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Full Length Research Paper

Iodine content of iodized salt available in retail outlets in Mthatha

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This study assesses the iodine content variations according to physical structure of salt and the socioeconomic status (SES). The cross sectional iodometric titration was used to determine iodine in salt samples according to the legal requirements of 40 - 60 ppm. Salt brands were purchased in a representative number of shops in Mthatha, South Africa and 66 samples were analyzed. The legal requirement was present in 38% of samples; hypo-iodinated and hyper-iodinated salts were shown in 26 and 36% of samples, respectively. There was a large variation of iodine among the salt brands (p = 0.00003) and SES (p < 0.0001). The higher variability of iodine was observed in fine salt than in coarse salt. Rates of low and excess iodine were higher in fine salt with lower SES than in coarse salt with higher SES. Urgent interventions, quality control and program monitoring of salt iodization are necessary.

Key words: Salt iodization, iodometric titration, poverty, Mthatha, Eastern Cape, South Africa.

INTRODUCTION

Iodine, atomic weight 126.9 g/atom, is in period 5 of the group VII halogens of the periodic table of elements. Iodine is of significance in human biology as a constituent of the thyroid gland's hormones (Figure 1) which are thyroxine 3,5,3',5'-tetraiodothyronine (T_4) and 3,5,3'-triiodothyronine (T_3). These hormones are synthesized by the iodination of tyrosine. About 90% of thyroid hormone secretions is 3,5,3',5'-tetraiodothyronine, 10% is 3,5,3'-triiodothyronine and less than 1% is 3,3',5'-triodothyonine (reverse T_3 or rT_3) (Genuth, 1993). These hormones are essential for healthy growth, differentiation and development (Alcock, 1996). T_3 is the more metabolically active hormone, whereas, rT3 is metabolically inactive (Lucas et al., 1996). Iodine comprises 65 and 59% of the weights of T_4 and T_3, respectively (Guyton and Hall, 2002).

Iodine occurs mainly as iodide which is widely but unevenly distributed in the earth's environment. Oceans contain most iodide. Iodide ions in seawater oxidize to form elemental iodine, which is volatile and evaporates into the atmosphere and returns to the soil by rain, completing the cycle. In many regions this cycle is slow and incomplete, making soils and groundwater deficient in iodine. Crops grown in these soils will be low in iodine concentration, which makes man and animals consuming food grown in these soils, deficient in iodine (WHO/ICCIDD/UNICEF, 2001). There are other factors which can deplete soil of iodine. Natural phenomena, such as cyclones which result in flooding of river deltas and manmade acts such as deforestation, irrigation, and poor agricultural practices contribute to soil depletion of iodine (UNICEF, 2002). The most common way iodine enters the body is through oral ingestion. Once in the body, it is converted into the iodide ion before it is actively absorbed from the gastrointestinal tract, into the circulation (Dunn, 2003). Iodate, the form of iodine found in iodized salt, is reduced in the gut and is quickly absorbed as iodide. Organically bound iodine is digested normally and the released iodide is absorbed. About 75% of thyroxine, taken orally for therapeutic purposes, is absorbed intact (Zimmermann et al., 2008). Iodine in the form of a red food dye (erythrosine) is absorbed less, only 2 - 5% bio-available (Sumar and Ismail, 1997).

