Chemical composition of the fillet, fins, bones and viscera of hybrid grouper (Epinephelus lanceolatus x Epinephelus fuscoguttatus)

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Abstract. Fish provides a rich source of protein, fatty acids and minerals. Being the world’s first hybridised grouper (TGGG) as a result of cross-breeding the giant grouper and tiger grouper, TGGG has proven to be more disease-resistant as compared to both of its parent species. It is important to determine the nutrients compositions of all parts of the fish as a means of widening its scope of usage. The objective of this study is to determine the chemical compositions from the fillet, fins, bones and viscera of TGGG. The results showed that the fins and fillet contained high levels of protein (fins: 68.12%; fillet: 78.63%) and low Na/K ratios (fins: 0.4; fillet: 0.1). Essential amino acids (EAA) in the fillet were comparable to FAO/WHO requirements. The lipid from viscera contained SFA as the major component, whereas other fish parts were rich in unsaturated FA. Both the fillet and fins had the same PUFA/SFA ratio (0.43) and was higher than bones (0.31) and viscera (0.25). Glycine and proline were the most abundant AA, while calcium was the major mineral in the bones. In summary, each part of the fish could be potential new sources of specific nutrient components.

1. Introduction
Fish provides a rich source of protein, fatty acids and minerals [1-2]. According to the Food and Agriculture Organization of the United Nations (FAO) report, more than 3.1 billion people depend on fish consumption that makes 20% of their animal protein intake [3]. Much attention has been focused on fish and its nutritional value in curbing the global issue of child malnutrition, particularly in underdeveloped countries. In the fish processing industry, fish are normally separated into edible (fillet and fins) for human consumption and the inedible portion (bones and viscera), which are discarded as animal feed. Every part of the fish consists of specific nutrients that are used according to its different functions, for example, the muscle is used for movement and locomotion, while the skeletal structure is for maintaining its body frame. Thus, the different nutrients could have been developed in each individual part of the fish as a means of ensuring their proper functions. By knowing the nutrients composition of the fish portion, this would provide useful information in assigning downstream value added products such as functional ingredients (bioactive peptides),...
supplements and even cosmetics [4]. For this reason, it is important to determine the nutritional composition of every part of the fish due to its potential major contribution to these industries.

Groupers belong to one of the largest and most widely distributed families of marine species and are found in temperate waters. Well-known as a special delicacy, this fish has been dominating the marine fish culturing industry, which is valued for its availability, flavour and size [5]. The hybridisation between two high-value groupers, namely the giant grouper (*Epinephelus lanceolatus*) and tiger grouper (*Epinephelus fuscoguttatus*), has led to the production of a hybrid grouper, TGGG that matures faster, more disease-resistant and nutritious compared to its parent species [6]. This hybrid grouper is the world’s first hybrid grouper that was successfully hybridised by Borneo Marine Research Institute (BMRI), Universiti Malaysia Sabah (UMS) in the year of 2006. This grouper is now known worldwide with its promising growth performance and has since taken the seafood industry by storm.

Many studies have shown that by-products such as fish skin and bones gelatine [7] and viscera [8] contain various nutrients that display various functional properties such as antioxidants and antihypertensive activities. However, there has not been any study conducted to determine the nutritional composition based on the different parts of a hybrid grouper. In order to explore the potential of the edible and inedible portions of the hybrid grouper as functional ingredients, it is essential to investigate the content composition of these parts. The knowledge of nutrients composition in the parts of the fish, especially on the inedible portions, would contribute to the value of by-products as well as in aiding the issue of fish waste management. Hence, the objective of the current study is to determine the nutritional composition of fillet, fins, bones (including fish head) and viscera of a hybrid grouper (TGGG).

