Research Article

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Comparative analysis of chemical composition of some commercially important fishes with an emphasis on various Malaysian diets

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Abstract: This study compares the chemical composition of cockle (*Anadara granosa*) and some commercially important marine (Asian seabass *Lates calcarifer*, grouper *Epinephelus bleekeri*, hardtail scad *Megalaspis cordyla*, longtail tuna *Thunnus tonggol* and Indian mackerel *Rastrelliger kanagurta*) and freshwater (sutchi catfish *Pangasius hypophthalmus*, Nile tilapia *Oreochromis niloticus* and eel *Monopterus albus*) fishes in Peninsular Malaysia. The results show that the proximate composition and trace metal content were significantly different ($P < 0.05$) among species investigated. The mean protein content was the highest in eel (19.1%) and the lowest in sutchi catfish (13.0%) and cockle (13.0%). The mean lipid content of Indian mackerel (3.9%) was higher than cockle (2.0%), followed by eel (1.3%) and longtail tuna (0.8%). The mean ash content was the highest in Indian mackerel (1.4%) and the lowest in cockle (0.9%). Zinc and manganese contents in cockle (Zn: 61.2 mg kg^{-1}, Mn: 22.7 mg kg^{-1}) were very high compared to other species investigated. The copper content was minimum in sutchi catfish (1.0 mg kg^{-1}) and a maximum in the hardtail scad (11.7 mg kg^{-1}). Trace metal content in sutchi catfish, Nile tilapia, grouper, longtail tuna, eel and cockle followed an order Zn > Mn > Cu, whereas Asian seabass, hardtail scad and Indian mackerel followed a different order Zn > Cu > Mn. Trace metal content in the tissue of the fishes examined was within safe limits for human consumption except Mn content in the cockle and Cu content in the hardtail scad, which is a matter of concern. When considering the daily fish fat, mineral and trace metal intake, marine fishes and shellfish are better than freshwater fishes.

Keywords: protein, lipid, Ash, trace metal, fish

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1 Introduction

As a highly accessible food source, fishes are widely consumed in Malaysia with a per capita consumption of 53 kg in 2002, which increased presently to nearly 59 kg [1]. Fish protein provides essential amino acids, while fish fat is rich in polyunsaturated fatty acids (PUFAs), which have beneficial effects on many diseases such as heart disease, diabetes, cancer and inflammatory disease [2,3]. PUFAs are important for maintaining the integrity of membrane of all living cells by producing prostaglandins, which regulate many body processes such as inflammation and blood clotting [4,5]. Some marine fish proteins protect against the development of diet-induced insulin resistance [5–7]. Regular consumption of fish can promote protection against invasion of human pathogens by providing antimicrobial peptides [8]. Furthermore, eating fish during pregnancy may help to reduce the risk of premature birth [2,9]. Apart from many health benefits associated with the consumption of fish, it is well accepted that they are an important component of the regular diet.

In Malaysia, about 60–70% of total animal protein is supplied by marine fisheries [10]. Among the wide

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variety of fishes in the region, Asian sea bass (*Lates calcarifer*), Indian mackerel (*Rastrelliger kanagurta*), longtail tuna (*Thunnus tonggol*), hardtail scad (*Megalaspis cordyla*), grouper (*Epinephelus bleekeri*), sutchi catfish (*Pangasius hypophthalmus*) and Nile tilapia (*Oreochromis niloticus*) are the most commonly consumed fishes due to high consumer preference and affordable market price. Apart from finfishes, many Malaysians consume shellfishes, mainly cockles (*Anadara granosa*). They prefer cockle because of its taste and texture. Nowadays, a few Malaysians also consume freshwater eel (*Monopterus albus*) because of its test and soft texture.

Historically in Malaysia, consumer did not consider nutritive value during selection of fish for consumption. The selection of fish was normally based on the availability, cost and taste. Nevertheless, selection of fish for consumption is continuously changing as awareness of nutritional value of fish is growing in Malaysian society. Nowadays, many Malaysians acknowledge the high nutritional value of fish proteins, lipids and essential trace metal. Fishes accumulate trace metals in their tissues from the aquatic environment mainly through their diet and to a limited extent by direct absorption from the water [11–13]. On consumption of fish, these metals are transferred to the human body [14]. Some of the trace metals play important roles in biological systems of fish and humans, some being essential to survival [15,16].

The common essential trace metals that are found in fish are zinc (Zn), manganese (Mn) and copper (Cu) [17–19]. Copper acts as a co-factor for enzymes involved in glucose metabolism and the synthesis of hemoglobin, connective tissue and phospholipids [20,21]. Zinc is an integral part of a number of metalloenzymes and acts as a catalyst for regulating the activity of specific zinc-dependent enzymes. Manganese acts either as an integral part of enzymes or as a co-factor for numerous enzymes involved in nitrogen, lipid and carbohydrate metabolism [20]. Trace metals can also have adverse and toxic effects at high concentrations in the human body [19,21]. It has been observed that higher than optimum level of copper in human body can cause nausea, vomiting, diarrhea, acute and chronic liver diseases, liver cirrhosis and permanent organs damage [19]. However, awareness of essential trace metals in food is also gradually growing in the Malaysian society. Therefore, determination of the concentration of trace metals in commercial fish is important to understand the benefits and possible risk of fish consumption for human health [22].

