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Mineral contents of selected marine fish and shellfish from the west coast of Peninsular Malaysia

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Abstract

The study was conducted to determine the mineral contents of 20 species of marine fish and 4 species of shellfish from the west coast of Peninsular Malaysia.Overall, the contents of micro minerals in all samples were below the permissible limits; except for oyster; with copper slightly higher than the limit set by FAO/WHO (1984), but below the limit set by Malaysian Food Regulations (1985); and zinc content higher than the limit set by Malaysian Food Regulations (1985), but below the limit set by FAO/WHO (1984). Meanwhile for macro minerals, most samples contained comparable sodium contents, significantly lower of potassium contents, higher calcium contents, and extremely higher of magnesium contents compared to the common ranges reported in the literatures. All samples were good sources of micro and macro minerals and could provide multi-health benefits if consumed in recommended amounts.

Introduction

Minerals present in food can be essential, non-essential or toxic to human consumption. Minerals such as iron, copper, zinc and manganese are essential and play important roles in biological systems. Meanwhile, mercury, lead and cadmium are toxic, even in trace amounts. However, essential minerals can also produce toxic effects at high concentrations (Sivaperumal *et al*., 2007).

Marine foods are very rich sources of various mineral components. The total content of minerals in raw flesh of marine fish and invertebrates is in the range of 0.6–1.5% of wet weight (Sikorski *et al*., 1990). However, variation in mineral composition of marine foods can occur due to seasonal and biological differences (species, size, dark/white muscle, age, sex and sexual maturity), area of catch, processing method, food source and environmental conditions (water chemistry, salinity, temperature and contaminant) (Rodrigo *et al*., 1998; Alasalvar *et al*., 2002; Turhan *et al*., 2004).

There were only a few previous studies focusing on the mineral content of local fish and shellfish.One recent study by Irwandi and Farida (2009) reported mineral and heavy metal contents of marine fin fish in Langkawi Island. Meanwhile, Agusa *et al*. (2005) studied 21 different trace elements in 12 different species of fish collected from different markets in Malaysia.The Nutrient Composition of Malaysian Foods also provided some mineral content database for certain species of fish and shellfish.However, it was found that these mineral content data were still very limited, in which most of the studies only focused on certain specific species, covered only a few different minerals, and involved only certain specific areas in the country. More studies need to be performed to provide consumers with more complete mineral content data of local fish and shellfish.

Therefore, this study was aimed to update on some existing data, and also to produce new data on mineral composition of local fish and shellfish. The west coast of Peninsular Malaysia was chosen as the location of study due to logistic reasons. This region is also the main contributors of marine landings production as compared to east coast of Peninsular Malaysia, Sabah, Sarawak and Federal Territory of Labuan; with the percentage of 50.16% of the total

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marine landings production of Malaysia and 67.34% of the marine landings production of peninsular areas (Department of Fisheries Malaysia, 2007).The significance of this study is to produce representative mineral content data,which include cobalt, copper, iron, manganese, zinc, sodium, potassium, calcium and magnesiumof local marine fish and shellfish.

Materials and Methods

Sampling method

A stratified random sampling procedure was used as it was the most suitable method in database work (Greenfield and Southgate, 2003). To ensure representativeness, ten fish landing areas along the west coast of Peninsular Malaysia were identified with the help of Lembaga Kemajuan Ikan Malaysia (LKIM). The locations are marked as L1 through L10, respectively (Figure 1).

At each of the collection sites, available samples were collected randomly according to species. All samples were fresh fish and shellfish caught within the period of 0 to 36 hours. All samples were immediately dipped in ice, kept and transported in polystyrene boxes to sustain freshness. Upon arrival at Universiti Putra Malaysia, the temperature of ice boxes were checked to ensure that they were still within the range of -4°C to 0°C. Then, fish and shellfish for nutrient determination were individually measured for total body weight and length. Only samples with weight within the narrow range for each species were included as primary samples (Table 1). Then, the samples were beheaded, gutted, washed and filleted. These primary samples were packed in sealed plastic bags and frozen at -20˚C.

