DETERMINATIONS OF MINERALS IN MARINE CRAB CHARYBDIS LUCIFERA (FABRICIUS, 1798)

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ABSTRACT. Crab meat is an excellent source of minerals, particularly calcium, iron, zinc, potassium and phosphours. The minerals in the edible parts of muscle of C. lucifera different sexes (male, female and berried female) were determined by digital flame photometer. Totally 11 minerals are reported in the present study. Seven (Sodium> Potassium >Magnesium >Calcium> Manganese> Iron >Zinc) minerals were reported in all sexes. Sodium was maximum (137.55 mg) and zinc was minimum (1.76 mg) in all sexes. Copper, mercury and cadmium were available in trace amount in all sexes. However, arsenic was in trace amount in berried females and totally absent in males and females. Among different sexes, berried females contain maximum amount of minerals (156.24 mg) followed by females (121.76 mg) and males (95.5 mg).

1. INTRODUCTION

Crab is highly nutritious and healthy owing to its protein content, unsaturated fatty acids, carbohydrates and mineral composition. Minerals constitute important components of hormones, enzymes and enzyme activators in human nutrition (Kirtpatrick and Coffin, 1974; Khan et al., 1987; Lall, 1989, 1995). Food source and environmental factors affect minerals content (Anthony et al., 1983; King et al., 1990; Lee et al., 1993; Skonberg and Perkins, 2003; Gokoglu and Yerlikaya, 2003; Yannar and Celik, 2006). Mineral components such as sodium, potassium, magnesium, calcium, iron, phosphorus and iodine are important for human nutrition (Sikorski et al., 1990). Therefore determining the minerals in crab species has a great importance due to the good effect on human health. Calcium and iron are necessary to maintain an optimal bone development. Crab meat is an excellent source of minerals, particularly calcium, iron, zinc, potassium and phosphours (Sifa et al., 2000; Adeyeye, 2002; Gokoglu and Yerlikaya, 2003; Naczk et al., 2007). The phosphorous (adenosine polyphosphate) act as a key substance for energy release and present in phospholipids (Decker and Tuczek, 2000). Both minerals being required during childhood and growing stages to prevent rickets and osteomalacia. Calcium also has an essential role in blood clotting, muscle contraction and nerve transmission. Iron is an important mineral; it is required to help our red blood cells deliver oxygen to the rest of the body. Iron is essential for many proteins and enzymes that maintain good health; transporting oxygen in the blood to all parts of the body as well as proper functioning of the liver. Zinc is a constituent of many enzymes and is essential for the proper functioning of these various enzymes. Zinc is essential for the metabolism and structural stability of nucleic acids. Zinc has been associated with a variety of bodily functions such as healing of wounds, reproduction, growth and maintenance of glucose tolerance in the body. The aim of this study is to demonstrate the nutritive value and thereby to encourage an increase in the consumption and utilization of C. lucifera.
2. MATERIALS AND METHODS

The male, female and berried females of *C. lucifera* were collected from Parangipettai landing centres. After reaching the laboratory they were washed carefully with distilled water to remove the dust and algal particles and ice killed. The carapace of the crabs was opened and the edible parts of muscle tissues were removed with sharp forceps. To the 5g of wet crab tissue samples, mixture of hydrochloric acid, nitric acid and perchloric acid at a ratio of 10:5:1 was added for digestion at 30 °C. The digests were filtered suitably and aspirated in digital flame photometer (Modal No.CL 22D, Elico pvt, India); the obtained values were expressed in mg/100g (Guzman and Jimeneza, 1992).

2.1. Statistical Analysis

The data was subjected to One-way analysis of variance (ANOVA) and difference between means were determined by Duncan’s multiple range tests (P<0.05) using SPSS version 17.0.

3. RESULTS

The mineral compositions of the *C. lucifera* muscle tissue is shown in table 14 & Fig. 8. Totally 11 minerals are reported in the present study. Seven (Sodium> Potassium >Magnesium >Calcium>Manganese> Iron >Zinc) minerals were reported in all sexes. Sodium was maximum (137.55 mg) and zinc was minimum (1.76 mg) in all sexes. Copper, mercury and cadmium were available in trace amount in all sexes. However, arsenic was in trace amount in berried females and totally absent in males and females. Among different sexes, berried females contain maximum amount of minerals (156.24mg) followed by females (121.76 mg) and males (95.5mg).

