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ORIGINAL RESEARCH ARTICLE

Biochemical composition of some catfishes from a coastal river of Bangladesh in relation to a biometric indicator

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ABSTRACT

The proximate contents (protein, lipid, ash, and moisture) of three catfish species (*Pangasius pangasius*, *Clupisoma garua*, and *Silonia silondia*) were investigated from a coastal river of Bangladesh. The proximate composition was determined using the AOAC (1990) standard procedure. The average length and weight of the fish samples used in the experiment were 21.50 ± 1.61 cm and 65.55 ± 13.12 g; 19.67 ± 0.21 cm and 50.74 ± 3.13 g; 18.2 ± 1.21 cm and 43.40 ± 10.42 g for *P. pangasius*, *C. garua*, and *S. silondia*, respectively. The *P. pangasius*, *C. garua*, and *S. silondia* were rich protein sources, with 20.19%, 18.86%, and 15.24%, respectively. On the other hand, the lipid and ash contents were ranged between 2.11% to 3.07% and 0.52% to 2.28% respectively. The present study disclused water as the most abundant element in fish bodies ranging from 75.05% (*P. pangasius*) to 79.60% (*S. silondia*). In log-transformed data, the weight of the fish body had a very significant positive relationship with most of the studied body constituents. In all three fish species, total length in log-transformed data and Fulton's condition factor showed a highly significant positive relationship with most of the studied body constituents. These findings suggest that biological differences like length and weight across species can influence the fishes biochemical composition that should be established.

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INTRODUCTION

Fisheries have played a momentous role in Bangladesh's economy as well as ensuring food security. Bangladesh is the world's third-largest producer of captured fisheries, behind China and India, and ranks fifth in overall fish production (FAO, 2018). Bangladesh's fisheries industry accounts for 60% of total animal protein consumption however fisheries fulfill about 20% of protein consumption world-wide. Coastal rivers and estuaries are among the world's most abundant aquatic resource environments (Roy *et al.*, 2022). However, Bangladesh's coastal regions are rich in fisheries resources (Siddik *et al.*, 2017, Rahman *et al.*, 2020a), and the Payra river in the country's southern part is one of the fisheries resource-rich zones. Payra river affords natural breeding grounds for a plethora of commercially significant fish species. Fish is one of the most cost-effective sources of animal protein and other essential elements, especially in impoverished countries.

It is a substantial source of highly unsaturated fatty acids (HUFA) and polyunsaturated fatty acids (PUFA), particularly omega-3 fatty acids like eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Erkan and Ozden, 2007; Huynh *et al.*, 2007). Market demand for fish has gradually expanded as a result of population growth and their perceived nutritional value. The nutritional value of fish products is determined by the amount of protein, lipids, minerals, and vitamins they contain. Fish proteins have a high value since they include a large number of necessary amino acids (Salma and Nizar, 2015; Shaji and

Hindumathy, 2013; Toppe *et al.*, 2007). On the other hand, PUFA generated from fish have been discovered to play an important role in human nutrition (Tanaka *et al.*, 1998). Several human illnesses, including cardiovascular disease, cancer, rheumatoid arthritis, and inflammation, have therapeutic and preventative benefits (Clandinin *et al.*, 1997; Raatz *et al.*, 2013). Fish muscle and bones also contain essential minerals (Ersoy and Zeren, 2009). Moreover, freshwater fish have different nutritional components depending on the species, size, sex, season, and geographical region (Huss, 1995; Zenebe *et al.*, 1998). The nutritional makeup of different freshwater fish species is poorly understood. Some proximate compositions, including protein, carbohydrates, lipids, moisture, and ash, must be measured on a regular basis to ensure that they comply with food regulations and commercial demands (Watermann, 2000). In addition to that, the nutritional content can be altered in addition to length and weight within the same species. However, the fishing community lacks knowledge regarding the size of fish caught during fishing. Considering the research gap, the present work was intended to determine the nutritive value of three catfish species from a Bangladeshi coastal river in connection to biometric indices.

MATERIALS AND METHODS

Sample collection

The three fish species *Pangasius pangasius*, *Clupisoma garua*, and *Silonia silondia* were collected and acquired fresh on the boats from fishermen on the Payra River from February 2019 to May 2019 (Figure 1). The fish samples were then transported to the Patuakhali Science and Technology University's Central Laboratory in Bangladesh with appropriate icing in an icebox with a fish/ice ratio of 1:2 (w/w). The mean length and weight of the fish which were used in this experiment were 21.50±1.61 cm and 65.55±13.12 g; 19.67±0.21 cm and 50.74±3.13 g; 18.2±1.21 cm and 43.40±10.42 g for *P. pangasius*, *C. garua*, and *S. silondia*, respectively.

