE III^{+}. Other qualitative information was compiled and used for detail explanation of production process, explaining variation of factors or conditions which might not be measurable in quantitative terms.

(e) Data analysis

All data analysis was performed using SPSS/PC^{+} (15) and SPSS for windows program (16). Descriptive statistics, by iodization process were calculated for iodine content, homogeneity between batches (within plant) and techniques (between plants), factors potentially related to level and homogeneity of iodine in salt. Correlation matrix among variables was done by Spearman correlation, since some variables were not normally distributed. Since there were only a few samples of coarse granule salt, therefore, all analysis was done with the fine granule salt.

Stepwise multiple regression was used to select factors explaining iodine content and homogeneity of iodized salt. Full model of these regression analysis were also examined. The regression analysis of factors affecting iodine content was done separately for each iodization process/model. Homogeneity of iodine was measured by the coefficient of variation (CV) of iodine content within batch. CV of each batch was used as an independent variable for stepwise multiple regression to identify factors explaining the homogeneity of iodization. Only the sample size of factories using the UNICEF model was large enough to do this analysis.

Phase III: Design of the quality control system for local health officers and iodized salt producers

Record form with instruction manual for salt quality checking were developed and given to provincial health officers in Mahasarakam and Nan provinces. Glass wares, chemicals and training were provided to science teachers of 3 high schools in both provinces in order to set up a titration test for iodine in salt. Until August 1999, eight high school, 7 in Mahasarakam and 1 in Nan, were joining with provincial health offices in their salt quality control programs in the provinces. Science teachers were trained for an iodometric titration method for 1 day by researchers. Then unknown iodized salt samples were sent to the schools as quality control samples, which their results of analysis would be sent back to researchers for verification.

Results and Discussions

1. *Number of iodized salt producers in Thailand*

The number of iodized salt producers from the preliminary survey was 119 premises and located in 34 provinces. Fifty percent of the producers were in the northeast and half of them were in Mahasarakam province. Thirty four percent of the producers were in the north, and they were mostly found in Nan province. About 90% of the producers were small size of the capacity less than 50 tons/month. In addition, there were 26 premises that bought the iodized salt from PM factory in bulk and repacked in small packages. Table 2 indicated the number of iodized salt producers based on the type of salt, fortification method and capacity. The highest number iodized salt producers using sea salt located in the central while the ones using rock salt located in the northeast.

Table 2 Number of iodized salt producers based on preliminary survey

Production Capacity (tons/mo)	Sea salt			Rock salt		
	Conveyor	Cement Mixer	Chamber/ Basin	Conveyor	Cement Mixer	Chamber/ Basin
>700	1	-	-	1	-	-
500-700	3	-	-	-	-	-
100-499	4	1	-	-	-	3
<100	3	23	3	2	28	47

Sixty percent of iodized salt producers used rock salt and 20% used sea salt. There was 20% of the producers used both kinds of salt. The fortification was mostly performed in the fine grain salt not the coarse grain one. Only 10% of the producers did both salt production and fortification. Most of them (90%) only did fortification in the salt, which produced from the other places.

For each fortification method (continuous or batch), there were still many modification of techniques and machines (shown in Appendix A), as follows.

(1) Continuous method

(1.1) UNICEF belt conveyor (UNICEF model)

This model was the most commonly used for the continuous method. Salt was continuously fed on to a belt conveyor, to the chamber which was installed with a mill and a spraying nozzle. Iodine solution was sprayed from the nozzle on the passing salt in the chamber. The iodized salt was then transferred to a screw conveyor where iodized salt was mixed and fallen on directly into the filling machine or the receptacle. The iodized salt from the conveyor was shoveled into a rectangular receptacle or on the floor for manual packing. This, in fact, was an unintentionally mixing step.

(1.2) Other models of the continuous process

(1.2.1) PM model

This model was used by only one factory (PM), which was in Nakhon Ratchasima province. Salt brine from underground was chemically purified and then passed through steam chest and evaporator. Residual water in the salt slurry was then removed by centrifugation until the moisture content of salt becomes 2-2.5%. The iodization process was performed continuously and automatically as salt was sent on the conveyor belt, which was installed with weighing unit underneath. The spraying rate of the iodine solution onto the salt depended on the incoming weight. The iodized salt at this stage could be packed and sold as a lower grade such as Kluae Thip brand. Otherwise, the iodized salt was further dried by fluidization process at 140 ^{0}C, where salt was blown into the drying chamber, thus, provided additional mixing. After drying, iodized salt was sold as a premium grade such as Kluae Prungthip brand.