Table-1. Minerals (mg/100g) in the muscle of *C. lucifera* (Values are mean of three values SE).

| S.No | Minerals | Male         | Female        | Berried female | Total          |
|------|----------|--------------|---------------|----------------|----------------|
| 1    | Calcium  | 11.20±0.45 c | 12.54±0.39 b  | 22.10±0.43 a   | 45.84±1.29     |
| 2    | Magnesium| 18.26±0.59 c | 22.15±0.54 b  | 31.20±0.36 a   | 71.61±2.12     |
| 3    | Iron     | 1.04±0.42 c  | 1.42±0.22 b   | 2.58±0.39 a    | 5.04±2.21      |
| 4    | Sodium   | 37.48±1.32 c | 46.71±0.47 b  | 53.36±0.51 a   | 137.55±0.58    |
| 5    | Potassium| 25.92±0.37 c | 36.79±0.15 b  | 43.28±0.52 a   | 105.99±0.38    |
| 6    | Zinc     | 0.31±0.39 c  | 0.53±0.38 b   | 0.92±0.47 a    | 1.76±1.29      |
| 7    | Copper   | Trace        | Trace         | Trace          | Trace          |
4. DISCUSSION

Marine foods are very rich sources of mineral components. The total content of minerals in the raw flesh of marine fish and invertebrates is in the range of 0.6 – 1.5% wet weight. Mineral components such as sodium, potassium, magnesium, calcium, iron, phosphorus and iodine are important for human nutrition (Sikorski et al., 1990). Crustaceans are also good sources of various minerals and high quality protein. Living organisms require trace amounts of some heavy metals including iron, cobalt, copper, manganese, molybdenum, strontium, vanadium and zinc. Excessive levels of these metals, however, can be detrimental to living organisms. Other heavy metals such as cadmium, lead and mercury have no known beneficial effect on organisms and their accumulation over time in the bodies of mammals can cause serious illness (Hawkes, 1997). The fish and shellfish can absorb minerals directly from the aquatic environment through gills and body surfaces. Almost all the elements that occur in seawater are found to some extent in aquatic animals and these includes Na, K, Ca, P, Al, Ba, Cd, I, Cr, Pb, Li, Hg, Ag, St and Va. Eyo (2001) reported that the mineral content of fish makes unavoidable in the diet, as it is a source of different minerals that contribute to good health.

Minerals serve as components of bones, soft tissues (Sulfur amino acids, metalloproteins) co-factors and co-activators of various enzymes important in human nutrition. Calcium, phosphorus, magnesium and electrolytes (sodium and potassium) are considered to be as macro elements and iron, copper, zinc, iodine, chromium, cobalt, manganese, molybdenum, selenium are considered as trace elements that are required for normal functioning, for instance the more soluble minerals such as Ca, P, Na, K and Cl are involved in the maintenance of acid-base balance and membrane potential. The main functions of essential minerals include skeletal structure, maintenance of colloidal system and regulation of acid-base equilibrium. Minerals also constitute an important component of hormones, enzymes and enzyme activators (Belitz and Grosch, 2001).

Considering the elemental composition of common food items (dairy products, meat, fish, cereals and fruits), C. pagurus hepatopancreas is a good source of Ca, Fe, Cu, Zn and Se (FAO/WHO, 2002; Martins, 2006). The more soluble minerals such as Ca, P, Na, K and Cl also have osmoregulatory function and the maintenance of acid-base balance and membrane potentials (Davis et al., 1992). Some elements such as Mg, Al, Ca, Fe, Co, Cu and Zn are necessary for maintenance of optimum health and thus are important from nutrition point of view. Metals such as Pb, Cd, as and Hg are detrimental to optimum health and have toxicological effect and the tissue samples are also used as the bio-indicator to assess bioavailability of contaminant concentrations in coastal water in environmental studies (Mohapatra et al., 2007). The concentration of minerals in the meat of crab species can be influenced by a number of factors such as seasonal and biological

|   | Manganese  | 1.30±0.38<sup>c</sup> | 1.62±0.30<sup>b</sup> | 2.80±0.28<sup>a</sup> | 5.72±2.38 |
|---|------------|-----------------------|-----------------------|-----------------------|-----------|
| 9 | Mercury    | Trace                 | Trace                 | Trace                 | Trace     |
| 10| Cadmium    | Trace                 | Trace                 | Trace                 | Trace     |
| 11| Arsenic    | -                     | -                     | Trace                 | -         |
| Total|          | 95.5±2.20<sup>c</sup>| 121.76±2.13<sup>b</sup>| 156.24±1.13<sup>a</sup>| 373.51±2.13 |

Absent: -; Different superscripts in the rows are significantly different (P<0.05)
differences (species, size, age, sex and sexual maturity), food source and environment (water chemistry, salinity, temperature and contaminants) (Kucukgulmez and Celik, 2008). The seasonal and sex differences observed are most probably related with the reproductive state and metabolism.