Published information indicates that nutritional values of fish may differ depending on species [23–25]. There is also some information on the evaluation of nutritional values of some fishes. However, comparison of the nutritional value between commonly consumed fish and shellfish by Malaysian is rarely addressed. Therefore, the present study compares the nutritional quality of commonly consumed fishes (Asian seabass *L. calcarifer*, grouper *E. bleekeri*, hardtail scad *M. cordyla*, longtail tuna *T. tonggol*, Indian mackerel *R. kanagurta*, sutchi catfish *P. hypophthalmus*, Nile tilapia *O. niloticus* and eel *M. albus*) and shellfish (cockle *Anadara granosa*) by Malaysian. The objective of this study is to compare the nutritional value (proximate composition and zinc, manganese and copper content) of cockles and commonly consumed fishes. In addition, considering the fish consuming habits of Malaysian, the daily intake of nutrients and trace metals of various diets containing fish and shellfish is estimated and compared using the annual 59 kg fish intake per person. This information would be very useful for consumers to conceptually increase their knowledge regarding the nutritional content and consumption of important fishes.

2 Materials and methods

2.1 Sample collection and preparation

All marine fishes (Asian seabass, grouper, Hardtail scad, Longtail tuna and Indian mackerel) were captured at the east coast of Peninsular Malaysia within latitude 3.78109 to 3.78598 and longitude 103.34611 to 103.41482. The freshwater fishes Nile tilapia and Sutchi catfish were collected from a private fish farm in Kuala Berang, Terengganu, Malaysia. Freshwater eel was collected from a fish market in Kuantan, Malaysia. Table 1 presents the summary of fish and shellfish weights. A total of three individuals were collected per species. After collection, fishes were immediately placed in an icebox and transported to the laboratory of Department of Biomedical Science, International Islamic University Malaysia (IIUM), Kuantan Campus. All fishes were eviscerated, beheaded and filleted in the laboratory. The cockle flesh was removed from its shell. The bones of all fish fillets were separated from the flesh. All samples were then cut into pieces and washed with tap water several times to remove all blood. The samples were packed in separate containers, labeled and stored

Table 1: Weight of fish and shellfish investigated

Species	Range (g)	Mean ± standard deviation
Asian seabass	387.2–434.6	405.6 ± 25.4
Grouper	320.5–427.5	389.9 ± 60.1
Hardtail scad	264.4–283.4	270.9 ± 9.2
Longtail tuna	356.7–411.7	381.7 ± 27.8
Indian mackerel	130.2–144.3	135.6 ± 7.6
Sutchi catfish	426.3–498.8	453.1 ± 39.8
Nile tilapia	224.4–2.53.1	229.9 ± 7.8
Eel	121.3–174.3	154.1 ± 28.6
Cockle	9.8–13.4	11.1 ± 2.0

in the freezer at −20°C until further laboratory analyses. According to the IIUM (international Islamic University Malaysia) research ethics, no ethical approval is needed to kill fish for scientific purpose.

2.2 Proximate composition analysis

Moisture, ash and fat contents were analyzed at the Natural Food Laboratory of Kulliyyah of Allied Health Science, whereas the protein content was analyzed at the Bioprocess Laboratory of Kulliyyah of Science, International Islamic University Malaysia, Malaysia. The moisture content was determined by drying flesh in an oven at 70°C until a constant weight was obtained [26]. Crude protein contents were determined by the Kjeldahl method through digestion by sulfuric acid (98%) at 420°C, distillation by sodium hydroxide (50% w/v) using distillation unit (model: Kjeltec 2200, Foss Analytical, Hoganas, Sweden) and titration by hydrochloric acid (0.1 N) [26]. Lipid content was analyzed using the Soxhlet extraction method using hexene as the solvent [26]. Ash content of the sample was determined by ash in a muffle furnace at 500°C for 22 hours by AOAC [26].

2.3 Mn, Cu and Zn content analysis

Trace metal content was analyzed at the Environmental Laboratory of Kulliyyah of Science, International Islamic University Malaysia, Malaysia. All samples were digested before analyzing Zn, Mn and Cu content using atomic absorption spectrometry (AAS) (model: SIMAA 6100 Perkin Elmer, USA). For digestion, a representative sample of up to 0.3 g was extracted and dissolved in 6 mL concentrated nitric acid (65%) (Merck, Germany) and 1 mL of hydrogen peroxide (Merck, Germany) for 45 min using a microwave heating unit (model: multiwave 3000, Canada). The sample and acids were placed in a quartz microwave vessel, which was sealed and heated in the microwave unit. After cooling, the vessel contents were filtered, centrifuged and allowed to settle and then diluted to 15 mL in falcon tubes. The tubes were sealed and kept under room temperature before analysis using atomic absorption spectrometry. All the digested samples were then analyzed three times for Zn, Mn and Cu using the atomic absorption spectrometry. The presence of minerals was detected using graphite furnaces atomic absorption spectrometry (GFAAS).