2. Materials and Methods

2.1. Sample preparation

The hybrid groupers (*Epinephelus lanceolatus* x *Epinephelus fuscoguttatus*, TGGG) were purchased of similar weights (800 – 850 g) from the BMRI’s hatchery, UMS, as this is the preferred consumable weight. All the fish were fed with the same commercially available marine fish feed, with 42% crude protein and 8% crude fat. The fish were collected from three different tanks (two fish from each tank) with similar recirculating aquaculture system (water temperature: 26 - 27°C; pH: 7.80 – 8.50; salinity: 28–30 ppt) as biological replicates. The pair of fish from each tank was pooled together as a single sample to ensure that there was sufficient amount available for analyses. The fish were weighed and transported to the laboratory in ice pack on the same day. On arrival at the laboratory, the fish were rinsed with distilled water, then cut and divided into four parts, namely: (1) fillet; (2) bones (including fish head); (3) fins and (4) viscera. These parts were then frozen immediately using liquid nitrogen and freeze dried in a freeze dryer for 24 hour. They were then blended using waring blender, packed in sealed bags, and then stored at -20°C for further used.

2.2. Proximate analysis

The proximate compositions of the samples were determined [9, 10]. The moisture content was determined by using the oven method at 105°C that was left overnight (AOAC 934.01), while the ash content was gravimetrically determined after heating at 550°C for 24 hour in a muffle furnace (AOAC 930.05). The fat content was extracted in a Soxtec system with petroleum ether (AOAC 991.36) and the protein content was determined by using the Kjeldahl method (AOAC 2001.11) (N x 6.25). The results were expressed on a dry weight (DW) basis and all measurements were performed in triplicates.

2.3. Amino acid analysis

The amino acids (AA) content of the samples were analysed with modifications [11-12]. The samples were hydrolysed with 6N HCl for 24 hours. On-line derivatisation was carried out by using Agilent 1200 series high performance liquid chromatography (HPLC). The result was expressed as g/100g
DW basis. The AA scores were calculated and compared with the FAO/WHO reference pattern [10-13]. All measurements of the AA were performed in triplicates.

2.4. Fatty acids analysis
The fatty acids (FA) of TGGG were analysed by Agilent 6890 gas chromatography equipped with a flame ionisation detector (GC-FID) (Agilent Technologies, Santa Clara, CA) fitted with a capillary BPX 70 column (30 m x 0.32 mm x 0.25 μm, SGE Analytical Science, Victoria, Australia) [14]. Identification and quantification of fatty acid methyl esters (FAMEs) were accomplished by comparing the retention times of the peaks with those of pure Supelco FAMEs standard (Sigma-Aldrich, St. Louis, MO) analysed under the same conditions. The results were expressed in mg/g DW basis and all measurements were performed in triplicates.

2.5. Mineral analysis
The mineral content of TGGG was determined according to Njinkoue et al. [15]. The samples were used for major [sodium (Na), potassium (K), magnesium (Mg), calcium (Ca)] and trace [zinc (Zn), iron (Fe), and copper (Cu)] mineral determination using Perkin Elmer Optima 5300 DV inductive coupled plasma optical emission spectrometer (ICP-OES) (Perkin Elmer, Waltham, MA). The results were expressed in mg/100g DW basis and all measurements were performed in triplicates.

2.6. Statistical analysis
All analyses were carried out in triplicate and the results were expressed as mean ± standard deviation (SD). The data obtained were analysed by one-way analysis of variance (ANOVA) followed by Tukey multiple range test using SPSS v.17 for Windows (SPSS, USA). The differences between means were considered to be significant at P < 0.05.

3. Result and Discussions
3.1. Proximate composition
The proximate composition of fillet, fins, bones, and viscera of freeze dried TGGG is shown in Figure 1. The moisture content showed no significant difference between the different fish parts (P > 0.05). The ash content was significantly higher in bones (P < 0.05), followed by fins, viscera and fillet. This was in agreement with the data reported in other fish species such as black sea anchovy [16], where the fish head had a higher level of ash content as compared to the viscera. The high ash content of TGGG in the current study indicates the presence of diverse minerals that are of significant amount.
such as black sea anchovy, skate, black pomfret, and *Channa* spp [2] [8] [16-17]. The high protein content of the fillet could be due to the presence of a relatively higher concentration of myofibrillar protein [18]. The protein content of the fillet and bone of TGGG were found to be higher than the dorsal flesh (71.24% DW) and bone (31.82% DW) of its parent species i.e. the giant grouper [1]. The fish protein content also varies depending on the species, nutritional condition and the type of fish [19]. The fat content of TGGG was in the range of 9.42 – 41.63% DW with viscera having 2 – 4 times higher in fat content (P < 0.05) than the other parts. These findings were in line with the previous studies conducted on skate and anchovy [16-17]. The high fat content of viscera could be attributed to the fish liver, which acts as the lipid storage site. The fat content in the dark muscle of a fish is usually several times greater than that of the white muscles. Fish of fast-moving, migratory species usually have more dark muscles and fat as compared to the slow moving species, which is mainly composed of white muscles [20]. The hybrid grouper is a demersal fish (bottom feeder) that tend to drift with ocean currents, therefore do not swim actively for long periods. Consequently, they do not possess much of the dark muscle required for prolonged aerobic activity, thus the muscle fat content is relatively lower than that of the pelagic fish such as tuna. It was discovered that the ash and protein content of TGGG’s fillet, bones and fins were higher than the other grouper species such as the giant and tiger grouper cultured in Malaysia [21, 22], where the fat content was comparable if not lower. This suggests that TGGG may have better nutritional values than its parent species and the other grouper species.