A pilot study that was performed independently showed insignificant differences in mineral contents of samples from different locations. This justify that the units of samples (primary samples) can be combined or composited by geographical locations as appropriate to minimize the number of analytical measurements and yet represent the contribution of that unit to the estimate of central tendency (Greenfield and Southgate, 2003). Thus, before analysis, three composite samples were prepared where same weight of samples (whole fillet) from L1, L2, L3 and L4 were mixed well as Composite 1; L5,L6 and L7 as Composite 2; while L8, L9 and L10 as Composite 3; for each species of samples (Figure 1). All composite samples were analysed separately and the data presented are the mean values of each of the species.

Mineral elements analysis

The preparation of samples for mineral elements analysis followed a method described by AOAC (1990). Approximately 5 g of sample was weighed into acid-washed crucible and dried in oven 105˚C for one day. Dried samples were then digested in furnace oven at 550˚C overnight. The ash was digested in 5ml of 65% nitric acid (HNO3) (Analar Grade) by boiling for about two minutes and cooling to room temperature. The cooled solution was filtered through Whatman filter paper (No. 41) and made up to 25 ml with 65% nitric acid (AOAC, 1990). Ten ml were transferred into 15 ml polypropylene test tube for injection into inductively-coupled plasma-optical

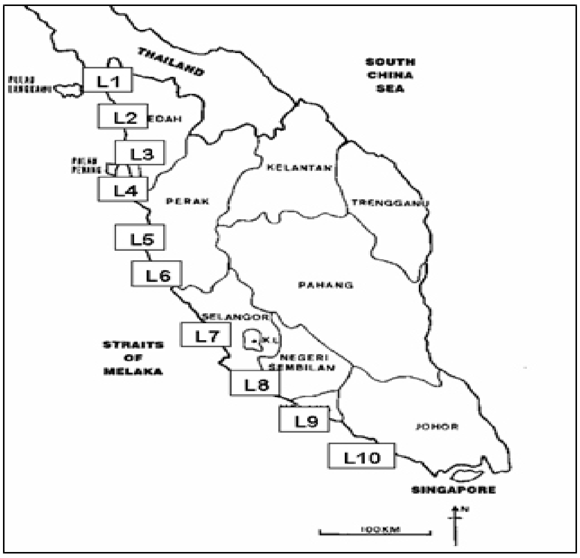

Figure 1. Location of samples collection sites

Table 1. List of samples with narrow range of weight and length

Common name	Local name	Scientific name	Habitat	Range of weight (g)	Range of length (cm)
Black pomfret	Bawal hitam	*Parastromateus niger*	Pelagic	780-1040	33-42
Silver pomfret	Bawal putih	*Pampus argentus*	Pelagic	100-200	15-25
Hardtail scad	Cencaru	*Megalapsis cordyla*	Pelagic	100-250	21-28
Golden snapper	Jenahak	*Lutjanus johnii*	Demersal	490-510	30-35
Indian mackarel	Kembung	*Rastrelliger kanagurta*	Pelagic	50-100	14-20
Sixbar grouper	Kerapu	*Epinephulussexfasciatus*	Demersal	480-750	33-36
Japanese threadfin bream	Kerisi	*Nemipterusjaponicus*	Demersal	100-230	18-25
Indian threadfin	Kurau	*Polynemusindicus*	Demersal	350-1450	36-59
Malabar red snapper	Merah	*Lutjanus argentimeculatus*	Demersal	580-760	28-37
Moonfish	Nyior-nyior	*Trachinotus blochii*	Demersal	400-1400	31-47
Dorab wolfherring	Parang	*Chirocentrus dorab*	Pelagic	200-900	40-71
Long-tailed butterfly ray	Pari	*Gymnura spp.*	Demersal	1300-1700	32-36
Large-scale tongue sole	Sebelah/Lidah	*Cynoglossusarel*	Demersal	50-100	24-32
Yellowstripe scad	Selarkuning	*Selaroidesleptolepis*	Pelagic	50-100	16-20
Gray eel-catfish	Sembilang	*Plotosus spp.*	Demersal	350-600	40-50
Fourfinger threadfin	Senangin	*Eleutheronematetradactylum*	Pelagic	150-300	27-32
Giant seaperch	Siakap	*Latescalcarifer*	Demersal	700-1000	38-42
Fringescale sardinella	Tamban	*Clupea fimbriata*	Pelagic	20-40	13-17
Spanish mackarel	Tenggiripapan	*Scromberomorusguttatus*	Pelagic	200-450	30-42
Longtail shad	Terubuk	*Hilsa macrura*	Pelagic	928	40-45
Cuttlefish	Sotong	*Sepia officinalis*	-	20-45	12-18
Prawn	Udangputih	*Metapenaeusaffinis*	-	10-20	12-17
Cockles	Kerang	*Anadara granosa*	-	10-20	2-5
Oyster	Tiram	*Ostrea spp.*	-	100-300	14-48

