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# Quality and Safety Determination of Blood Cockle (*Tegillarca granosa*) Meat, Alexandria, Egypt

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**ABSTRACT**

This work was designed to determine the quality and safety of blood cockle (*Tegillarca granosa*) meat. Cockle samples (length and weight 3- 9cm and 25- 37g, respectively) were obtained from El-Madia beach, Alexandria during February and March 2022. The values of the cockle flesh's moisture (81.13%), crude protein (12.39%), fat (1.22%), ash (1.05%) and carbohydrates content (4.21%ww) were determined. The most abundant EAAs were leucine (6.67), phenylalanine+ tyrosine (5.84) and methionine (1.64) g/100g protein. Total SFAs, MUFAs, and PUFAs recorded 52.61%, 21.81%, and 25.5%, respectively. Lipid health indices; ∑ω-3/ω-6, IA, IT and h/H recorded 4.97%, 1.48, 0.58 and 1.09, respectively. Macro minerals; Na, K and Ca recorded 3735.1, 1859.8 and 677.3 ppm, respectively. Chemical pollutants; Pb, Cd, Cr, Co, As and twenty four components of pesticides were detected in flesh samples. However, values of pollutants were under the permissible limits, except for chlorpyrifos (52.8881ppb), recording higher concentration of OCPs than the MPLs (20ppb). In conclusion, based on their values of AAs, FAs, minerals and pollutants, the cockle samples proved their high quality and safety. Therefore, blood cockle have a good source of nutritive value and safety for human consumption, excluding chlorpyrifos component which should be considered since its value was higher than the permissible level.

## INTRODUCTION

Blood cockles have a soft flat-shaped body and a pair of hard shells; they live in intertidal areas. They breathe by two gills and a mantle section and produce the hemoglobin in the blood fluid. Moreover, they are very profitable for not requiring high skills, adding to their accessibility to marketing and export **(Harith *et al.*, 2016; Yulinda *et al.*, 2020)**. There are 8,000 blood cockles' species in the world, and they are consumed as raw, boiled, steamed, fried, baked and as a snack **(Yurimoto *et al.*, 2014)**. Fresh, frozen, or processed cockles (*Tegillarca granosa*) are very popular edible shellfish and available in Korea markets. Its reproductive cycle could be divided into five stages; March to May for early stage, April to June for late active stage, May to July for ripe

stage, July to August for spent stage, September to March for recovery as well as a resting stage. There are several factors; environmental issue, smuggling and overharvesting and low food availability in culture areas that led to seed and adult cockle mortalities **(Kim *et al.*, 2009; Peng *et al.*, 2021)**. Although bivalve molluscs have low fat content, they have nutraceutical value for human health for containing monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) such as EPA (C20:5n-3) and DHA (C22:6n-3) **(Taylor & Savage, 2006; Martinez-Pita *et al.*, 2012; Grienke *et al.*, 2014)**. With regard to the effect of chemical pollutants on safety of cockle, the concentrations of metals in the cockle *Anadara granosa* **(Linnaeus, 1758**) ranged from 0.11- 0.82ppm for Cd, 0.10- 0.54ppm for Pb, 10.22- 19.04ppm for Zn, 0.02- 1.47ppm for Hg, 1.79- 4.76ppm for Cu and 1.64- 3.79ppm for Cr **(Soegianto *et al.*, 2020)**. Additionally, the levels of heavy metals in the *A. granosa* flesh were as follows: Pb (0.118- 0.138ppm), Cd (0.074- 0.077ppm) and Hg (0.140- 0.163ppm). However, these cockles are suitabile for human consumption **(Riza *et al.*, 2021)**. Concerning pesticides residues, **Mukhtar *et al.* (2020)** found that the levels of booster biocides in the major blood cockle (*T. granosa*) recorded 98.92ppb for *Irgarol*, 1051, 40.31ppb for diuron and its metabolites, respectively, 41.42ppb for 3,4-dichloroaniline (3,4-DCA) and 29.76ppb for chlorothalonil. Therefore, this study was performed to determine the quality and safety of blood cockle (*Tegillarca granosa*) flesh collected from El-Madia beach, Alexandria during February and March 2022.

