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# HIGH VARIABILITY OF IODINE IN IODIZED SALT AND URINE FROM RURAL HOUSEHOLDS IN SIDAMA ZONE, SOUTHERN ETHIOPIA: A CROSS-SECTIONAL STUDY

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## ABSTRACT

Iodine is essential for the synthesis of thyroid hormones which regulate the metabolic processes of most cells and play important roles in human growth and development. Iodine deficiency has long been one of the most common nutritional problems in the world. Ethiopia, particularly the study population (Sidama) has a history of severe iodine deficiency. The purpose of the study was to assess urinary iodine concentration, level of goiter in mothers and school-age children and household salt iodine concentration in households 10 months after launch of the national salt iodization program. A cross-sectional study was conducted on a randomly selected sample of women and schoolchildren. Goiter was assessed by palpation. Concentrations of iodine in salt, urine and water were analyzed by inductively coupled plasma mass spectrometry (ICP-MS). The study included 193 mothers and 76 children. The median (IQR) urinary iodine concentration (UIC) was 143 (84, 202) µg/L in the mothers and 187 (102, 278) µg/L in the children. Mothers' UIC ranged from 17 to 767.2 µg/L and children's UIC ranged from 19 to 739 µg/L. Goiter prevalence was high in both mothers (76%) and children (79%). The median household salt iodine concentration (SIC) was 8.1 (4.3, 13.4) ppm (mg/kg) with a range of 0 to 42 ppm. None of the water samples contained iodine above the detection limit of 1 µg/L. Despite the launch of the salt iodization program in Ethiopia, 94% of the study participants were not aware that they used iodized salt and 88% did not know the benefits of iodized salt. The major source of iodine for this population was iodized salt; however, the salt at household level contained minimal but variable amounts of iodine. Low concentration of iodine in salt may be further compounded by storage, handling and cooking techniques. The high variability of salt iodine concentration (SIC) was also reflected in the UIC of the mothers and children.

**Key words:** Iodized salt, urinary iodine, goiter, children, mothers, southern Ethiopia



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## INTRODUCTION

Iodine is a chemical element found in trace amounts in the human body and is primarily obtained through the diet [1]. Iodine is essential for the synthesis of thyroid hormones which regulate the metabolic processes of most cells and play important roles in human growth and development [2].

Iodine deficiency is one of the most common nutritional problems of the world. Globally, it was estimated in 2009 that 2 billion people, most of them in low income countries, suffered inadequate intakes of iodine [3]. Due to its multiple effects on human health, iodine deficiency is referred to as iodine deficiency disorders (IDDs) [4]. Enormous progress towards eliminating iodine deficiency has been made however, the deficiency continues to reappear even in medium and high income countries [5].

In a survey conducted in Ethiopia in 2005, goiter prevalence was 35.8% among 15 to 49 years old women and 40% in school age children. In the southern region of the country, of 1702 women examined for goiter, 43.2% had palpable and 17.7% had visible goiter, which is a total goiter prevalence of 60.9%. In school children in the same region, the prevalence of goiter was 56.2%. These data show that Ethiopia, particularly the southern region, was severely affected by iodine deficiency [6, 7].

Iodine is widely distributed in the environment as iodide. Iodine found in the soil can be washed away by leaching, flooding and erosion, which leaves the soil and drinking water depleted of iodine. Plants grown in this soil will be low in iodine content and hence animals and humans that rely on these plants will most likely become iodine deficient [8]. For people who reside in iodine-deficient areas, the best ways to alleviate iodine deficiency are using iodized salt and diversifying local food with foods from iodine-sufficient areas. Iodine containing fertilizers, livestock feed, and compounds used in irrigation and milk processing can increase iodine content in foods including dairy products [3].

A review of reports from 30 low income countries showed that urinary iodine concentration (UIC) was significantly correlated with household iodized salt availability [9]. In a prospective study of women 18 to 65 years old in Denmark, a lower median thyroid volume was observed 4 years after a mandatory salt iodization (13 ppm iodine) program. Further, a large relative decline of thyroid volume was observed in the younger females from places where iodine deficiency had been more serious compared to mild [10]. A national survey on iodine deficiency was conducted in Tanzania after twelve years of a salt iodization program. The iodine status of school children, aged 6 to 18 years, was assessed by goiter level (n = 140,358) and UIC (n = 4523). Total goiter significantly decreased from 61% in the 1980s to 12.3% in 2004 and the median UIC was found to be 204µg/L [11].