Sample preparation

The fish were dissected using a clean stainless-steel knife after morphometric measurements. The head and viscera were discarded. The fishes were gutted, and eviscerated using a clean stainless-steel knife after morphometric measurements and thoroughly washed in flowing tap water. The edible component which consists of the meat and skin was sliced into pieces after removing the central vertebra and crushed to reflect the sections consumed by the natives. For lipid analysis, the fresh edible component was employed right away. For protein, and ash, and water retention analyses, the samples (edible part or clean central vertebra) were oven-dried at 45°C for 48 hours and homogenized completely in a commercial blender with stainless steel blades.

Proximate analysis

The moisture content of the sample was determined by using a hot air oven (HAS/50/TDIG/SS, Genlab, UK) by drying the sample at 105°C±2°C until a constant weight was attained (AOAC, 1990). Bligh and Dyer's (1959) technique was used to calculate the total lipid, which utilizes chloroform/ methanol (1/1, v/v). The crude protein content was estimated by remodeling the nitrogen content obtained by Kjeldahl's technique (Bloc Digest 12, JP Selecta, Spain), which used a 6.25 conversion factor to convert total nitrogen to crude protein (Anderson and Ingram, 1993; AOAC, 1990). The ash content was measured after a 20-hour burn at 550°C (AOAC, 1990). Carbohydrates were not tested because they are present in little levels and so do not make up a substantial component of the fish in this study (Caulton and Bursell, 1977; Elliott, 1976; Salam and Davies, 1994; Weatherley and Gill, 1987). Three different fish were used in each of the tests.

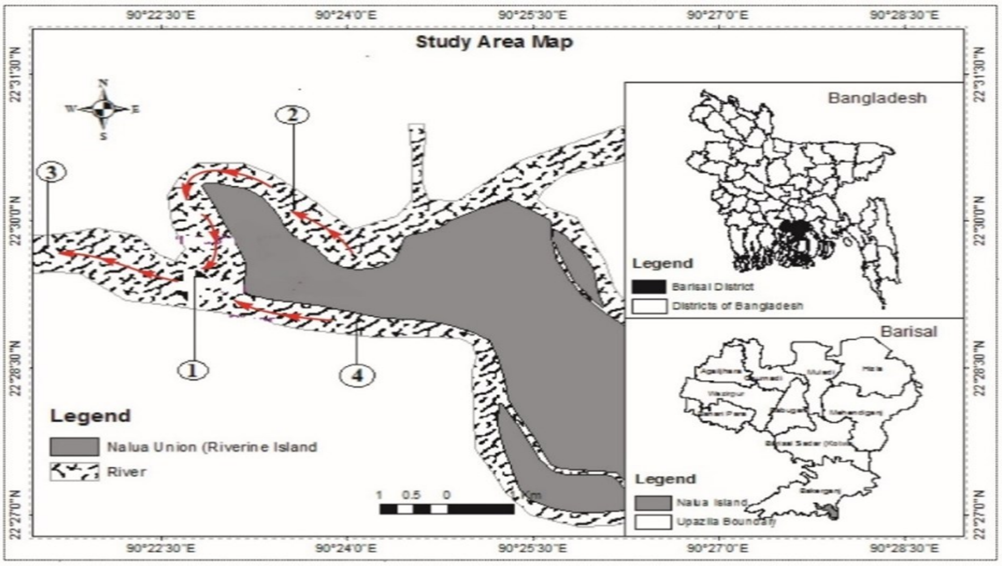

Figure 1. *The map shows a reference to the record and geographical location of the study area in Payra River, Patuakhali. The red arrows on the map indicate the direction of water flow in the Payra river system. 1) Karkhana river (Pandab point)- Latitude (22° 29´40.31''N) and Longitude (90° 21´23.10''E); 2) Karkhana river- Latitude (22° 29´18.23''N) and Longitude (90° 22´54.39''E); 3) Khairabad Nadi- Latitude (22° 30´34.52''N) and Longitude (90° 21´24.88''E); and 4) Bighai river- Latitude (22° 48´45.25''N) and Longitude (90° 21´14.17''E).*

Condition factor

The condition factor K which describes the overall health of fish was calculated using the following equation (Fulton, 1904): $K = 100 \times W / L^b$ where, K = condition factor; W = the weight of the fish (g); L = the total length of the fish (cm); and b = the value obtained from the length-weight equation.

Statistical analysis

The results are based on the average of three evaluations. The information was presented in the form of mean ± standard deviation. To assess the differences among species a one-way ANOVA was utilized. The significance of the variables was determined at $P<0.05$. The statistical analysis was done with SPSS 25.0 for Windows (SPSS, Chicago, IL, USA), and the regression, coefficient of correlation, and t-test were done with Microsoft Office (version 2019).

