A Review on Heavy Metals Accumulation in Coastal Bivalves used in Seafood Industry: Guide to Safely consumption of Seafood

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Abstract- Bivalve is one of the most nutritionally balanced seafood but is highly correlated with heavy metal toxicity and ultimately causing public health impacts. Several biological and geochemical factors are influencing the uptake and bioaccumulation of heavy metals in bivalves which leads to destroy aquatic ecosystem and becoming risk of food consumption. Cadmium, lead, copper, zinc and mercury are widely reported as trace metals bioaccumulation in bivalves due to industrial wastages and domestic discharges from urbanized areas. Though, a number of studies have performed to identify the presence of heavy metals in different bivalve species, limited researches have exclusively focused on relationship between nutritional composition and available heavy metals in different bivalve species with regards to safe human consumption.

Keywords- Bioaccumulation, Bivalve, Heavy metals, Seafood

I. Introduction

Pollutants are substances that affect the physical, chemical and biological characteristics of biotic and abiotic components of the ecosystem, thereby, posing a threat to biodiversity [16]. In the sequence, heavy metal is a major pollutant in ecosystems that could be lethal to living organisms including humans [23]. Heavy metals are referred as metals which have an atomic weight higher than sodium and a specific gravity more than 5.0 [28]. They are considered as the most important form of pollution in the aquatic environment because of their toxicity and accumulation by marine organisms.

Molluscs are a very diverse invertebrate that is broadly distributed throughout the world. Among the molluscans, bivalves are highlighted due to their economic values in the world export market and also a well-known for seafood products. Depledge and Rainbow (1990) [4] stated on the significance of trace metal levels with regard to the well-being of marine invertebrates and their use in bio monitoring studies. Though, they are highly characterized in seafood industry and environmental sciences, it has some potentials to cause public health issues by the way of transferring concentrated heavy metals in their tissues to human body as a seafood. Thus, the study on heavy metal bioaccumulation in coastal bivalves provide significant information on the potential impact of seafood on public health to minimize health risks.

II. NUTRITIOANAL BENETITS OF BIVALVES

The per capita consumption of seafood is rapidly increasing with the fast growth of world population. In the modern world, people have started giving more priority to their health consciousness, so, in order to fulfill the required nutrients, the consumers are initiated to pay additional attention in taking of seafood in view of its nutritional superiority than all other accessible and available food sources [14]. Nevertheless, lack of research studies have been focused on bivalve with regard to their nutritive value for human consumption.

Idayachandiran *et al.* (2014) [14] reported that the tissue of *D. cuneatus* coastal bivalves contain 80.56% of both essential and nonessential amino acids. The total amino acids composition in *Perna viridis C. madrassensis* and *Meretrix casta* was about 95.76, 98.4 and 65.17% respectively. The results revealed that *D. cuneatus* bivalve meat is a potential source for food value due to high quality protein, as well as balanced essential amino acids. Other than proteins and amino acids, the bivalves are rich with fatty acids profile. The total percentage composition of saturated fatty acids (SFA), mono unsaturated fatty acids (MUFA) and poly unsaturated fatty acids (PUFA) was about 35.93, 14.16 and 34.84 % respectively in *D. cuneatus*. Further, C16:0 and C18:0 were found to be predominant fatty acids in *Mytilus plantensis* [14].

Generally, seafood products provide a significant and healthy part of the human diet because it provides an inexpensive source of easily digestible proteins with a high biological value, essential minerals such as iodine and selenium and vitamins including vitamins A, D and B12 [26]. Additionally, the bivalve muscle contains little saturated fat and significant amount of Vitamin C. They are also a good source of minerals such as calcium (Ca), potassium (K), zinc (Zn), iron (Fe), phosphorus (P) and copper (Cu). However, there must be a safety concern related to the consumption of seafood products due to the presence of a wide variety of chemical contaminants especially heavy metals.

III. IMPORTANCE OF BIVALVES AS BIOINDICATORS

Discharge of untreated domestic sewage primarily from densely populated areas [2], industrial effluents and mining wastes are introduced significant amount of trace metals into marine environment often resulted in vulnerable ecological and environmental degradation [6] [32], ultimately this circumstance become more threatening to the survival of aquatic organisms. As the consequences, natural habitat of aquatic organisms is widely destructed and their natural occurrence of biodiversity is also dramatically getting depleted [5] [18]. The heavy metal concentration of Zn and cadmium (Cd) were reported at the industrial zone in 1147 - 3500 µg/L and 15.2 - 17.9 µg/L individually. This condition was to be possible for induction of synergistic effects on smaller aquatic organisms [27]. Thereby, continuous assessment on monitoring processes of pollution problems in the coastal environment become more essential to protect the incredible natural resources, moreover engage with research activities on distribution of heavy metals in the aquatic ecosystem in environmental pollution.