In Ethiopia, the salt iodization program was launched early in 2012. Data were collected in early 2013 and approximately a year later, the Ethiopian Public Health Institute reported 95.2% national iodized salt coverage (above 0 ppm) with 42.7% of the households having salt with iodine greater than 15 ppm. Households with salt within the

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national standard (20 to 40 ppm) were 23.2% [12]. However, to the best of our knowledge, no study has reported the impact of the salt iodization program on urinary iodine or goiter in the southern part of the country following the launch of the salt iodization program. Further, local knowledge about the health benefits of iodine subsequent to initiation of the national program had not been assessed.

The purpose of the present study was to assess urinary iodine concentration, goiter in mothers and school-age children and household salt iodine concentration in a sample of households 10 months after launch of the national salt iodization program. Moreover, knowledge of mothers about IDDs as well as their practices and utilization of iodized salt were assessed.

## MATERIALS AND METHODS

### Study area and design

The study was conducted in Sidama zone, southern Ethiopia, where iodine deficiency was severe prior to the national salt iodization program [13-15]. The study area has a variety of climate conditions and its elevation ranges from 1678 m to 1809 m above sea level. The major staple foods are corn and enset *(Enset ventricosum)* [16].

Before the study began, ethical approval was obtained from Oklahoma State University, USA, Hawassa University, Ethiopia, and Ministry of Science and Technology, Ethiopia. The study participants were recruited from eight kebeles (the smallest administrative unit) from a randomly selected sample of households which included women (n = 193) and their school age children (n = 76). Households were selected using random numbers from lists of households available in the kebele health center. Any woman or school age child available in the house during the time of data collection was invited to participate. Study participants were given a detailed explanation of the objectives of the research, and consent forms were read to the women. Women signed for themselves and their children before data collection was started. Because 90% of dietary iodine is excreted in the urine, UIC is a commonly used indicator for iodine status of a community [17]. Each participant collected a urine sample in a plastic cup; samples were transferred to tightly sealed vials for subsequent analyses. Water samples from eight communal water tap points and from nearby Lake Awassa were collected for iodine analysis. A 10 g salt sample was collected from each household.

Each mother's knowledge, attitudes and practices about iodized salt, iodine deficiency, goiter and other related factors were assessed using open-ended questions, which were re-coded for analysis. Socio-demographic data were collected by interview using structured questionnaires.

### Laboratory analysis and goiter assessment

Urinary and drinking water iodine concentrations were analyzed by inductively coupled plasma mass spectrometry (ICP-MS Elan 9000, Perkin Elmer, Norwalk, CT). Salt iodine concentration (SIC) was analyzed with a digital electronic iodine checker (WYD, UNICEF) and validated using inductively-coupled-plasma mass spectrometry. Measured SIC using the two methods demonstrated a good correlation ($r = 0.745$, $p < 0.001$).


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Goiter of mothers and children was determined by palpation based on the following grades: grade 0, no palpable or visible goiter; grade 1, palpable goiter not visible with neck in normal position; and grade 2, visible goiter with neck in its normal position [17]. Goiter was assessed by an experienced health officer.

**Statistical analysis**

Data were analyzed using SPSS statistics for Windows v. 20.0 (Armonk, NY: IBM Corp.). Frequency, percentage and median (IQR) were used to present the data. Pearson's correlation coefficients and the Chi square test were used to test for association. To test whether or not the means of three or more groups were equal, we used Tukey's honestly significant test (Tukey's HSD) and for two groups we used independent-sample t tests.

## RESULTS and DISCUSSION

**Descriptive results**

Demographic and socio-economic characteristics of study participants are presented in Table 1. The mean (SD) age of the mothers was 25.6 (8.1) and of the children was 9.6 (4.4) years. The mean household size was 5.7 (2.1) and mean number of children was 3.2 (1.8). Among the children who participated in this study, 60% were males. Of the respondents, 55% had some formal education.