## MATERIALS AND METHODS

### Blood cockle samples

Live blood cockle (*Tegillarca granosa*) samples were collected from El-Madia beach, Alexandria during February and March 2022. Cockles (length and weight ranged from 3- 9cm and 25- 37g, respectively) were preserved in an icebox containing crushed ice and transported to the Fish Processing Technology Lab., th National Institute of Oceanography and Fisheries (NIOF), Egypt. Afterward, they were washed with tap water and manually shucked to remove the shells. The flesh was washed, drained, packed in polyethylene bags and frozen at -18$^{o}$C until further analysis.

### Analytical methods

#### *Proximate composition*

Chemical composition **(AOAC, 2005)** of cockle flesh was determined. Moisture content was determined by drying the samples until a constant weight was obtained using a drying oven (Unitemp laboratory oven, Greenfield-Oldham, England) at 105±2$^{o}$C. Total protein (TN×6.25) was determined by Micro-Kjeldahl method. Crude fat was determined by Soxhleat using petroleum ether 40-60$^{o}$C. Ash content was assessed using an electric Muffle Furnace at 550$^{o}$C until a constant weight was obtained. The carbohydrate content was estimated by subtracting the sum of percentage of moisture, crude fat, crude protein and ash contents from 100.

***Amino acids (AAs) composition***

Total amino acids (TAAs) were determined according to the methods of **Campanellal *et al.* (2002)** as follows: 100mg of the sample was mixed with 5mL H2O and 5mL of 6 M HCl and then heated at 120$^{o}$C for 24h and filtered. Finally, 1mL of the filtrate was injected to HPLC (An Agilent 1260 series). The separation was carried out using Eclipse Plus C18 column (4.6mm×150mm i.d., 3.5µm). The mobile phase consisted of buffer sodium phosphate buffer pH 7.8 (A) and ACN:MeOH:H2O 45:45:10 (B) at a flow rate 0.64ml/ min. The mobile phase was consecutively programmed in a linear gradient (Table 1) as follows:

**Table 1.** The consecutively programmed mobile phase in a linear gradient

| **Time (Min)** | **0.0** | **0.5** | **20** | **20.1** | **23.5** | **23.6** | **25** |
|---|---|---|---|---|---|---|---|
| A % | 98 | 98 | 43 | 0.0 | 0.0 | 98 | 98 |
| B % | 2 | 2 | 57 | 100 | 100 | 2 | 2 |

A: Buffer sodium phosphate buffer; pH 7.8; B: 45; ACN: 45; MeOH: 10 $H_2O$.

The DAD was monitored at 338nm (Bandwidth 10nm). The fluorescence indicator was adjusted as the following: From 0- 17min at 340/ 450nm (Excitation/Emission) and from 17- 25min at 266/ 305 (Excitation/Emission). The column temperature was maintained at 40°C. The results obtained were expressed as g/100g protein (DW).

***Fatty acids (FAs) composition***

Preparation of fatty acid methyl esters from crude lipids was performed according to the procedure of **Radwan (1978)**. A sample of total lipids (50mg) was transferred into screw-cap vial; 2ml of benzene and 10ml 1% sulphuric acid ($H_2SO_4$) in absolute methanol were added. The vial covered under stream of nitrogen gas before heating in an oven at 90ºC for 90min. Ten ml of distilled water was extracted with 5ml of petroleum ether thrice. The three petroleum ether extracts were combined and concentrated to its minimum volume by using steam of nitrogen. Gas chromatographic analysis was carried out using ACME model 6100 GC (Young LIN Instrument Co., Korea) fitted with a split injector and FID detector. Nitrogen was used as the carrier gas with a flow rate of 0.5 ml/ min. The components were separated on 30m SP-2380 fused-silica capillary column with 0.25mm i.d. and 0.2µm film thicknesses (Supelco, Bellefonte, PA), and the detector temperature was set at 260°C. The injector temperature was set at 220ºC and in split mode (split ratio 1:50). The column was initially maintained at 140ºC for 5min, and the temperature was subsequently increased to 240ºC at a rate of 4ºC/ min. A standard mixture of methyl esters was analyzed under identical conditions prior to running the samples. The retention time of the unknown samples of methyl esters were compared to those of standard. The relative percentage of area was obtained by using the following