RESULTS AND DISCUSSION

Fishes are excellent sources of protein Which is thought to be the most significant biomolecule in fish and other aquatic organisms (Varadharajan and Soundarapandian, 2014). The protein content in the three fishes were ranging from 15.24% (*S. silondia*) to 20.19% (*P. pangasius*), which is higher than many other species (Figure 2). The protein content of the three species differs significantly ($p < 0.05$) in the current study. It has long been assumed that fish protein has a significant nutritive benefit (Sargent, 1997). Additionally, aquatic protein is easily digested and contains important amino acids like methionine and lysine, which are missing in terrestrial animal proteins (Tacon and Metian, 2013). As a result, these fishes can be a valuable source of protein for low-income or marginalized individuals.. This finding is similar to that of Fagbuaro *et al.* (2014) and Ayanda *et al.* (2019), who discovered protein levels ranging from 19 to 22%. Disparities in the absorption and conversion potentials of important nutrients in varied diets can explain these differences. In this situation, changes in protein composition may occur as a result of sex, size, dietary preferences, and species differences.

Fish oil consumption is beneficial to human health because of its nutritional makeup. The lipid content of these fish ranges from 2.11% (*P. pangasius)* to 3.07% *(S. silondia)*, which can be proved beneficial to human health (Figure 3). Consumption of lean fish has been linked to a lower incidence of metabolic syndrome in adults, according to more recent research (Torris *et al.*, 2016). The fat content of this fish was slightly lower than that of Osman *et al.* (2001), who used the same fat extraction process. Fish fat content varies depending on species, seasons, and geographical differences, therefore changes in fat content could be attributable to a variety of factors. Maturity and age differences in similar species may potentially have a role in the large disparities in total lipid content (Piggot and Tucker, 1990). According to Ackman (1989), fish can be divided into four categories based on their fat content: lean fish (less than 2% fat), low fat (2-4% fat), medium fat (4-8% fat), and high fat (8-12% fat) (more than 8

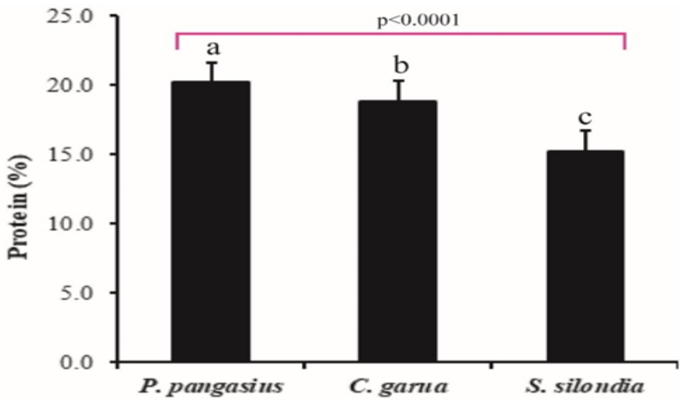

Figure 2. *A comparison of the protein content in three catfish species collected from the Payra river. Values are significantly different at 5% (p < 0.05).*

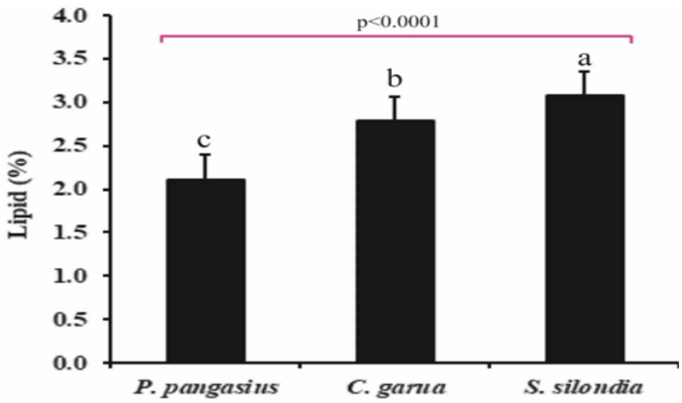

Figure 3. *A comparison of the lipid content in three catfish species collected from the Payra river. Values are significantly different (p < 0.05).*

