Available online at www.elixirpublishers.com (Elixir International Journal)

Food Science

Elixir Food Science 40 (2011) 5421-5424

ISSN: 2229-712X

The levels of some essential elements in marine organisms (fish and mollusk) widely consumed in Ghana

L. A Sarsah[1,2,*], E. Quarshie[3], Y. Serfor- Armah[1], A.A Golow[1], C. Mensah[4] and S. Adu[4]

[1]Department of Nuclear Sciences and Applications, Graduate School of Nuclear and Allied Sciences, University of Ghana, P. O.Box AE 1, Atomic – Accra, Ghana.

[2] Radiopharmacy and Nuclear Medicine Centre, Radiological And Medical Sciences Research Institute, Ghana Atomic Energy Commission, P. O. Box LG80, Legon – Accra.

[3]Department of Chemistry, National Nuclear Research Institute, Ghana Atomic Energy Commission, Box LG80, Legon -Accra

[4]Radiation Protection Institute, Ghana Atomic Energy Commission, Box LG 80, Legon -Accra.

ARTICLE INFO

Article history:

Received: 29 August 2011;

Received in revised form:

26 October 2011;

Accepted: 5 November 2011;

Keywords

Ghana, INAA,

Marine Organisms,

Essential elements,

SeafoodAuthor for correspondence.

ABSTRACT

The aim of this work was to determine the concentrations of some essential elements (Br, Ca, Fe, Mg, Mn, Na, K and Cl) in the muscle of three species of commercial fish, *Dentex macrophthalmus, Sardinella maderensis, Engraulis encrasicolus* (fin fishes) and a Mollusk (*Cymbium cymbium*) consumed in Ghana. The concentrations of the elements in the four marine organisms from different areas along the coast of Ghana were determined using Instrumental Neutron Activation Analysis (INAA). The irradiation using thermal neutrons were done using the Ghana Research Reactor – 1 (GHARR – 1) facility at Ghana Atomic Energy Commission, Kwabenya. Only the edible tissues of the marine organisms were analyzed. The range of concentrations of the essential elements measured in the studied samples were : Br (2.7-33mg/kg), Ca (2150-9300mg/kg), Fe (50.2-90.3mg/kg), Mg (3300-7700mg/kg), Mn (0.18-9.88mg/kg), Na (3600-21700mg/kg), K (9900-17400mg/kg), Cl (3960-9400mg/kg). The precision in terms of relative standard deviation was within ±4. The accuracy of the method was evaluated by analyzing a reference material. Our values were within ±3% of the certified or information values in all cases.

Introduction

One of the major concerns of man is his dietary habits which is gaining importance almost everyday. Therefore ingestion, both in amount and quality, of the nutrients for good functioning of the human organism is fundamental. Among the products available, seafood is currently considered one of the most interesting. Marine foods are very rich sources of mineral components which are classified as essential because they are necessary in trace amounts for the functioning of biological systems. Most of these elements are detected in fish and shell fish.

Seafoods are healthy, nutritious and highly essential in a balanced diet, being an important source of proteins and lipids of high biological value. Although nutrient composition data for common food, including some marine organisms (mostly fish) are widely available, knowledge of the elements present in fish is confined to selected minerals and trace element levels, especially for heavy metals, are known for a few marine organisms only. The following marine organisms, *Dentex macrophthalmus, Sardinella maderensis, Engraulis encrasicolus and Cymbium cymbium* chosen for this study are available and abundant in the Ghanaian coastal waters throughout the year. The marine organisms play an important role in human nutrition in Ghana, and for that matter they need to be carefully monitored to ensure that they contain some essential elements.

Twenty-one inorganic elements made up of 6 major minerals (Ca, Na, K, Mg, P, and Cl) and 15 trace elements (As, Co, Cr, Cu, F, Fe, I, Mn, Mo, Ni, Se, Si, Sn, V and Zn) are now considered as being essential to human life. Each major mineral is required in several hundred milligrams/day while the traces are required in few milligrams daily (M.C. Linder, 1991).

For example Magnesium plays a major role in overall cell functions. An adequate serum magnesium concentration may be necessary to maintain renal function and protect the kidneys from damage. Iron is an essential element for living cells, and a lack of iron is associated with anaemia. Two of the most abundant ions that are controlled in dialytic patients are sodium and potassium. Sodium is the major indicator of body tonicity. Potassium is the most important intracellular cation that maintains the cell's osmotic pressure and acid–base balance in the human body. Calcium helps to form and maintain healthy bones (Bogden & Klevay, 2000).