(1.2.2) Screw conveyor

This model was modified from the UNICEF model. Instead of feeding salt on belt conveyor, salt is fed and iodized on the screw conveyor.

(1.2.3) Modified belt conveyor

The machine was similar to the UNICEF model but no milling chamber, therefore iodine solution was fed on one end of the belt conveyor instead of the milling chamber. The dimension of the machine was also different from the UNICEF model.

(1.2.4) Submersion

Iodization was performed in the washing processes of sea salt. Potassium iodate was added into the concentrated brine used for soaking coarse granule raw salt before grinding. The other pratice was dropping potassium iodate solution into salt slurry before sending to storage area.

(2) Batch method

(2.1) Mechanical method

The mechanical method that was widely used was designed by modification of cement mixer used in construction work, therefore it was called here as a modified cement mixer. Modified cement mixer of all models generally had mixing tank of cylindrical shape, and made of plastic or stainless steel. All mixers were operated by a motor and either the mixing blade or the mixing tank rotates. Salt was filled into the mixing tank and machine started. The amount of iodine solution injected was controlled by a timer. After the iodine injection finished, the mixing may be continued briefly before iodized salt was removed and put into a receptacle for packing.

There are several models of modified cement mixer. However, only three models were found at the sites visited, as follows.

(2.1.1) Model developed by Nutrition Division, Ministry of Public Health (MOPH), to be called MOPH model.

(2.1.2) Model developed by the Chiangmai Technical College, to be called Chiangmai model.

(2.1.3) Model developed by Sakonnakhon Technical College, to be called Sakon model.

(2.2) Manual method

Non-mechanical salt iodization methods were performed by placing salt on the floor (floor model) or in large containers, such as wooden trough (trough model), plastic basin (basin model) and bamboo bin (bin model). Iodine solution was sprayed on to the salt by using watering can, pesticide sprayer, or spraying bottle and the mixture was then mixed by hand or household utensils e.g. shovel, hoe, plastic trash tray. The mixing process was done either as a big pile or a small pile.

The above information indicated the problem on quality control of the iodized salt since there were so many small-scale producers of different fortification technique. These producers could not afford their own titration laboratories. Meanwhile, such a variety of iodization methods also made it hard for the local health officers to perform their monitoring processes properly.

2. *Factors affecting iodine content in iodized salt*

Table 3 shows the iodine content of salt from various production methods and scales. The median values of measured iodine content in samples from all production method were above 50 ppm. The variation, however, was very wide for most methods, with the lower end values of as low as 4.2 ppm by the plastic basin, manual mixing method. Only the Chiangmai model which had the low end of 43.4 ppm, which is above the legalized value of iodine content in iodized salt. On the high ends, all methods were as high as 100 - 300 ppm, and exceptionally high in the MOPH model (624 ppm).

Table 3 Average iodine content in salts from different iodization models

Model (No. of samples)	Measured iodine content (ppm) (Median and range)
UNICEF (66)	57.3 (15.4 – 148.1)
MOPH (38)	55.6 (8.8 – 624)
Chiangmai (23)	70.3 (43.4 – 282.5)
Sakon (12)	60.6 (24.6 – 209.6)
Floor (38)	50.1 (9.6 – 161.4)
Trough (33)	63.8 (16.1 – 334.4)
Basin (25)	80.1 (4.2 – 289.6)
Bin (11)	52.3 (12.7 – 127.0)[b]

Further examination of the iodine content in iodized salt showed that over 50% of iodized salt produced by various methods, except the Bin model, were above 50 ppm (Table 4). Over 20% of samples among the models, except Sakon, Floor and Bin, were higher than 100 ppm. On the other hand, in four models (UNICEF, Floor, Basin and Bin), 20% or more had iodine below 30 ppm, Therefore, both too low and too high iodine contents remained the problems for iodized salt in Thailand. The Bin model, which mainly supplied salt to Nan and other mountainous areas in the north, the area having very high goiter rate (17, 18) is worth noting.

Table 4 Distribution of iodized salt by ppm of iodine by iodization model

Model	**% of samples by ppm of iodine**			
(No. of samples)	**< 30**	**30 - 50**	**51 - 100**	**$\geq$ 100**
UNICEF (66)	19.7	21.2	36.4	22.7
MOPH (48)	10.4	31.3	35.4	22.9
Chiangmai (26)	0	19.2	50	30.8
Sakon (12)	8.3	33.3	41.7	16.7
Floor (52)	25	25	42.3	7.7
Basin (25)	20	4	36	40
Trough (36)	5.6	25	36.1	33.3
Bin (11)	36.4	18.1	36.4	9.1

As described in the previous sections, characteristics of salt and several steps were involved in the iodization of salt might affect the iodine content of salt. This section would attempt to delineate the contributions of these factors on iodine content in the iodized salt produced. For the PM model and others which only one site each was visited, these regression analyses cannot be done.