The median UIC of mothers was 143 µg/L and of the children was 187 µg/L, which is above the cutoff (100 µg/L) for defining an adequate iodine area [17] (Table 2). Only one mother and one child had UIC below 20 µg/L. Overall, based on UIC, 67.5% of the mothers and 77% of the children had adequate, more than adequate or excessive iodine intakes (Figure 1).

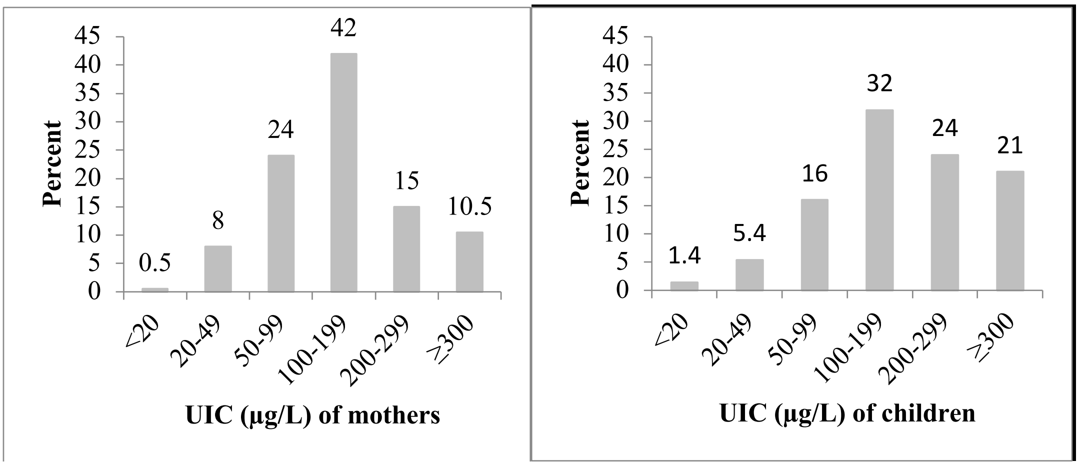


**Figure 1**: **Distribution of urinary iodine concentrations (UIC) in a sample of mothers and children from Sidama zone, 10 months after Ethiopia's national salt iodization program was initiated**

Although children had less "visible goiter" than women, goiter prevalence was high in both mothers and children. Most (76%) of the women and 79% of the children had either

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palpable or visible goiter. This prevalence of goiter was far above what would be defined as a public health problem [17] (Table 2). Mean UIC was not significantly different based on goiter in either mothers or children or between male and female children (Table 3). However, older mothers had significantly higher UIC compared to younger ones [$F(3, 186) = 4.17$, $p = 0.007$]. Tukey's Post Hoc test showed women age 29 years and above had significantly higher urinary iodine concentration than women age 17 to 20 years old ($p = 0.003$). Children's age, was associated with level of goiter ($X^2 = 13.3$, $p = 0.01$) but not with UIC, and there were not significant differences in goiter by sex in children (Table 3).

**Salt iodine concentration**

A markedly high variation was observed in SIC. Nearly 79% of the salt samples were below the minimum (15 ppm) for adequately iodized salt (Table 2). Only 21% of the salt samples were within the recommended 15 – 40 ppm. One salt sample that measured 162 ppm was considered an outlier and excluded from analyses. Otherwise, SIC ranged between 0 ppm to 42 ppm. Water iodine concentration was analyzed from eight communal tap water points and from the lake but all water samples were below the detection limit of 1 µg/L (1 ppb).

**Mother's awareness of salt iodization and causes of goiter**

Nearly 94% of women interviewed 10 months after the launch of salt iodization in Ethiopia did not know whether or not the salt they were using was iodized (Table 4). Except one woman, all of the women thought the salt they were buying from the market for cooking was rock (non-iodized) salt and only 24 women (12%) knew the benefits of iodized salt. Among those, 23 women said iodized salt prevents goiter. Of the 39 women (20%) who claimed to know the causes of goiter, only ten related goiter to lack of iodine in salt or to iodine itself.

