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Evaluation of Essential Elements and Trace Metal Contaminants in Commercial and Traditional Edible Salts in Zambia

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Abstract: **Background: Edible salt is the most commonly used food additive worldwide. Therefore, any contamination of table salt could be a health hazard. In rural areas of Zambia most of the edible salts are traditionally processed and there is no proper purification to reduce contamination arising from environmental contaminants.**

Objectives: The main objective this study was to determine essential elements and heavy metal contaminants in traditionally processed unrefined table salt samples consumed in Kaputa, Kasempa and Mpika districts and to compare them with commercially prepared refined salts and the standards established for human health.

Materials and Methods: Three traditionally processed table salt samples namely Chibwa, Kaputa and Ingwe were sourced from the local markets in Mpika, Kaputa and Kasempa districts respectively and analysis of various trace metals was done using the standard methods.

Results: Copper content in Kaputa (2.22ug/g) and Chibwa (2.32ug/g) salt was slightly higher than the maximum codex set standard of 2.0ug/g.In addition iron content in Kaputa salt (14.98 ug/g) was higher than the maximum acceptable level. Lead content in all the samples analysed was within the acceptable limits, while Cadmium content was higher in the commercially processed coarse salt sample (0.58ug/g) than the traditionally processed salts. The mean magnesium content in commercially processed salts (Fine and Corse) (0.64ug/g) was lower than the traditionally processed salts (2.88ug/g).Kaputa salt had exceedingly very high potassium content (2238ug/g) than all the samples analyzed. Among the traditional salts, chibwa salt had the highest iodine content (46.60ug/g) comparable to that of commercial coarse salt, which had the same iodine content.

Conclusion: Traditionally processed edible salts compared very well with the commercially processed edible salts and in some circumstances, the levels of some elements like cadmium where found to be higher in commercial salts than in traditionally processed salts. Chibwa salt from Mpika had very acceptable iodine content and therefore it's an ideal salt to be used in rural areas where iodine fortification is not done.

Keywords: **Edible salt, Sodium Chloride, Copper, lead, Iodine, Iron, Cadmium.**

1. INTRODUCTION

Common salt is a mineral composed primarily of sodium chloride (NaCl), a chemical compound belonging to the larger class of salts; salt in its natural form as a crystalline mineral is known as rock salt or halite. Salt is present in vast quantities in seawater, where it is the main mineral constituent; the open ocean has about 35 grams of solids per litre, a salinity of 3.5% (1). Depending on the conditions and the time of formation, natural salt deposits are of three types. Mineral sedimentary deposits constitute the first type; these deposits, formed in previous geological epochs, are large stratified or stocklike and doom-shaped deposits of solid salt at various depths below the surface. Salt springs and brines, which together constitute the second type of deposit, are formed as a result of the leaching of natural salts by underground water at great depths. More than 50% of the rock salt produced is derived from these deposits by precipitation. Present-day salt deposits (Salt lakes, salt marshes), the third type of deposit, are inferior in size and content to mineral deposits. However, since they are both widespread and more accessible, they are occasionally of commercial importance. Seas and oceans are also placed in this category; Natural salts are sometimes extracted from seawater by evaporation or freezing. Present-day salt deposits provide approximately 20 percent of the natural salts produced. Minerals and trace elements are required in small amounts but are essential for processes in the body. They are necessary for tissue structure, enzyme systems, fluid balance, cellular function and neurotransmission. Many elements which are present in food, such as iron and copper are essential for human life since they play an important role in biological systems. These elements can also produce toxic effects when their intake is excessively elevated. Other elements like mercury, arsenic, lead and cadmium are non-essential elements as they are toxic even at low concentrations (2,3). Trace metals have a unique property of accumulation over a period of time along a food chain. Metals that are deposited in the environment may accumulate in the food chain and cause ecological damage and also poses threat to human health (4). These health concerns are quiet considerable. For example cancer, damage to the nervous system have all been documented in humans as a result of metal consumption (5).

Edible salt is biologically necessary because it provides two important macro elements of sodium and chlorine for human body. Furthermore, it improves food taste, could serve as a preservative, and elongates shelf life. Generally, salt is the most additive used in food industry (6). Salt brings out natural flavors and makes food acceptable, protects food safety by retarding the growth of spoilage microorganisms, gives proper texture to processed foods, serves as a control agent to regulate the rate of fermentation in food processing, strengthens gluten in bread, provides color, aroma and appearance consumers expect and is used to create the gel necessary to process meats and sausages. Salt also contains natural medicinal sources and also serves other tasks as well including being used for meat curing, tanning hides and can even be added to boost soap recipes. Sodium helps muscles and nerves to work properly by assisting muscular contraction and transmission of nerve signals. It also helps regulate blood pressure and blood volume and body fluid balance. Sodium also helps the human body to sustain a regulate blood pH level which is an indicator of good health. Therefore it possesses the power to rejuvenate the body's bio systems, thus, a power remedy for many healthy problems.