Factors considered included particle size (PARTICLE, high value denotes small particle size), moisture content (MOISTURE), type of injection nozzle (NOZZLE, subjective scoring by wellness of spraying), dispersion of KIO_3 solution (DISPERSION, high values denote good dispersion), regularity of nozzle cleaning (CLEANING), ratio of amount of KIO_3 solution to salt (RATIO), amount of salt used/batch (SALT PILE), mixing (MIXING, high values denote good mixing), rotation of worker (ROTATION, high values mean good performance), supervision by owner (SUPERVISION). By multiple regression analysis using the full model and stepwise regression, different variables which contributed significantly to the iodine content were selected and shown in Table 5.

Table 5 List of variables, which contributed significantly to the iodine content of each iodization model

Model	Variable selected
UNICEF	SUPERVISION
MOPH	RATIO
Chiangmai	RATIO, PARTICLE
Sakon	MIXING
Floor	SALT PILE
Trough	DISPERSION, RATIO
Basin	DISPERSION
Bin	ND*

* The regression was not determinable.

Table 5 shows that certain variables were selected for each model of fortification in the multiple regressions. In most cases, the unselected ones were also the important factors that should be recognized in all models, however they might have been too small variations or too small sample sizes for several variables and therefore dropped out in the selection process. Close supervision, correct ratio of iodine to salt, appropriate mixing period after fortification, optimum size of salt pile for mixing, good dispersion pattern of iodine solution and fine salt particle size were the factors that significantly affected the iodine content in salt.

The regression was not determinable in the Bin model, due to small sample size, and there was little or no variation in several factors due to similarities in steps taken and practices among the sampled producers. The Bin model was solely, done in Nan province, only a few producers were available for the sampling.

There was an interesting feature about the Bin model, however. The turnover of salt stock varied from one day to two weeks or more. The iodine content of freshly prepared iodized salt was only 16.5 ppm, compared to 127 ppm in the sample taken from the lower part of the bin, which was stored for over two weeks. This seems to indicate the possibility that iodine was migrated along with water that was adsorbed on the salt granules from the top to bottom of the bin. The longer period the iodized salt was stored, the more likely that the iodine content of salt in the lower part of the bin became very high. Thus, the iodized salt from Nan may contain either too low or too high iodine contents due to their practices on iodization and storage of iodized salt. Analogous to these phenomena, such migration problem could be found if iodized salt was not packed in well-sealed package such as a plastic line-woven sack (normally reused from a fertilizer bag). It was, therefore, recommended that iodized salt should be packed in a sealed polyethylene or propylene bag.

3. Factors affecting homogeneity of iodized salt

Homogeneity of iodine in iodized salt was expressed by coefficient of variation (%CV), (i.e. SD/Mean x 100). If iodine contents from different points in each salt pile are similar, the % CV is low, indicating good homogeneity.

Table 6 shows the degree of homogeneity of iodized salts produced by using different iodization methods. On average, most models had acceptable degree of homogeneity, however the wide ranges of %CV could be observed within each model. There was still variation in degree of homogeneity of iodized salt which was produced from different producers using the same iodization method.

Table 6 Homogeneity of iodization by iodization model

Model	Median %CV (Range)
UNICEF (22)	18.6 (5.2 – 75.3)
MOPH (12)	11.3 (1.2 – 70.2)
Chiangmai (6)	14.9 (2.8 – 44.4)
Sakon (5)	28.0 (0 – 54.6)
Floor (16)	20.2 (2.4 – 107.6)
Trough (13)	12.9 (1.6 – 87.7)
Basin (4)	9.1 (0.6 – 27.9)
Bin (4)	22.4 (1.1 – 31.1)

Table 7 shows the distribution of samples %CV range by iodization method. The Trough and MOPH models had 46 and 42% of the samples, respectively, with %CV less than 10. Bin model had the highest proportion of sample with %CV above 30%, while most other models had about 20-33% at this range of CV. None of the sample in the Basin model had %CV above 30.

Table 7 Distribution of %CV by iodization model

Model (No. of batches)	% of samples in each range of CV		
	<10	10 - 30	>30
UNICEF (22)	27.3	40.9	31.8
MOPH (12)	41.7	33.3	25
Chiangmai (6)	33.4	33.3	33.3
Sakon (5)	40	40	20
Floor (18)	27.8	38.9	33.3
Trough (13)	46.2	22	30.8
Basin (4)	50	50	0
Bin (4)	25	25	50

Due to limited sample size in most of the process/iodization model, it is only possible to examine the factors affecting homogeneity for the UNICEF model. No attempt was made to examine this relationship in the batch process.