The aquatic environment and its inhabitants are exposed and sensitive to effects of environmental pollution from heavy metal contamination. Aquatic animals accumulate large quantities of these xenobiotics and the accumulation depends upon the intake and elimination from their body (Karadede et al., 2004). Among different aquatic organisms; oysters, crab and mussels, accumulate large quantities of heavy metals due to their habitat and feeding nature. Many metals (Co, Cu, Mn, Fe and Zn) are essential trace elements for aquatic organisms and are involved in biochemical processes such as enzyme activation.

Totally 11 minerals are reported in the present study. Among these 7 (Sodium> Potassium >Magnesium >Calcium>Manganese >Iron >Zinc) minerals are reported in all sexes. Sodium is maximum (137.55 mg) and zinc is minimum (1.76 mg) in all sexes. Comparatively berried females (156.24 mg) contain maximum amount of minerals than females (121.76mg) and males (95.5mg). These are very much comparable with the studies of Hagashi et al. (1979), Anon (1999), Thirunavukkarasu (2005), Sudhakar et al., (2009), Soundarapandian et al. (2013c) and Soundarapandian et al. (2014). Okogolo and Yerlikaya (2003) investigated the mineral contents of blue crab C.sapidus and swim crab P.pelagicus and suggested that Na, Ca, Zn, Cu values for blue crab and swim crab were not significantly different. Trace elements content in haemolymph of mud crab was observed by Jintana Salaenoi et al. (2006). The mineral contents of green tiger shrimp and speckled shrimp were showed seasonal differences (p<0.05), except the Ca content in green tiger shrimp. The average Ca contents of green tiger shrimp and speckled shrimp were 60.28mg/10 g and 60.44 mg/10 g, respectively (Yanar and Celik, 2006). Chen et al. (2007) reported the concentration of nine elements (Zn, Fe, K, Na, Mn, Cu, Mg, Ca, and P) in different tissues of crab meat and edible viscera of Chinese mitten crab, E. sinensis. Mohapata et al. (2007) studied the concentration of 10 elements (ppm) (K, Ca, Mn, Fe, Cu, Zn, Br, Sr and Pb) in S.serata, S. tranquebarica, P.monodon, P.indicus and M.rosenbergii. Sudhakar et al. (2009) recorded the minerals content of hard and soft shell crabs of P.sangiunolentus.

In the present study sodium and potassium alone is contributed 50%. Calcium is maximum in berried females (22.10mg) than females (12.54mg) and males (11.20mg) of C.lucifera. Similar results were reported in P.sangiunolentus (Sudhakar et al., 2009), S.tranquebarica (Thirunavukkarasu, 2005), E.sinesnis (Chen et al., 2007), C.amnicola (Moronkola et al., 2011), P.potamios (Bilgin and Fidanbas, 2011), C.amnicola and U.tangeri, (Udo Paul Jimmy and Vivian Nnena Arazu, 2012), C.armatum and C.amnicola (Omotayo et al., 2013), C.natator (Soundarapandian et al., 2013c) and P.vigil (Soundarapandian et al., 2014), C.lophous (Kathirvel et al., 2014) and S. hydrodroma (Varadharajan and Soundarapandian, 2014). Calcium also has an essential role in blood clotting, muscle contraction and nerve transmission. Calcium is nutritionally very important (up to 1.9% Ca is available in the human body) and provides rigidity to the skeleton and plays a role in many metabolic processes (FAO/WHO, 2002). It is also essential for hard tissue structure, blood clotting, muscle contraction, nerve transmission and osmoregulation and as a cofactor for enzymatic procession (Lovel, 1989). The higher Ca content in male crabs are likely because this species has a sexual dimorphism, in which males have bigger claws and harder exoskeletons (composed by calcium phosphate). Particularly during the premoult period of C.pagurus, hepatopancreas accumulates Ca that is likely used in the exoskeleton calcification (Luquet and Marin, 2004).