Salt might be contaminated by various chemical substances in different amounts and forms that may harm the consumers' health. Some studies showed that heavy metals are found in edible salt (7, 8). The strong and consistent correlation reported between the intake of salt and salted food and the incidence of stomach cancer and other pre-cancerous lesions could be attributed to the possible contamination of salt with heavy metals especially arsenic (9). Due to the daily consumption of table salt, any contamination, even at low levels, could create health risks to the consumers. Therefore, the concentration of heavy metals in table salt should be rigorously controlled, considering the participation of this ingredient in food preparations for humans (10). In Zambian rural settings, most of the edible salts consumed are processed in a traditional way and the constituents of these salts usually not known.

Ingwe salt was obtained from Kasempa in the Northwestern province of Zambia. Muddy water from swampy areas rich in natural salt is collected and placed into a container with a small hole at the bottom. Water is poured into the container and as it drips, it carries along concentrated salt. The salty water is collected in a clay bowl placed underneath the container. Thereafter, water in the bowl is left to dry and the bowl is broken and the exposed dry salt is wrapped in fresh large leaves to avoid absorption of atmospheric moisture.

In Zambia, villagers living near chibwa swamp from the Mpika district in Muchinga province perform a unique mineral extraction process using tall grass that grows near Lwitikila river. Chibwa and Kaputa salts are normally harvested from the stems of the local grass known as Kasemembe Mpango (Local language). At night, drops of water form on the ground when atmospheric vapour condenses and this water in form of dew is concentrated with salt. The dew accumulates onto the Kasemembe Mpango grass and in due course the dew together with the grass dries up. Thereafter, local people harvest the grass by cutting about an inch from the ground. The grass is fully sun dried and burnt on a concrete slab or any hard surface. They harvest the grass from August through October, before the rainy season starts. Once, the rains begin, the grass does not yield any salt. After the grass is cut and dried, it is burned in order to remove the organic components. The salt remains in the ashes. The ashes are put into a container, such as a calabash or gourd with a small hole at the bottom. Then water is slowly filtered through the ashes, then the water dissolves the salts and carries it through tiny holes at the bottom of the calabash. The resulting brime is collected for evaporation. Direct heat evaporation is used to remove the water, a process that can take up to six hours. To do this, the brime is first poured into a clay pot and boiled on an open fire so more brime is added as water evaporates. This produces a thick salt solution that eventually fills the pot. The pot now acts as a casting mould. When it is removed from the fire and then broken apart, a ball of salt remains. Thereafter, the bowl is left to dry. After fully dried, the clay bowl is broken so as to expose the solidified salt. The salt is wrapped in big leaves from a plant known as Mufungilwa Mpango (local name) to avoid salt absorbing atmospheric water because this type of salt is highly hygroscopic.Villagers have been making Chibwa salt for generations and no one knows who developed this method. It is amazing however that the same basic science behind modern salt processing is found in this remote part of rural Zambia. The mineral content of these salts is not known as there is a risk of contamination from other elements in the soils.

The aim of this study was to determine essential elements and heavy metal contaminants in traditionally processed unrefined table salt samples consumed in the Luapula, Northwestern and Muchinga Provinces of Zambia and to compare them with commercially prepared refined salts and the standards established for human health.

2. MATERIALS AND METHODS

Sampling:

Three traditionally processed table salt samples namely Chibwa, Kaputa and Ingwe were sourced from the local markets in Mpika, Kaputa and Kasempa districts respectively. 25 grams of each salt was used for analysis of essential metals and heavy metal contaminants. Commercially processed fine and coarse salts were bought from the local supermarket and 25 gram of each salt was prepared for analysis of essential metals and heavy metal contaminants.