Statistically, it was shown that the additional mixing step was the only factor that required in order to lower %CV (i.e. good homogeneity) of the iodized salts for the UNICEF model. Table 8 shows %CV by level of mixing from 3 plants. It was found that only machine mixing was not adequate to have homogeneous iodine level in iodized salt. Simple spread the salt pile already improved the homogeneity. The best result was obtained when additional mixing by shoveling was done.

Table 8 Mixing characteristics and average %CV in UNICEF model

Mixing characteristics	Average %CV ± SD
I. Only machine mixing (screw conveyor)	41 ± 8
	51
II. Machine mixing and spreading salt pile	23 ± 9
	27 ± 27
III. Machine mixing and shoveling	18 ± 9
	19 ± 12
	11 ± 6

Similarly, for the MOPH model, homogeneity appeared to depend on the duration of the machine mixing time (Table 9).

Table 9 Mixing time and average %CV of modified cement mixer (MOPH model)

No. of plants	Mixing time (min)	Average %CV ± SD
2	1	42 ± 19
2	3	8 ± 2
3	> 3	7 ± 6

4. Iodine content and homogeneity of the PM model

Since the PM model is the largest in terms of capacity (1,500 tons/month) and the only factory that produces iodized salt by using a continuous process of iodization with long duration operation, it is therefore discussed separately.

The mean iodine content of all samples (21 samples) collected from the factory showed rather high values (101 ± 28 ppm). However, %CV was below 10 (7 ± 6%) in most batches of sampling (5 out of 7). Three subsequent samples after the iodization step, but before entering drier, were collected. The iodine contents were very inconsistent (2219 and 86 ppm), indicating that a mixing step (in this case fluidization) was needed to reduce non-homogeneity.

The Statistical Quality Control method, which is proposed by ICCIDD for quality control of iodized salt, could be used only in the PM factory, since the factory had the operation duration long enough for sample collection. The overall mean of the five hourly samples from the PM factory was 106.6 ± 8.7 ppm, which was assumed to be the level set by the factory. The upper control limit (UCL) and lower control limit (LCL) were calculated to be 115 and 97 ppm, respectively. During the operation, samples which were outside of the control limit could be found. However, machine was adjusted accordingly on time, and resulted in better values during the later hour; any fluctuation can be timely corrected. Since the factory had a titration laboratory which monitor iodine content every hour. Although there was some fluctuation, overall, the system seemed to function reasonably well. However, the iodine content of iodized salt from the PM factory tended to be much higher than the legalized level. The PM factory would need to consider adjusting the concentration of iodine solution in order to lower the iodine content in the product to more acceptable range.

5. Evaluation of iodine test kits used in Thailand (MBI and I-kits)

Since test kit is a tool that is widely used for quality control of iodized salt in Thailand by both producer and inspector, the test on the agreement of available test kits against the standard titration method was therefore necessary. Data on uses of I-kit by a well-trained technician (technician I) and iodized salt producers were collected. The widely distributed test kit, the MBI kit was also tested by another technician (technician II). The agreements are reported between use of each test kit versus titration as kappa values which are interpreted as follows (15): < 0.2 = poor, 0.21 – 0.4 = fair, 0.41 – 0.6 = moderate, 0.61 – 0.8 = good and 0.81 – 1.0 = very good.

The highest kappa value was found between the use of I-kit by the well-trained technician I (k = 0.599), indicating moderate agreement. The kappa values for the uses of I-kit by iodized salt producers and MBI kit (technician II) against the titration method were very poor (<0.1). In using the I-kit by the well-trained technician, the percentage of correct reading by range of color on the I-kit chart was at least 60% up to 74% of samples in each range. The proportion of correct reading when the I-kit was used by the well-trained technician was quite consistent regardless of the concentration. In untrained personnel using either I-kit or MBI kit, serious misclassification of iodine content was observed. For example, when the sample contained < 10 ppm, 17% was misclassified as being adequate (i.e. 30-49 ppm). Test kit cannot be used even for semi-quantitatively controlling the quality of iodized salt if the personnel has not been trained. The test kit is useful and absolutely needed for qualitative quality control. It is a perfect tool used for screening the iodized salt from unfortified salt and can roughly be used for estimating range of the fortification level.