Magnesium is maximum in berried females (31.20mg) than females (22.15mg) and males (18.26mg). Magnesium was already reported in P.sangiunolentus (Sudhakar et al., 2009), S.tranquebarica (Thirunavukkarasu, 2005), E.sinesnis (Chen et al., 2007), C.amnicola (Moronkola et al., 2011), P.potamios (Bilgin and Fidanbas, 2011), C.amnicola and U.tangeri, (Udo Paul Jimmy and Vivian Nnena Arazu, 2012), C. armatum and C.amnicola (Omotayo et al., 2013), C.natator (Soundarapandian et al., 2013c) and P.vigil (Soundarapandian et al., 2014), C.lophous (Kathirvel et al., 2014) and S. hydrodroma (Varadharajan and Soundarapandian, 2014).
Magnesium is important for human nutrition and it is required for the body’s enzyme system. In addition to maintain bone health, magnesium acts in all cells of soft tissues, where it forms part of the protein-making machinery and necessary for energy metabolism. Magnesium is cofactor for enzyme systems (Food and Nutrition Board, National Research Council, 1989).

Iron was already reported in *E.sinensis* (Chen et al., 2007), *C.amnicola* (Moronkola et al., 2011), *P. potamios* (Bilgin and Fidanbas, 2011), *C.amnicola and U.tangeri* (Udo Paul Jimmy and Vivian Nneka Arazu, 2012), *C. armatum and C.amnicola* (Omotayo et al., 2013), *C.natator* (Soundarapandian et al., 2013c) and *P.vigil* (Soundarapandian et al., 2014), *C.lophous* (Kathirvel et al., 2014) and *S. hydrodroma* (Varadharajan and Soundarapandian, 2014). Iron is one of the very important essential trace elements since it has several vital functions in the human system. It serves as a carrier of oxygen to tissues from the lungs by red blood cell. Adequate Fe in the diet is very important for avoiding some major health problems (Belitz and Grosch, 2001; Camara et al., 2005). Adequate iron in the diet is very important for decreasing the incidence of anaemia, which is considered a major health problem, especially in young children. Iron deficiency occurs when the demand for iron is high, e.g., in growth, high menstrual loss, and pregnancy, and the intake is quantitatively inadequate or contains elements that render the iron unavailable for absorption (Blitz and Grosch, 2001; Camara et al., 2005). Transition metal ions, particularly Cu and Fe, have been known as the major catalysts for oxidation (Thanonkaew et al., 2006). Copper and iron are important minerals found in fish as respiratory pigment, while cobalt is present in vitamin B_{12}.

Sodium contribution is maximum in the present study irrespective of the sex. In individual contribution sodium is maximum in berried females (53.36mg) followed by females (46.71mg) and males (37.48mg) of *C.lucifera*. Sodium was already reported in *P.sanguinolentus* (Sudhakar et al., 2009), *S.tranquebarica* (Thirunavukkarasu, 2005), *E.sinensis* (Chen et al., 2007), *C.amnicola* (Moronkola et al., 2011), *P. potamios* (Bilgin and Fidanbas, 2011), *C.amnicola and U.tangeri* (Udo Paul Jimmy and Vivian Nneka Arazu, 2012), *Cardisoma armatum and C.amnicola* (Omotayo et al., 2013), *C.natator* (Soundarapandian et al., 2013c), *P.vigil* (Soundarapandian et al., 2014), *C.lophous* (Kathirvel et al., 2014) and *S. hydrodroma* (Varadharajan and Soundarapandian, 2014). Sodium is the principal cation of the extra cellular fluid and regulator of its volume. Sodium also helps to maintain acid-base balance and is essential for nerve system. Potassium is maximum in berried females (43.28mg) than females (36.79mg) and males (25.92mg) of *C.lucifera*. Potassium was already reported in *S.tranquebarica* (Thirunavukkarasu, 2005), *E.sinensis* (Chen et al., 2007), *P.sanguinolentus* (Sudhakar et al., 2009), *C.amnicola* (Moronkola et al., 2011), *P. potamios* (Bilgin and Fidanba, 2011), *C.amnicola and U.tangeri* (Udo Paul Jimmy and Vivian Nneka Arazu, 2012), *Carmatum and C.amnicola* (Omotayo et al., 2013), *C.natator* (Soundarapandian et al., 2013c), *P.vigil* (Soundarapandian et al., 2014), *C.lophous* (Kathirvel et al., 2014) and *S. hydrodroma* (Varadharajan and Soundarapandian, 2014). Potassium is important to maintain the pH, storage and transfer of energy and nucleotide synthesis.