Table 2. Micro minerals content of samples

Samples	Micro minerals (ug/100g wet sample, mean ± SD)				
	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Manganase (Mn)	Zinc (Zn)
Black pomfret	0.57 ± 0.00[ab]	54.25 ± 0.06[ab]	897.47 ± 5.52[a]	15.74 ± 0.03[a]	288.43 ± 1.71[abcde]
Silver pomfret	0.54 ± 0.00[ab]	90.28 ± 0.08[abcde]	683.53 ± 6.50[a]	16.93 ± 0.04[ab]	284.62 ± 0.47[abcde]
Hardtailscad	0.93 ± 0.00[b]	156.56 ± 0.08[cdef]	1357.87 ± 1.80[a]	21.24 ± 0.05[ab]	398.60 ± 0.35[bcdef]
Golden snapper	0.97 ± 0.00[b]	68.56 ± 0.37[abc]	351.74 ± 2.02[a]	7.54 ± 0.03[a]	163.98 ± 0.79[ab]
Indian mackarel	0.59 ± 0.00[ab]	88.68 ± 0.38[abcde]	513.17 ± 0.41[a]	11.87 ± 0.02[a]	464.47 ± 0.44[ef]
Sixbar grouper	0.54 ± 0.00[ab]	82.44 ± 0.52[abcd]	217.10 ± 0.78[a]	12.39 ± 0.02[a]	235.69 ± 0.37[abcde]
Japanese threadfin bream	0.10 ± 0.00[ab]	92.81 ± 0.26[abcde]	286.59 ± 0.19[a]	13.38 ± 0.01[a]	147.87 ± 0.31[a]
Indian threadfin	0.52 ± 0.00[ab]	101.73 ± 0.22[abcde]	335.09 ± 0.67[a]	10.62 ± 0.06[a]	243.43 ± 0.53[abcde]
Malabar red snapper	0.28 ± 0.00[ab]	197.06 ± 0.14[e]	412.42 ± 1.23[a]	16.58 ± 0.03[ab]	259.54 ± 0.51[abcde]
Moonfish	0.04 ± 0.00[a]	95.13 ± 0.53[abcde]	331.05 ± 0.14[a]	12.71 ± 0.02[a]	303.41 ± 0.65[abcde]
Dorab wolfherring	0.40 ± 0.00[ab]	98.85 ± 0.24[abcde]	236.35 ± 0.54[a]	59.51 ± 0.08[c]	340.78 ± 0.48[abcdef]
Long-tailed butterfly ray	0.71 ± 0.00[ab]	181.91 ± 0.20[ef]	336.96 ± 1.06[a]	28.78 ± 0.04[abc]	233.19 ± 0.11[abcde]
Large-scale tongue sole	0.34 ± 0.00[ab]	43.23 ± 0.19[a]	175.62 ± 0.36[a]	38.24 ± 0.05[abc]	182.84 ± 1.04[abc]
Yellowstripe scad	0.30 ± 0.00[ab]	141.26 ± 0.67[bcdef]	454.95 ± 0.36[a]	18.78 ± 0.02[ab]	449.49 ± 0.49[def]
Gray eel-catfish	0.66 ± 0.01[ab]	183.12 ± 0.95[ef]	495.49 ± 1.79[a]	25.96 ± 0.16[abc]	344.03 ± 0.60[abcdef]
Fourfinger threadfin	0.27 ± 0.00[ab]	92.86 ± 0.76[abcde]	249.23 ± 0.97[a]	8.00 ± 0.03[a]	244.26 ± 0.90[abcde]
Giant seaperch	0.34 ± 0.00[ab]	39.76 ± 0.15[a]	363.33 ± 1.85[a]	8.62 ± 0.00[a]	299.51 ± 0.53[abcde]
Fringescale sardinella	0.54 ±0.00[ab]	51.35 ± 0.22[ab]	551.73 ± 2.78[a]	23.67 ± 0.09[abc]	387.71 ± 1.06[bcdef]
Spanish mackarel	0.34 ± 0.00[ab]	60.50 ± 0.37[ab]	319.89 ± 0.50[a]	9.31 ± 0.02[a]	227.27 ± 0.87[abcd]
Longtail shad	0.87 ± 0.00[ab]	40.72 ± 0.01[a]	659.69 ± 0.04[a]	53.81 ± 0.00[bc]	413.57 ± 0.07[cdef]
Cuttlefish	0.28 ± 0.00[ab]	163.93 ± 0.37[def]	252.07 ± 1.23[a]	11.93 ± 0.01[a]	413.83 ± 1.52[cdef]
Prawn	0.68 ± 0.00[ab]	294.58 ± 0.92[g]	977.09 ± 1.89[a]	34.72 ± 0.01[abc]	573.91 ± 1.62[f]
Cockles	5.53 ± 0.01[d]	134.29 ± 0.09[abcdef]	6208.55 ± 23.63[c]	209.50 ± 0.73[d]	817.65 ± 1.65[g]
Oyster	3.81 ± 0.00[c]	1258.34 ± 0.03[h]	3954.83 ± 1.04[b]	181.92 ± 0.05[d]	14671.24 ± 5.96[h]