6. Quality control system for local health officers and iodized salt producers

The quality control system designed was divided into 2 parts:

(1) Inspector part

It was aimed to assist the local health officer to understand the factors affecting the content and homogeneity of iodine in salt, sampling method, sample size, problem investigation and trouble shooting. The information was provided via record form and instruction manual (Appendix B). Now the provincial health officers in Mahasarakam and Nan provinces were using the record form routinely in their inspection activities.

(2) Analytical part

The one-day training provided to science teachers was good enough for them to perform a reliable iodometric titration analysis. The results of their quality control samples were all in the acceptable ranges. Costs of chemicals used for analysis of one sample (duplicate) was about 0.50 – 1 Baht. With this model, there had been cooperation between two government sectors in the community i.e. health and education. At Mahasarakam province, it was shown that the iodine content and homogeneity in salt was better than before implementing the quality control scheme. This model should be one of the powerful tools for quality assurance of iodized salt in the community. Besides, it also emphasized the role of local high schools in serving the community need by integrating the activity into the locally-designed curriculum was the current educational strategy.

Reference

1. ลือชา วนรัตน์. การผลิตและการกระจายเกลือเสริมไอโอดีนในระดับชุมชน และอุตสาหกรรมครัวเรือน. กรุงเทพมหานคร. โรงพิมพ์องค์การสงเคราะห์ทหารผ่านศึก. 2537.
2. กระทรวงสาธารณสุข.ประกาศกระทรวงสาธารณสุข ฉบับที่ 153 (พ.ศ. 2537).ราชกิจจานุเบกษา ฉบับประกาศทั่วไป เล่ม 111 ตอนพิเศษ 15 ง. 2537.
3. Ministry of Public Health. Tracking progress towards the sustainable elimination of Iodine Deficiency Disorder in Thailand. 1997 June 23- July 8; MOPH, Thailand & ICCIDD & UNICEF, Thailand; 1997.
4. คณะอนุกรรมการพิจารณาการแสดงคุณค่าทางโภชนาการบนฉลากอาหาร. สารอาหาร ที่แนะนำให้บริโภคประจำวันสำหรับคนไทยอายุตั้งแต่ 6 ปีขึ้นไป. สำนักงานคณะกรรมการอาหารและยา. กระทรวงสาธารณสุข. กรกฎาคม. 2538.
5. Fradkin JE, Woff J.Iodide-Induced Thyrotoxicosis. Medicine 1983; 62 (1): 1-20.
6. ICCIDD. Iodine-Induced Hyperthyroidism report of a workshop March 1996. Thyroid 1998; 8 (1): 82-100.
7. Mosbeck A, Galvan G, Bauer P, Eber O, Atefie K, Kroiss A and others. The incidence of hyperthyroidism in Austria from 1987 to 1995 before and after an increase in salt iodization in 1990. Eur. J. Nucl. Med. 1998; 25(4): 367-74.
8. Todd Ch, Allain T. Gomo ZAR, Haster JA, Ndiweni M, Oken E. Increase in thyrotoxicosis associated with iodine supplements in Zimbabwe. Lancet 1995; 346: 1563-4.
9. Bourdoux PP, Ermans AM, Mukalay A, Filetti S, Vigneri R. Iodine-induced thyrotoxicosis in Kivu, Zaire. Lancet 1996; 347: 552 -3.
10. กองโภชนาการ กรมอนามัย. การศึกษาความคงตัวของไอโอดีนในเกลือเสริมไอโอดีนและน้ำเสริมไอโอดีน. กระทรวงสาธารณสุข. 2540.
11. บรรพต ตันธีรวงศ์. ปราโมทย์ สีอร่ามรุ่งเรือง, วรสุดา ยูงทอง, เนาวรัตน์ แตงไทย, การสำรวจสถานการณ์การคุ้มครองผู้บริโภคด้านผลิตภัณฑ์สุขภาพของประเทศไทย พ.ศ.2540. กรุงเทพมหานคร: สำนักงานคณะกรรมการอาหารและยา. 2540.

12. ประณีต ผ่องแผ้ว, รังสรรค์ ตั้งตรงจิตร, วีนัส ศุภวันต์, เบญจลักษณ์ ผลรัตน์, นิยมศรี วุฒิวัย, อุดมศักดิ์ มหาวีรวัฒน์ และคณะ. ปริมาณสารไอโอดีนในเกลือไอโอดีนที่ผลิตและจำหน่ายในพื้นที่ที่มีอุบัติการณ์ของโรคขาดสารไอโอดีนในภาคตะวันออกเฉียงเหนือของประเทศไทย. อาหาร. 2539. 26 (2): 108 – 17.