As indicated in Table 5, most women added salt to food near the end of cooking, but 38% said they cooked the salt together with the food. Most women stored their salt in an empty plastic water bottle.

**Urinary Iodine Concentration (UIC) and Goiter**

The most efficient way to alleviate iodine deficiency disorders is to implement universal salt iodization [3]. Compared to previous studies from the region [13-15], present study showed marked improvement in urinary iodine and salt iodine concentrations following the launch of salt iodization in 2012 in Ethiopia. However, prevalence of goiter remained high in mothers (76%) and in children (79%). Guidance from WHO/UNICEF/ICCIDD suggests that goiter is likely to take some time to reverse [17]. Urinary iodine concentration (UIC) and level of goiter may not correlate as a program is introduced because UIC reflects recent iodine intake and goiter is a result of long-term iodine deprivation. In a cross-sectional study in Guinea-Bissau in school age children, rate of goiter was high (73.5%) despite median UIC of 110 µg/L [18]. Similarly, in a longitudinal continuous study in Chinese population iodized salt was not associated with rate of goiter [19]. Knowledge of importance of iodine was low and needs effective intervention.


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**Variability of urinary iodine concentration (UIC) and salt iodine concentration (SIC)**

Compared to previous studies the pattern of UIC distribution in both mothers and children is shifting towards iodine adequacy. In consecutive years from 2007 to 2010 in similar study areas in Sidama, the proportion of study participants with UIC below 100 µg/L (an indicator of iodine inadequacy) was nearly 100%. In 2007, 99% of the school-age children involved in the study had UIC below 20 µg/L [13]. In 2009, 89% of the pregnant women had UIC below 50 µg/L with 60% below 20 µg/L [14]. Similarly, in 2010, the proportion of women with UIC below 100 µg/L was 96% [15]. In the present study the proportion of mothers and children with UIC below 20 µg/L was almost zero. Most of the mothers (67.5%) and children (77%) had UIC above 100 µg/L. However, mothers' UIC ranged from 17 to 767.2 µg/L and children's UIC ranged from 19 to 739 µg/L. This high variability in UIC could suggest potential risk for iodine-induced hyperthyroidism [20] and emphasizes the need for continuous monitoring of Ethiopia's relatively new salt iodization program.

Other than salt, the study population had poor dietary sources of iodine [15]. The iodine concentration of their drinking water was also below the detection limit of ICP-MS (1 ppb). If local water supplies are extremely low in iodine, food grown locally also is expected to have low iodine concentrations [21]. Hence, the high variability in UIC could be explained from the high variability observed in SIC ($X^2 = 4.43$, $p = 0.034$). Salt iodine concentration ranged from 0 ppm to 42 ppm with one outlier of 162 ppm. The variability in SIC is a great concern because it is highly likely that one can get salt with little iodine one day and excessively iodized salt another day. Women typically buy small amounts of salt to use for one to three days. The ultimate goal of a universal salt iodization program is to alleviate iodine deficiency but if not closely monitored, both inadequate and excessive iodine intake could be a problem [5]. According to a national report, some salt in Ethiopia was being iodized manually using knapsack sprayers and small scale iodization machines, which make it difficult to produce homogeneously iodized salt [12]. Also, iodine lost from salt by inappropriate storage [17] may contribute to the high variability in SIC. The percentage of households with adequately iodized salt (≥ 15 ppm) in other parts of the country ranged from 8% to 33% [22-24].

Although consumer awareness is necessary for a quick improvement and demand for a better product, it could be too early to comment on the Ethiopian salt iodization program. In Saudi Arabia, 20 years after a universal salt iodization program was implemented, SIC showed variation from 0 to 112 ppm [25]. Despite a mandatory salt iodization program in Cambodia, a drastic decrease in the iodine content of salt was observed from 22 ppm in 2011 to 0 ppm in 2014. Presumably this drop in salt iodine content was due to infiltration of non-iodized salt from the production site to the market and/or due to inappropriate packaging of iodized salt [26]. Long-term experience from different countries has shown that salt iodization programs can only be effective and sustainable with strong monitoring strategies and commitment from government, donors, producers, distributors and consumers [27].