### 3.2. Amino acid composition

The AA composition of TGGG is presented in Table 1. The total content of AA in TGGG was in the range of 27.38 – 63.33 g/100g DW. This was higher than the data reported on the fillet and bones portions of giant grouper (0.15 – 0.42 g/100g) [1]. Overall, the AA in the fillet were significantly higher (P < 0.05) as compared to the other fish parts except for glycine and proline where the bones showed the highest level. The EAA/AA ratio ranging from 0.38 – 0.51 suggests that almost 50% of the AA in TGGG were of EAA. This ratio was higher than the fillet and bone of giant grouper (0.3) [1]. Data obtained also revealed that the content of lysine was found to be highest in the fillet that represents 11.02% of the total AAs and 21.72% of total EAA. This was in line with the previous study that reported on the fillet of farmed rainbow trout [23]. From the experiment, it has been demonstrated that the fish fins had a similar AA composition trend as the fillet portion.

The non-essential amino acids (NEAA) of TGGG was in the range of 15.06 – 31.19 g/100g DW. For all of the fish parts, glutamate was the highest NEAA, representing 14 – 16% of its total AA. It was in accordance with the previous data reported by Zuraini et al. [2] in *Channa* spp fish where the AA with the highest presence were aspartic and glutamic acids. Conversely, it is worthy to note that the glycine content was significantly higher in the bones as compared to the other fish parts (P < 0.05), due to its high level of ash content. This was shown by the significant positive correlation (R² = 0.745, P < 0.01) (data not shown) between the ash and the glycine contents. This result was in agreement with previous findings that showed a positive correlation between glycine content and the amount of ash on a dry matter basis in lumpfish and ballan wrasse [24]. Moreover, glycine, which is one of the major components of human skin collagen, together with other EAA such as alanine, proline, arginine, serine, isoleucine and phenyl alanine form a polypeptide that will promote skin rejuvenation and tissues healing [2]. Due to the presence of connective tissues, high amount of proline was also found in the bones and fins portions besides glycine [16]. Previous studies reported that glycine, alanine, glutamic and aspartic acid are the main AA contributes to the sweetness and umami taste of fish fillet [25, 26]. The percentage of these AA with respect to total AA of the fillet portion of TGGG (39%) was five times higher than the level reported on giant grouper (7%) [1], but comparable to others freshwater fish such as snakehead fish (39%) [2] and rainbow trout (30%) [23]. This result suggested that the fillet portion of TGGG could have a better flavour quality than its parent species.
Table 1. Amino acids content of the fillet, bones, fins, and viscera of TGGG.