equation:
Area (%) = FAX =AX /AR × 100
Where: FAX= Fatty acid to be quantified;
AX= Area of the methyl esters, and
AR= Total area of the chromatogram.

**Indices of atherogenic (IA), thrombogenic (IT), and hypocholesterolemic/ hypercholesterolemic (h/H)**

The indices of atherogenicity (IA) and thrombogenicity (IT) contents were calculated **(Ulbricht & Southgate, 1991)** based on the sample's fatty acids of *T.granosa* according to the following equations:

$IA = [12:0 + (4 \times 14:0) + 16:0]/ [\Sigma MUFA + \Sigma PUFA\ (n-6) + (n-3)]$

$IT = (14:0 + 16:0 + 18:0) / [(0.5 \times \Sigma MUFA) + (0.5 \times \Sigma PUFA\ (n-6)) + (3 \times \Sigma PUFA\ (n-3)) + (n-3)] / (n-6).$

The hypocholesterolemic/hypercholesterolemic index **(Santos-Silva *et al.*, 2002)** of the **T.granosa** sample was calculated as follows:

$h/H = (18:1n-9 + 18:2n-6 + 20:4n-6 + 18:3n-3 + 20:5n-3 + 22:5n-3 + 22:6n-3)/ (14:0 + 16:0).$

***Minerals composition***

Major, micro and heavy metals; Na, Ca, K, Cu, Fe, Mn, Zn, Se, Cr, Co, Pb, Cd and As were determined by ICP-ES Agilent 5100 VDV according to standard methods (**US EPA method 200.7** and US EPA Method 6010 C) in ICP-OES Lab., Institute of Graduate Studies and Research (IGSR) Alex. One gram powder of blood cockle flesh was taken and 10ml Nitric acid (65% conc.), 2ml of H2O2 and 1ml of deionized water were added and then digested by hot plate till a clear color was obtained. Clear samples were filtered using Whatman No. 42 filter paper and made up to 25ml measuring flask with deionized water. The results were expressed as ppm.

***Pesticide residues***

Twenty-three organochlorine pesticides residues (OCPs) were determined as reported by **Koc and Karakus (2011)** using TSQ 8000 GC/MS. The results were expressed as ppb.

**Statistical analysis**

The results obtained were expressed as mean and standard deviation (Mean ± SD).

## RESULTS AND DISCUSSION

### 1. Morphometric measurements

Table (2) shows the morphometric measurements of blood cockle (*Tegillarca granosa*) samples. The data showed that blood cockle samples have 3- 9cm length, 27-35 units/ kilogram, 22- 25% flesh, 59-62% shells and 10-13% blood. It is well known that,

the blood cockle (*Tegillarca granosa*) has played a major role in economic importance in Malaysia since 1948. Variation in the morphometric measurements in this study is due to several factors, such as environmental conditions, species, season, stage of reproductive cycle, age and food content **(Yurimoto *et al.*, 2014; Peng *et al.*, 2021)**.