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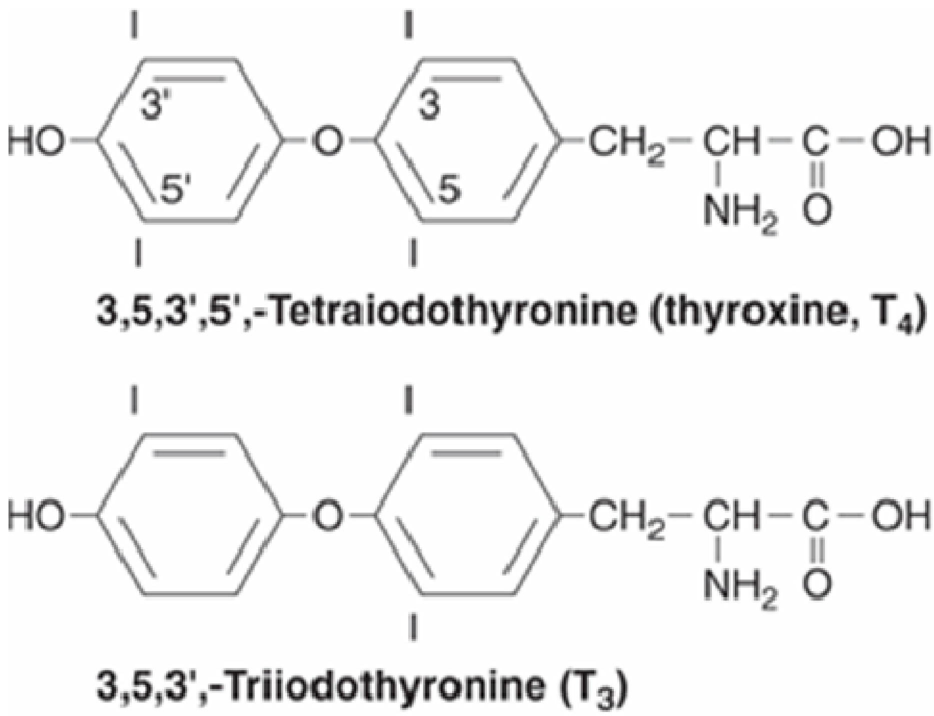

Figure 1. The chemical structure of thyroid hormones.
Source: Barrett KE, Barman SM, Boitano S, Brooks H: Ganong's Review of Medical Physiology, 23rd Edition: http://www.accessmedicine.com. Copyright © The McGraw-Hill Companies, Inc, All rights reserved.

Iodide is cleared from circulation by the thyroid for synthesis of thyroid hormones and the excess is excreted by the kidneys with the urine. The uptake of circulating iodide by the thyroid depends on the iodine status of the individual. When the iodine status of an individual is optimal, less than 10% of the absorbed iodine will be taken up, whereas more than 80% is absorbed in iodine deficient individuals (WHO, FAO, 2004). The salt iodization program has been complicated by an increase in the incidence of hyperthyroidism, but the latest data suggest that the number of new cases is now declining. The iodine deficiencies and excesses in Africa are due to country salt iodization programs that provide either insufficient or excessive amounts of iodine (Jooste and Zimmermann, 2008).

In South Africa several cases of endemic goitre were seen in European women in 1936 on farms in the districts of Kenhardt and Upington in the North-Western Cape Province. Research proved that this endemic goitre was not due to an inherent primary iodine deficiency but mainly to the general presence of harmful quantities of fluorine in drinking water. There were certain areas in the northern and north-western parts where goitre was due to primary iodine deficiency. Kalk, Sitas and Patterson concluded in their paper, that the national predominance of follicular cancer indicated that significant iodine deficiency existed in South Africa as a whole (Kalk et al., 1997). The surveys conducted at Ndunakazi, a rural community in KwaZulu-Natal demonstrated goitre prevalence and median urinary iodine level ranges that indicated iodine deficiency of moderate severity (Benade et al., 1997). Endemic goitre caused by iodine deficiency was also found to be a public health problem in the different communities of Langkloof area. This varied in severity from mild in Joubertina, to moderate in Haarlem and Louterwater, to severe in Krakeel (Jooste et al., 2000).

Surveys on urinary iodine concentration (UIC) were conducted in children before the introduction of universal salt iodization in several geographically separated communities in South Africa by Kalk, Paiker, van Arb, and Pick in 1994. These were Shongwe district of Mpumalanga, near Thohoyandou in the Northern Province, Letaba district in the north-east and in the Peddie district of the Eastern Cape. In 1995, the UIC's were surveyed in 5 year-old children of Soweto and Johannesburg area. Only one iodine-replete group was identified, that is non-black Africans in Johannesburg. The rest of the communities were iodine deficient, ranging from severe in Shongwe and Letaba to mild in far north and Soweto (Kalk et al., 1998).