13. Sullivan KM, Houstom R, Cervinskas J, Gorstein J. Monitoring universal salt iodization programmes; 1995 January; Geneva: PAMM/MI/ICCIDD. 1995.

14. ภิญโญ พานิชพันธ์, พิณทิพ รื่นวงษา. การพัฒนาชุดตรวจสอบภาคสนามสำหรับตรวจสอบเกลือของไอโอดีนใน iodized salt ในประเทศไทย. กรุงเทพมหานคร. ภาค วิชาเคมี คณะวิทยาศาสตร์ มหาวิทยาลัยมหิดล. 2540.

15. Marija JN. SPSS/PC.Chicago: SPSS Inc; 1993.

16. Marija JN. SPSS for window release 6.0, Chicago: SPSS Inc; 1993.

17. กองโภชนาการ กรมอนามัย. งานควบคุมโรคขาดสารไอโอดีนในประเทศไทยอดีต – ปัจจุบันและอนาคต. กรุงเทพฯ: กรุงเทพมหานคร. 2535.

18. กรมอนามัย. การประชุมสัมมนาระดับชาติ เรื่อง "การควบคุมโรคขาดสารไอโอดีนในประเทศไทย", 3-5 มีนาคม 2535. กรุงเทพฯ: องค์การสงเคราะห์ทหารผ่านศึก. 2535.

APPENDIX A

FIGURE OF THE STUDIED IODIZATION MODELS

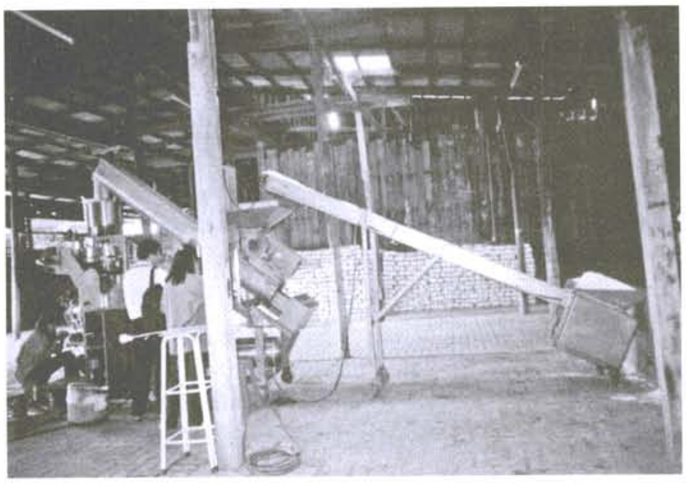

Figure 1 UNICEF model

Figure 2 Screw conveyor

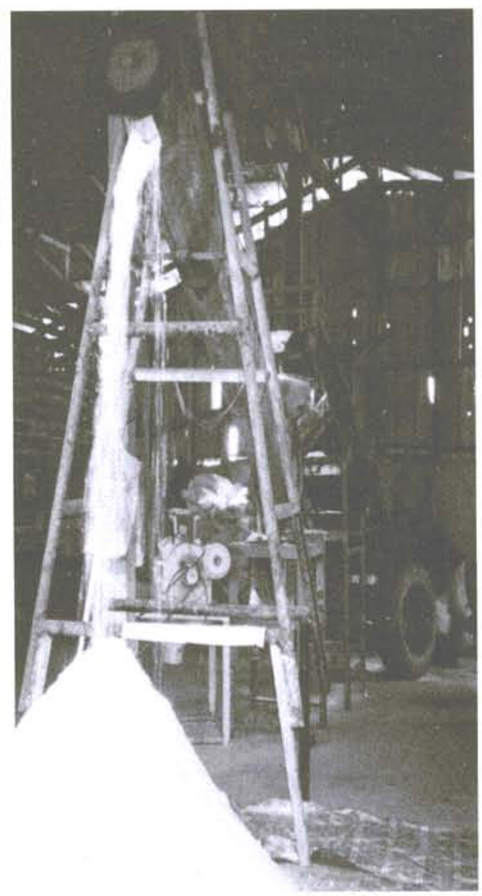

Figure 3 Modified belt conveyor

Figure 4 Submersion

Figure 5 Modified cement mixer

(MOPH model)