**Table 2.** Morphometric of blood cockle (*T. granosa*).

| Characteristic | Range |
|---|---|
| Total length(cm) | 3 - 9 |
| Units of kilogram | 27 - 35 |
| Yield of flesh (%) | 22 - 25 |
| Yield of shell (%) | 59 - 62 |
| Yield of Blood (%) | 10 - 13 |

**2. Proximate composition**

The proximate composition (ww) of blood cockle (*T. granosa*) flesh contained moisture 81.13%, crude protein 12.39%, fat 1.22%, ash 1.05% and carbohydrates content 4.21%, as shown in Table (3). Except the ash content, these results agree with those of **Okumuş and Stirling (1998**) who showed that, the chemical composition (ww) of cockle flesh ranged from 11.7– 13.9%; protein, 1.1– 2.5%; lipids and 1.6–2.7% ash content. Moreover, the most dominant component was protein content, followed by carbohydrates content **(Mirsadeghi *et al.*, 2011, 2013)**. **Hamza (2022)** found that, fresh spider conch (*Lambis lambis*) meat contained 79.20% moisture, 11.66% protein, 1.49% lipids, 2.05% ash and 3.30% carbohydrates.

**Table 3.** Proximate composition of blood cockle (*T. granosa*) flesh

| Constituent (%) | Wet weight (WW) | Dry weight (DW) |
|---|---|---|
| Moisture content | 81.13±0.31 | - |
| Dry matter | - | 18.70±0.06 |
| Crude Protein | 12.39±0.14 | 65.21±0.74 |
| Total lipids | 1.22±0.14 | 6.39±0.76 |
| Ash | 1.05±0.09 | 5.58±0.38 |
| *Total carbohydrates | 4.21±0.22 | 22.82±0.55 |

Data (n=3) are expressed as mean ± SD, *Total carbohydrates were calculated by differences.

However, deducting carbohydrates, our results disagree with those of **Leiwakabessya and Lewerissa (2017**) who showed that, the chemical composition of *Strombus luhuanus* flesh were 72.52- 73.42% water content, 17.45- 17.94% protein, 1.25- 1.41% fat, 2.65- 4.57% ash and 4.21- 4.58% carbohydrate, while the corresponding values for *lambis lambis* were 77.20- 77.90%, 15.52- 16.97%, 1.23- 1.29%, 2.84- 1.68% and 3.21- 2.16%, respectively. In addition, protein content (65.21%, DW) of *T.granosa*

was lower than that recorded in the study of **Tabakaeva *et al.* (2018**) who found that, the protein of *Andara broughtonii* was 68% (DW). Additionally, **Moniruzzaman *et al.* (2021)** found that the moisture, protein, lipid, ash and carbohydrates content of *Andara granosa* were 88.8%, 8.44%, 0.36%, 1.47% and 0.91% (DW). This variation in composition is attributed to the variety in species, seasonal condition, water temperature, food intake and geographical locality **(Almonacid *et al.* 2014; Irisarri *et al.*, 2015; Chakraborty *et al.*, 2016; Tri Nguyen *et al.*, 2017**; **Zhu *et al.*, 2018)**.

### *2.1. Amino acids (AAs) composition*

Amino acids composition (g/100g protein) of blood cockles (*T. granosa*) flesh is presented in Table (4). Data showed that *T. granosa* flesh contained 9 essential amino acids (EAAs) (tryptophan was not determined) and 7 non-essential amino acids (NEAAs). Total of EAAs and NEAAs recorded 23.32 and 28.16g/ 100g protein, respectively.

**Table 4.** Amino acid composition (g/100g protein) of blood cockles (*T. granosa*) flesh

| **Essential amino acids (EAAs)** | ***T. granosa* flesh** | | ***FAO pattern requirements** | **Non-essential amino acids (NEAAs)** | |
|---|---|---|---|---|---|
| Isoleucine | 2.21 | | 3 | Aspartic acid | 4.82 |
| Leucine | 6.67 | | 5.90 | Glutamic acid | 9.77 |
| Lysine | 3.41 | | 4.50 | Glycine | 1.16 |
| Methionine | 1.64 | | 1.60 | Alanine | 4.66 |
| Phenylalanine | 2.99 | 5.84 | 3.80 | Arginine | 5.74 |
| Tyrosine | 2.85 | | | Proline | 0.04 |
| Histidine | 0.97 | | 1.50 | Serine | 1.97 |
| Threonine | 1.57 | | 2.30 | | |
| Valine | 1.01 | | 3.90 | Total NEAAs | 28.16 |
| Tryptophan | *ND | | 0.6 | | |
| Total EAAs | 23.32 | | 27.10 | | |