An examination of the use iodized salt within the food industry will serve to help with the surveillance and monitoring of the national salt iodization programmed by providing information on the iodine content of non-discretionary salt use. This information could potentially have implications in terms of the regulatory levels of iodine in iodized salt and it may also contribute to a more accurate understanding of the amount of iodine consumed by South Africans in general (Harris et al., 2003) and those from Mthatha, Eastern Cape Province, in particular. According to the recent pilot study conducted in Mthatha (Mswelanto and George, 2008), the iodine content of salt at retail level varies significantly from the legal requirements across the salt brands sold in Mthatha.

MATERIALS AND METHODS

Study design and setting

This cross-sectional and audit study using biochemical methods was conducted between June and December 2009. The study was designed according to the Helsinki II Declaration. Clearance was obtained from the Ethics Committee of the Faculty of Health Sciences at the Walter Sisulu University, in Mthatha, South Africa (Appendix A). Mthatha city, Eastern Cape Province, South Africa, served as the study setting. Mthatha is in the King Sabatha Dalindyebo local municipality, of the OR Tambo district. This setting was chosen because of the finding of persistent iodine deficiency and the unexpected prevalence of excess urinary iodine excretion among the school children (Mswelanto and George), the most vulnerable portion of the population (WHO/ICCIDD/UNICEF, 2001).

Data collection

Different salt brands were randomly chosen from the shelf in each of the selected retailers. The anonymity and confidentiality of salt brands was maintained by use of codes. Sealed plastic packets of salt brands were bought in 500 g/1 kg/5 kg quantities. The actual quantity depended on the smallest available packet of salt in the store. In total, fourteen brands of fine salt and eight of coarse salt (including one medium salt) were purchased.

Study sampling

Representative shops of Mthatha city were selected randomly from the list of retailers situated in central, eastern, northern, western, and southern parts of Mthatha city: two shops from the central point and five retailers from each cardinal geographical point were chosen.

Methodology and chemical analysis

The salt samples were kept unopened in the sealed plastic bags in the dark until analyzed. All the measurements were performed by the same person (the author) according to the quality control laboratory for iodized salt. Measurements were done in triplicate. The iodine content of iodized salt containing potassium iodate was quantitatively estimated by the iodometric titration method (Mannar and Dunn, 1995). The principle of the method is based on the following reaction steps: Addition of sulphuric acid liberates free iodine from the iodate in the salt sample. Excess potassium iodide is added to help solubilize the free iodine, which is quite insoluble in pure water under normal conditions (step 1). Free iodine is consumed by sodium thiosulfate in the titration step (step 2). Starch is added towards the end of the titration and so the loss of the blue colour, or endpoint, which occurs with further titration, indicates that all the remaining free iodine has been consumed by thiosulphate. The amount of thiosulphate used is proportional to the amount of free iodine liberated from the salt. Starch is added as an external (indirect) indicator of this reaction and reacts with free iodine to produce a blue colour (DeMaeyer et al., 1979).

The level of thiosulphate in the burette was recorded and then converted to parts per million (ppm) using the conversion table recommended by (Mannar and Dunn, 1995) (Appendix B). Caution was taken to avoid violent and dangerous reaction by adding acid to water and never water to acid and stirring the solution was adding. Preparations of 0.005 M sodium thiosulfate ($Na_2S_2O_3$), 2 N sulphuric acid (H_2SO_4), 10% potassium iodide (KI, AR) and soluble chemical starch were performed according to the methods of Mannar and Dunn (1995).

Quality control

The equipment was regularly calibrated. The measurements were reliable, accurate and timely as validation and quality assurance or control issues were adhered to. The intra-assay coefficient of variation (CV) for these measurements was 9.6% at 79 ppm (Appendix C). With good technique and reliable methodology, the precision should be < 15% CV (DeMaeyer et al., 1979).