| Amino acids | Fillet       | Bones       | Fins        | Viscera      |
|-------------|--------------|-------------|-------------|--------------|
| Essential   |              |             |             |              |
| Arginine    | 4.21 ± 0.14a | 2.67 ± 0.06c| 3.66 ± 0.12b| 2.07 ± 0.04d |
| Isoleucine  | 2.80 ± 0.07a | 1.08 ± 0.10c| 2.01 ± 0.07b| 1.17 ± 0.10c |
| Lysine      | 6.98 ± 0.14a | 1.29 ± 0.05c| 5.69 ± 0.10b| 1.16 ± 0.01c |
| Leucine     | 5.31 ± 0.10a | 1.95 ± 0.06c| 3.81 ± 0.33c| 2.21 ± 0.07c |
| Methionine  | 1.96 ± 0.02a | 0.90 ± 0.08c| 1.53 ± 0.12b| 0.82 ± 0.07c |
| Phenylalanine| 2.48 ± 0.03a| 1.14 ± 0.11c| 1.94 ± 0.08b| 1.13 ± 0.11c |
| Tryptophan  | 0.75 ± 0.02a | 0.36 ± 0.02c| 0.48 ± 0.01b| 0.23 ± 0.04d |
| Tyrosine    | 1.88 ± 0.03a | 0.78 ± 0.08c| 1.40 ± 0.05b| 0.77 ± 0.09c |
| Valine      | 2.89 ± 0.03a | 1.35 ± 0.12c| 2.22 ± 0.05b| 1.41 ± 0.11c |
| Non-essential |        |             |             |              |
| Alanine     | 4.30 ± 0.06c | 3.06 ± 0.13c| 3.87 ± 0.06b| 2.36 ± 0.04d |
| Aspartate   | 6.11 ± 0.12a | 2.89 ± 0.02c| 4.60 ± 0.05b| 2.62 ± 0.03d |
| Glutamate   | 10.04 ± 0.97a| 4.85 ± 0.06c| 7.63 ± 0.40b| 4.10 ± 0.08c |
| Glycine     | 3.90 ± 0.30ab| 4.67 ± 0.06c| 4.75 ± 0.18a| 2.69 ± 0.02c |
| Histidine   | 1.81 ± 0.07a | 0.78 ± 0.06d| 1.33 ± 0.10b| 1.08 ± 0.05c |
| Proline     | 2.45 ± 0.08c | 2.99 ± 0.10a| 2.70 ± 0.11b| 0.90 ± 0.01d |
| Serine      | 2.58 ± 0.05a | 1.47 ± 0.14c| 2.16 ± 0.15b| 1.32 ± 0.05c |
| Total AA    | 63.33 ± 0.65a| 33.69 ± 0.94c| 52.05 ± 0.27b| 27.38 ± 0.70d |
| Total EAA   | 32.14 ± 0.61a| 12.97 ± 0.75c| 25.01 ± 0.20b| 12.31 ± 0.69c |
| Total NEAA  | 31.19 ± 1.24a| 20.71 ± 0.24c| 27.04 ± 0.36b| 15.06 ± 0.04d |
| EAA/AA      | 0.51 ± 0.02a | 0.38 ± 0.01c| 0.48 ± 0.01a| 0.45 ± 0.01b |

Values are mean ± SD, n=3
Mean without a common superscript letter (a-d) across the same row is significantly different at P < 0.05 level by Tukey multiple range test.
AA, amino acids; NEAA, non-essential amino acids; DW, dry weight

Table 2. The AA score of the fillet, bones, fins, and viscera of TGGG.

| EAA Reference protein (mg/g protein) | Fillet | Bones | Fins | Viscera |
|-------------------------------------|--------|-------|------|---------|
| Threonine                           | 34     | 107.51| 68.17| 97.84   | 98.36 |
| Valine                              | 35     | 105.01| 62.32| 93.38   | 100.01|
| Methionine*                         | 25     | 99.86 | 58.62| 89.88   | 81.32 |
| Lysine                              | 58     | 153.00| 36.00| 144.08  | 49.28 |
| Isoleucine                          | 28     | 127.17| 62.21| 105.56  | 103.30|
| Leucine                             | 66     | 102.37| 47.88| 84.77   | 82.64 |
| Phenylalanine*                      | 63     | 88.13 | 49.60| 77.90   | 74.74 |
| Tryptophan                          | 11     | 86.88 | 53.55| 63.99   | 51.45 |

* Methionine+Cysteine
# Phenylalanine+Tyrosine
AA, amino acid; EAA, essential amino acid
The AA scores evaluate the actual abundance of individual EAA found in food material and relate it to dietary requirements or a reference protein [10, 27]. The AA scores are shown in Table 1. The high AA scores in fillet and fins indicate that the presence of EAA in these fish parts have a high biological value. Hence, differences in the limiting AA (the amino acid that is in shortest supply in relation to need) for the different parts of the fish have been observed, for instance, tryptophan is the limiting AA for fillet and fins, while lysine is the limiting AA for bones and viscera. This was different from the data reported on the fillet of *Pseudobagrus ussuriensis* where methionine was identified to be the limiting amino acid [26].