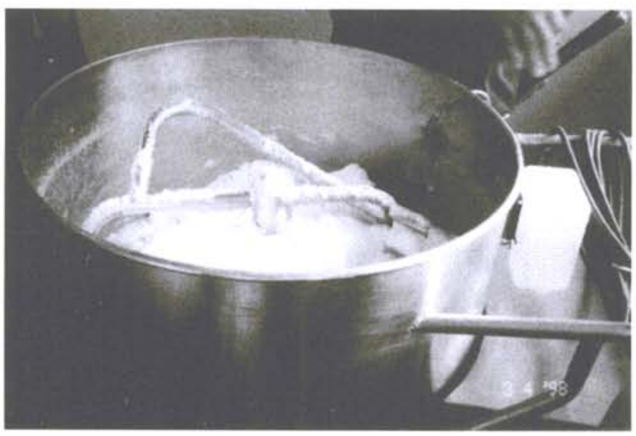

Figure 6 Modified cement mixer

(Sakorn model)

Figure 7 Modified cement mixer

(chiangmai model,large shape)

Figure 8 Modified cement mixer
(chiangmai model,small shape)

Figure 9 Floor model

Figure 10 Wooden trough
(Trough model)

Figure 11 Plastic basin (Basin model)

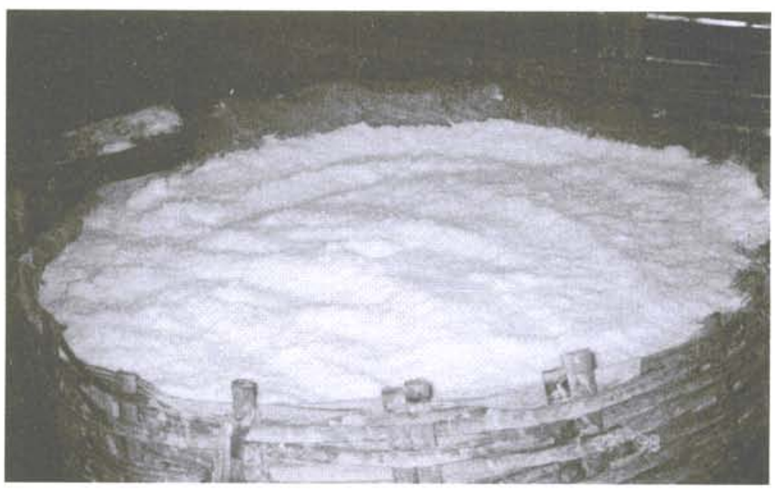

Figure 12 Large bamboo bin (Bin model)

APPENDIX B

RECORD FORM FOR QUALITY CONTROL OF IODIZED SALT

FOR MOPH OFFICER

Date _______ / ______ / ______

Producer: ____

Name of factory ____

Address ____

Tel. ______________________ Fax. __________________________

Brands: (1) ____________________ (2) ______________________

(3) ____________________

Part I: Estimation of iodine concentration in salt (by calculation)

Objective: To evaluate the knowledge of producer on iodized salt production by using interview and observation.

(1.1) Technique (s) used for iodization

a. continuous process using conveyors (UNICEF model)
b. batch process using mixing machines (MOPH and Technical college models)
c. batch process using trough
d. batch process using plastic basin
e. batch process using floor
f. others, identify ________________________________

(1.2) Estimation of iodine concentration in iodized salt by calculation

(a) amount of potassium iodate powder used is ______________ gram

(b) amount of water used for preparing iodine solution is ______ liter

(c) concentration of iodine in iodine solution (by calculation)

is ______________ ppm

(d) ratio of salt to iodine solution used in the mixing:

- weight of salt = __________________ kilogram

- volume of iodine solution = __________________ liter

(e) calculation of iodine concentration in salt

$$= \frac{\text{vol. of iodine solution (l) x conc. of iodine in iodine solution (ppm)}}{\text{wt. of salt (kg)}}$$

= ______________ ppm

(1.3) From the calculation, iodine concentration in iodized salt is

( ) Higher than the acceptable range

( ) Within the acceptable range (30 – 50 ppm)

( ) Lower than the acceptable range

(1.4) Feedback or advice:

____

____

____

Part II: Analyses of iodine content and homogeneity of iodine in iodized salt

Objective: To sample iodized salt from the production site to analyze for iodine content and homogeneity of iodine in iodized salt.

(2.1) Sampling

Sample	Code
From sampling point no.1	______
From sampling point no.2	______
From sampling point no.3	______
From sampling point no.4	______
From sampling point no.5	______

Iodine solution analysis

Concentration of iodine in iodine solution (from titration) is __________ ppm

Compared to value from the calculation in (1.2), the value from titration is:

( ) Much higher

( ) Close

( ) Much less

(2.2) Suggestion:

____

____

____

____

____

____

INSTRUCTION MANUAL FOR USING THE RECORD FORM

FOR QUALITY CONTROL OF IODIZED SALT FOR MOPH OFFICER

Part I: Estimation of iodine concentration in salt (by calculation)

Objective: To evaluate the knowledge on iodization of salt by using interview and observation.