Analysis of Unrefined and Refined Table Salts:

Graphite furnace atomic absorption spectroscopy (model AA240 G, Varian, Inc.) was used for measurement of heavy metal (Pb, Cd, Cu, Fe) in edible salt samples. The procedure applied by Soylak et al. (11) and Peker et al. (12) was used to determine heavy metal content in all salt samples . Briefly, 2.0 g of salt sample was dissolved in 20 ml of distilled water. After adding 1.0 mg of dysprosium, precipitates of dysprosium hydroxide was formed and ammonia was used to adjust the pH of the solution (pH11). The tube is slowly and carefully shaken for several seconds and allowed to stand for 10 min. The precipitate is centrifuged at 3,000 rpm for 10 min and the supernatant is discarded. A small precipitate adheres to the bottom of the tube. Then, 1 ml of 1 M HNO3 is added to dissolve the precipitate. The final volume was completed to 2.0 ml with distilled water. An aliquot 100 µl of the solution was introduced into Graphite furnace atomic absorption spectroscopy for measurement of Pb, Cd, Fe, Cu. Mineral elements like: magnesium, iodine and sodium were determined by titrimetric method of analysis according to the procedure described by Onwuka (13).

Statistical analysis:

The data's obtained for the elemental analysis for both the micronutrients and the heavy metals were subjected to statistical analysis using standard procedures of analysis of variance and multiple range testing of the mean difference at 5% significant level.

3. RESULTS AND DISCUSSION

Table 1: Essential elements in some selected traditionally and commercially processed salts in Zambia.

Sample Identity	%NaCl	Mn (ug/g)	K (ug/g)	I (ug/g)	P (ug/g)	Cu (ug/g)	Fe (ug/g)
Commercial fine table salt	99.9	0.76	358	20.10	200	0.15	1.54
Commercial Coarse table salt	99.7	0.53	244	46.60	200	1.05	0.41
Chibwa (Mpika)	99.1	2.71	824	46.60	800	2.32	10.52
Kaputa	99.2	3.86	2238	5.30	800	2.22	14.98
Ingwe (Kasempa)	98.9	2.07	803	0.10	800	1.70	0.83

Table 1 shows the concentration of essential elements in traditionally and commercially processed salts. Sodium chloride concentration is very important in the salt; its concentration determines how concentrated or salty the salt would be. All the samples analyzed had acceptable percentage of sodium chloride. The minimum permitted NaCl content is 97%, according to Codex legislation (14).

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Copper content obtained from the salt samples ranged from 0.15- 2.35ug/g, iron ranged from 0.41- 14.98 ug/g, phosphorous ranged from 200 to 800 ug/g, while manganese content ranged from 0.53 to 3.86 ug/g and iodine content ranged from 0.10ug/g to 46.60ug/g.

Chibwa and Kaputa salt had levels of copper above the recommended codex standard. WHO recommended 2.0mg/kg maximum of copper content. Copper is a heavy metal and much consumption of it can be dangerous to human health. It is advisable that salt contains less quantity of this metal or if possible not to contain it at all (15). At low concentration, copper is essential for human health; however, high levels of these elements are toxic (16,17). Despite the positive effects of optimal levels of copper, harmful effects may occur if the threshold level is exceeded. Wilson's disease (hepatocelluar degeneration) is one of the diseases linked to the excess copper in the body. It results from dysfunction of the copper transmission, which occurs due to the lack of suitable enzyme to catalyze the process of copper deletion from detached bonds with albumins and binding to ceruloplasmin. The condition leads to neuron degradation, liver cirrhosis, and occurrence of colorful rings on the cornea (18,19).

The maximum permitted level of iron in food grade is 10 ug/g according to the codex standards. Iron is essential for life and though considered a trace element, diet lacking in iron can contribute to iron deficiency anaemia (20), however, too much iron may be toxic to humans. Our results show that Kaputa salt had the highest content of iron and the concentration was above the acceptable levels.

The Magnesium content of all the salt samples analyzed were found to conform with the recommended quantity of 3.0ug/g max.The magnesium content obtained for the entire sample tested fall within the range obtained by Mohammed and Filli (15). Magnesium plays an essential role in skeletal development, protein synthesis, muscle contraction and neurotransmission.

Iodine content is one of the most important elements required in salt. There is a serious campaign on salt iodization in Zambia. all salts that are sold in the markets are expected to be iodized . The result from the table shows that three salt samples were found very low iodine content. The African organization for standardization (ARS) specifies 50ug/g of iodine content in salt at factory level and is not expected to be lower than 30ppm at market level. Among the traditionally processed salts, chibwa salt from Mpika was found to have an acceptable level of iodine 46.60 ug/g and this result was comparable to that found in commercially prepared table salts. Surprising enough, Sairam salt (Fine) had iodine levels below the accept levels despite the salt being fortified with iodine. The problem could be attributed to poor storage conditions of salt.

