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Essential mineral content of common fish species in Chanoga, Okavango Delta, Botswana

O. Mogobe*, K. Mosepele and W. R. L. Masamba

Okavango Research Institute, University of Botswana, P/Bag 285, Maun, Botswana.

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Developing countries remain overwhelmed by nutritional problems caused mainly by poverty, natural disasters and political instabilities. The aim of this study was to determine essential mineral content of some common fish species in the Okavango Delta, Botswana and assess their potential in enhancing mineral intake. Atomic Absorption Spectrometry was used for determination of Ca, Mg, Fe, Zn, Cu, Mn; flame photometry for Na and K; UV-VIS Spectrometry for P. *Marcusenius altisambesi, Schilbe intermedius, Brycinus lateralis, Oreochromis andersonii, Barbus poechii*. Only edible flesh was analysed for large fish (>130mm) while small fish (<130mm) were analysed whole. Single factor ANOVA analyses show that all minerals analysed except copper varied significantly between species, ($p \leq 0.05$) and the small species, *Barbus poechii* has the highest mineral content. The concentration ranges of minerals were within FAO mean concentration ranges for fish and comparable to values obtained from other previous studies. The results show that fishes of Chanoga have a good supply of minerals and can be used for enhancing mineral intake and protecting the community from mineral deficiency diseases.

Key words: Fish species, macro-nutrients, micro-nutrients, mineral content, Okavango Delta.

INTRODUCTION

In human nutrition, essential elements are those chemical elements that are required for the normal maintenance of the human body (Jiang et al., 2015). These elements (Ca, Mg, Na, K, Fe, Zn, Cu, Mn) participate in several biochemical reactions; calcium, magnesium and phosphorus are crucial in the formation of bones and teeth; sodium and potassium work together in the transmission of nerve impulses and keeping electrolyte balance; zinc is mostly found as a cofactor in enzyme reactions, iron forms part of the haemoglobin molecule which transport oxygen around the body (Alas et al., 2014; Kwansa-Ansah et al., 2012). When these elements are not adequately provided to the body, mainly by dietary intake, the individual may suffer from mineral deficiency diseases for example anaemia, osteoporosis, goitre, stunted growth and genetic disorders (Bhandari and Banjara, 2014; Fumio et al., 2012; Hsieh et al., 2011; Watanabe et al., 1997).

The World Health Organisation reported that about 2 billion of the world's population is suffering from mineral and vitamin deficiencies and the majority of these are in the third world countries (FAO/WHO, 2001). In Botswana,

*Corresponding author. E-mail: omogobe@ori.ub.bw; kmosepele@ori.ub.bw; wmasamba@ori.ub.bw. Telephone: +267 6817211. Fax +267 6861835.

about 29% of children under the age of five are reported to have impaired growth (stunted) and 11% underweight (UNICEF, 2009). The country uses over US$78 million every year in treating effects of vitamin and mineral deficiency illnesses (UNICEF, 2004; World Bank, 2009).

Fish is commonly found in natural water bodies and well known for its superior nutritional quality with a very good supply of essential minerals (Fawole et al., 2007; Pirestani et al., 2009, Kawarazuka and Bene, 2011). This resource is accessible to poor and vulnerable communities prone to nutrient deficiency diseases. Current strategies used for mitigating nutritional deficiencies are focussing on mineral supplementation and food fortication (Bhadari and Banjara, 2015) which are effective of course but unsustainable, especially for developing countries. Food based strategies are considered sustainable and currently being evaluated for enhancing mineral intake. Fish has a big potential for this strategy because it can provide a variety of nutrients, including essential elements to the body (Kawarazuka and Bene, 2011). Minerals commonly found in fish flesh are sodium, potassium, calcium, magnesium, phosphorus, sulphur, iron, manganese, zinc, copper, and iodine (Dana et al., 1985; Waterman, 1980). However it is reported in the literature that the nutritional quality of fish depends on species, age, size, diet and water quality (Daczkowska-Kozon and Sun-pan, 2011; Martinez-Valverde et al., 2000; Rebole et al., 2015; Silva and Chamul, 2000).

Chanoga is a lagoon located at the lower part of the Okavango delta, Ngamiland district, Botswana. Ngamiland is a rural district and the inhabitants are the poorest in the country (CSO, 2003). People of the delta rely on fish as a major source of livelihood (Kgathi, 2004; Mosepele, 2000). Although accepted as a readily available resource in the district, used for home consumption, bartering, selling locally and to other Southern African Development Community (SADC) countries, the nutrient content of the common fish species in the Okavango Delta is unknown. No literature could be found on nutritional quality of fish species of the district.