Considering the fish consuming habits of Malaysian, the daily intake of nutrients and trace metals of four diets containing fish and shellfish are estimated and compared using the annual 59 kg fish intake per person. Diets include only marine fishes (diet 1: Asian sea bass, grouper, hardtail scad, longtail tuna and Indian mackerel), marine fishes and shellfish (diet 2: Asian sea bass, grouper, hardtail scad, longtail tuna, Indian mackerel and cockle), only freshwater fishes (diet 3: sutchi catfish, Nile tilapia and eel) and mixture of all marine and freshwater fishes and shellfish (diet 4: Asian sea bass, grouper, hardtail scad, longtail tuna, Indian mackerel, sutchi catfish, Nile tilapia, eel and cockle).

2.4 Statistical Analysis

Proximate composition and trace metals data were statistically analyzed using SPSS version 16.0. They were checked for normality (by the Kolmogorov–Smirnov test) and homogeneity of variance (by Levene's test) before analysis [27,28]. Only the percent data had to be arcsine transformed before analysis. Nutrients contents of all fishes, cockle and various diets were compared through one-way analysis of variance (ANOVA). If an ANOVA was significant, differences between the means were analyzed by the Tukey test for unplanned multiple comparisons of means ($P < 0.05$).

3 Results and discussion

3.1 Proximate composition of fish

Information about proximate composition and trace metal content of commercially important fishes is very useful for nutritionists to aid them in dietary formulations, nutrient labeling, processing, and dietary product development. We determined proximate compositions and zinc, manganese and copper contents of some economically important fishes. Proximate composition and trace metals content were significantly different among fish species (Table 2). Several authors [29–32] reported similar significantly different proximate compositions and trace metal contents in different fishes.

Moisture content was significantly different ($P < 0.05$) among species (Table 2 and Figure 1a). The highest moisture was observed in cockle (87%), while the lowest was observed in hardtail scad (75%). There was no significant difference in the moisture content of sutchi catfish, Nile tilapia, Asian sea bass, grouper and eel ($P > 0.05$). Similarly, the moisture contents of Asian seabass, hardtail scad, longtail tuna and Indian mackerel were similar with no significant differences noted ($P > 0.05$). The moisture content of hardtail scad and Indian mackerel in the present study concurs with Nurnadia et al. [33], who reported the moisture content of 77.7% for hardtail scad and of 76.6% for Indian mackerel. Ravichandran et al. [25] observed the moisture content of 77.9% for Nile tilapia that agrees well with the present study.

Mean protein content was the highest in eel and the lowest in cockle (Figure 1b). Mean protein content of Indian mackerel was higher than that of sutchi catfish, Nile tilapia, grouper, hardtail scad, longtail tuna and cockle. Protein contents of Asian sea bass and Indian mackerel were not statistically different ($P > 0.05$). Asian sea bass had higher protein content than sutchi catfish, hardtail scad, longtail tuna and cockle. Protein contents of Asian sea bass, Nile tilapia and grouper were also statistically similar ($P > 0.05$). There is no previous study to compare directly with the protein content of fishes observed in the present study except hardtail scad, Indian mackerel, eel and cockle. The observed protein content of cockle and Indian mackerel concurs with Nurnadia et al. [33], who observed the protein content of 16.0% and 20.5% for cockle and Indian mackerel, respectively. The observed protein content of eel is in agreement with Rahman et al. [30]. However, the protein content of hardtail scad in the present study is lower than that of the protein content of hardtail scad (20.9%) observed by Nurnadia et al. [33]. The inconsistency between two studies could be potentially explained by differences in factors such as fish size, capture season, capture location and fertility cycle.

Table 2: The ANOVA results (one-way ANOVA) of proximate and mineral composition.

Variable	DF (degree of freedom)	*F*-ratio	Significance (*p* value)
Moisture	8, 18	36.66	*
Ash	8, 18	10.25	*
Protein	8, 18	16.94	*
Lipid	8, 18	309.92	*
Zn	8, 18	56.61	*
Mn	8, 18	257.93	*
Cu	8, 18	62.24	*

*$P < 0.001$

The mean lipid content in the fish flesh ranged from 0.2 to 3.9% (Figure 1c). The mean lipid content of Indian mackerel was higher than cockle, followed by eel and longtail scad. Longtail scad had higher lipid content than sutchi catfish, Nile tilapia, Asian sea bass, grouper and hardtail scad. The lipid content of cockle in the present study concurs with Nurnadia et al. [33], who observed similar lipid content in cockle (1.9%). In another study, Rahman et al. [30] recorded 2.0% as a mean lipid content of cockles collected from the east coast of peninsular of Malaysia. The lipid content of Indian mackerel and hardtail scad in the present study is higher and lower, respectively, than that studied by Nurnadia et al. [33]. However, the observed lipid content of Indian mackerel concurs with Rahman et al. [30]. The lipid content of Nile tilapia in the present study is similar with Ravichandran et al. [25], who reported the lipid content of 0.45% for Nile tilapia. However, the fat content among various species may be influenced by multiple factors, such as composition of food, geographical location, age, stage of sexual maturity and catch season [34].