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**Utilization of iodized salt**

Maintaining the sustainability of a salt iodization program requires its own multi-dimensional commitment, and retaining the iodine in the salt in turn requires careful storage and handling in the market and the household as well as proper utilization methods. Iodine is a volatile trace element and hence it can easily be lost from improper storage, handling and cooking processes. The WHO/UNICEF/ICCIDD manual suggests that 20% of iodine from salt will be lost between production and the household, and another 20% will be lost during cooking [17]. Even greater losses were found in a study in Wukro, Northern Ethiopia that reported that 57% of the salt iodine available at the production level was lost by the time it reached the household [28].

The stability of iodine in salt can be affected by moisture content of the salt, impurities, alkalinity or acidity, heat, light and humidity [29]. In the present study except for two mothers who added salt to food after cooking, the rest cooked the salt with food. Most stored the salt in containers likely to contain moisture, which could contribute to iodine loss. Only five women purchased salt from retail shops; the remainder (97%) purchased salt from the open market. From our observation, salt sold in the open market is highly exposed to impurities, warm temperature and humidity.

**Knowledge related to iodized salt**

Due to the launch of the salt iodization program in Ethiopia, it may have been assumed that the general population understood the importance of iodine and that all salt in the market was iodized. However, 94% of the participants in our study reported they did not use iodized salt and 88% did not know the benefits of iodized salt. Of the relatively few mothers who reported knowing the benefits of iodized salt, all but one said it prevents goiter but none mentioned cognitive effects. The women suggested causes of goiter to be drinking dirty water, drinking tap water, or drinking rainwater, but only five percent said lack of iodine or lack of iodized salt. Although prevalence of goiter was high and visible in the community, knowledge of causes and of prevention of iodine deficiency disorders (IDDs) was minimal.

The fact that the majority of the mothers said they did not use iodized salt does not indicate the salt was not iodized, but rather that they did not know the difference between iodized and non-iodized salt. From our survey the iodized salt to the merchant was packed in 50 kg bags. Rural people, however. purchased minute amounts of salt. Therefore, there was no way for even the ones who could read to know the information labeled on the 50 kg bags. For effective transfer of information about iodine content and minimizing the loss as a result of poor storage conditions, packaging of iodized salt in smaller amounts would be worthwhile.

## CONCLUSION

In conclusion, by far the most important source of iodine for this population should be iodized salt; however, the salt contained minimal but variable amounts of iodine. Low concentration of iodine in salt may be further compounded by storage, handling and cooking techniques. Until large-scale machinery based salt iodization and effective monitoring strategies are fully established, it is difficult to sustain a good quality salt


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iodization program. Moreover, mechanisms should be devised to control the infiltration of non-iodized salt to the local market. In order to encourage the community to say 'No!' for non-iodized salt, it is indispensable to create awareness of causes, consequences and prevention of IDDs.

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**Authors' Contributions**

Both authors have contributed to design, analysis and writing of this manuscript.

**Conflict of interests**

The authors declare no potential competing interests with respect to financial, authorship, or publication of this article.

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**Table 1: Socio-demographic characteristics of study participants**

| | Mean (SD) | Frequency (%) |
|---|---|---|
| Mothers (n = 193) | | |
| Mothers age (years) | 25.6 (8.1) | |
| Household size | 5.7 (2.1) | |
| Number of children | 3.2 (1.8) | |
| Mothers education (%) | | |
| - No formal education | | 87 (45) |
| - Some education | | 106 (55) |
| Children (n = 76) | | |
| Children's age (years) | 9.6 (4.4) | |
| Children's gender (%) | | |
| - Male | | 46 (60) |
| - Female | | 30 (40) |


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**Table 2: Urinary iodine concentration of mothers and children and salt iodine concentration from Sidama zone, southern Ethiopia**

| | Median (IQR) | Frequency (%) |
|---|---|---|
| Maternal UIC (µg/L) | 143 (84, 202) | |
| Maternal goiter | | |
| - No goiter | | 46 (24) |
| - Palpable goiter | | 50 (26) |
| - Visible goiter | | 97 (50) |
| Children's UIC(µg/L) | 187 (102, 278) | |
| Children's goiter | | |
| - No goiter | | 16 (21) |
| - Palpable goiter | | 47 (62) |
| - Visible goiter | | 13 (17) |
| Household SIC (ppm) | 8.1 (4.3, 13.4) | |
| - < 5 ppm | | 55 (28.6) |
| - 5 – 9.9 ppm | | 61 (31.8) |
| - 10 – 15 ppm | | 35 (18.2) |
| - > 15 ppm | | 41 (21.4) |
| - SIC range | 0 to 42 ppm | |