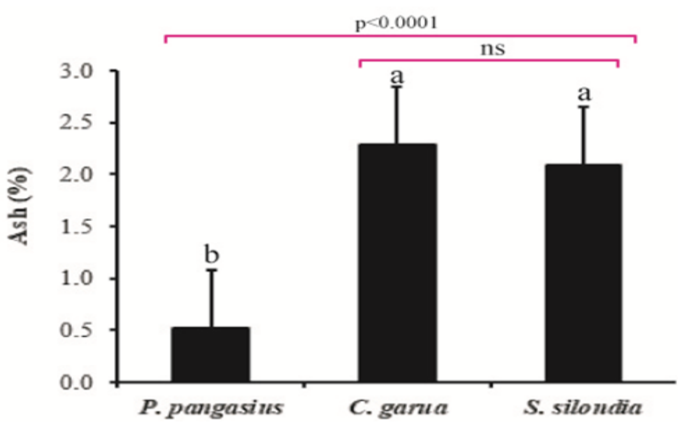

Figure 4. *A comparison of the ash content in three catfish species collected from the Payra river. Values are significantly different (p < 0.05).*

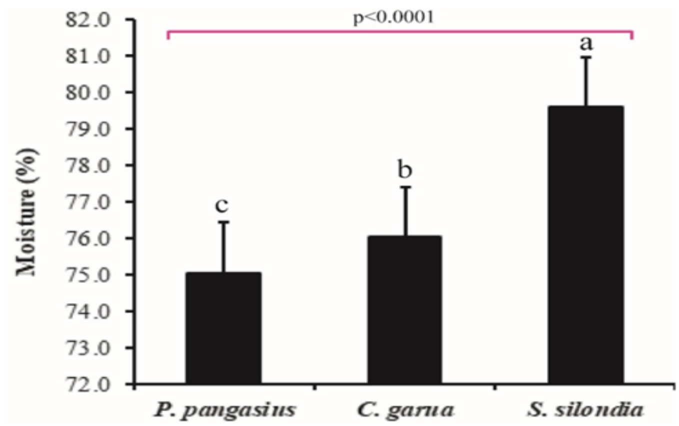

Figure 5. *A comparison of the moisture content in three catfish species collected from the Payra river. Values are significantly different (p < 0.05).*

Table 1. Condition factor of three catfish species collected from Payra river.

Parameters	*P. pangasius*	*C. garua*	*S. silondia*	*p*-value
Total length	$21.50^{a}\pm1.61$	$19.67^{ab}\pm0.21$	$18.2^{b}\pm1.21$	0.037
Total weight	$65.55^{a}\pm13.12$	$50.74^{ab}\pm3.13$	$43.40^{b}\pm10.42$	0.081
Condition factor	$0.66^{a}\pm0.05$	$0.67^{a}\pm0.06$	$0.71^{a}\pm0.03$	0.410

Table 2. Descriptive parameters of log wet body weight (g) vs log body components (g) in three catfish species taken from the Payra river.

Species	Relationships	r^2	a	b	SE	*t* - Statistics
P. pangasius	Log weight of body (x) vs Log protein contents (y)	0.26^{*}	0.006	1.29	0.001	0.59
	Log weight of body (x) vs Log lipid contents (y)	0.86^{*}	-0.09	0.48	0.004	-2.58
	Log weight of body (x) vs Log ash contents (y)	0.33^{*}	-0.57	0.16	0.02	0.71
	Log weight of body (x) vs Log moisture contents (y)	0.02^{ns}	-0.0008	1.87	0.0006	-0.15
C. garua	Log weight of body (x) vs Log protein contents (y)	0.62^{*}	0.15	1.00	0.004	1.29
	Log weight of body (x) vs Log lipid contents (y)	0.99^{*}	-0.32	0.99	0.0008	-13.69
	Log weight of body (x) vs Log ash contents (y)	0.21^{*}	-0.49	0.49	0.03	0.51
	Log weight of body (x) vs Log moisture contents (y)	0.65^{*}	-0.04	1.96	0.001	-1.36
S. silondia	Log weight of body (x) vs Log protein contents (y)	0.37^{*}	-0.05	1.27	0.01	-0.76
	Log weight of body (x) vs Log lipid contents (y)	0.16^{ns}	-0.06	0.59	0.02	-0.44
	Log weight of body (x) vs Log ash contents (y)	0.18^{*}	0.08	0.14	0.04	0.47
	Log weight of body (x) vs Log moisture contents (y)	0.18^{*}	0.008	1.88	0.002	0.47

SE: Standard Error; $^{*}p < 0.05$; ns: Not significant; a: Intercept; b: slope; r^2: correlation coefficient.

Table 3. Descriptive variables of log total length (cm) vs log total body constituents (g) of three catfish species collected from Payra river.