Based on the lipid content, all fish examined in the present study can be classified as lean fish (the fish lipid content lower than 2%) except Indian mackerel [36]. This result indicates that Indian mackerel is better than other fishes (Asian sea bass, longtail tuna, hardtail scad, grouper, sutchi catfish, Nile tilapia and eel) and shellfish (cockle) as it is an excellent source of fish fat and polyunsaturated fatty acids particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [35,36]. However, this article does not report the composition fatty acids in fish and shellfish.

The ash content of fish is referred to as the total mineral content of fish. In this study, the mean mineral content was the highest in Indian mackerel (1.4%) and the lowest in cockle (0.9%) (Figure 1d). There is no

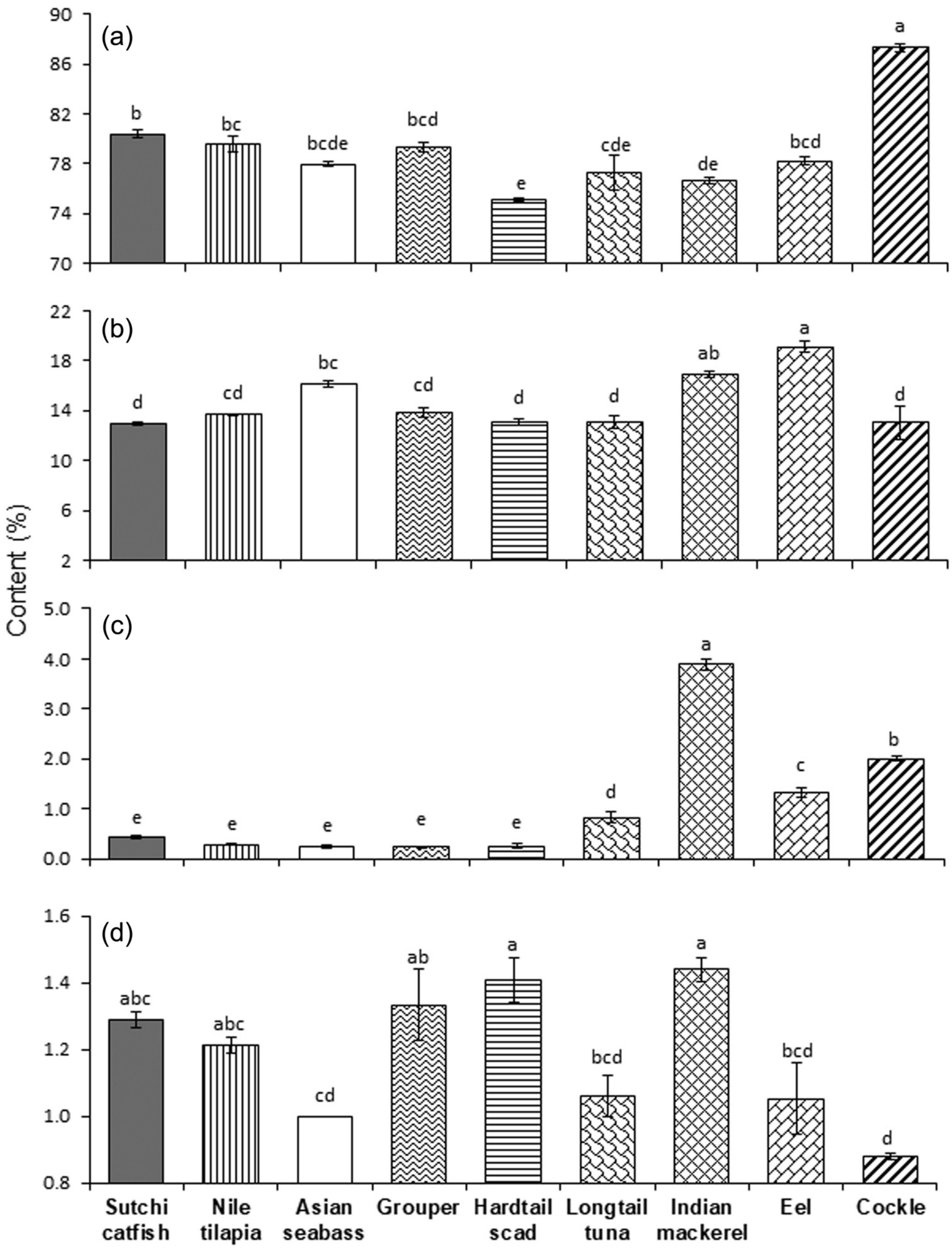

Figure 1: Mean (±standard error) moisture (a), protein (b), lipid (c) and mineral (d) contents of different fishes. Bars with no letter in common are significantly different ($P < 0.05$) based on the Tukey test.