### 3.3. Fatty acid composition

The FA profile of TGGG is presented in Table 3. All the TGGG parts had a higher level of saturated fatty acids (SFA) as compared to the monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA). The SFA and MUFA concentration in the fillet of TGGG were found to be comparable to the fillet of giant grouper [1] and other marine fish such as mackerel and pomfret found in Malaysia [28]. Moreover, the fatty acids were also approximately 20% higher than the content found in the fillet of humpback grouper [14].

#### Table 3. The fatty acid profiles of the fillet, bones, fins, and viscera of TGGG.

| Fatty acid | Carbon no. | mg/g DW | Fillet | Bones | Fins | Viscera |
|------------|------------|---------|--------|-------|------|--------|
| **SFA**    |            |         |        |       |      |        |
| Lauric acid| C12:0      |         | 0.25 ± 0.01<sup>a</sup> | 0.14 ± 0.01<sup>b</sup> | 0.07 ± 0.01<sup>c</sup> | 0.26 ± 0.04<sup>a</sup> |
| Myristic acid| C14:0      |         | 3.22 ± 0.07<sup>a</sup> | 4.09 ± 0.21<sup>b</sup> | 2.15 ± 0.14<sup>d</sup> | 10.58 ± 0.08<sup>a</sup> |
| Palmitic acid| C16:0      |         | 22.77 ± 1.48<sup>c</sup> | 27.56 ± 1.13<sup>b</sup> | 14.67 ± 0.88<sup>d</sup> | 65.29 ± 0.28<sup>a</sup> |
| Stearic acid| C18:0      |         | 6.70 ± 0.36<sup>c</sup> | 7.79 ± 0.38<sup>b</sup> | 4.48 ± 0.15<sup>d</sup> | 20.59 ± 0.08<sup>a</sup> |
| Arachidic acid| C20:0      |         | 0.25 ± 0.02<sup>b</sup> | 0.28 ± 0.01<sup>b</sup> | 0.18 ± 0.01<sup>c</sup> | 0.93 ± 0.01<sup>a</sup> |
| Behenic acid| C22:0      |         | 0.23 ± 0.01<sup>b</sup> | 0.26 ± 0.01<sup>b</sup> | 0.22 ± 0.01<sup>c</sup> | 1.26 ± 0.02<sup>a</sup> |
| Lignoceric acid| C24:0     |         | 0.76 ± 0.03<sup>b</sup> | 0.35 ± 0.02<sup>d</sup> | 0.57 ± 0.13<sup>c</sup> | 2.40 ± 0.02<sup>a</sup> |
| **MUFA**   |            |         |        |       |      |        |
| Palmitoleic acid| C16:1      |         | 3.76 ± 0.06<sup>d</sup> | 4.86 ± 0.27<sup>b</sup> | 2.67 ± 0.15<sup>d</sup> | 9.77 ± 0.08<sup>a</sup> |
| Oleic acid | C18:1      |         | 20.86 ± 1.41<sup>c</sup> | 24.44 ± 0.94<sup>b</sup> | 13.67 ± 0.51<sup>d</sup> | 44.89 ± 0.36<sup>a</sup> |
| Erucic acid| C22:1      |         | 2.78 ± 0.06<sup>b</sup> | 1.05 ± 0.05<sup>d</sup> | 1.82 ± 0.41<sup>c</sup> | 5.22 ± 0.07<sup>a</sup> |
| **PUFA**   |            |         |        |       |      |        |
| Linoleic acid| C18:2      |         | 12.24 ± 0.23<sup>b</sup> | 10.99 ± 1.03<sup>c</sup> | 8.02 ± 0.93<sup>c</sup> | 20.92 ± 2.82<sup>a</sup> |
| Linolenic acid| C18:3      |         | 2.54 ± 0.02<sup>b</sup> | 1.66 ± 0.09<sup>c</sup> | 1.71 ± 0.26<sup>c</sup> | 4.34 ± 0.07<sup>a</sup> |
| ∑FA        |            |         | 76.39 ± 3.46<sup>b</sup> | 83.48 ± 4.13<sup>b</sup> | 50.24 ± 3.58<sup>d</sup> | 186.44 ± 3.42<sup>a</sup> |
| ∑SFA       |            |         | 34.20 ± 1.92<sup>c</sup> | 40.47 ± 1.77<sup>b</sup> | 22.35 ± 1.32<sup>d</sup> | 101.31 ± 0.41<sup>a</sup> |
| ∑MUFA      |            |         | 27.41 ± 1.32<sup>c</sup> | 30.35 ± 1.26<sup>b</sup> | 18.16 ± 1.07<sup>d</sup> | 59.87 ± 0.50<sup>a</sup> |
| ∑PUFA      |            |         | 14.79 ± 0.24<sup>b</sup> | 12.66 ± 1.12<sup>c</sup> | 9.73 ± 1.20<sup>c</sup> | 25.26 ± 2.88<sup>a</sup> |
| ∑PUFA/∑SFA |            |         | 0.43 ± 0.02<sup>a</sup> | 0.31 ± 0.02<sup>b</sup> | 0.43 ± 0.03<sup>a</sup> | 0.25 ± 0.03<sup>c</sup> |