Species	Relationships	r^2	a	b	SE	*t* - Statistics
P. pangasius	Log total length (x) vs Log protein contents (y)	0.03^{ns}	0.006	1.29	0.001	0.18
	Log total length (x) vs Log lipid contents (y)	0.55^{*}	-0.20	0.59	0.008	-1.12
	Log total length (x) vs Log ash contents (y)	0.06^{ns}	-0.55	0.20	0.03	0.26
	Log total length (x) vs Log moisture contents (y)	0.23^{*}	-0.007	1.88	0.0006	-0.55
C. garua	Log total length (x) vs Log protein contents (y)	0.27^{*}	-0.60	2.05	0.006	-0.60
	Log total length (x) vs Log lipid contents (y)	0.81^{*}	-1.77	1.71	0.005	2.12
	Log total length (x) vs Log ash contents (y)	0.01^{ns}	-0.70	1.26	0.04	-0.11
	Log total length (x) vs Log moisture contents (y)	0.29^{*}	0.18	1.63	0.001	0.64
S. silondia	Log total length (x) vs Log protein contents (y)	0.34^{*}	-0.18	1.41	0.01	-0.72
	Log total length (x) vs Log lipid contents (y)	0.14^{*}	-0.22	0.76	0.02	-0.40
	Log total length (x) vs Log ash contents (y)	0.16^{*}	-0.29	0.48	0.04	0.44
	Log total length (x) vs Log moisture contents (y)	0.16^{*}	0.02	1.86	0.002	0.44

SE: Standard Error; $^{*}p < 0.05$; ns: Not significant; a: Intercept; b: slope; r^2: correlation coefficient.

percent fat). As a result, these fish fall into the low-fat category. Moreover, ash is the inorganic remnant of burnt organic matter and is used to determine an organism's mineral content. The ash content of the three fishes varies between 0.52% (*P. pangasius*) and 2.28% (*C. garua*), which is low (Figure 4). This differs with the findings of Ayanda *et al.* (2019), who found ash levels ranging from 2.91 percent to 7.56 percent in several fish samples from the Ogun River, which are greater than the current findings but comparable to Ayanda *et al.* (2018). Seasonal changes, age, sexes, sizes, sexual maturity, food supplies, and availability in an organism's environment, as well as other factors like water chemistry, salinity, temperature, and pollutants, may all affect mineral concentrations (Hassan, 1996; Kucukgulmez *et al.*, 2006). Generally, moisture is another important component of a fish's body composition. A sample's moisture content is a measure of how much water it possesses. The amount of water in the three fish varies from 75.05% (*P. pangasius*) to 79.60% (*S. silondia*) (Figure 5). Fish have soft skin, which provides for easy water permeability at the skin-water contact, allowing them to easily absorb more water. Organisms benefit from high moisture content because it allows for smooth enzymatic reactions. High moisture content in fish, on the other hand, might be a negative since it makes the fish more susceptible to microbial spoilage, accelerates oxidative destruction of polyunsaturated fatty acids, and lowers the quality of the fish, reducing its preservation time (Omolara and Omotayo, 2009).

The condition factor of the three species ranged between 0.66 (*P. pangasius*) to 0.71 (*S. silondia*) but there was no significant difference among them (Table 1). Before the nutritional profiling as well as the onset of the reproduction period fishes are subjected to the determination of condition factors (Lal and Naeem, 2021; Rahman *et al.*, 2020b). Though there was no significant difference among the condition factor, there was a significant difference among the proximate composition of the three catfish in the current study. So, it can be said that proximate composition was not dependent on the condition factor of any fish species. Strong correlations were observed when the total values of each proximate composition variable, such as protein, lipid, ash, and moisture, were transformed into logarithms, and regressions were run against log wet body weight and log total

Table 4. The association between Fulton's condition factor and percentage body contents of three catfish species was collected from the Payra river.

Species	Relationships	r^2	a	b	SE	*t* - Statistics
P. pangasius	Fulton's condition factor (x) vs (%) Protein (y)	0.76^{*}	19.56	0.95	0.03	1.80
	Fulton's condition factor (x) vs (%) Lipid (y)	0.15^{ns}	2.32	-0.32	0.05	-0.42
	Fulton's condition factor (x) vs (%) Ash (y)	0.70^{*}	0.19	0.49	0.02	1.55
	Fulton's condition factor (x) vs (%) Moisture (y)	0.96^{*}	73.99	1.61	0.02	5.39
C. garua	Fulton's condition factor (x) vs (%) Protein (y)	0.53^{*}	17.03	2.76	0.22	1.06
	Fulton's condition factor (x) vs (%) Lipid (y)	0.97^{*}	3.39	-0.90	0.01	-5.97
	Fulton's condition factor (x) vs (%) Ash (y)	0.15^{ns}	1.64	0.96	0.19	0.42
	Fulton's condition factor (x) vs (%) Moisture (y)	0.55^{*}	78.29	-3.41	0.26	-1.11
S. silondia	Fulton's condition factor (x) vs (%) Protein (y)	0.52^{*}	21.35	-8.60	0.30	-1.04
	Fulton's condition factor (x) vs (%) Lipid (y)	0.28^{ns}	4.78	-2.41	0.14	-0.63
	Fulton's condition factor (x) vs (%) Ash (y)	0.33^{*}	-0.46	3.60	0.18	0.71
	Fulton's condition factor (x) vs (%) Moisture (y)	0.31^{*}	74.31	7.47	0.40	0.68

SE: Standard Error; $^{*}p < 0.05$; ns: Not significant; a: Intercept; b: slope; r^2: correlation coefficient.

length, except for log moisture contents, which had no significant relationship with log body weight in *P. pangasius*, and log lipid contents, which had no significant relationship with log body weight in *P. pangasius*. Tables 2 and 3 provide the regression parameters for these relationships.