Statistical analysis

Data were presented as mean ± standard deviation (SD) with their 95% confidence intervals (95% CI) for iodine concentration (quantitative/ continuous parameter) and as proportions (%) for qualitative variables such as anomalies of iodine content (under-iodization, excess and not complying with legal requirements, or socioeconomic status). The frequency distribution of iodine content of salt brands was displayed in histogram, box plots and curve constructed from the density with standard deviation, mean and the number of samples. Central tendency (dispersion of iodine content) was defined by the mean, median and modes. The variability of the iodine content was defined by SD, standard error of the mean (SEM), range (minimum to maximum), amplitude (maximum – minimum) and box plot (minimum to 25th percentile, 25th percentile to 50th percentile or median, 50th percentile to 75th percentile and 75th percentile to maximum). Interquartile range included values between 25th percentile (quartile 1) and 75th percentile (quartile 3) including the median (quartile 2 or 50th percentile). These values were considered the normal range of iodine content in Mthatha. The symmetry of the distribution of iodine content was defined by kurtosis, skewness, SE of skewness and SE of kurtosis.

One way analysis of variance, (ANOVA) with Bonferroni 'post – hoc' test for correction, was used to test for significant changes in the mean iodine concentration in the salt between different groups of salt brands. The Chi –square test was used to compare proportions of anomalies of iodine concentration between groups of samples (salt brands) and SES categories. P-value of < 0.05 was considered for statistical significance of differences between groups of salt brands. The statistical analysis was conducted with Statistical Package for Social Sciences (SPSS) version 15 (SPSS Inc, Chicago, IL, USA).

RESULTS

In total, 66 samples from 22 brands of salt were assayed. Figure 2 displays a normal distribution of iodine

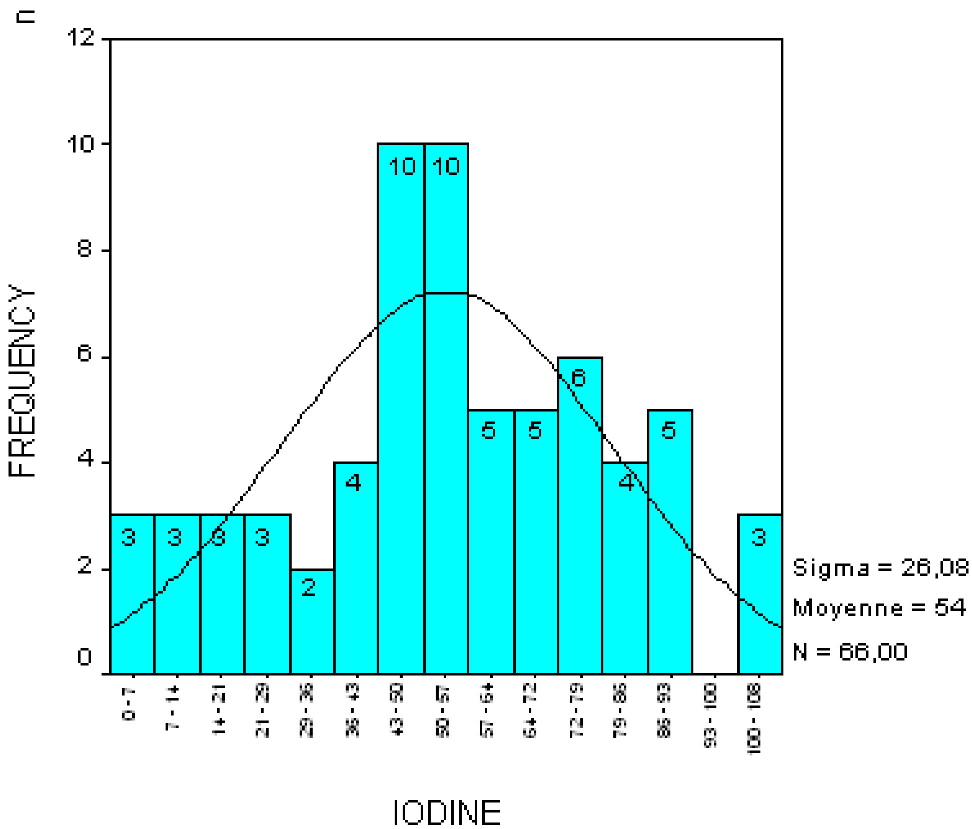

Figure 2. Frequency distribution of iodine concentrations for all samples.