The aim of this study was to quantify for the first time, the essential mineral content of common fish species found in the Okavango delta and identify the species with high mineral content which can be recommended for use in combating mineral deficiencies in the country and the SADC region. The study will also contribute to nutrition education, promote the nutritive value of fish and encourage the development of national food composition database.

MATERIALS AND METHODS

Study site

Fish samples were collected from a lagoon in Chanoga, a small village in close proximity to the main district centre of Maun, located at the lower end of the Okavango delta. Chanoga presented a good study site because it is one of the active fishing spot in the district.

Sampling

Samples were collected from Chanoga between February and March 2013 using the multi-panel, multi-filament experimental nets. This technique is known as 'non-selective' fishing technique and involves using nets with different mesh sizes, from 16 to 150 mm stretched mesh, so that the samples are representative of the fish population. The nets were set for approximately 12 hovernight (1800 - 0600 h) and removed the next day. Fish were then removed from the different panels and sorted according to species and size in separate bowls. From each bowl, individual fish samples were identified to species level, weighed, sexed, and measured to the nearest millimetre from the tip of snout to the caudal fin. The samples were kept in cooler boxes with ice and transported to the laboratory where they were kept in a freezer waiting for analysis. The common fish species (*Marcusenius altisambesi, Schilbe intermedius, Brycinus lateralis, Oreochromis andersonii, Barbus poechii*) and popular with subsistence fishers were selected in the laboratory and prepared for mineral analysis.

Sample preparation

To prepare fish samples for analysis, the standard AOAC Official Method 937.07 (AOAC, 2000) was followed. Larger fishes were eviscerated, deboned, head and fins removed, then washed with ultra-pure water. The flesh samples were then homogenised with a blender. For small fish samples (≤100 mm), the whole fish sample was homogenised. Samples were bagged in new sandwich plastic bags and kept in a freezer until analysis. Five individual fishes represented each species analysed.

Mineral analysis

Atomic Absorption Spectrometer (AAS) and flame photometer were used for determination of mineral content in fish flesh. Calcium, magnesium, zinc, iron and copper were determined by flame AAS. Sodium and potassium were measured by flame photometer and phosphorus by UV-Vis spectrophotometer. Lanthanum was used to compensate for ionisation interferences in the analysis of Ca and Mg.

In all mineral analyses, samples (1.000 g) were incinerated in porcelain crucibles at 450°C overnight, and then treated with 5 ml of 6 M HCl, boiled to dryness on a hot plate, cooled and the residue re-dissolved with 10 ml of 0.1 M nitric acid. The solutions were left standing for 2 h and then transferred to 50 ml volumetric flasks, topped with ultra-pure water and used for determination of Ca, Mg, K, Na, Zn, Cu, Mn, and Fe. Phosphorus was analysed by uv-vis spectrophotometer using molybdate-ascorbic acid colorimetric method at 823 nm wavelength, according to AOAC method 995.11.

Quality assurance

Two sample blanks, containing reagents only, were carried out with each batch. Duplicate samples from each individual sample were analysed. At least 5 individual fishes represented each species. In-house quality control sample was analysed in duplicate with each batch. Ultra-pure water was used for rinsing and reagents preparation. All reagents used were of analytical grade.

Statistical analysis

Excel spread sheet was used to enter data and then single factor

Table 1. Fish species caught at Chanoga lagoon, Okavango Delta, Botswana (March 2013).

Scientific name	Common name	Local name (Segxerekhu)	Average length (mm)	No. of individual fish samples
Schilbe intermedius	Silver catfish	Lerehe	208	5
Oreochromis andersonii	Three spot tilapia	Mbweya	217	5
Marcusenius altisambesi	Bulldog	Nja	183	5
Brycinus lateralis	Stripped robber	Manthe	96	5
Barbus poechii	Dash tail barb		120	5

Table 2. Macro-nutrients content of fish flesh samples (mg/100 g of wet weight).

Fish species	Na	K	Ca	Mg	P
S. intermedius	112±22	350±94	662±346	34±7	596±242
O. andersonii	86±18	249±21	413±150	35±12	435±286
M. altisambesi	131±18	443±25	629±282	35±7	777±199
B. lateralis	101±14	245±13	959±215	58±5	1012±111
B. poechii	145±12	366±29	1290±281	48±5	1375±325
P-values	0.0003	0.000008	0.0004	0.007	0.001

All values (average ±standard deviation of n=5 independent samples). P-values show the significant differences between species at P≤0.05.

Table 3. Micro-nutrients content of fish flesh samples (mg/100 g of wet weight).