Plant materials along the coast of Ghana accumulate these essential elements and pass it on to the fishes that feed on them and then to human beings through a food chain. Marine and estuarine macroalgae have long been known to concentrate metals to levels many times higher than those found in the surrounding waters (W. A. P. Black and R. L. Mitchell, 1959). For example it has been confirmed in earlier observations that seaweeds found along the Ghanaian coastal waters are good accumulators of Br, Ca, Cl, Fe, K, Mg and Na (Serfor-Armah et. al., 2006).

The level of most of these essential elements in various marine organisms consumed by almost all Ghanaians is unknown. Instrumental neutron activation analysis (INAA) has been used to analyze the essential elemental composition of four

Tele:

E-mail addresses: joesarsah@yahoo.com

marine organisms (*Dentex macrophthalmus, Sardinella maderensis, Engraulis encrasicolus and Cymbium cymbium*), which will provide useful information on their nutritive value.

The aim of this work was to determine the concentrations of the following essential elements Br, Ca, Fe, Mg, Mn, Na, K and Cl in flesh of the marine organisms along the coast of Ghana.

Materials and Methods

Sample Collection

Four different species of marine organisms (fish and mollusk) were sampled along the coast of six selected communities in Ghana. The communities are Prampram, Tema, Apam, Elmina, Sekondi, and Axim (figure 1). At each sampling site, the marine organisms freshly brought to the coast were bought and collected into well labelled polyethylene bags. The samples collected were made up of three fish species: *Dentex macrophthalmus*, *Sardinella maderensis*, and *Engraulis encrasicolus*. The mollusk species was *Cymbium cymbium*. The samples were transferred into a thermo-insulated box and kept on ice, sent to the laboratory and stored in the refrigerator. Sample collection was on monthly basis from May 2009 to April 2010.

In this work, the various marine organisms were chosen for the investigations into the levels of the essential elements in the chosen marine organisms along some selected coastal towns in Ghana. This is because:

- the organisms are available and abundant throughout the year.
- they are widely consumed by the Ghanaian populace.
- they are easy to sample and identify and also have sufficient tissue for the analysis of the elements of interest.
- Also the various sampling sites were chosen because they are very active sites when it comes to fishing as well as being the coastlines that always harvest the marine organisms chosen for this work.

Sample Preparation

The samples were washed several times with de-ionized water to clean them from sand and other entangled materials. The scales of the fish samples were removed using a stainless steel knife. The shell of the mollusk species were crushed and removed leaving only the tissue. The samples were washed several times again with de-ionized water. The tissue of both the fish and mollusk species were cut into pieces, put in Petri-dishes and then kept in the refrigerator for about 48 hrs. The fish and mollusk samples were then removed and freeze-dried using the freeze-dryer (Christ freezedryer) for 72 hrs. The individual fish and mollusk species were ground and homogenized using a blender. 200mg each of the samples was weighed and packaged into an ultra-clean polyethylene foil and wrapped. The foil was heat-sealed and packaged into polyethylene vials and heat-sealed.

Sample irradiation, counting and analysis

All prepared samples and standards were irradiated using the Ghana Research Reactor -1

(GHARR-1) facility at the GHARR-1 centre of the National Nuclear Research Institute (NNRI) of the Ghana Atomic Energy Commission (GAEC). The reactor was operated at a half-full power of 15 kW and at a thermal neutron flux of $5 \times 10^{11} ncm^{-2}s^{-1}$. The capsules were sent into the inner irradiation sites of the reactor by means of a pneumatic transfer system, operating at a pressure of 0.25 atms. The irradiation time (t_i), decay time (t_d) and counting time (t_c) were chosen according to the sample matrix, the elements of interest and the half-lives of the elements of interest. Elements such as Mn, Mg, Ca, and Cl were analyzed via their short-live nuclides with half-life ($T_{1/2}$) of less than a few hours using t_i of 2 minutes, decayed for 1 minute and counted for 10 minutes. Nuclear data for the elements of interest is available (IAEA-TECDOC-564, 1990). For medium-lived nuclides (Na and K), the samples were irradiated for 1 hour and allowed to decay for 24 hours and counted for 10 minutes. For the long-lived nuclide, Fe, the samples were irradiated for 4 hours and allowed to decay for 30 days and counted for 10 hours. Samples and standards were irradiated and counted under identical conditions. Counting of irradiated samples and standards were done using a PC-based gamma-ray spectrometry system. Accuracy and precision of the analytical techniques were assessed by the simultaneous activation of standard reference material NIST – SRM 1566 Oyster Tissue. Our values compared favourably with the certified values for all the elements with a bias less than 5%.