Table 1. Central tendency, variability, skewness and ranges of all measurements of iodine (ppm).

Statistics	Values
Central tendency	
Mean	53.7
Median	51.9
Modes	many
Variability	
Standard deviation	26.1
Standard error of the mean	3.2
Range	0 - 105
Skewness	-0.389
Standard error of skewness	0.582
Kurtosis	-0.136
Standard error of kurtosis	0.295

concentration for all samples. Three samples of salt were without iodine. The descriptive statistics which define measures of central tendency, dispersion, variability, kurtosis and skewness are shown in Table 1. Despite its normal distribution, multiple modes were shown and a mild flattening of this curve was observed. The highest frequency distribution was observed between 43 and 57 ppm of iodine. The range and percentiles values of iodine concentration are shown in Table 2. The amplitude of iodine values was 105 ppm. The interquartile or normal interval (reference values) of all samples was around 40 - 75 ppm. There were a few samples with high variability of

Table 2. Range and percentiles of iodine concentration values.

Statistics	Values
Minimum	0
Maximum	105
Percentiles	
10th	15.6
20th	31.1
25th	38.1
30	45.6
40	48.5
50	51.9
60	58.2
70	70.4
75	73.0
80	78.3
90	89.9

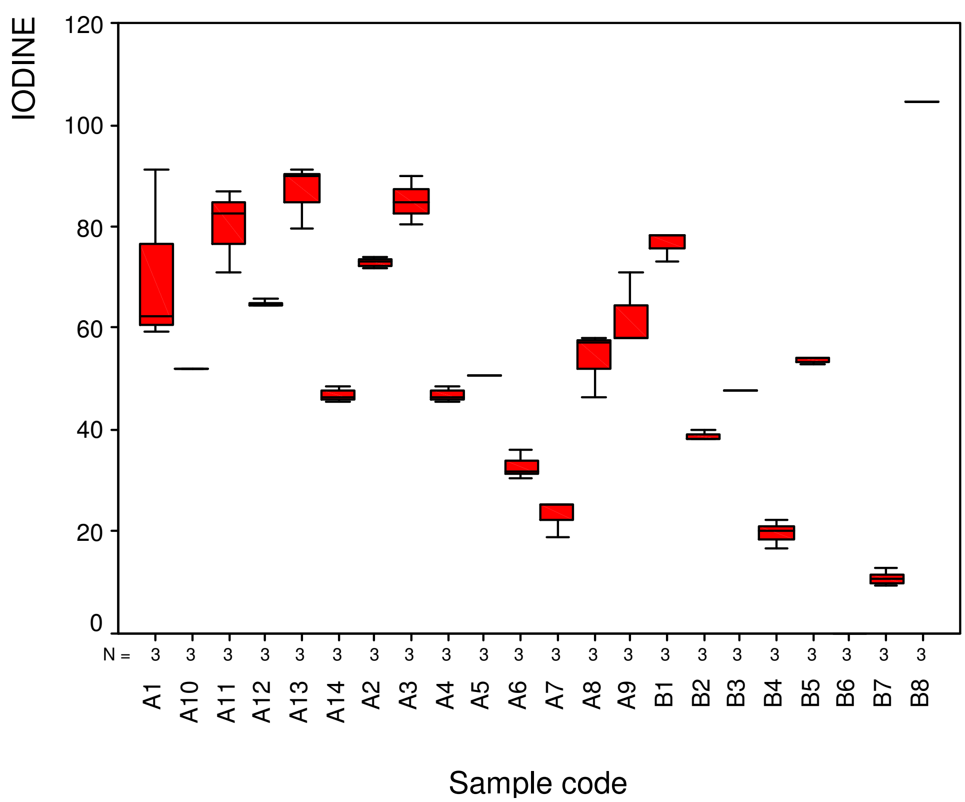

Figure 3. With box plots for iodine concentration, shows a lack of variability of the measurements.

salt iodine concentrations (Figure 3).