Fish species	Fe	Zn	Cu	Mn
S. intermedius	3.73±0.44	3.95±0.94	0.17±0.06	0.39±0.26
O. andersonii	4.15±0.64	1.63±0.25	0.02±0.05	0.06±0.13
M. altisambesi	1.65±0.82	4.60±0.92	0.11±0.03	0.26±0.17
B. lateralis	6.40±1.54	6.48±3.20	0.15±0.16	0.38±0.24
B. poechii	6.39±5.21	8.47±1.86	0.21±0.09	1.08±0.32
P-values	0.02	0.00008	0.06	0.0002

All values (average ±standard deviation of n=5 of independent samples). P-values show the significant differences between species at P≤0.05.

ANOVA at $P \leq$ 0.05 significant level was applied to compare concentrations of minerals between species. Mean concentration values and standard deviations are given for each analysis.

RESULTS

Fish species

Table 1 shows the five species caught at Chanoga Lagoon in the month of February to March 2013. Five individual fishes for each species were selected from the catch and transported to the laboratory for analysis. Average lengths of each fish are given together with the scientific names, common and local names.

Mineral composition of the fish species

Essential minerals analysed were Na, K, Ca, Mg, P (macro nutrients) and Fe, Zn, Cu and Mn (micro-nutrients). Only the fish flesh for the larger species were analysed because most people in the Okavango district consume the flesh only and throw away the rest but the smaller fishes are eaten whole. The concentration levels of the essential minerals are given in Tables 2 and 3.

To compare the results obtained in this work against similar studies carried out in other parts of the world, Table 4 was developed from existing literature values. Food and Agricultural Organisation (FAO) average values for fish composition have been included in the table to compare present work values with internationally expected ranges of fish flesh.

DISCUSSION

Macronutrients

Table 2 shows the concentration levels of macronutrients

Table 4. Comparison of mineral concentration (mg/100 g) in fresh water fish of this work with past studies.

Element	FAO concentration range in fish muscles (FAO 2001)	Lagoon in Botswana 'This work'	Lake in Bangladesh (Begum et al., 2005)	Lagoon in USA (Moeller et al., 2003)	River in Sudan (Mohamed et al., 2010)	Lake in Poland (Luczyiska et al. 2009)
Na	30-134	86-145	381	36-400	180-280	148-328
K	19-502	245-443	-	-	954-1210	1429-2387
Ca	19-881	413-1290	499	760-2200	107-588	53-103
Mg	4.5-452	34-48	219	27-140	68-75	84-143
P	68-550	435-1375	-	-	727-935	1047-1261
Fe	1-5.6	1.65-6.39	13	2.30-9.0	1.7-6.1	0.80-1.13
Zn	0.23-2.1	1.63-8.47	6	0.32-6.6	4.6-8.8	1.70-5.85
Cu	0.001-3.7	0.02-0.21	0.5	0.17-0.6	0.09-0.14	0.10-0.20
Mn	0.0003-25.2	0.06-1.08	1.7	0.21-2.2	-	0.05-0.20

in five fish species. Percentage contributions to recommended daily intakes were calculated.

Sodium

Sodium is good for muscle functioning (Alas et al., 2014) and its concentration ranged between 86 to 145 mg/100 g, which falls within FAO mean ranges of 30-134 mg/100 g. It is also comparable to studies by Martinez-Valverde et al. (2000) in Spain and Tao et al. (2012) in farmed fish in China. However the results are at the lower end compared to some studies carried out in freshwater fishes of four other countries shown in Table 4; Bangladesh (381 mg/100 g), USA (36-400 mg/100 g), Sudan (180-280 mg/100 g) and Poland (148-328 mg/100 g). The lower sodium concentrations obtained in this study may be attributed to low levels of sodium in the water and therefore less trophic transfer and accumulation of this mineral in fish flesh. Although sodium is important for muscle functions and electrolyte balancing, it is not usually a problem in mineral deficiencies as it is frequently used to salt food. The concentration levels of sodium differed significantly between species (P=0.0003) (Table 2) with *B. poechii* having the highest sodium content of 145 mg/100 g.