* **FAO/WHO/UNU (2002)**, *ND =Not determined

The most abundant EAAs were leucine (6.67), phenylalanine+ tyrosine (5.84) and methionine (1.64), compared to pattern requirements **(FAO/WHO/UNU, 2002**). On the other side, high values of NEAAs were found in glutamic (9.77), followed by arginine (5.74) and aspartic (4.82) g/100g protein. **Tri Nguyen *et al.* (2017**) found that taurine, glutamic, lysine and arginine were the most abundant amino acids in the amino acid profiles. While, **Hossen *et al.* (2014)** reported that, blood cockle have a high nutritional value and contains high levels of essential amino acids. Our results are in accordance with those of **Leiwakabessya and Lewerissa (2017**) who postulated that, the amino acids composition of *S. luhuanus* and *L. lambis* flesh consisted of 15 AAs in which nine

were essential amino acids and the other six were non-essential amino acids. Glutamic acid showed a high percentage and the highest was found in flesh of *L. lambis*, while the lowest percentage was histidine.

In addition, **Moniruzzaman *et al.* (2021)** found that glutamic was highly present in the mollusc species. However, **Tabakaeva *et al.* (2018)** postulated that, *Andara broughtonii* contained high levels of amino acids, viz. glycine, glutamic, aspartic, alanine, leucine, Lysine and arginine. Moreover, **Moniruzzaman *et al.* (2021)** found that, AAs composition of *A. granosa* varied, compared to the results of this study. Additionally, **Hamza (2022)** found that, the total EAAs and NEAAs of fresh spider conch (*Lambis lambis*) meat were 25.29 and 40.01mg/100g, respectively. The amino acid composition of bivalve varies depending on species, size, seasonal conditions and geographical location (**Yurimoto *et al.*, 2014; Peng *et al.*, 2021**).

### *2.2. Fatty acid composition*

Table (5) demonstrates fatty acid composition (%FAs) of blood cockle (*T. granosa*) flesh. Results showed that, total saturated fatty acids (SFAs), monounsaturated FAs (MUFAs), polyunsaturated FAs (PUFAs) and others recorded 52.61%, 21.81%, 25.5% and 0.08%, respectively. The major dominant FAs were C16:0 (28.79%), C18:1 ω- 9c (16.77%) and C20:5 ω-3 (13.98%) of SFAs, MUFAs and PUFAs, respectively while the lowest FAs were C10:0 (0.67%), C22:1 ω- 9 (0.92%) and C18:3 ω-3 (0.75%), respectively. Our results agree with those of **Hossen *et al.* (2014)** who noted that blood cockle is a source of unsaturated fats (omega 3). Moreover, **Moniruzzaman *et al.* (2021)** found that, the total SFAs, MUSFAs and PUSFAs of *A. granosa* were 53.7, 33.6 and 12.7%, respectively. On the other hand, our results for FAs composition disagree with those reported in the study of **Tri Nguyen *et al.* (2017**) who showed that, n-3 PUFA was the major fatty acids (28.7–37.0% of total FAs, which was predominantly DHA and EPA (7.9–17.4%). Furthermore, **Hamza (2022)** detected that, the total SFAs and USFAs of fresh spider conch (*Lambis lambis*) meat recorded values of 24.29 and 60.12, respectively.