The mean values of salt iodine content varied significantly (ANOVA P-corrected = 0.00003) across the measurements within the brands of salt (Figure 4). The mean, SD, SEM, 95% CI and Range of Iodine concentrations by Salt Brands, Physical Structure and SES are shown in Tables 3 and 4. The salt brands not complying with legal requirements were more likely to be fine (6 brands with excess of iodine and 2 brands with low iodine content) than coarse (2 brands with excess

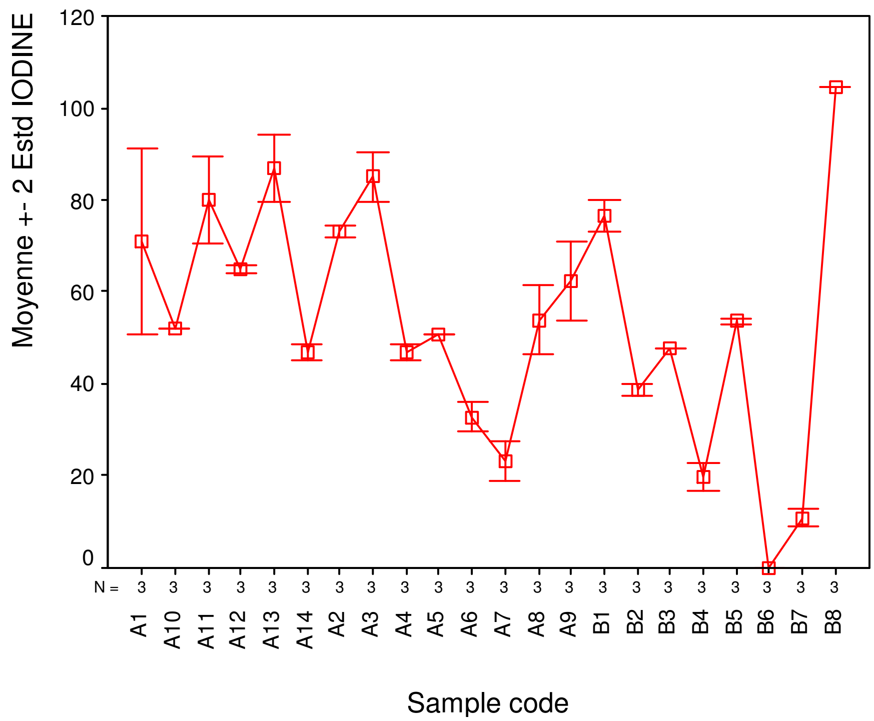

Figure 4. Mean values of iodine concentrations across the groups of salt brands.

Table 3. Mean, SD, SEM, 95% CI and Range of Iodine concentrations in fine Salt Brands and by SES.

Salt brand code	Physical structure	SES	Mean	SD	SEM	95% CI	Range
A1	Fine	Low	70.9	17.5	10.1	27.4 - 114.4	59 - 91
A2	Fine	Low	73.0	1.1	0.6	70.3 - 75.7	72 - 74
A3	Fine	Low	85.0	4.8	2.8	73.1 - 96.8	80 - 90
A4	Fine	High	46.9	1.6	0.9	42.9 - 50.8	46 - 49
A5	Fine	High	50.8	0.0	0.0	50.8 - 50.8	51 - 51
A6	Fine	Low	32.8	2.8	1.6	25.8 - 39.8	31 - 36
A7	Fine	High	23.3	3.7	2.1	14.1 - 32.5	19 - 25
A8	Fine	High	54.0	6.4	3.7	38.1 - 69.9	47 - 58
A9	Fine	Low	62.4	7.3	4.2	44.2 - 80.7	58 - 71
A10	Fine	High	51.9	0.0	0.0	51.9 - 51.9	52 - 52
A11	Fine	Low	80.1	8.22	4.8	59.6 - 100.5	71 - 87
A12	Fine	Low	64.9	0.6	0.4	63.3 - 66.4	65 - 66
A13	Fine	Low	86.8	6.4	3.7	70.9 - 102.7	79 - 91
A14	Fine	High	46.9	1.6	0.9	42.9 - 51.0	46 - 49