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**Table 3: Comparisons in maternal and child UIC by level of goiter, age and child sex; and association between children age and sex with goiter**

| | UIC (µg/L) Mean (SD) | p value | Child goiter (%) | Chi-square test | p value |
|---|---|---|---|---|---|
| Maternal goiter | | 0.167 | | | |
| - No goiter | 189 (139) | | | | |
| - Palpable goiter | 147 (77) | | | | |
| - Visible goiter | 158 (115) | | | | |
| Maternal age (years) | | 0.007 | | | |
| - 17 – 20 | 134 (75) | | | | |
| - 21 – 24 | 154 (102) | | | | |
| - 25 – 28 | 164 (125) | | | | |
| - ≥ 29 | 213 (143) | | | | |
| Child goiter | | 0.348 | | | |
| - No goiter | 182 (102) | | | | |
| - Palpable goiter | 226 (166) | | | | |
| - Visible goiter | 278 (216) | | | | |
| Child age (years) | | 0.166 | | 13.3 | 0.01 |
| - 5 – 8 | 238 (166) | | 26 (34.2) | | |
| - 9 – 12 | 256 (183) | | 16 (21.0) | | |
| - ≥ 13 | 162 (116) | | 18 (23.7) | | |
| Child sex | | 0.403 | | 3.8 | 0.15 |
| - Male | 210 (163) | | 36 (50) | | |
| - Female | 243 (160) | | 20 (29) | | |

Maternal goiter, maternal age and children goiter were analyzed by ANOVA and children age and sex were analyzed by Chi-square test

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**Table 4: Knowledge, attitudes and practices concerning household salt and goiter of women from Sidama zone, southern Ethiopia**

| Questions to the women | Frequency | Percent |
|---|---|---|
| What kind of salt do you use? | | |
| - Rock salt | 192 | 99.5 |
| - Packed iodized salt | 1 | 0.5 |
| Do you use iodized salt? | | |
| - Yes | 12 | 6.2 |
| - No | 181 | 93.8 |
| Do you know the benefits of iodized salt? | | |
| - Yes | 24 | 12.4 |
| - No | 169 | 87.6 |
| What is the benefit of iodized salt? (n = 24) | | |
| - Prevents goiter | 23 | 95.8 |
| - Makes one strong | 1 | 4.2 |
| Do you know the causes of goiter? | | |
| - Yes | 39 | 20.2 |
| - No | 154 | 79.8 |
| What are the causes of goiter? (n = 39) | | |
| - Drinking dirty water | 14 | 35.9 |
| - Lack of iodine in salt | 8 | 20.5 |
| - Drinking tap water | 4 | 10.3 |
| - Drinking rain water | 4 | 10.3 |
| - Lack of food | 2 | 5.1 |
| - Lack of salt | 2 | 5.1 |
| - Lack of iodine | 2 | 5.1 |
| - Drinking untreated water | 1 | 2.6 |
| - Drinking river water | 1 | 2.6 |
| - Hereditary | 1 | 2.6 |


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**Table 5: Utilization and handling of salt by women from Sidama zone, southern Ethiopia**

| Questions to the women | Frequency | Percent |
|---|---|---|
| When do you add salt to food when cooking? | | |
| - Cook together | 73 | 37.8 |
| - At the end | 120 | 62.2 |
| How much salt (tsp) do you add to each food that you cook? | | |
| - One | 130 | 67.4 |
| - Two | 59 | 30.6 |
| - Three | 4 | 2 |
| How do you store your salt? | | |
| - In a tight bottle | 21 | 10.9 |
| - In a water bottle | 133 | 68.9 |
| - In a plastic bag | 38 | 19.7 |
| - Cover with paper | 1 | 0.5 |

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