Different letters in same column show significant difference at $p<0.05$ (Tukey Post-Hoc Test)

emission spectrometer (ICP-OES) (Perkin Elmer, USA). Samples were then analysed for its micro minerals content (cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn)) and macro minerals content (sodium (Na), potassium (K), calcium (Ca), magnesium (Mg)). Sample blank (65% nitric acid) was analysed together with each batch of samples.

Data analysis

Data were analysed using SPSS (Scientific Package of Social Science) version 17.0. The mean, standard deviation (SD), and one-way ANOVA test followed by Tukey post-hoc analysis were performed to compare differences in the mean of mineral contents of different species of fish and shellfish.

Results and Discussion

Micro minerals content

This study includes analysis of both micro and macro minerals content in fish and shellfish samples. Table 2 shows the micro minerals (cobalt, copper, iron, manganese, zinc) contents in samples. Data are expressed as microgram per 100 gram (µg/100g) wet samples, to be consistent with consumer needs and assist layman to simply estimating their mineral intake from common serving size of fish or shellfish.

The content of cobalt in all samples was between 0.04 to 5.53 µg/100g wet samples. The lowest was in moonfish (0.04 + 0.00 µg/100g wet sample); meanwhile cockles and oyster showed significantly higher (Tukey post hoc test, $p<0.05$) cobalt content compared to other samples. Hokin *et al*. (2004) found that the cobalt content in fresh fish in Australia was 0.4 µg/100g wet sample, which is comparable to the values for fish samples in the current study. Guerin *et al*. (2011) also reported the same range of cobalt content in fish samples from French; with average of 0.005 mg/kg or 0.5 µg/100g samples. Normal daily intake of cobalt was reported to be in the range of 2.5 to 3.0 mg/day, meanwhile poisoning can only occur when intake is greater than 23-30 mg cobalt daily (Hokin *et al*., 2004). The finding shows that local fish and shellfish can provide quite low amount of cobalt compared to the normal daily intake of the mineral. However, the mineral can also be obtained from other food sources such as chocolate, condiments, nuts, seeds and others.

The copper contents in fish and shellfish samples of this study were within a broad range of 39.76-1258.34 µg/100g wet sample. The lowest was shown in giant sea perch, while the highest was in oyster.