iodine and 3 brands with low iodine content). The majority (n = 13/15) of salt brands sold in low SES were not complying with the legal requirement (4 brands with low iodine content and 9 brands with excess iodine content), whereas, only 1/7 brands had low iodine content in high SES. Figure 5 shows the proportions of categories of iodine concentrations below (L40) legal requirement, within legal (40 - 59) requirement and above (UP 60) legal requirement. Thus, 62% of salt brands were not complying with the legal requirements.

DISCUSSION

Major findings

The present study assessed the iodine content within the salt brands sold in representative samples of shops in Mthatha, Eastern Cape province, South Africa. Globally, the result demonstrated a lack of implementation of successive mandatory regulations of salt in South Africa (Jooste et al., 1999). The quality of salt brands was

Table 4. Mean, SD, SEM, 95% CI and range of iodine concentrations in coarse salt brands and by SES.

Salt Brand Code	Physical structure	SES	Mean	SD	SEM	95% CI range
B1	Coarse	low	76.5	3.1	1.8	68.9-84.1	73-78
B2	Coarse	low	38.8	1.2	0.7	35.8-41.8	38-40
B3	Coarse	low	47.6	0.0	0.0	47.6-47.6	48-48
B4	Coarse	low	19.7	2.7	1.5	13.1-26.4	17-22
B5	Coarse	high	53.6	0.6	0.4	52.1-55.2	53-54
B6	Coarse	low	0.0	0.0	0.0	0 - 0	0 - 0
B7	Coarse	low	10.9	1.6	0.9	6.9-15.0	10-13
B8	Coarse	low	104.7	0	0	105-105	105 - 105

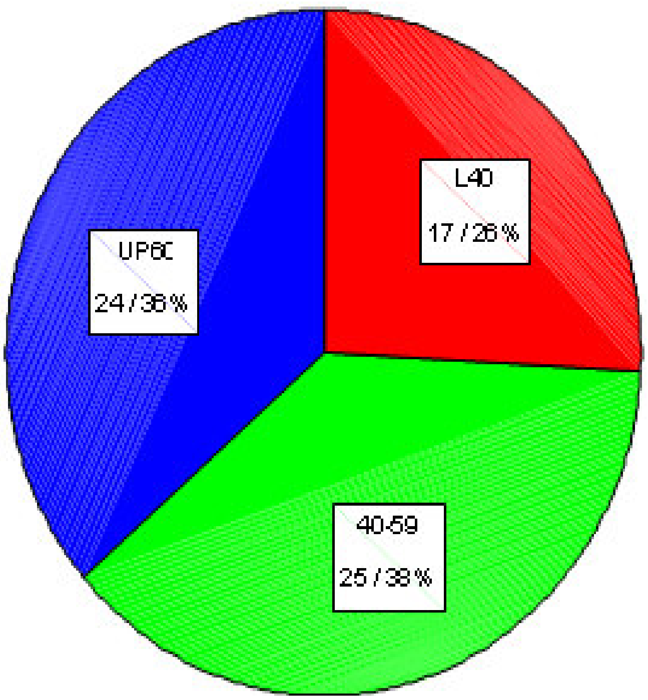

Figure 5. Categories of iodine concentrations.

doubtful macroscopically as the sand particles were observed in fine salt. However, the taste, odour, texture, shelf life did not change for all salt brands (Food Standards Australia New Zealand, 2007). Salt has become the most common accepted amongst other vehicles for iodine fortification such as bread, sweets, milk, sugar, cereal grains and water. This is due to the following reasons: 1) salt is almost universally consumed by virtually all sections of a community irrespective of socioeconomic level; 2) all normal adults consume it at nearly the same level throughout the year in a given region; 3) iodine added to salt either as potassium or sodium iodide or iodate does not impart any colour, taste or odour to the salt; 4) iodization of salt is done at a low cost (Mannar and Dunn, 1995).