significant difference among the mineral contents of Indian mackerel, Hardtail scad, grouper, Nile tilapia and sutchi catfish ($P > 0.05$). Similarly, the mineral contents of sutchi catfish, Nile tilapia, Asian sea bass, longtail tuna, eel and cockle were statistically same ($P > 0.05$). Mineral contents of Indian mackerel and hardtail scad were significantly higher than the mineral contents of Asian sea bass, longtail tuna, eel and cockle ($P < 0.05$). The values of the mineral content of hardtail scad and Indian mackerel in the present study agree with Nurnadia et al. [33], who observed mineral content of 1.1% and 1.3% in hardtail scad and Indian mackerel, respectively. In the case of cockle's mineral content, our observed value is similar to the value observed by Rahman et al. [30] but lower than the value recorded by Nurnadia et al. [33]. However, the mineral contents of fish and shellfish vary depending on a variety of factors, including species, diet, and environmental variables particularly salinity, temperature, season, and geographical location.

Considering the fish consuming habits of Malaysian, daily intake of nutrients and trace metals of four different fish diets are estimated and compared using the annual 59 kg fish intake per person (Figures 2 and 3). The estimated daily fish protein intake (24.7 g day^{-1}) is significantly higher by consuming diet 3 (freshwater fish only: sutchi catfish, Nile tilapia and eel) compared to consuming other diets (diet 1: 23.6 g day^{-1}, diet 2: 23.2 g day^{-1} and diet 4: 23.7 g day^{-1}) (Figure 2a), whereas an opposite result is observed in the case of the daily fish fat intake (Figure 2b). When considering daily mineral intake, all diets are almost similar (Figure 2c). However, the estimated daily protein intake by consuming diet 3 is closer to the recommended protein intake for Malaysian [37]. According to the National Coordinating Committee on Food and Nutrition Ministry of Health Malaysia [37], the recommended Malaysian's daily protein intake is 12–62 g per person depending on age and gender. This result indicates that consuming diet 3 (freshwater fish) is better than consuming other diets (diet 1, diet 2 and diet 4) in the case of daily mean protein intake.

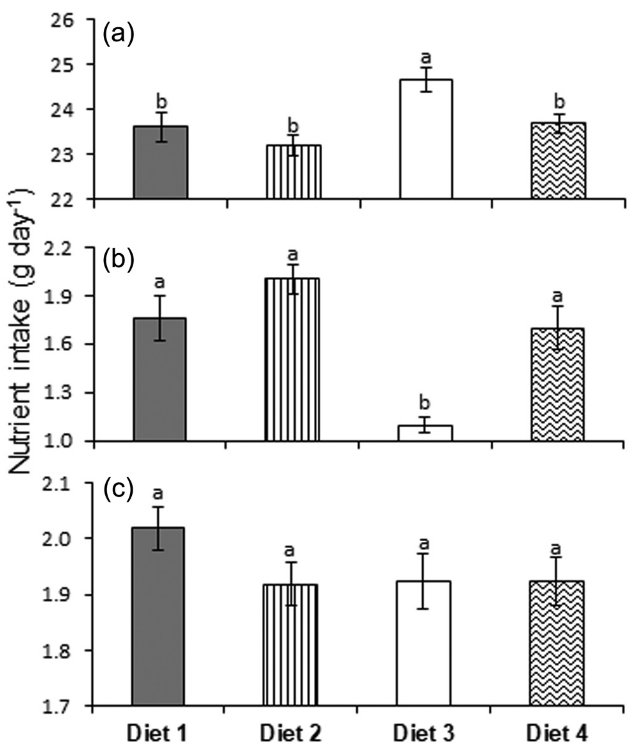

Figure 2: Mean (± standard error) protein (a), lipid (b) and mineral (c) intake (g day^{-1}) of various diets consisted of various fishes. Diet 1: only marine fishes (Asian sea bass, grouper, hardtail scad, longtail tuna and Indian mackerel), diet 2: marine fishes and shellfish (Asian sea bass, grouper, hardtail scad, longtail tuna, Indian mackerel and cockle), diet 3: only freshwater fishes (sutchi catfish, Nile tilapia and eel) and diet 4: mixture of all marine and freshwater fishes and shell fish (Asian sea bass, grouper, hardtail scad, longtail tuna, Indian mackerel, sutchi catfish, Nile tilapia, eel and cockle). Bars (n = 3) with no letter in common are significantly different (P < 0.05) based on the Tukey test.