Potassium content ranged from 244ug/g to 2234ug/g. Kaputa salt had very high content of exceeding the content in other salt samples by far. Another study need to be done to ascertain the reason as to why the potassium content is high as compared to other salt samples. There is need also to improve on the purification of Kaputa salt so as to reduce on the potassium content. In trace quantities, potassium plays an important role in acid-base regulation, fluid balance, muscle contraction and nerve conduction. Hyperkaleamia is a condition which occurs when there are high levels of potassium in the blood stream. The main symptoms of hyperkalemia include decreased blood pressure, stomach cramps and vomiting.

Phosphorus is present in all cells in the body and is essential for bone health and, in conjunction with the B vitamins, the metabolism of fats, proteins and carbohydrates. The concentration of phosphorous in all the three traditionally processed table salts was 800ug/g more than the commercially prepared salts of Sairam (Fine and Granular).The reason for the increase may be due to incomplete purification of the traditionally processed salts.

Table 2: Toxic metal contaminants in some selected traditionally and commercially Processed salts

Sample Identity	**Co (ug/g)**	**Pb (ug/g)**	**Cd (ug/g)**
Codex standards		**2.0**	**0.5**
Commercial fine table salt	0.04	0.10	0.360
Commercial Coarse table salt	0.08	0.10	0.580
Chibwa (Mpika)	0.15	0.10	0.400
Kaputa	0.13	0.10	0.198
Ingwe (Kasempa)	0.08	0.10	0.260

Table 2: shows the level of toxic metal contaminants in traditionally processed and commercially processed table salts The result showed that the values obtained were significantly different from each other at ($p \leq 0.05$). Cadmium content ranged from 0.198- 0.580 ug/g, while cobalt ranged from 0.04 -0.15 ug/g.

Toxic elements are fairly widespread in the environment and edible salts may contaminate to some of them. They can enter to human body by ingestion of edible salts. The intake of heavy metals by human through salt ingestion depends on their food habits. Lead content in all the samples analysed was 0.10 ug/g. Lead is one of the most toxic heavy metals that accumulates in the body and data published in literature indicates that its excessive intake harm different systems and organs such as central and peripheral nervous system, gastrointestinal tract, muscles, kidneys, and hematopoietic system (21). The maximum permitted level of lead in food-grade salt is 2.0 μg/g according to the Codex legislation (14). Lead content in all the samples was within the codex specification of 2.0ug/g of lead content. Our results for lead are much lower than those reported in literature, where lead content has been reported to be in the range of 0.5-1.64 ug/g in refined and unrefined table salt samples from Turkey, Egypt and Greece. However, the content was higher than that the 0.03 ug/g reported in Brazil (11).

In our study, Commercially processed salt had higher levels of Cadmium exceeding the 0.5ug/g acceptable level. All the traditionally processed salts had levels below the acceptable limits. However, in comparison to other countries, the levels of Cd found in the present study was higher. In Turkey, Cadmium content found in refined and unrefined salt was < 0.14-0.3 μg/g and 0.14- 0.21 μg/g, respectively. In other countries such as Brazil, Egypt, and Greece, Cadmium concentration in table salts were reported in a range of 0.01-0.03 μg/g, 0.18-0.22 μg/g and 0.18-0.19 μg/g, respectively (11).

Cobalt content in the samples analyzed ranged from 0.04 to 0.15 ug/g. The highest content was found in Chibwa salt and these levels are below the toxic levels. Cobalt is essential for humans because it is an integral part of vitamin B-12, which supports red blood cell production and the formation of myelin nerve coverings. Toxicity can occur from excess inorganic cobalt found as a food contaminant. Beer drinker's cardiomyopathy and congestive heart failure have been traced to cobalt introduced into beer during manufacturing . Increased intake may affect the thyroid or cause overproduction of red cells, thickened blood, and increased activity in the bone marrow (22).

4. CONCLUSION

Traditionally processed edible salts compared very well with the commercially processed edible salts and in some circumstances, the levels of some elements like Cadmium where found to be higher in commercial salts than in traditionally processed salts. Chibwa salt from Mpika had very acceptable Iodine content and therefore it's an ideal salt to be used in rural areas where Iodine fortification is not done. On the other hand the excessively higher concentration of Potassium in Kaputa salt is a source of worry and interventional measures need to be put in place to ensure that the salt is properly purified may by setting up a processing plant in that area. However, further studies need to be carried out to assess the impact of such high potassium levels on the community.

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