Zinc is maximum in berried females (0.92mg) than females (0.53mg) and males (0.31mg) of *C.lucifera*. Zinc was already reported in *S.tranquebarica* (Thirunavukkarasu, 2005), *E.sinensis* (Chen et al., 2007); *P.sanguinolentus* (Sudhakar et al., 2009); *C.amnicola* (Moronkola et al., 2011), *P. potamios* (Bilgin and Fidanbas, 2011), *C.amnicola and U.tangeri* (Udo Paul Jimmy and Vivian Nneka Arazu, 2012), *C. armatum and C.amnicola* (Omotayo et al., 2013), *C.natator* (Soundarapandian et al., 2013c), *P.vigil* (Soundarapandian et al., 2014), *C.lophous* (Kathirvel et al., 2014) and *S. hydrodroma* (Varadharajan and Soundarapandian, 2014). Zinc is an essential trace element for all living species, since it is an important component of several enzymes and plays an essential role in a number of biological processes involved in growth and development (FAO/WHO, 2002). MacFarlane et al. (2000) reported higher Cu and Zn accumulation in females than males of semaphore crab, *Helioecius cordiformis*.

Manganese is maximum in berried females (2.80mg) than females (1.62mg) and males (1.30mg) of *C.lucifera*. It is already reported in *S.tranquebarica* (Thirunavukkarasu, 2005), *E.sinensis* (Chen et al., 2007), *P.sanguinolentus* (Sudhakar et al., 2009), *C.amnicola* (Moronkola et al., 2011).
et al., 2011), Potamon potamios (Bilgin and Fidanbas, 2011), C.amnicola and U.tangeri (Udo Paul Jimmy and Vivian Nneka Arazu, 2012), C. armatum and C.amnicola (Omotayo et al., 2013), C.natator (Soundararapandian et al., 2013c), P.vigil (Soundararapandian et al., 2014), C.lophous (Kathirvel et al., 2014) and S. hydrodroma (Varadharajan and Soundararapandian, 2014). Manganese is important for the development of bones. It also act as an activator of enzyme systems, but the connection with the deficiency symptoms in crustacean is not entirely clear. Copper, mercury, cadmium and arsenic are available very less in the present study. C.lucifera contains sufficient nutrients and minerals that are beneficial to humans as food. It could especially serve as supplements to patients deficient in them if taken appropriately. It could also be concluded that the concentration of minerals in these species is within WHO recommended safe limits for elements in aquatic organisms. From the study berried females bear maximum amount of minerals than females and males. So, it is recommended to consume berried females and females to get maximum minerals.

References

[1] Adeyeye, E.I. (2002). Determination of chemical composition of the nutritionally valuable parts of male female common West African freshwater crab. Sudanautes africanus africanus. Int.J. Food Sci.Nutr., 52(3): 189-196.
[2] Anon, (1999). Results from the USDA, nutrient database for standard reference crustaceans, Crab. blue, cooked, moist head. Blue crab-nutrition html. pp. 1-3.
[3] Anthony, J.E., P.N.Hadgis, R.S.Milam, G.A.Herzfeld, L.J. Taper and S.J.Ritchey, (1983). Yields, proximate composition and mineral content of finfish and shellfish, J. Food Sci., 48:313.
[4] Belitz, H.D. and W.Grosch. (2001). Schieberle, P.Lehrbuch der Lehbensmittelchemie, Aufl. Springer Verlag, berlin heidelberg New York.
[5] Bilgin, S and Z.U.C. Fidanbaş. (2011). Nutritional properties of crab (Potamon potamios Olivier, 1804) in the lake of Eğirdir (Turkey). Pak. Vet. J., 31(3): 239-243.
[6] Camara, F., M.A. Amaro, R.Barbera and G.Clemente, (2005). Bioaccesibility of minerals in school meals; comparision between dialysis and solubility methods. Food Chem., 92; 481-489.
[7] Chen, H.P and N.R.Zhang, (2007). Scan statistics with weighted observations, JAS Theory and Methods, 102:592-602.
[8] Decker, H and F. Tuczek. (2000). Tyrosinase/catechooxidase activity of hemocyanins: Structural basis and molecular mechanism. T. Biochem. Sci., 25: 392-397.
[9] Eyo, A.A. (2001). Fish processing technology in the tropics. National Institute for freshwater, Fisheries Research University of Ilorin press, pp. 66-70.
[10]FAO/WHO, (2002). Human vitamines and mineral requiementrs. Report of joint food and Agricultural Organizations of the United Nations/World Health Organization Expert Consultation.Bankok, Thailand.
[11]Food and Nutrition Board, National Research Council, (1989). Recommended Dietary allowances, 10th edn. Washington, DC; National academy Press.
[12]Gokoglu, N and P. Yerlikaya. (2003). Determination of proximate composition and mineral contents of blue crab (Callinectus sapidus) and swim crab (Portuns pelagicus) caught off the Gulf of the antalya. Food Chem., 80: 495-498.
[13]Guzman, H.M and C.E.Jimeneza. (1992). Concentration of coral reefs by heavy metals along the Carribean cost of Central Africa (costarica and panama) Mar.Poll.Bull., 24(11): 554-561.
[14] Hagashi, T., A. Asakawa, K. Yamaguchi and S. Konoso. (1979). Studies on flavour components in boiled crabs. Bull. Japan Soc. Sci. Fish., 45(10):1325-1329.