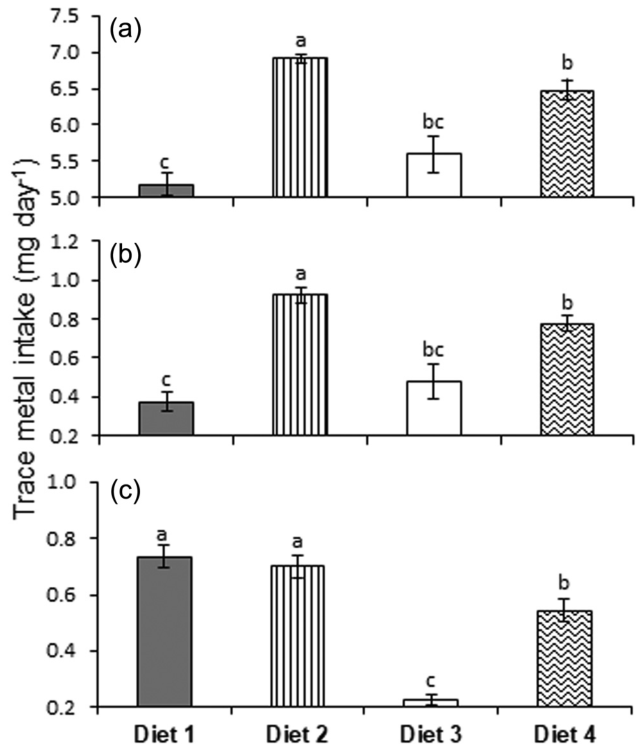

Figure 3: Mean (± standard error) zinc (a), manganese (b) and copper (c) intake (mg day^{-1}) of various diets consisted of various fishes. Diet 1: only marine fishes (Asian sea bass, grouper, hardtail scad, longtail tuna and Indian mackerel), diet 2: marine fishes and shellfish (Asian sea bass, grouper, hardtail scad, longtail tuna, Indian mackerel and cockle), diet 3: only freshwater fishes (sutchi catfish, Nile tilapia and eel) and diet 4: mixture of all marine and freshwater fishes and shell fish (Asian sea bass, grouper, hardtail scad, longtail tuna, Indian mackerel, sutchi catfish, Nile tilapia, eel and cockle). Bars (n = 3) with no letter in common are significantly different (P < 0.05) based on the Tukey test.

3.2 Trace metal contents of fish

Zn, Mn and Cu contents in the cockle and fishes investigated are presented in Figure 4. The mean Zn content in fish flesh varied from 21 to 97 mg kg^{-1}. The Zn content in all fish fleshes were lower than the maximum Zn level permitted for fish (150 mg kg^{-1}) by FAO/WHO [38]. The recommended dietary allowance (RDA) for zinc in human is 15 mg day^{-1} for men, 12 mg day^{-1} for women, 10 mg day^{-1} for children and 5 mg day^{-1} for infants [39]. Harmful health effects generally begin at levels from 10 to 15 times of the RDA. In the present study, the greatest