M. casta has been commonly used to study about bioaccumulation and toxicity of heavy metals [19] [30] and it could also be used as a biological indicator for early detection of pesticide pollution [5]. *M. casta* is the only commercially important bivalve in the western and northwestern part of Sri Lanka [17]. As well these areas are recently undergone to urbanization, thus, detection of heavy metals in *M. casta* bivalve is more important to prevent public health issues.

Bioaccumulation of contaminants from sediments to benthic organisms and their subsequent transfer through the food web provides an exposure pathway to higher-level organisms. Benthic molluscs have proved as useful bio monitors in marine and estuarine ecosystems [21]. Variation of heavy metal concentrations in different bivalve species was assessed in Malaysian coast [35]. However, use of benthic invertebrates for an instance bivalve as bioindicator organisms has several advantages because of their limited mobility and shell size [12]. Nevertheless, it has also some drawbacks such as most of the benthic organism have short life cycles and have a stronger seasonal cycles in abundance and activities [12]. Therefore, the assessment of the levels of heavy metals pollution in bivalves which are used as bioaccumulation indicators has become an important task in preventing risks to public health.

A number of studies have reported that the green mussel (*Perna viridis*) is a potential biomonitoring agent for heavy metals in the aquatic environment [3] [15] [29] [34] and there was a significant correlation between mussel and concentration of mercury (Hg) and Cd in sediment. Sediments are an important source of metals to filter feeders, among mussels and oysters [35]. Soft mussel tissues of *P. viridis* is suitable to be used as a bioindicator for heavy metal contamination due to its natural capacity to accumulate elevated concentration of Hg, lead (Pb) and Cd.

IV. FACTORS INFLUENCE ON HEAVY METALS BIOACCUMULATION

Bivalves have great ability to concentrate heavy metals such as Cd, Pb, Zn and Cu from sea or their found [22]. The mechanism of bioaccumulation of trace metals in bivalves are mainly depend on biological and geochemical factors [1]. Biological factors include age, size, sex, genotype, phenotype, feeding activity, reproductive state and physiological conditions of the animals whereas geochemical influences are different sampling locations, seasonal fluctuations [36], salinity, temperature, pH, sediment grain size, dissolved oxygen, water hardness and hydrological features of the system [9]. However, researchers were failed to detect the biochemical pathways by which trace metals are concentrated in sea water by organisms.

Climatic changes primarily rise of environmental temperature would enhance accumulation of pollutants such as trace metals and pesticides in aquatic organisms. The concentration of Zn (1.92 - 255.16 mg/kg) in bivalves was very high compared to other metals like chromium (Cr), Cd, Pb, Zn and Cu with maximum concentration during pre-monsoon [31]. The similar finding was stated by Eustace, (1974) [10], that accumulation of Zn in mussels and oysters were higher than the permitted limit. High concentrations of Zn, Cu, Fe, manganese (Mn), and Hg in oyster (*Crassostrea madrasensis*) tissues from Cochin harbor indicated that the concentrations were higher during breeding period and also when the salinity is comparatively higher in estuary during October to April [24] [31]. Therefore, researchers have introduced culturing of seafood species which can able to withstand in extreme temperature, salinity and low quality water factors.

Moreover, biological activity which emphasizes the uptake and storage of heavy metals by bivalves have sound relationship with the chemical state of heavy metals in the water because past studies have proved through the experimental studies on the uptake of Pb and Cd in mussels (*Mytilus edulis*) in the sea water while in the natural state [13]. The study has stated that Pb was densely accumulated mainly in kidneys when Pb was available in the form of labile inorganic complex but when Pb was complexed with citrate a drastic increment of the metal was observed in all the tissues and the highest concentration again found in kidneys. Thus, aggregation of heavy metals in bivalves could be controlled by the way of converting the chemical state of heavy metals into either an inactivated form or inaccessible biological form and the effective application of waste water treatment to industrial pollutants before releasing into the sea.