In this study, the condition factor was determined to be between 0.66 to 0.71, with a positive impact on all body contents except percent lipid in *P. pangasius*, percent lipid and percent moisture in *C. garua*, and percent protein and percent lipid in *S. silondia*. Except for percent Lipid in *P. pangasius*, percent Ash in *C. garua*, and percent *S. silondia*, Fulton's condition factor demonstrated a strong association with all percent body constituents (Table 4). In log-log regressions, Salam and Davies (1994), Naeem and Salam (2010), and Khalid and Naeem (2018) all discovered a significant positive relationship between total body components and body weight or length. The slope (b) of the log-log relationships between body constituents and body weight or length, when compared to b = 1 for weight or b = 3 for length (an isometric slope), is a good predictor of the isometric or allometric increase of these constituents with increasing weight or length (Tables 2 and 3), as also documented by Naeem and Salam (2010). As demonstrated in Table 4, Fulton's condition factor shows a substantial ($p < 0.05$) association with the majority of the proximal composition. These statistically significant ($p < 0.05$) associations are similar to those found by Naeem and Salam (2010). In *Aristichthys nobilis*, however, Naeem and Ishtiaq (2011) found no significant association between condition factor and body contents. For different fish species, the link between condition factor and Percentage body components may be significant or non-significant. The tiniest fish restore their energy stores the fastest in the spring, as one might predict given their lower body size (Jobling, 1995); yet, the larger fish species continue to grow their fat content.

Conclusion

The nutritional value of three distinct species investigated in this study suggest that the fish species are excellent providers of a variety of essential nutrients. However, the results of this investigation revealed significant differences in the proximate composition of three fish species, which were linked to the size, and weight of the capture samples. The present findings may help customers to pick fish based on nutritional value while also updating the food composition database.

Conflicts of interest

The authors declare that there is no conflict of interest.

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REFERENCES

Ackman, R. G. (1989). Nutritional composition of fats in seafoods. *Progress in Food & Nutrition Science*, *13*, 161-289.

Anderson, J. M., & Ingram, J. S. I. (1993). Tropical Soil Biology and Fertility: A Handbook of Methods (second ed.), CAB International, The Cambrian News, Aberstwyth, United Kingdom, pp. 221.

AOAC. (1990). Official Methods of Analysis of the Association of the Official Analysis Chemists. Association of Official Analytical Chemists (15th ed.), AOAC International, Washington, DC.

Ayanda, I. O., Dedeke, G. A., Ekhator, U. I., & Etiebet, M. K. (2018). Proximate Composition and Heavy Metal Analysis of Three Aquatic Foods in Makoko River, Lagos, Nigeria. *Journal of Food Quality*, 1-6.

https://doi.org/10.1155/2018/2362843

Ayanda, I. O., Ekhator, U. I., & Bello, O. A. (2019). Determination of selected heavy metal and analysis of proximate composition in some fish species from Ogun River, Southwestern Nigeria. *Heliyon*, *5*(10), e02512, https://doi.org/10.1016/j.heliyon.2019.e02512

Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, *37*, 911-917, https://doi.org/10.1139/o59-099

Caulton, M., & Bursell, E. (1977). The relationship between changes in condition and body composition in young Tilapia rendalli Boulenger. *Journal of Fish Biology*, *11*(2), 143-150, https://doi.org/10.1111/j.1095-8649.1977.tb04107.x

Clandinin, M. T., Foxwell, A., Goh, Y. K., Layne, K., & Jumpsen, J. A. (1997). Omega-3 fatty acid intake results in a relationship between the fatty acid composition of LDL cholesterol ester and LDL cholesterol content in humans. *Biochimica et Biophysica Acta*, *1346*, 247-252, https://doi.org/10.1016/s0005-2760(97)00040-4

Elliott, J. M. (1976). Body composition of brown trout (*Salmo trutta* L.) in relation to temperature and ration size. *Journal of Animal Ecology*, *45*(1), 273-289, https://doi.org/10.2307/3779