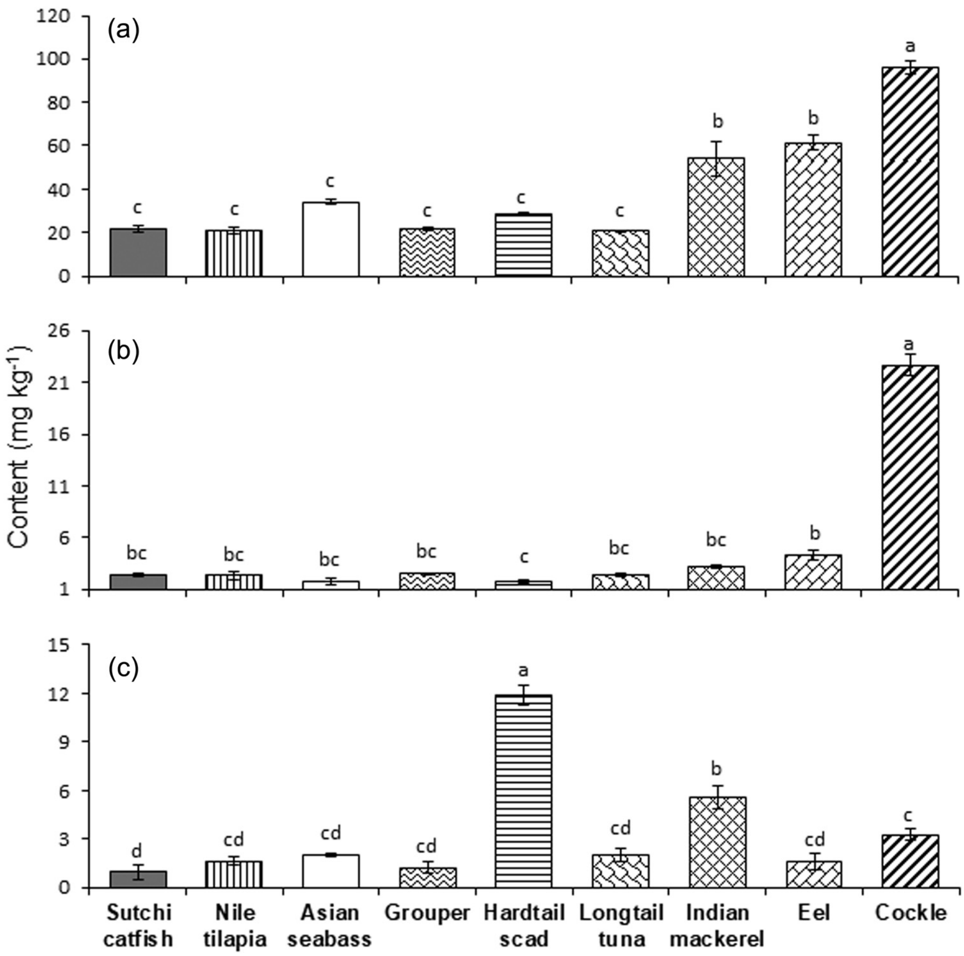

Figure 4: Mean (± standard error) zinc (a), manganese (b) and copper (c) contents of different fishes. Bars with no letter in common are significantly different (P < 0.05) based on the Tukey test.

Zn concentration was observed in cockle. The Zn contents of Eel and Indian mackerel were significantly higher than sutchi catfish, Nile tilapia, Asian sea bass, grouper, hardtail scad and longtail tuna (P < 0.05) (Figure 4a). The Zinc contents of Eel and Indian mackerel were statistically similar (P > 0.05). Similarly, the Zn contents of sutchi catfish, Nile tilapia, Asian sea bass, grouper, hardtail scad and longtail tuna were statistically similar (P > 0.05). However, the Zn content obtained for Asian seabass, Indian mackerel, longtail tuna, hardtail scad, Nile tilapia and eel agree well with the reported Zn content, which are presented in Table 3. Zinc concentration in cockle was very high compared to other investigated species. Zinc concentration in cockle is to be expected as mentioned by CeliK and Oehlenschlager [40], who stated that the molluscs generally contain very high concentration of Zn. According to the study by Boscolo et al. [41], bivalve mollusc has a high capacity and propensity to concentrate trace metals.

Greatest Mn content was also observed in cockle (22.7 mg kg^{-1}), while the lowest was observed in hardtail scad (1.7 mg kg^{-1}) (Figure 4b). The permissible limits for Mn set by WHO [38] is 1 mg kg^{-1}. Permissible limits for Mn in many countries are much higher than the WHO limit. For example, the permissible limit for Mn in Nigeria is 5 mg kg^{-1} [50]. However, Mn concentrations for the various fish species investigated are higher than the permissible limits set by FAO but lower than the permissible limits set by FEPA except cockle [50]. United States National Research Council recommends safe and adequate daily intake levels for Mn that range from 0.3 to 1 mg day^{-1} for children up to 1 year, 1–2 mg day^{-1} for children up to age 10 years and 2–5 mg day^{-1} for children aged 10 years and older [51]. The Mn content in eel was higher than that in hardtail scad (P < 0.05). The Mn contents of sutchi catfish, Nile tilapia, Asian sea bass, grouper, longtail tuna, Indian mackerel and eel were statistically similar (P > 0.05). Similarly, the Mn contents

Table 3: Reported Zn, Mn and Cu content (mg kg^{-1}) in various fishes

Species	Zn	Mn	Cu	Ref.
Asian seabass (*Lates calcarifer*)	84.3	–	2.7	[18]
Indian mackerel (*Rastrelliger kanagurta*)	37.4	–	2.8	[18]
Indian mackerel (*Rastrelliger kanagurta*)	54.1	3.1	5.6	[30]
Japanese threadfin bream (*Nemipterus japonicus*)	73.4	–	2.7	[18]
Malabar tonguesole (*Cyanoglossus macrostomus*)	38.1	–	2.8	[18]
Bluefin jack (*Caranx melampygus*)	76.0	–	3.6	[18]
Nile tilapia (*Oreochromis niloticus*)	17.4	15.2	2.2	[42]
Nile tilapia (*Oreochromis niloticus*)	78.7	8.9	15.5	[43]
Nile tilapia (*Oreochromis niloticus*)	20.3–33.1*	–	1.7–3.1*	[44]
Nile tilapia (*Oreochromis niloticus*)	29–45	–	2.3–5.5	[45]
Common carp (*Cyprinus carpio*)	30.3	–	2.5	[46]
Longtail tuna (*Thunnus tonggol*)	0.4–17.5	0.1–12.6	8.3–10.3	[47]
Hardtail scad (*Megalaspis cordyla*)	17.5	–	3.5	[48]
Eel (*Monopterus albus*)	59.3	–	0.8	[49]
Eel (*Monopterus albus*)	61.2	4.2	1.6	[30]
Cockle (*Anadara granosa*)	96.2	22.7	3.3	[30]

*Dry weight basis

of sutchi catfish, Nile tilapia, Asian sea bass, grouper, hardtail scad, longtail tuna and Indian mackerel were statistically similar ($P > 0.05$). The manganese content of longtail tuna in the present study concurs with Yousuf [47], who reported the Mn content of 0.1–12.6 mg kg^{-1} for longtail tuna. The Mn content in Nile tilapia observed in the present study was lower than the reported Mn content for Nile tilapia (Table 3).