There are many other techniques that offer comparable sensitivity, but Neutron Activation Analysis (NAA) has other important benefits such as high selectivity and simultaneous multi-element detection capability (Ehmann, W.D. et al. 1991), arising from the fact that radionuclides decay with characteristic half-life and γ-ray energies. Nuclides can generally be selectively determined on the basis of their unique γ-ray energies, so a single irradiation of a sample can often yield data for several elements at once.

Another advantage of NAA is that the analysis can be performed on a solid sample. Many instrumental techniques require a liquid sample, to that end; most chemical procedures include a sample digestion as in reverse-phase extraction chromatography (RPEC) (Chung, Y.S., et al. 1988) or elution step, in order to remove the trace elements from the column prior to analysis. Typically elements are stripped from the column with acid or organic solvent prior to the quantification by AAS (Sarzanini, C.,et al. 1987), AES (Beauchemin, D.et al. 1989), ICP-MS (Martin-Esteban et al. 1995) or visible spectrophotometer (Van der Sloot,et al. 1977). The elution step is disadvantageous in that it tends to lower the attainable concentration factor of the preconcentration procedure and may not always be quantitative or reproducible.

The precision was calculated as a percentage of relative standard deviation (%RSD) of 3 replicate samples of the prepared material, and it was less than 5%.

Results and discussion

A total of 8 elements namely Ca, Cl, Fe, K, Mg, Mn, Br and Na were detected in the muscle tissue of the marine organisms. These elements, their corresponding concentration and the mean deviation in the various marine organisms are shown in Table 2. The precision was calculated as a mean deviation of three measurements.

In table 1 we compared the accuracy of the reported values of some of the elements of the standard reference material NIST – SRM 1566 Oyster Tissue with those obtained in this work. Our values agree very well with the reported values within the limits of experimental errors. The Value of Br was not reported but its accuracy can be said to be good, since the other measured elements compare favourably with the reported values.

Of the 8 elements detected, five (Na, K, Mg, Ca, and Cl) are classified as major elements while Mn is a trace element. Br is neither described as major nor trace element. All the marine organisms contain detectable levels of all the 8 elements, and out of the six major elements considered essential to life (M.C. Linder, 1991), the tissue of the marine organisms contained five

(Na, K, Mg, Ca, and Cl) indicating that the marine organisms are potential sources of minerals.

The availability of these elements and their concentrations varied between the selected marine organisms (Table 2). The element with the highest concentration was Sodium (21700 mg/kg) which was recorded in *Cymbium cymbium* whilst the least concentration (3600 mg/kg) was recorded in *Sardinella maderensis*. Both concentrations are higher than the RDA recommendation of 1500mg (Nelson, David L.; Michael M. Cox ,2000-02-15). The element with the lowest concentration was Mn and was detected in *Cymbium cymbium* (0.18mg/kg). The concentrations in *Sardinella maderensis* (2.54mg/kg) and *Engraulis encrasicolus* (9.88mg/kg) were a little higher than the RDA recommendation for Mn for men, which is 2.5-5.0mg/kg, whiles the concentrations of Mg in all the marine organisms far exceeded the RDA recommendation of 300mg/kg (RDA Recommended Dietary Allowance, 10^{th} ed.)

The elements Fe, Ca, K and Cl all exceeded the RDA recommendation, but their high concentrations in the marine organisms makes it suitable for human consumption. Several factors may account for the high concentrations of the elements in the marine organisms. These factors may include the concentrations of the elements in the Ghanaian coastal waters. However most of these essential elements found in these marine organisms are through the food chain. Phytoplankton, bacteria, fungi and other small organisms absorb these materials from the surrounding water. These are then eaten by the marine organisms, and eventually man.

The detection of five major elements considered essential to life and two trace elements in the marine organisms indicates that the organisms contains a rich source of minerals. These elements form the main electrolyte of the body, maintaining tissue homeostasis and also form the major structural components of bones and teeth (M. C. Linder, 1991).