(1.1) Technique(s) used for iodization: Indicate the technique(s) that the producer used during the inspection (can be more than one).

(a) continuous process using conveyors (UNICEF model)

(b) batch process using mixing machines (MOPH and Technical college models)

(c) batch process using trough

(d) batch process using plastic basin

(e) batch process using floor

(f) others, specify ____________________

(1.2) Estimation of iodine concentration in iodized salt **by calculation**

By following these steps, you can calculate iodine concentration in salt based on the producer's information in order to check for correctness of the amounts of ingredients used.

Information needed and steps of calculation

(a) amount of potassium iodate powder used is ___A___ gram

(b) amount of water used for preparing iodine solution is ___B___ liter

(c) concentration of iodine in iodine solution (by calculation)

$$= \frac{A \times 600}{B} = \underline{\quad C \quad} \text{ ppm}$$

(d) ratio of salt to iodine solution used in the mixing:

- weight of salt = ___D___ kilogram
- volume of iodine solution = ___E___ liter
- calculation of iodine concentration in salt

$$- \frac{\text{vol. of iodine solution (l) x conc. of iodine in iodine solution (ppm)}}{\text{wt. of salt (kg)}}$$

$$= \frac{E \times C}{D} = \_\_\_\_\_\_\_\_\_\_ \text{ ppm}$$

(1.3) From the calculation, iodine concentration in iodized salt is

( ) Higher than the acceptable range

( ) Within the acceptable range (30 – 50 ppm)

( ) Lower than the acceptable range

From the calculation, an inspector will be able to decide if the iodine concentration is within the acceptable range, and record in no. (1.3) of the form.

(1.4) Feedback or advice (based on calculation)

If the calculation shows that iodine concentration (1.3) is not within the acceptable range, one should consider the following factors.

(a) concentration of iodine solution

- If concentration of iodine in salt is too high or low, try to either proportionally decrease or increase amount of potassium iodate powder, and recalculate the concentration before providing advice.

(b) If the concentration of iodine solution is already correct, consider the ratio of amount of salt to iodine solution.

- Advise the producer to increase amount of salt, if the calculation indicates too high iodine in salt.
- Advise the producer to decrease amount of salt, if the calculation indicates too low iodine in salt.

(c) Advise the producer to use precise measurement or proper estimation of potassium iodate powder, water and salt.

Part II: Analyses of iodine content and homogeneity of iodine in iodized salt

Objective: To sample iodized salt from the production site to analyze for the iodine content and homogeneity of iodine in iodized salt.

(2.1) Sampling

Samples should be taken from the freshly prepared iodized salt. They should be sampled from at least 3-5 spots of a salt pile for each production batch. To avoid confusion, sample must be systematically coded, and the code must be recorded in the record form. Make sure that the label is properly put and not removable during transportation to the laboratory for analysis. Iodine solution may also be sampled if needed.

Sample	Code
From sampling point no.1	________________
From sampling point no.2	________________
From sampling point no.3	________________
From sampling point no.4	________________
From sampling point no.5	________________

2.2 Calculation of average iodine content and degree of homogeneity of iodine in iodized salt

2.2.1 Average iodine content

In order to minimize the effect of non-homogeneity, the average value of iodine contents from at least 3 sampling spots should be used for evaluating iodine concentration of iodized salt from that premise. Average value is calculated by:

$$X = \frac{\text{Sum of iodine contents in all samples}}{\text{Total number of Sample}}$$

2.2.2 Calculation of degree of homogeneity of iodine in iodized salt

Degree of homogeneity of iodine can be indicated as Percent Coefficient of Variation (%CV), which calculated by dividing the standard deviation (SD) of the iodine contents in all samples with their mean value, and multiplied by 100, as shown in the equation.

$$\% \text{ CV} = \frac{\text{standard deviation (SD) x 100}}{\text{Mean (X)}}$$

Part III Suggestion

In order to troubleshoot the problem, the information on both average amount and % CV are required. Suggestion can be done based on the following information.

1. If the average amount of iodine is too either high or low and % CV is also too high.
   1.1 Add the mixing step or increase the mixing time and sampling again for analysis.
   1.2 Check the information from the interview in part I; if is correct, check the measurement methods for salt and iodine solution.
2. If the average amount of iodine is within the acceptable range but % CV is too high.
   2.1 Add the mixing step or increase the mixing time and sampling again for analysis.
3. If the average amount of iodine is too either high or low but % CV is not high.
   3.1 Check the information from the interview in part I; if it is correct, check the measurement methods for salt and iodine solution.