Table 3. Macro minerals content of samples

Samples	Sodium (Na)	Macro minerals (mg/100g wet sample, mean ± SD) Potassium (K)	Calcium (Ca)	Magnesium (Mg)
Black pomfret	52.46 ± 0.27bcd	10.08 ± 0.04abc	28.62 ± 0.21abc	944.03 ± 5.38abcd
Silver pomfret	47.64 ± 0.08abc	13.96 ± 0.07bcd	21.62 ± 0.05ab	925.37 ± 1.49abcd
Hardtailscad	34.63 ± 0.02abc	15.28 ± 0.03bcd	39.52 ± 0.08abcde	874.53 ± 0.72abc
Golden snapper	27.25 ± 0.11ab	12.81 ± 0.08bcd	21.36 ± 0.09ab	660.67 ± 3.41ab
Indian mackarel	33.01 ± 0.03abc	10.22 ± 0.05abc	33.42 ± 0.02abcd	710.99 ± 1.93ab
Sixbar grouper	25.89 ± 0.08ab	14.88 ± 0.05bcd	57.99 ± 0.28bcdef	792.52 ± 2.93abc
Japanese threadfin bream	49.54 ± 0.23abcd	6.58 ± 0.02ab	16.76 ± 0.07ab	618.38 ± 1.42a
Indian threadfin	36.66 ± 0.18abc	14.93 ± 0.05bcd	20.18 ± 0.14ab	847.81 ± 3.36abc
Malabar red snapper	38.09 ± 0.21abc	17.13 ± 0.06cd	37.64 ± 0.14abcde	898.40 ± 3.64abcd
Moonfish	22.42 ± 0.01a	12.76 ± 0.09bcd	29.95 ± 0.10abc	670.14 ± 0.54ab
Dorab wolfherring	40.60 ± 0.10abc	20.42 ± 0.03d	116.63 ± 0.33gh	1314.50 ± 2.03cde
Long-tailed butterfly ray	76.76 ± 0.06de	12.64 ± 0.03abcd	127.59 ± 0.73h	964.04 ± 1.32abcd
Large-scale tongue sole	36.70 ± 0.25abc	10.16 ± 0.07abc	65.21 ± 0.17cdef	682.60 ± 4.33ab
Yellowstripe scad	43.97 ± 0.02abc	10.98 ± 0.01abcd	83.29 ± 0.17fg	937.36 ± 0.37abcd
Gray eel-catfish	29.71 ± 0.06ab	14.01 ± 0.02bcd	16.50 ± 0.03ab	716.34 ± 1.95ab
Fourfinger threadfin	30.38 + 0.19ab	11.07 ± 0.03abcd	12.89 ± 0.04a	680.12 ± 2.72ab
Giant seaperch	35.26 ± 0.07abc	15.62 ± 0.02bcd	16.17 ± 0.02a	808.44 ± 1.10abc
Fringescale sardinella	23.34 ± 0.08a	11.22 ± 0.05abcd	78.38 ± 0.34efg	669.66 ± 2.61ab
Spanish mackarel	36.20 ± 0.04abc	13.53 ± 0.06bcd	19.70 ± 0.01ab	874.74 ± 2.74abc
Longtail shad	25.25 ± 0.01ab	15.47 ± 0.00bcd	73.58 ± 0.01def	925.18 ± 0.12abcd
Cuttlefish	86.24 ± 0.25ef	3.13 ± 0.02a	19.43 ± 0.07ab	1317.30 ± 5.53cde
Prawn	59.24 ± 0.12cde	17.31 ± 0.07cd	36.30 ± 0.04abcd	1220.60 ± 3.11bcde
Cockles	113.89 ± 0.15fg	12.35 ± 0.02abcd	41.32 ± 0.10abcde	1450.50 ± 1.91de
Oyster	115.23 ± 0.02g	9.82 ± 0.00abc	48.02 ± 0.01abcdef	1534.80 ± 0.26e

Different letters in same column show significant difference at p<0.05 (Tukey Post-Hoc Test)