Conclusion

All the marine organisms chosen for this work contains five major elements as well as three elements essential to life. Some of these elements were detected in high concentrations; hence the marine organisms are safe for human consumption.

Acknowledgements

The authors of this research appreciate some financial support from National Nuclear Research Institute and the Department of Chemistry, Ghana Atomic Energy Commission. We are also thankful to the staff of NAA laboratory and the team of Reactor operators of GHARR-1 Centre.

Fig. 1: Map of Southern Ghana showing the sampling sites

References

Beauchemin, D., Berman, S.S., Anal. Chem.(1989). Determination of Trace metals in reference water standards by Inductively Coupled Plasma Mass Spectrometry with On-line Preconcentration, Analytical Chemistry (61) pages 1857-1862.

Black, W.A.P., and R.L. Mitchell.(1952). Trace elements in the common brown algae and seawater. J. Mar. Biol. Assoc. UK 30: 575-584. ...

Bogden, J. D., & Klevay, L. M. (2000). Clinical nutrition of the essential trace elements
and minerals: The guide for health professionals. Humana Pr Inc.

Chung, Y.S., Barnes, R.M.,(1988). Atomic Spectrometry, Journal of Analytical chemistry., (3), 1079.

Ehmann, W.D., Vance, D.E.,(1991). Radiochemistry and Nuclear Methods of Analysis, Wiley, Toronto page 257.

Esteban et. al (1995). On-line Preconcentration of Aluminium with immobilized Chromotrope 2B for the Determination by flame atomic absorption Spectrometry and Inductively Coupled Plasma Mass Spectrometry Anal. Chem. Acta., Volume 304, Number 1 pages 121-126 (6)

M. C. Linder,(1991) Nutrition and metabolism of the major minerals in : Nutritional Biochemistry and Metabolism with Clinical Applications, M. C. LINDER (Ed.), 2^{nd} ed., Appleton and Lange, USA.

Nelson, David L.; Michael M. Cox (2000-02-15). *Lehninger Principles of Biochemistry, Third Edition* (3 Har/Com ed.). W. H. Freeman. pp. 1200.

Practical Aspects of Operating NAA Laboratory, IAEA-TECDOC-564, Vienna, 1990. P. 197.

Sarzanini et al. (1987). Comparison of Anion exchange methods for Preconcentration of trace Aluminium., Anal. Chem. 59 (3), pages 484-486.

RDA Recommended Dietary Allowances, 10^{th} ed., National Academy Press, Washington, D.C., 1989, p. 1.

Van der Sloot, H. A., J. (1977). The Determination of Vanadium in sea and surface waters., Journal of Radioanalytical and Nuclear Chemistry, Vol. 35, Number 1, 139-146.

Serfor-Armah et al., (2006). Determination of selected elements in red, brown and green seaweeds species for monitoring pollution in the coastal environment of Ghana. Journal of Radioanalytical and Nuclear chemistry, Vol. 269, No.3., 711-718.

Table 1. Results of standard reference material NIST – SRM 1566 Oyster Tissue showing reported values and local laboratory values (mg/kg)

Element	Reported Value	This work
Ca	838±20	800±25
Mg	1085±23	1142±30
Mn	18.5±0.2	20.8±0.5
Na	3297±53	3314±49
Br	N.R.	9.80±0.64
Cl	5140±100	5480±106
Fe	205±6.8	200±4.2
K	6520±90	6620±60

N.R. : Not reported

Table 2 : Mean values of elemental concentrations of the marine organisms with standard deviations (mg/kg)

Element	*Cymbium cymbium*	*Dentex macrophethalmus*	*Sardinella maderensis*	*Engraulis encrasicolus*
Br	33±1.0	1.11±0.14	4.1±0.5	6.9±0.5
Ca	9300±900	4100±400	2150±800	2980±800
Cl	3960±200	4100±60	6600±100	9400±150
Fe	64.5±9.68	90.3±13.55	84.3±12.65	50.2±12.55
K	9900±600	17400±900	15800±300	13400±300
Mg	4510±600	5300±600	7700±800	3300±600
Mn	0.18±0.03	0.54±0.08	2.54±0.38	9.88±1.48
Na	21700±40	3600±500	5600±20	6700±20