[15] Hawkes, S.J. (1997). What is a heavy metal. J. Chem. Edu., pp. 74-134.

[16] Jintana Salaenoi, Anchanee Sancharoen, Amara Thongpan and Mingkwan Mingmuang. (2006). Morphology and hemolymph composition changes in red sternum mud crab (Scylla serrata). Kasetsari, J. Nat. Sci., 40; 158-166.

[17] Karadede, H., S.A. Oymak and E. Unlu, (2004). Heavy metals in mullet, Liza abu and catfish, Silurus triostegus from the ataturk Dam lake (Euphrates), Turkey. Environ. Int., 30:183-188.

[18] Kathirvel, K. A. Eswar, T. Manikandarajan, K. Ramamoorthy, G. Sankar and R. Anbarasu, (2014). Proximate composition, amino acid, fatty acid and mineral analysis of box crab, Calappa lophus (Herbst, 1782) from Parangipettai, Southeast Coast of India. J. Environ. Sci. Toxicol. Food Technol., 8 (5): 50-57.

[19] Khan, A.H., M. Ali, S.K. Biswas and D.A. Hadi. (1987). Trace elements in marine fish from the Bay of Bengal. The sc. total environ., 61-121-130.

[20] King, I., M.T. Childs, C. Dorset, J.G. Ostrander and E.R. Monsen, (1990). Shellfish: Proximate composition, minerals, fatty acid and sterols. J. American Diet. Ass., 90:677-685.

[21] Kirtpatrick, D.C and D.E. Coffin, (1974). The trace metal content of representative Canadian diets in 1970 and 1971. Can. Ins. Food Technol. J., 7: 56-58.

[22] Kucukgulmez, A. and M. Celik, (2008). Amino acid composition of blue crab (Callinectes sapidus) from the North Eastern Mediterranean Sea. J.Appl. Biolog.Sci., 2 (1): 39-42.

[23] Lall, S.P. (1989). The mineral. In: Halver, J.E. (ed.) Fish nutrition 2nd edn. Academic press, New York, pp. 219-257.

[24] Lall, S.P. (1995). Macro and trace elements in fish and shell fish. In: Reuiter, A.(ed.) fish and fishery products, composition nutritive properities and stability, willing for CAB International. pp. 187-214.

[25] Lee, E., S.P. Meyer and J.S. Godber, (1993). Minced meat crab cake from blue crab processing by-products development and sensory evaluation. J. Food Sci., 58: 99-103.

[26] Luquet, G. and F. Marin. (2004). Biomeralization in crustaceans: storage strategies. Comptes Rendus Palevol., 3(6-7): 515-534.

[27] MacFarlane, G.R., D.J. Booth and K.R. Brown, (2000). The Semaphore crab, Helioecius cordiformis: Bio-indication potential for heavy metals in estuarine systems. Aquat. Toxicol., 50: 153-166.

[28] Martins, I. (2006). Food composition table. Health Institute Dr.Ricardo jorge.Centre of Nutrition and food safety of health Ministry, Lisbon, Portugal, p. 355.