Erkan, N., & Ozden, O. (2007). Proximate composition and mineral contents in aquacultured sea bass (*Dicentrarchus labrax*), sea bream (*Sparus aurata*) analyzed by ICPMS. *Food Chemistry*, 102(3), 721-725, https://doi.org/10.1016/j.foodchem.2006.06.004

Ersoy, B., & Özeren, A. (2009). The effect of cooking methods on mineral and vitamin contents of African catfish. *Food Chemistry*, 115, 419-422, https://doi.org/10.1016/j.foodchem.2008.12.018

Fagbuaro, O., Majolagbe F. A., & Oso, J. A. (2014). Proximate composition and mineral content of the land crab *Sudanonautes africanus*. *Journal of Scientific Research and Reports*, *3*(2), 349–355, https://doi.org/10.9734/JSRR/2014/4440

FAO. (2018). The state of world fisheries and aquaculture (opportunities and challenges). Food and Agricultural Organization of the United Nations, Rome.

Fulton, T. W. (1904). The rate of growth of fishes. 22nd Ann. Rep. Fish. Board Scotland 3, 141-241.

Hassan, M. (1996). Influence of pond fertilization with broiler dropping on the growth performance and meat quality of major carps. University of Agriculture, Faisalabad, Pakistan. Ph.D. thesis.

Huss, H. H. (1995). Quality and quality changes in fresh fish. FAO Fisheries Technical Paper No. 348, Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy.

Huynh, M. D., Kitts, D. D., Hu, C., & Trites, A. W. (2007). Comparison of fatty acid profiles of spawning and non-spawning Pacific herring, *Clupea harengus pallasi*. *Comparative Biochemistry and Physiology B: Biochemistry and Molecular Biology*, *146*(4), 504-511, https://doi.org/10.1016/j.cbpb.2006.11.023

Jobling, M. (1995). Environmental biology of fishes. London. Chapman and Hall.

Khalid, M., & Naeem, M. (2018). Proximate analysis of grass carp (*Ctenopharyngodon idella*) from Southern Punjab, Pakistan. *Sarhad Journal of Agriculture*, *34*(3), 632-639, https://doi.org/10.17582/journal.sja/2018/34.3.632.639

Kucukgulmez, A., Celik, M., Yanar, Y., Ersoy, B., & Cikrikci, M. (2006). Proximate composition and mineral contents of the blue crab (*Callinectes sapidus*) breast meat, claw meat and hepatopancrease. *International Journal of Food Science & Technology*, *41*(9), 1023-1026, https://doi.org/10.1111/j.1365-2621.2006.01159.x

Lal, V., & Naeem, M. (2021). Proximate composition analysis of marine fish, *Terapon jarbua*, from Pakistan. *Sarhad Journal of Agriculture*, 37(1), 290-295, http://dx.doi.org/10.17582/journal.sja/2021/37.1.290.295

Naeem, M., & Ishtiaq, A. (2011). Proximate composition of *Mystus bleekeri* in relation to body size and condition factor from Nala Daik, Sialkot, Pakistan. *African Journal of Biotechnology*, *10*(52), 10765-10763, https://doi.org/10.5897/AJB10.2339

Naeem, M., & Salam, A. (2010). Proximate composition of freshwater Bighead carp, *Aristichthys nobilis* in relation to body size and condition factor from Islamabad, Pakistan. *African Journal of Biotechnology*, 9(50), 8687-8692, https://doi.org/ 10.5897/AJB10.888

Omolara, O., & Omotayo, O. (2009). Preliminary Studies on the effect of processing methods on the quality of three commonly consumed marine fishes in Nigeria. *Biokemistri*, *21*(1), 1-7.

Onyeike, E. N., Ayoologu, E. O., & Ibegbulam, C. O. (2000). Evaluation of the nutritional value of some crude oil in polluted freshwater fishes. *Global Journal of Pure and Applied Sciences*, *6*, 227-233.

Osman, H., Suriah, A. R., & Law, E. C. (2001). Fatty acid composition and cholesterol content of selected marine fish in Malaysian waters. *Food Chemistry*, *73*(1), 55-60, https://doi.org/10.1016/s0308-8146(00)00277-6

Pagamunici, L. M., Souza, A. H. P., Gohara, A. K., Souza, N. E., Gomes, S. T. M., & Matsushita, M. (2014). Development, characterization and chemometric analysis of a gluten-free food bar containing whole flour from a new cultivar of amaranth. *Ciência e Agrotecnologia*, 38, 270-277, https://doi.org/10.1590/s1413-70542014000300007

Piggot, G.M., & Tucker, B.W. (1990). Seafood: Effects of Technology on Nutrition. New York, USA: Marcel Dekker, Inc.