Potassium

Like sodium, potassium is also important for muscle contractions, transmission of impulses in the nerves and sugar metabolism. The concentration of Potassium ranged between 245 - 443 mg/100 g which is within FAO range of 19 - 502 mg/100 g. Other studies (Alas et al., 2014; Tao et al., 2012; Martinez-Valverde et al., 2000) obtained ranges of 321 - 441 mg/100 g in Turkey, 301 - 402 mg/100 g in China and 286-446 mg/100 g in Spain respectively which are all very close to values obtained in this study. The relatively low values of potassium obtained in this study further suggest the low K concentration in the Chanoga Lagoon, Okavango delta (as with sodium above). The studies from Sudan (Mohamed et al., 2010) and Poland (Luczynska et al., 2009) shown on Table 4, obtained much higher K concentration levels (954 - 1210 mg/100 g and 1429 - 2387 mg/100 g) respectively. The highest concentration of Potassium in this work (443 mg/100 g) was obtained from a larger fish, *M. altisambesi*. Again the differences in concentration between species were significant, with a P value of 0.000008. The recommended daily allowance (RDA) of K for males aged between 25-50 years is 800 mg. Consumption of 100 g of *M. altisambesi* fish flesh will provide 31-55% of the potassium daily requirement, assuming cooking will not affect the quantity of the mineral.

Calcium

Calcium is important for bone formation and fish is known to be a good source of this mineral, especially small fish (Kawarazuka and Bene, 2011; Roos et al., 2007; Larsen et al., 2000).

In this study calcium ranged from 413 to 1290 mg/100 g; figures within FAO mean values of 19-881 mg/100g and comparable to Mohamed et al. (2010) study (107-588 mg/100 g) and Luczyiska et al. (2009) who obtained 53-103 mg/100 g.

The recommended daily intake of calcium for adults is 1000 - 1300 mg (FAO/WHO, 2001); these results present fishes of Chanoga as excellent sources of calcium, especially the small fish species, *B. lateralis and B. poechii* which had higher calcium levels of 959 mg/100 g and 1290 mg/100 g respectively, contributing over 100% of Ca daily requirement. Based on these results, it can be assumed that regular consumption of these fishes will provide good bone formation and maintain skeletal integrity.

Magnesium

Magnesium is also a component of bones and the concentration levels ranged from 34 - 58 mg/100 g, within the FAO range of 4.5-452 mg/100 g but at a lower end. These results are comparable to values obtained by Adeniyi et al. (2012), of 29 - 41 mg/100 g and an average of 36.4 mg/100 g obtained by Martinez-Valverde et al. (2000). Comparison to other studies on Table 4 shows that the present work obtained much lower magnesium concentrations and Okavango delta fish are not very good sources of magnesium. The recommended daily intake of magnesium for adults is 220-260 mg (FAO/WHO, 2001), and fishes here can contribute 13-22% of this requirement in a 100 g fish flesh portion. The species with the highest content of magnesium (58 mg/100 g) was *was B. lateralis* and again there was significant concentration variability between species for this mineral.

Phosphorus

Phosphorus is a major constituent of bones together with calcium and magnesium. This mineral showed significant concentration variability between species ranging from 435 - 1375mg/100g, the highest P content of 1375mg/100g obtained from the small fish species (*B. Poechii)* which is consumed whole. The P concentration range obtained in this work is higher than the FAO range of 68-550mg/100, and other freshwater fish obtained by Alas et al. (2014), (232 - 426 mg/100 g) and Tao et al. (2012), (198 - 240 mg/100 g). Research carried out in Sudan and Poland shown in Table 4 has comparable results, Mohamed et al. (2010) obtained 727 - 935 mg/100 g and Luczynska et al. 2009 got 1047 - 1261 mg/100 g. The recommended dietary allowance for adults is 700 mg of P and fishes in this lagoon can contribute at least 62% of the daily requirement in 100g portion of fish. Again the fish species have high phosphorus content.

Micronutrients

Micronutrient deficiencies are widespread in populations of developing countries (Kawarazuka and Bene, 2011) Fish accumulate minerals in the head and viscera, so consumption of small fishes which is eaten whole, can contribute significantly towards micronutrients intakes. Table 3 shows the concentration ranges for iron, zinc, copper and manganese in five freshwater fish species of Chanoga obtained in this study.

Iron

Fe is important for a number of physiological functions in the body, but most importantly for transporting oxygen around the body. Iron deficiency causes anaemia, one of the commonest mineral deficiency diseases in Africa with 206 million people at risk (Latham, 1997). The Fe concentration in Chanoga fish was 1.65 - 6.4 mg/100 g. The recommended nutrient intake of iron for female adults between the ages of 19-50 years is 24 mg/day. Based on this work, *B. Poechii* can provide 27% of daily iron requirement for women if 100 g of fish is consumed, or a plate portion containing 4 small fishes of *B. Poechii* will provide sufficient supply of Fe for the day. The past studies on Fe content in fish shown on Table 4 also agree with our study except for Bangladesh values which are more than double (13 mg/100 g) our values (6.4 mg/100 g). The differences could be due to differences in environmental conditions, fish diet, water quality and species studied. Study by Guerin et al. (2011) carried out with fish from a French market reported much lower concentration levels of Fe (0.13 - 1.9 mg/100 g). The literature reviewed for this work show a high variation in the concentration of iron in fish from country to country. The fish species from Chanoga which gave the highest concentration of Fe is *B. lateralis and B. poechii* (6.4 mg/100 g), both small fishes, in agreement with past studies that small fishes are a good source of micronutrients. Significant variation in Fe concentration between the five species analysed were observed, with $P<0.05$.