All samples, except oyster contained copper lower than the permissible limit set by FAO/WHO (1984), 10 ppm or 1000 µg/100 g food. Although copper in oyster was slightly higher than the level set by FAO/WHO (1984), however the level was still under the permissible limit set by Malaysian Food Regulations (1985); which was 30 ppm or 3000 µg/100 g food. The copper content of local oyster in current study was higher than in oyster from French, with average of only 2.1 µg/100g sample (Guerin *et al*., 2011). Meanwhile, a local study by Irwandi and Farida (2009) previously showed far higher copper contents in golden snapper, indian mackerel, sixbar grouper, japanese threadfin bream and spanish mackerel with concentrations of 1155, 1395, 1148, 1260 and 1174 µg/100g wet samples; compared to current findings of 68.54, 88.68, 82.44, 92.81, and 60.51 µg/ 100g wet samples, respectively. The high concentrations of copper in this previous study could be attributed to natural of anthropogenic metal sources affecting the study location of Langkawi Island, situated in the east Peninsular Malaysia (Irwandi and Farida, 2009).

There was a wide variation of iron contents in samples; with the lowest at 175.62 + 0.36 µg/100g wet sample (large-scale tongue sole), and the highest at 6208.55 + 23.63 µg/100g wet sample (cockles) Findings of the current study were in agreement with previous study; which reported iron values of 7830 µg/100g sample in cockles, and 442 µg/100 g samples in fish samples (Guerin *et al*., 2011). Besides cockles, oyster also contained significantly higher (Tukey post-hoc test, $p<0.05$) iron content compared to other samples; with the mean concentration of 3954.83 + 1.04 µg/100g wet sample. These findings were true as shellfish were usually high in minerals such as iron and copper compared to fish (Oksuz *et al*., 2009). However, most of the samples (except black pomfret and silver pomfret) showed lower concentrations of iron when compared with previous data reported in the Nutrient Composition of Malaysian Foods (Tee *et al*., 1997). This discrepancy could be due to factors affecting the iron content; such as species, individuals, and sampling period (Yilmaz *et al*., 2010).

The fish samples of this study contained low manganese contents (7.54-59.51 µg/100g wet samples); which were significantly lower compared to previous finding in fresh fish in Saudi Arabia (175.1 µg/100g wet sample) (Ganhi, 2010). Meanwhile, the manganese contents in oyster (181.92 µg/100g wet sample) and cockles (209.50 µg/100g wet samples) were higher compared to other samples; but were still significantly lower when compared with previous local findings, ranged between 1680-2435 µg/100g wet samples (Irwandi and Farida, 2009). The content of manganese in all samples were found to be lower than the permissible limit set by FAO/WHO (1984), 5.4 ppm or 540 µg/100 g food. There is no limit revealed for manganese in Malaysian standards.

The zinc content in fish samples ranged between 147.87-464.47 µg/100g wet sample. Meanwhile cuttlefish, prawn, cockles and oyster contained 413.83, 573.91, 817.65 and 14671.24 µg/100g wet samples; respectively. Cockles and oyster were significantly higher (Tukey post-hoc test, $p<0.05$) in zinc compared to all samples. Irwandi and Farida (2009) found higher zinc content in golden snapper, indian mackerel, sixbar grouper, japanese threadfin bream and spanish mackerel with mean concentration of 4939, 3433, 3870, 3723 and 3881 µg/100g samples; compared to 163.98, 464.47, 235.69, 147.87, and 227.27 µg/100g wet samples, respectively in the current study. All samples contained zinc lower than the limit set by FAO/WHO (1984) (150 ppm or 15000 µg/100g). However, oyster was found to contain zinc higher than the permissible limit set by Malaysian Food Regulations (1985) (100 ppm or 10000 µg/100g).

Macro minerals content

Table 3 shows the macro minerals (sodium, potassium, calcium and magnesium) contents in samples; expressed as milligram per 100 gram (mg/100g) wet sample. The sodium contents in samples ranged between 22.42 to 115.23 mg/100g wet samples; with most of the samples showed values less than 60 mg/100 g wet samples. Cuttlefish, cockles and oyster contained higher sodium content at 86.24, 113.89 and 115.23 mg/100g wet samples, respectively. Lourenco *et al*. (2009) showed the same trend as sodium was found to be considerably higher in shellfish than in fish. However, current study showed lower concentration of sodium in cuttlefish (86.24 mg/100g wet sample) compared to previous finding of 266 mg/100 g muscle weight by Lourenco *et al*. (2009).