**Table 5. Fatty acids (FAs) composition (% of total FAs) of blood cockle (*T. granosa*) flesh**

| FA | % | FA | % | FA | % |
|---|---|---|---|---|---|
| *STFAs | | **MUFAs | | ***PUFAs | |
| C10:0 | 0.67 | C16:1 ω- 9c | 4.12 | C18:2 ω-6c | 4.27 |
| C12:0 | 0.96 | C18:1 ω- 9c | 16.77 | C18:3 ω-3 | 0.75 |
| C14:0 | 10.02 | C22:1 ω- 9 | 0.92 | C20:5 ω-3 | 13.98 |
| C16:0 | 28.79 | | | C22:6 ω-3 | 6.50 |
| C18:0 | 8.33 | | | | |
| C20:0 | 2.63 | ∑ MUFAs | 21.81 | ∑ PUFAs | 25.50 |
| C22:0 | 1.21 | | | | |
| ∑ STFAs | 52.61 | | | | |

*SFAs: Saturated fatty acids, **MUFAs: Monounsaturated fatty acids, ***PUFAs: Polyunsaturated fatty acids.

Lipid health indices of fatty acids of blood cockle (*T. granosa*) flesh are presented in Table (6). The ratio of SFA: UFA recorded 1.11, ∑PUFA- ω-3 was higher than ω-6. ∑ω-3/ ω-6 was 4.97%, DHA/EPA and PUFA/SFA recorded 0.46 and 0.49%, respectively. These results are higher than those reported by **Moniruzzaman *et al.* (2021)** who found that, ∑PUFAs- ω-3 and ∑PUFAs- ω-6 of *A. granosa* recorded 8.9 and 2.5, respectively. The ratio of n-6: n-3 FAs is reflected in an index for human and animal health development on coronary heart disease, cancer and autoimmune diseases by evaluating the nutritional value of a dietary lipid **(Simopoulos, 2002**; **Calder, 2006)**. In this work, the results coincide with those of the **WHO (2013**), where the ratio between n-6 and n-3 should not exceed <5:1. In Table (6), the values of LA, IT and h/H were 1.48, 0.58 and 1.09, respectively. Our results are higher than the values of ω-3/ω-6 (3.6) and lower than values of IA (1.74) and IT (1.1) of *A. granosa* as reported by **Moniruzzaman *et al.* (2021)**. Values of IA and IT for the mollusc species concur with results for marine oyster and freshwater snail species **(Chakraborty *et al.*, 2016; Ghosh *et al.*, 2017)**. High levels of IA and IT can cause a cardiovascular disease in human (**Bobe *et al.*, 2004 and Moniruzzaman *et al.*, 2021)**. Nowadays, the ratio of SFAs:USFAs and ω-6:ω-3 of fresh spider conch (*Lambis lambis*) meat recorded 0.40:1 and 2.08:1, respectively (**Hamza, 2022)**.

**Table 6.** Lipid health indices of fatty acids of blood cockle (*T. granosa*) flesh.

| Index | Value | Index | Value | Index | Value |
|---|---|---|---|---|---|
| (SFAs): UFAs) | 1.11 | ∑ω-3/ω-6 | 4.97 | IA | 1.48 |
| ∑PUFAs- ω-3 | 21.23% | DHA/EPA | 0.46 | IT | 0.58 |
| ∑PUFAs- ω-6 | 4.27% | PUFA/SFA | 0.49 | h/H | 1.09 |

EPA: Eicosapentaenoic acid, DHA: Docosahexaenoic acid, IA: Index of atherogenicity, IT: Index of thrombogenicity, h/H: Index of hypocholesterolemic/hypercholesterolemic.