[29] Mohapatra, A., T.R. Rautray, V. Vijan, R.K. Mohanty and S. K. Dey, (2007). Trace elements characterization of some food crustacean tissue samples by EDXRF technique, Aquacult., 270: 552-558.

[30] Moronkola, B. A., R. A. Olowu, O. O. Tovide and O. O. Ayejuyo. (2011). Determination of proximate and mineral contents of crab (Callinectes amnicola) living on the shore of Ojo river, Nigeria. Sci. Revs. Chem. Commun., 1(1): 1-6.

[31] Naczk, M., J. Williams, K. Brennam, Liyanaspathiramra and F. Shahidi. (2007). Compositional characteristics of green crab (Carcinus sapidus). Food Chem., 88: 429-434.
[32] Omotayo, F., O. James Abayomi James, M. Folasade Adesola and O. Abimbola Olawale. (2013). Quality analysis of freshwater crab *Cardisoma armatum* and marine blue crab *Callinectes amnicola* Collected From Yaba, Lagos Nigeria. Nat. Sci., 11(8):22-29.

[33] Sifa, L., C. Wanqi, Z. L. Shuming Chenhong, Z. Jinlang and W. Cheghui. (2000). Quality analysis of Chinese mitten crab *Eriocheir sinensis* in Yangchenghu Lake. J. Fish. China, 7(3): 71-74.

[34] Sikorski, Z.E, A. Lolakowska and B.S. Pan. (1990). The nutrition compostion of the major groups of marine food oraganisms. In: Sikorski Z.E.(Ed.).Resources Nutritional compositon and Preservation. Boca Raton, Florida:CRC Press-Inc, pp. 30-52.

[35] Skonberg, D.I. and B.L. Perkins (2003). Nutrient composition of green crab (*Carcinus maenas*) leg meat and claw meat. Food Chem., 77(4): 401-404.

[36] Sivalnivan, P., D. Varadharajan and C. Sivasubramanian (2013c). Mineral composition of edible crab, *Charybdis natator* Herbst (Crustacea:Decapoda). Bio. biomed., 5(4):99-101.

[37] Sivalnivan, P., D. Varadharajan and S. Ravichandran. (2014). Mineral composition of edible crab *Podophthalmus vigil* Fabricius (Crustacea: Decapoda): Arthropods, 3(1):20-26.

[38] Sivalnivan, M., K. Manivannan and P. Soundarapandian. (2009). Nutritive value of hard and soft shell crabs of *Portunus sanguinolentus* (Herbst). Internat. J. A. Vet. Adv., 1(2): 44-48.

[39] Sivalnivan, M., K. Manivannan, P. Soundarapandian and G. Ananthan. (2009a). Effect of unilateral eyestalk ablation on the biochemical changes of edible portunidae crab *Portunus sanguinolentus* (Herbest). Middle-East J. Sci. Res., 4(3): 153-157.

[40] Thanonkaew, A., S. Benjakul, W. Visessanguan and E.A. Deckar. (2006). The effect of metal ions on lipid oxidation, colour and physiological properties of cuttlefish (*Sepia pharaonis*) subjected to multiple freeze thaw cycles. Food Chem., 210-219.

[41] Thirunavukkarasu, N. (2005). Biology, nutritional evaluation and utilization of mud crab *Scylla tranquebarica* (Fabricius, 1798). Ph.D. Thesis, Annamalai University, India, p. 126.

[42] Udo Paul Jimmy and Vivian Nneka Arazu. (2012). The proximate and mineral composition of two edible crabs *Callinectes amnicola* and *Uca tangeri* (Crustacea: Decapoda) of the cross river, Nigeria. Pakistan J. Nut., 11 (1): 78-82, 2012.

[43] Varadharajan, D and P. Soundarapandian. (2014). Proximate composition and mineral contents of freshwater crab *Spiralothelphusa hydrodroma* (Herbst, 1794) from Parangipettai, South East Coast of India. J. Aquacult. Res. Develop., 5(2):1-6.

[44] Yannar, Y and M. Celik. (2006). Seasonal amino acid profiles and mineral contents of green tiger shrimp (*Penaeus seminsulcatus* De Haan, 1844) and speckled shrimp (*Metapenaeus monoceros*, Fabricius, 1789) from the eastern Mediterranean. Food Chem., 94: 33-36.