Values are mean ± SD, n=3

Mean without a common superscript letters (a-d) across the same row is significantly different at P < 0.05 level by Tukey multiple range test.

DW, dry weight; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids

The SFA content had been arranged in the following descending order: viscera > bones > fillet > fins. High composition of SFA in the viscera of TGGG suggested that it could be used as an alternative...
lipid source in the fish feed. The high SFA and MUFA found in TGGG was in line with the previous literature reported on the fish found in warm or temperate regions, such as _Channa_ spp fish and giant catfish [2] [19]. The major PUFA presence in all portions of TGGG was the n-6 PUFA (linoleic acid). The viscera showed higher FA compositions, which could be due to the lipids undergoing more enzymatic activities in the liver, thus producing larger amounts of free fatty acids in term of oils [29].

The FA composition of fillet, bones and fins, with the exception of viscera, consisted mainly of unsaturated FA (>50%) in relation to the total FA amount. The FA compositions of the dietary fats, particularly some of the individual FA, are of great importance in human health and nutrition. A lower intake of saturated fat and an increase in the PUFA to SFA ratio have been associated with a lower risk of human coronary heart disease. Thus the PUFA/SFA ratio is one of the parameters used in assessing the nutritional quality of the lipid fraction in foods [10] [16]. In the current study, the fillet (0.43) and fins (0.43) had a significantly higher PUFA/SFA ratio (P < 0.05), while viscera (0.25) had the lowest ratio. This was in accordance with the findings reported in black sea anchovy [16]. The PUFA/SFA ratio of the fillet was lower than other marine species such as mackerel (7.36) and black pomfret (6.54) [28], but higher than other freshwater fish species such as giant catfish (0.39) and silver carp (0.27) [30].

3.4. Mineral composition

The mineral content of TGGG is shown in Table 4. Among the macro minerals, Ca was most abundant in the bones, fins, and viscera. The bones showed the highest Ca content (P < 0.05) as compared to the other fish portions. This was in accordance with the previous studies, whereby the addition of bones increased the level of the Ca content [12] [31]. This is because the fish bone is made up of 60 – 65% of hydroxyapatite crystals that composed of calcium and phosphorus [32]. The high minerals content in fish bones suggested that this part of the fish might be a cheap and nutritious source to complement a starch-based diet [3].