Sevillano-Morales *et al.* (2015) [33] stated that presence of mercury level shows a great variability among marine species by which mercury concentrations were significantly lower in bivalves than other type of marine species though bivalves have filtering diet pattern. Yap *et al.* (2007) [35] mentioned that there is also a strong correlation between uptake and accumulation of trace metals in filter-feeders whereas they accumulate metal concentrations in water. Consequently, the aquatic biodiversity is being destroyed due to often disposal of waste materials into coastal areas. As a result, aquatic living organisms become dangerous and threatening organisms to human being in terms of food.

V. EFFECT OF CONSUMPTION OF SEAFOOD

Jensin and Jernelov, (1969) [18] has reported that hazards to human health are also caused by frequent consumption of seafood due to the high concentration of heavy metals in aquatic environment. Since bivalve molluscs are owned at the top position in aquatic food chain, seafood concentrates high levels of Pb, Hg and Cd like heavy metals in their body [2] [23]. Pregnant women, breast feeding mothers and young children are more vulnerable groups who can easily affected by contaminated food with high toxicity. Thus, the European Food Safety Authority (EFSA) recommends the above-mentioned groups to take account on a different variety of fish species in order to minimize the risk related to Methyl-Hg accumulation to toxic level, but to reduce the predatory fish consumption such as swordfish and tuna as well as seafood products [8].

Pastorelli *et al*., 2012 [26] proved that the mean concentrations of Cd in blue mussel and carpet shell clam were 616 mg/kg and 159 mg/kg respectively. The highest level of Cd concentration was observed in blue mussel and amounted to 70% of the maximum limits established for these seafood species. However, Pb concentration was comparatively lower than Cd in blue mussel that was about 166 mg/kg, despite, blue mussel showed higher Pb concentration than carpet shell clam. Therefore, EFSA and the Food and Agriculture Organization/ World Health Organization (FAO/WHO) Joint Expert Committee on Food Additives (JECFA) are specified the tolerable weekly intakes (TWI) and provisional tolerable weekly intakes (PTWIs) for Cd, Pb and Hg in human consumption.

Lakshmanan and Nambisan (1983) [20] described the ability of *P. viridis* to concentrate considerable quantities of heavy metals like mercury, copper, zinc and lead from the environmental water in their tissues especially in gills. Dumalagan *et al.* (2010) [7] has studied about the presence of trace metals in soft tissues of mussels (*P. viridis*) obtained from selected seafood markets in Manila and reported that highest values were obtained only for copper and lead with of 10.4 mg/kg and 2.3 mg/kg respectively, however, those obtained values are exceeded the Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) [25] guideline for safe human consumption and thus, represents a health risk.

Fang *et al.* (2003) [11] outlined that the recovery rates of heavy metals in South China bivalves with respect to certified reference values which is represented in Table 1. Significant differences ($p<0.05$) were observed between highest and lowest values for each metals in oysters, clams and mussels with regards to different coastal sites in South China. Fang *et al.* (2003) [11] concluded that although Cd and Cr concentrations in the three bivalve species exceed the local regulatory levels, only Cd levels of oysters collected from the western bank of Lingdingyang waters are higher than both the human daily acceptable limits and the local regulatory levels, therefore, proper precaution should be implemented in consuming a large numbers of oysters for extended periods.

Table 1. Certified values of the standard reference material (Standard Oyster Tissue 1566a) and the recovery percentages of different metals.

	Cd	Cu	Zn	Pb	Ni	Cr
Certified values, µg/g dry weight	4.15 ±0.38	66.30 ±4.30	830 ±57	0.37 ±0.01	2.25 ±0.44	1.43 ±0.46
Concentration found, µg/g dry weight	3.94 ±0.13	60.88 ±2.21	807.8 ±14.9	0.37 ±0.64	2.09 ±0.20	1.43 ±0.25
Recovery percentage	94.85 ± 3.1	91.73 ±1.73	96.98 ±1.80	99.40 ±18.4	92.97 ±8.63	100.3 ±17.2

Moreover, *P. viridis* are usually consumed nutrient dissolved in polluted seawater then hazard materials will be accumulated in soft tissues. Putri *et al*. (2011) [29] mentioned that there were no significant differences ($p>0.05$) observed to accumulate heavy metals with respect to their body size. Further, FAO determined that regular intake of human consuming mussels (at 40 µg/100 ml of lead in blood) causes health effect on central nervous system which shows clinical symptoms like fatigue, headache, anemia and paralysis of the nerves. Prolonged exposure may lead to coma, mental retardation and death. Hence, frequent intake of seafood products is not good and recommended for human health. Thus, an awareness program should be performed to the general public regarding the potential hazard associated with consuming metal-contaminate seafood.

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