Zinc

Zinc plays a number of roles in body functions; it is a component of many metallo-enzymes, important for gene expression and cellular growth. The FAO ranges of 0.23 - 2.1 mg/100 g are lower than the range for this work (1.63 - 8.47 mg/100 g) and all the other studies on Table 4. Tao et al. (2012) also obtained lower values (0.64 - 0.81 mg/100 g) in farmed fish in China; French market fish gave a range of 0.13 - 2.5 mg/100 g (Guerin et al., 2011); a study from Turkey gave a range of 0.57 - 1.3 mg/100 g (Alas et al., 2014) for fish caught from Beysehir Lake. Fish caught in Black and Aegean seas gave concentration range of 3.5 - 10.6 mg/100 g (Uluozlu, et al., 2007), closer to the values for this work. *B. Poechii* has the highest Zinc concentration of 8.47 mg/100 g followed by *B. Lateris* (6.48 mg/100 g). These results are in agreement with results obtained by Kawarazuka and Bene (2011), in studies carried out in Bangladesh and Cambodia which showed higher zinc concentration ranges for small Bangladesh fishes (1.1 - 4.0mg/100g) and lower concentrations for larger Bangladesh fishes (1.4 - 1.5 mg/100 g). The zinc recommended dietary allowance for adults is 8-11 mg and *B. Poechii* can provide 100% of this requirement in a 100g plate portion, making this species a high quality source of zinc, superior to most species in other parts of the world. This species would be beneficial to children with stunted growth, a problem reported to exist in Botswana (UNICEF, 2009).

Copper

Like zinc, copper is also a part of many enzymes but occur in very low levels in food. According to Wildman and Medeiros (2000), the recommended daily requirement of copper in human nutrition ranges between 1.5 - 2.5 mg.

Concentration of copper in fish species from this work varies between 0.02 - 0.21 mg/100 g. This is much lower than the recommended daily intake, assuming a single serving of 100 g fish per day, but this is not a concern because copper deficiencies are rare. Table 4 comparisons show that all the four studies have similar concentration ranges of Cu. This shows that Chanoga fish are not a very good source of copper like other fish species from literature. There is no significant difference in Cu concentrations (P=0.06) between species, however *B. Poechii* still displays a higher mineral content with a concentration of 0.21 mg/100 g .

Manganese

Manganese is also important in enzyme activities. Manganese concentration levels in fish for this study ranged between 0.06 - 1.08 mg/100 g, within the FAO values (0.0003 - 25.2 mg/100 g). The highest concentration of manganese was found in *B. Poechii* again, further highlighting the superiority of this fish species in mineral content and the potential for it to provide a wide range of essential minerals. Some past studies found lower manganese concentration range in fish compared to this study; (Alas et al., 2014) found 0.028 - 0.040 mg/100 g in fleshy part of fish in Turkey, Kwansa-Ansah et al. (2012) obtained 0.30 - 0.41 mg/100 g in tilapia fish species in Lake Volta, Ghana. For this work, the highest level was obtained from *B. Poechii* with a concentration of 1.08mg/100g.

The recommended dietary allowance for Mn is 3.8 mg (Pirestani et al. 2009) and the small fish can contribute 28% of the daily manganese requirement if 100 g of fish is consumed.

Conclusions

This study provides baseline data on mineral composition of some common fish species in Chanoga, Okavango Delta. This study revealed that fishes of Okavango Delta are a good source of essential minerals and their mineral content varies significantly with species. Small fish species, *Barbus Poechii*, has the highest concentration of most essential minerals compared to the other species investigated in this study. The five species investigated gave this overall mineral concentration sequence; *B. poechii>B. lateralis>M. altisambesi>S. intermedius>O. andersonii*. Based on the results from this work, with assumption that 100 g of fish flesh is consumed, *B. Poechii* can provide over 100% of recommended daily intake of calcium and zinc, 62% of P, 27% of iron and 28% of manganese. The information generated from this study could be used as a baseline data for developing food composition database/tables for Botswana. Further research is needed to expand on this study.

Conflict of interests

The authors did not declare any conflict of interest.

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