The concentrations of potassium were quite low for all samples. The lowest was in cuttlefish with potassium content of 3.13 mg/100g wet sample, which was significantly lower when compared with finding of Lourenco *et al*. (2009), at 289 mg/100g sample. Meanwhile, the highest was dorab wolfherring, with potassium content of 20.42 + 0.03 mg/100 g wet sample. Oksuz *et al*. (2009) reported potassium levels of 99.6 0 mg/100 g samples (french rose shrimp) and 64.49 mg/100 g samples (red shrimp), which were far higher compared to prawn (17.31 mg/100g wet sample) in the current study. Besides, Erkan and Ozden (2007) also reported significantly higher values compared to the current findings; at the mean average of 459.7 mg/100g (sea bass) and 393.8 mg/100g (sea bream).

The range of calcium content in all samples was between 12.89 and 127.59 mg/100g wet sample. Dorab wolfherring and long-tailed butterfly ray showed higher calcium content compared to others; at mean concentrations of 116.63 and 127.59 mg/100g wet samples, respectively. Most of other samples contained calcium level below 50 mg/100g wet sample. Meanwhile, Irwandi and Farida (2009) showed calcium concentration in the range of 0.57-3.03 mg/100g sample; with significantly lower calcium values in five common samples of golden snapper (0.57 mg/100g), Indian mackerel (1.51 mg/100g), sixbar grouper (3.03 mg/100g), japanese threadfin bream (1.04 mg/100g) and spanish mackerel (1.02 mg/100g); compared to the current findings of 21.36, 33.42, 57.99, 16.76, and 19.70 mg/100g wet samples, respectively. However, the calcium contents in shellfish samples in the current study were in agreement with values reported for rose shrimp (49.5 mg/100g) and red shrimp (32.25 mg/100g) in French (Oksuz et al., 2009).

Overall, magnesium was found to be the mineral with highest concentration in all samples compared to all minerals analysed. The mean concentrations of the mineral ranged between 618.38 and 1534.80 mg/100g wet samples. Oksuz *et al*. (2009) reported magnesium values of 38.2 and 57.9 mg/100 g wet samples for rose shrimp and red shrimp samples, which were significantly lower compared to the current findings. Erkan and Ozden (2007) also reported magnesium values at 32.6 mg/100g (sea bass) and 22.2 mg/100g (sea bream); which were significantly lower compared to all samples in the current study. This could be due to the difference of species, seasons, area of catch and many other physical and environmental conditions in these studies.

Conclusion

Generally, the levels of micro minerals in all samples were within acceptable range for safe human consumption. However, oyster showed copper content slightly higher than the limit set by FAO/WHO (1984), but below the limit set by Malaysian Food Regulations (1985); and zinc content higher than the limit set by Malaysian Food Regulation (1985), but below the limit set by FAO/WHO (1984). Other than that, shellfish (especially cockles and oyster) were found to contain higher levels of micro minerals compared to the fish samples. For macro minerals, most samples showed values of sodium within the range found in most literatures. Meanwhile, findings of the study showed significantly lower of potassium contents, higher calcium contents, and extremely higher of magnesium contents compared to the common ranges reported in the literatures. Generally, shellfish samples were found to contain higher amount of sodium and magnesium; but comparable amounts of potassium and calcium when compared with fish samples. However, all fish and shellfish samples can be considered as good sources of calcium and magnesium. Therefore, it is recommended to consume fish and shellfish regularly as it could provide most of minerals needed by human body. However, consumption of shellfish, especially cockles and oyster should be monitored in people with high blood pressure for their fairly high of sodium contents and low potassium contents. It is also suggested to limit oyster intake to less than 100 grams to avoid any possible toxic effects due to their high content of copper and zinc.

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