Raatz, S.K., Silverstein, J.T., Jahns, L., & Picklo, M.J. (2013). Issues of fish consumption for cardiovascular disease risk reduction. *Nutrients*, *5*, 1081-1097, https://doi.org/10.3390/nu5041081

Rahman, M.A., Ullah, M.R., Kabir, M.A., Alam, M.A., Rahman, M., & Hossen, M.F. (2020a). Artificial propagation of indigenous yellowtail catfish (*Pangasius pangasius*): Experiences and challenges. *Aquaculture*, 735215, https://doi.org/10.1016/j.aquaculture.2020.735215

Rahman, M. A., Hossain, M. A., Ullah, M. R., & Iqbal, M. M. (2020b). Reproductive biology of Gagora catfish (*Arius gagora*) at Meghna river system , Kushiara. *International Journal of Aquatic Biology*, *8*(6), 383–395.

Roy, N., Ullah, M.R., Rahman, M.A., Hasanuzzaman, M., Tareq, A., & Chakma, S. (2020). Biochemical Composition and Gross Energy Value of Garua Bachcha, *Clupisoma garua* from a Coastal River, Bangladesh. *International Journal of Biological & Medical Research*, *11*(2), 7017-7022.

Salam, A., & Davies, P.M.C. (1994). Body composition of northern pike (*Esox lucius* L.) in relation to body size and condition factor. *Fisheries Research*, *19*(3-4), 193-204,. https://doi.org/10.1016/0165-7836(94)90038-8

Salma, E.O., & Nizar, M. (2015). Atlantic Mackerel amino acids and mineral contents from the Tunisian middle eastern coast. *International Journal of Agricultural Policy and Research*, *3*, 77-83.

Sargent, J. R. (1997). Fish oils and human diet. *British Journal of Nutrition*, *78*, S5–S13. https://doi.org/10.1079/bjn19970131

Shaji, S.A., & Kannan, H.C. (2013). Chemical composition and amino acid profile of *Sardinella longiceps* collected from Western coastal areas of Kerala, India. *Journal of Biology and Earth Sciences*, *3*, 129-134.

Siddik, M. A. B., Chaklader, M. R., Hanif, M. A., Nahar, A., Ilham, I., Cole, A., & Fotedar, R. (2017). Variation in the life-history traits of a Schilbid catfish, *Clupisoma garua* (Hamilton, 1822) in the waters of southern Bangladesh. *Chinese Journal of Oceanology and Limnology*, 35, 1189-1196, https://doi.org/10.1007/s00343-017-6008-6

Tacon, A. G. J., & Metian, M. (2013). Fish matters: importance of aquatic foods in human nutrition and global food supply. *Reviews in Fisheries Science*, *21*, 22-38, https://doi.org/10.1080/10641262.2012.753405

Tanaka, T., Saha, S.K., Tomomori, C., Ishima, R., Liu, D., Tong, K. I., & Ikura, M. (1998). NMR structure of the histidine kinase domain of the *E. coli* osmosensor EnvZ. *Nature*, *396*(6706), 88-92, https://doi.org/10.1038/23968

Toppe, J., Albrektsen, S., Hope, B., & Aksnes, A. (2007). Chemical composition mineral content and amino acid and lipid profiles in bones from various fish species. *Comparative Biochemistry and Physiology Part B*, *146*(3), 395-401. https://doi.org/10.1016/j.cbpb.2006.11.020

Torris, C., Molin, M., & Cvancarova, M.S. (2016). Lean fish consumption is associated with lower risk of metabolic syndrome: A Norwegian cross-sectional study. *BMC Public Health*, *16*, 347, https://doi.org/10.1186/s12889-016-3014-0

Varadharajan, D., & Soundarapandian, P. (2014). Proximate composition and mineral contents of freshwater crab *Spiralothelphusa hydrodroma* (Herbst, 1794) from Parangipettai, South East Coast of India. *Journal of Aquaculture Research and Development*, *5*(2), 1-6, https://doi.org/10.4172/2155-9546.1000217

Waterman, J. J. (2000). Composition and quality of fish. Torry Research Station. Edinburgh. UK.

Weatherley, A., & Gill, H.S. (1987). Growth increases produced by bovine growth hormone in grass pickerel, *Esox americanus vermiculatus* (Le Sueur), and the underlying dynamics of muscle fiber growth. *Aquaculture*, 65(1), 55-66, https://doi.org/10.1016/0044-8486(87)90270-5

Zenebe, T., Ahigren, G., Gustafsson, B., & Boberg, M. (1998). Fatty acid and lipid content of *Oreochromis niloticus* L. in Ethiopian lakes. Dietary effects of phytoplankton. *Ecology of Fresh Water Fish*, 7, 146-158, https://doi.org/10.1111/j.1600-0633.1998.tb00181.x