The present results have shown an increase of the average of salt iodine (54 ppm) , compared to average values of 14 - 42 ppm reported in SA 13 years ago (Jooste et al., 1997). One would be tempted to say that it was an improvement in fortification process of salt necessary to prevent iodine deficiency and endemic goitre (Jooste et al., 2001). However, the interquartile values of iodine salt content sold in Mthatha was 40 - 75 ppm. The upper limit of this normal range in the study is higher than 60 ppm recommended by the legal requirement in South Africa (Jooste et al., 1999). This means that the average value is not a good tool to assess the progress in salt iodization as the mean was greatly influenced by the range and amplitude of the present measurements: 0 ppm for the minimum and 105 ppm for the maximum. The present study has shown an unexpectedly high rate (62%) of salt brands not complying with the legal requirements: 26% of brands with low iodine content and 36% of brands with excess iodine content. The big concern raised by the present findings is the markedly high variation in the iodine content across the retailed salts in general and within a few fine salt samples. Salt may be under iodized during the production and fortification stages. Weaknesses in salt quality assurance in salt production such as inconsistencies in salt/iodate mixing and non-adherence to salt regulation by salt producers and traders are incriminated (UNICEF/PAM/MI/ICCIDD/WHO (1995) Assey et al. (2009). The lack of providing a continuous supply of potassium iodate and the limited iodization technologies are the factors incriminated in the iodine variability of salt samples (Assey et al., 2007; 2008).

The variability, the amount and the anomalies of iodine salt content in this study were higher with fine salt samples and between fine and coarse salt as previously reported by Jooste in South Africa (Jooste et al., 2001). The different sizes of particles, the impurities (more frequent in fine salt) the humidity and the volatile status of iodine may explain these differences. The distribution of repacked agricultural salt which is not iodized in South Africa (Jooste et al., 2001) may be sold in the well patronized retailers of Mthatha, the poorest district of Eastern Cape province. Indeed, low SES in Mthatha was more likely to be exposed to both low concentration of iodine salt content and excess of iodine salt content (Jooste et al., 2001). Poor people are known to be price sensitive and are more likely to choose the cheapest salt available (Jooste, 2005).

Clinical implications and public health perspective

The present results have significant implications in the clinical practice of nutrition and endocrinology and in prevention of iodine disorders as well as in the implementation of mandatory iodization on Public Health perspectives. The majority of salt brands sold in Mthatha city will expose the population to both iodine deficiency and excess of iodine. Iodine deficiency is a risk factor for retarded mental and physical development, hypothyroidism, endemic goitre, reproductive failure and childhood mortality (WHO, UNICEF, ICCID (29). In cases of excess of iodine salt content, individuals will be at risk for the development of hyperthyroidism and autoimmune diseases.

The present study urges the national and the provincial authorities of the Department of Health to re-think salt iodization as an urgent public health imperative in Mthatha. Optimal iodine nutrition in Mthatha can be achieved by informing, educating and convincing both consumers and salt producers of the health benefits of adequate salt iodisation. The commitment of salt producers and shop owners in marketing accurately iodized salt according to WHO/UNICEF/ICCIDD) and South African law and policies (Jooste et al., 1999) is important. Frequent, periodic and functional internal quality control of the iodization process is needed. Regular external monitoring and audit is also necessary. The department of Medical Biochemistry, WSU, is ready to collaborate with the department of health and bureau of standards in training producers to use the titration method. The relevant authorities of South Africa are invited to revise the regulation to a level of 40 - 75 ppm for iodized salt, according to the interquartile (normal range) observed in this study.

Conclusion

The present study showed a cause for concern of adequate iodization of salt sold in Mthatha. The majority of salt brands investigated were found to be not in compliance with the legal requirements. People with low socioeconomic status are more likely to purchase salt with either low or excess iodine content. Urgent interventions and programmed monitoring are necessary.

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