The copper content in the fish flesh ranged from 0.97 to 11.87 mg kg^{-1}, with a minimum observed for the sutchi catfish and a maximum for the hardtail scad (Figure 4c). Copper concentrations in all species were lower than the FAO/WHO limit (10 mg kg^{-1}) except hardtail scad [38]. The safe and adequate daily intake of Cu is 1.5–3 mg for adults, 1.5–2.5 mg for children aged 11 years and older, 1–2 mg for children between 7 and 10 years, 1–1.5 mg for children between 4 and 6 years, 0.7–1 mg for children between 1 and 3 years and 0.4–0.7 mg for infants [52]. The Cu content of Indian mackerel was higher than that of sutchi catfish, Nile tilapia, Asian sea bass, grouper, longtail tuna, eel and cockle ($P < 0.05$). The copper contents of Nile tilapia, Asian sea bass, grouper, longtail tuna, eel and cockle were statistically similar ($P > 0.05$). Similarly, the Cu contents of sutchi catfish, Nile tilapia, Asian sea bass, grouper, longtail tuna and eel were statistically similar ($P > 0.05$). The Cu content observed in this study for Asian seabass and Nile tilapia agrees with the reported copper content (Table 3). However, the Cu contents in Indian mackerel and hardtail scad were higher than the reported value (Table 3).

The metal content in Sutchi catfish, Nile tilapia, grouper, longtail tuna, eel and cockle followed an order Zn > Mn > Cu, whereas Asian seabass, hardtail scad and Indian mackerel followed a different order Zn > Cu > Mn. Metabolic requirements for specific trace metals in the individual species, differences in diet preferences and area of capture may account for these differences [18,53,54]. According to Jenne and Luoma [55], the bioavailability of trace metals is influenced by the physiological and ecological properties of organisms, the form of dissolved trace elements, the chemical and physical properties of water and trace metal speciation in sediments.

The observed differences of trace metals content between the present study and previous studies can be explained by the fact that the concentrations of these metals depend to a great extent on age, sex, biological cycle, season, nutrient availability, temperature and salinity of the water may contribute to variations in the trace metal concentrations in fishes [56]. Trace metals and nutrients enter into the aquatic environment by many ways. However, after entering the aquatic ecosystem, the majority of nutrients and trace metals bound to the sediments [57,58]. Therefore, trace metal content in the aquatic sediment is normally very high [59,60]. They are released into surface waters through the upwelling of nutrient-rich waters. Trace metals are bio-accumulated in the lower portion of the food chain and transferred gradually to the higher portion of the food chain [18]. Such a pathway was implied to explain the elevated trace metals contents in fish from Mauretania and India [18,61].

Based on the observed trace metal intake in various fish and shellfish, the estimated average daily Zn and Mn intake is significantly higher by consuming diet 2 (Zn: 6.9 mg day^{-1}, Mn: 0.9 mg day^{-1}) compared to other diets (Figure 3a and b). When considering daily average Cu intake per person, diet 1 (0.7 mg day^{-1}) and diet 2 (0.7 mg day^{-1}) are almost same and both are higher than diet 3 (0.2 mg day^{-1}) and diet 4 (0.5 mg day^{-1}). However, the estimated daily Zn, Mn and Cu intake by consuming diet 2 is almost similar to the recommended Zn, Mn and Cu intake for Malaysian by National Coordinating Committee on Food and Nutrition Ministry of Health Malaysia [30], who recommended daily Zn, Mn and Cu intake 4–9.9, 1.2–2.3 and 0.3–0.9 mg day^{-1}, respectively, depending on age and gender. This result indicates that diet 2 (marine fishes and shellfish: Asian sea bass, grouper, hardtail scad, longtail tuna, Indian mackerel and cockle) is better than consuming other diets (diet 1, diet 3 and diet 4) in the case of daily average Zn, Mn and Cu intake.

4 Conclusion

From the results of this study, the tissue Zn, Mn, Cu contents of the fishes were within safe limits for human consumption. However, Mn enrichment in the cockle and Cu enrichment in the hardtail scad collected from the east coast of peninsular Malaysian is a matter of concern. This study provides essential baseline data with which future studies can be compared and evaluated. The data provided in this study will contribute substantially to the knowledge about the proximate composition and the contents of the essential trace element Zn, Mn and Cu in the edible part of a considerable number of important fish species. Consuming freshwater fishes is slightly better than consuming marine fishes in the case of daily protein intake. When considering the intake of daily fish fat, mineral and trace metals (Zn, Mn and Cu), consuming marine fishes and shellfish is better than consuming freshwater fishes. This article will remove the existing knowledge gaps of the consumer, nutritionist and the interested scientific community.

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