Generally, the K content was higher than the Na content in all of the tested fish parts, with fillet showing the highest K content (P < 0.05), which was 7 times higher than its Na counterpart. This was in accordance with the results shown in some fish species such as salmon, trout, and mackerel. Nevertheless, there are other fish species that possess a higher content level of Na than K, such as cod, blue whiting and saithe [12].

| Mineral | Fillet       | Bones        | Fins         | Viscera       |
|---------|--------------|--------------|--------------|---------------|
| Na      | 268.3 ± 20.8<sup>a</sup> | 694.1 ± 58.04<sup>a</sup> | 429.6 ± 32.1<sup>b</sup> | 424.5 ± 33.2<sup>b</sup> |
| K       | 1911.1 ± 200.4<sup>a</sup> | 704.1 ± 72.4<sup>c</sup> | 1038.6 ± 114.3<sup>b</sup> | 460.6 ± 40.8<sup>b</sup> |
| Mg      | 136.2 ± 12.3<sup>b</sup> | 202.8 ± 4.5<sup>a</sup> | 193.2 ± 10.3<sup>a</sup> | 126.9 ± 4.8<sup>b</sup> |
| Ca      | 138.1 ± 10.1<sup>d</sup> | 874.6 ± 357.1<sup>a</sup> | 688.1 ± 187.4<sup>b</sup> | 978.7 ± 47.6<sup>e</sup> |
| Na/K    | 0.1 ± 0.02<sup>d</sup> | 1.0 ± 0.02<sup>a</sup> | 0.4 ± 0.02<sup>c</sup> | 0.9 ± 0.01<sup>b</sup> |
| Zn      | 2.4 ± 0.3<sup>b</sup> | 7.9 ± 0.3<sup>a</sup> | 7.4 ± 0.9<sup>a</sup> | 7.6 ± 0.5<sup>a</sup> |
| Fe      | 1.9 ± 0.8<sup>b</sup> | 3.7 ± 0.4<sup>b</sup> | 1.8 ± 0.4<sup>b</sup> | 14.5 ± 1.1<sup>a</sup> |
| Cu      | 0.7 ± 0.1<sup>b</sup> | ND            | 0.8 ± 0.2<sup>b</sup> | 2.1 ± 0.1<sup>a</sup> |

Values are mean ± SD, n=3

Mean without a common superscript letter (a-d) across the same row is significantly different at P < 0.05 level by Tukey multiple range test.

Ca, calcium; Cu, copper; DW, dry weight; Fe, iron; K, potassium; ND: Not detected; Mg, magnesium; Na, sodium; Zn, zinc

The higher level of K content in relative to the Na content in TGGG leads to a low Na/K ratio ranging from 0.1 – 1.0. The Na/K ratio of the fillet of TGGG was lower than other marine fish such as...
Pseudotolithus typus (0.2) [15]. The intake of a high Na/K ratio has been related to high incidences of hypertension. Therefore, with the low Na/K ratio in TGGG, it has the ability to reduce fluid retention and high blood pressure without the risk of upsetting the K balance [10]. It is worthy to note that the bones have a significantly higher level of Mg content (P < 0.05), followed by the fins, fillet and viscera.

For trace mineral, a high Zn content was observed in the bones, fins, viscera and the fillet portion showed the lowest value. The fillet of TGGG contained lower Zn composition than the fillet of torpedo scad (2.83 mg/100g) and belangeri’s croaker (2.10 mg/100g) [33]. On the other hand, Fe was significantly higher in viscera, followed by bones, fillet, and fins respectively. The high Fe content in bones and viscera as compared to the other parts could be due to the presence of fragments of blood that remained in the fish after the slicing and portioning processes. A similar result was reported in a previous study where the Fe concentration was higher in a combination of fish flesh and bones as compared to the flesh alone [31]. The Fe content in the bones portion of TGGG was higher than the bone of salmon (3.2 mg/100g) and trout (3.6 mg/100g) [12].

4. Conclusions
There is a great difference in the nutritional value found in the fillet, bones and viscera of TGGG. The fillet and fins portion of TGGG contained higher protein and AA than the reported data of its parent species i.e the giant grouper. The fillet of TGGG could be a high quality protein source because of its EAA concentration that was comparable to the FAO/WHO requirements. Lipid from viscera was high in SFA such as palmitic acid and stearic acid, whereas other fish parts were rich in unsaturated fatty acids such as oleic acid. Based on the PUFA/SFA ratio, the lipid quality of the fillet and fins was better than the bones and viscera. The results also showed that the bones were rich in glycine, proline and marco-minerals especially Ca. This study showed that each part of the TGGG contained specific nutrient for complementing diets as well as for value added functional ingredients.

5. References
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