### 2.3. Minerals composition

Mineral composition (ppm) of blood cockle (*T. granosa*) flesh is presented in Table 7. Values of macro minerals recorded Na, K and Ca for cockle flesh recorded 3735.1, 1859.8 and 677.3ppm, respectively while micro minerals recorded Fe 73.7, Cu 1.31, Mn 4.20, Zn 30.9 and Se 0.20 ppm. **Hossen *et al.* (2014)** showed that blood cockle contains minerals, especially calcium, phosphorus, iron, iodine and zinc. Deficiency in minerals can cause biochemical, structural and functional pathological changes **(WHO, 2013)**. Minerals added significant elements of hormones, enzymes and enzyme activators in human nutrition. Na, K, Mg, Ca, Fe, P and S have significant role in human nutrition **(USDA, 2003)**. In this work, data varied than those reported by **Sohail *et al.* (2016)** who found that, the macro minerals for freshwater mussels (*Anodonta anatina*) had a high concentration of Ca (46838 ppm), Na (2706 ppm), P (6921 mg/kg) and Mn (7207 ppm). Moreover, our results are lower than those reported by **Hamza (2022)**; fresh spider conch (*Lambis lambis*) meat contained 20898.33ppm for Na, 10098.33 ppm for K, 6000ppm for

Ca, 93.70 ppm for Fe, 15.43ppm for Zn, and 15.50ppm for Cu. This variation in minerals composition is due to species, age, season, feed intake, environmental conditions.

**Table 7.** Minerals composition (ppm) of blood cockle (*T. granosa*) flesh

| Element | Concentration (ppm) | Element | Concentration (ppm) |
|---|---|---|---|
| **Macro minerals** | | **Micro minerals** | |
| Na | 3735.1±2.8 | Fe | 73.7±0.06 |
| K | 1859.8±1.40 | Cu | 1.31±0.001 |
| | | Mn | 4.20±0.01 |
| Ca | 677.3±0.51 | Zn | 30.9±0.02 |
| | | Se | 0.20±0.00 |

Blood cockle is a source of minerals, especially Ca, P, Fe, I and Zn (**Hossen *et al.*, 2014)**. Nowadays, **Moniruzzaman *et al.* (2021)** revealed that both of the marine and freshwater mussels and snails are good sources of minerals. In this work, the results of Zn nd Cu were disagreed with those reported by **Soegianto *et al.* (2020)**; they found that the levels of Zn and Cu in *Anadara granosa* ranged from 10.22-19.04 and 1.79 to 4.76 ppm, respectively.

## 3. Chemical pollutants

### 3.1. Heavy metals

Heavy metal tendency have different capacities to filter or accumulate heavy metals of different species of oyster and mussel (**Reinfelder *et al.*, 1997**). Also, bivalves as indicators of heavy metal pollution since seasonality could affect the absorption of heavy metals (**Abdel-Wahab *et al.*, 2022**). Concentrations Pb, Cd, Cr, Co and As recorded 0.11, 0.21, 2.72, 2.72 and 1.45 ppm as shown in Table 8.

Table 8. Heavy metals concentrations of blood cockle (*T. granosa*) flesh.

| Heavy metals | Concentrations (ppm) | *MPLs |
|---|---|---|
| Lead (Pb) | 0. 11±0.000 | 2.0 |
| Cadmium (Cd) | 0. 21±0.000 | 0.5 |
| Chromium (Cr) | 2.72±0.002 | 1 |
| Cobalt (Co) | 2.70±0.002 | - |
| Arsenic (As) | 1.45±0.01 | - |

*MPLs: Maximum Permissible levels, **EOS (2005), and FAO/WHO (1989)**

These results were lower than permissible limits reported by **EOS (2005),** and **FAO/WHO (1989)** and agreement with those reported by **Riza *et al.* (2021)** who found that the values of heavy metal in *A. granosa* flesh were still far below the thresholds,

demonstrating the *A. granosa* suitability for human consumption. Chromium (Cr) bioaccumulation of marine molluscs was usually lower than the freshwater (**Boening, 1999**). Cr level (2.72ppm) is higher than reported by **Benard *et al.* (2020)** who found that Cr concentration in *Crassostrea virginica* recorded 0.008–0.010 ppm. Our results are lower except Co (<0.001ppm) than those reported by **Hamza (2022)**; fresh spider conch (*Lambis lambis*) contained 13.40ppm for Pb, 46.70ppm for As. Our results agree with those findings by **Soegianto *et al.* (2020**) who reported that the concentrations of metals in *A. granosa* ranged from 0.11-0.82 ppm for Cd, 0.10-0.54 ppm for Pb and 1.64 to 3.79 ppm for Cr. Also, the levels of heavy metals in the *A. granosa* flesh recorded Pb (0.118-0.138ppm), Cd (0.074-0.077ppm) however, these cockles were suitability for human consumption (**Riza *et al.*, 2021**).

### 3.2. Pesticides residues

Concentrations (ppb, ww) of organochlorine pesticides (OCPs), organophosphorus (OPPs), synthetic pyrethroid (SP) and fungicide in the blood cockle (*T. granosa*) flesh are exhibited in Table 9. Results showed that 15 components of OCPs, 6 OPPs, 2 SP and only one component of fungicides were recorded in investigated cockle samples. The values of Σ DDT, Σ HCH, Σ Endosulfan, Σ Aldrin, Σ Heptachlor and endrin-N were 1.238, 1.985, 5.379, 0.757, 1.726 and 2.030 ppb, respectively. However, all concentrations of OCPs and SP which contained flesh of investigated samples were highly lower than the maximum permissible limits (MPLs 300 ppb) as recommended by **EPA (2007); FAO/WHO (2007)**; **FDA (2020).** Concerning OPPs, their concentrations were lower than MPLs except the chlorpyrifos (52.8881ppb) higher than permissible limit (20 ppb). Our results of chlorothalonil are lower than those reported by **Mukhtar *et al.* (2020**), they found that the chlorothalonil in the major blood cockle (*T. granosa*) was 29.76ppb.

Table 9. Concentrations (ppb, ww) of pesticides residues of blood cockle (*T. granosa*) flesh.

| Component | Concentrations (ppb) | *MPLs (ppb) |
|---|---|---|
| **Organochlorine pesticides (OCPs)** | | |
| 4,4-DDD_N | 0.773 | |
| 4,4'-DDT | 0.301 | 5000 |
| 4,4DDE_N | 0.164 | |
| Σ DDT | 1.238 | |
| Alpha-BHC_N | 0.494 | |
| Beta-BHC_N | 0.051 | |
| Delta-BHC_N | 0.300 | 300 |
| Gama-BHC_N | 1.140 | |
| Σ HCH | 1.985 | |
| Endosulfan_1_N | 2.773 | |
| Endosulfan_11_N | 0.439 | 300 |
| Endosulfan_sulfate_N | 2.167 | |
| Σ Endosulfan | 5.379 | |
| Aldrin_N | 0.423 | |
| Dialdrin_N | 0.334 | 300 |
| Σ Aldrin | 0.757 | |
| Heptachlor_N | 0.519 | |
| Heptachlor_epoxide_N | 1.107 | 300 |
| Σ Heptachlor | 1.726 | |
| Endrin_N | 2.030 | 300 |
| **Organophosphorus (OPPs)** | | |
| Malathion | 1.9883 | - |
| Chlorpyrifos | 52.8881 | 20 |
| Fenpropathrin | 4.0846 | 10 |
| Chlorothalonil | 4.3506 | 20 |
| Diazinon | 7.1150 | 2000 |
| Ethoprophos | 4.1480 | 10 |
| **Synthetic pyrothroid (SP)** | | |
| Lambda-cyhalothrin | 5.3374 | 3000 |
| Fenpropathrin | 4.0846 | 10 |
| **Fungicides** | | |
| Metalaxyl | 1.7115 | - |

*MPLs: Maximum permissible limits (**EPA, 2007; FAO/WHO, 2007; FDA, 2020)**.

## CONCLUSION

Based on these data, blood cockle samples have a high quality and safety according to their containing of AAs, Fat, minerals and chemical pollutants values which were under permissible limits exception chlorpyrifos (52.8881ppb) was higher concentration of OPPs than the MPLs (20 ppb). This study recommends that blood cockle is considered a good source for human consumption especially after technological treatment to reduce the limits of chemical pollutants.

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