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Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security : Manuscript returned to draft

6 messages

Srimathi Anandan <srimathi.anandan@hindawi.com> Wed, Jul 12, 2023 at 6:32 PM
To: Hafrijal Syandri <syandri_1960@bunghatta.ac.id>
Cc: Deepanaa Rajadurai <deepanaa.rajadurai@hindawi.com>

Hindawi

Dear Dr. Hafrijal Syandri,

We have reviewed you manuscript "Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security " with ID No. 6639837. We found the following issues which need to be solved before moving on:

- **Authors & Affiliations**
  - - While checking your manuscript you have mentioned that two different email addresses for co-author are Dr. Harfiandri Damanhuri on the system "d.harfiandri@bunghattt.ac.id". Whereas in the cover letter file you have mentioned "d.harfiandri@bunghatta.ac.id". Can you please confirm your preferred email address for the further process?
- **Relevance Check**
  - - You have mentioned that there is no conflict of interest in the system and the manuscript file but you have provided funding grant details too. Hence please confirm whether there is any conflict of interest for you and the co-author

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King regards,
Srimathi Anandan

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hafrizal syandri <syandri_1960@bunghatta.ac.id> Thu, Jul 13, 2023 at 10:57 AM
To: Srimathi Anandan <srimathi.anandan@hindawi.com>

Dear
Srimathi Anandan
Editor Team International Journal of Food Science

Thank you for your email on July 12, 2023; We have revised the email (d.harfiandri@bunghatta.ac.id and changed it to harfiandri@bunghatta.ac.id). Additionally, we have revised manuscript No. 6639837, especially part Acknowledgements related to the conflict of interest.

Best Regards
Hafrijal Syandri
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Srimathi Anandan <srimathi.anandan@hindawi.com> Thu, Jul 13, 2023 at 2:24 PM
Reply-To: Srimathi Anandan <srimathi.anandan@hindawi.com>
To: syandri_1960@bunghatta.ac.id
Cc: syandri_1960@bunghatta.ac.id, deepanaa.rajadurai@hindawi.com

Dear Dr. Syandri,

Thank you for the email.

While checking the email address d.harfiandri@bunghatta.ac.id is verified one, could you please update this in the system as well as in the cover letter?

Best Regards,
Srimathi Anandan

Srimathi Anandan
Editorial Screener

e. srimathi.anandan@hindawi.com

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[Quoted text hidden]
, hafrizal syandri <syandri_1960@bunghatta.ac.id> wrote:
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Srimathi Anandan <srimathi.anandan@hindawi.com> Thu, Jul 13, 2023 at 2:25 PM
To: Hafrijal Syandri <syandri_1960@bunghatta.ac.id>
Cc: Deepanaa Rajadurai <deepanaa.rajadurai@hindawi.com>

Hindawi

Dear Dr. Hafrijal Syandri,

We have reviewed you manuscript "Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security " with ID No. 6639837. We found the following issues which need to be solved before moving on:

- **Relevance Check**
  - - While checking the email address d.harfiandri@bunghatta.ac.id is verified one could you please update this in the system as well as in the cover letter?

> *This paper has been returned to draft for the reasons listed above. Please could you log into your account and address these points as soon as possible? Once completed, please could you resubmit the manuscript in the same manuscript number "6639837" and do not start a new submission.*

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King regards,
Srimathi Anandan

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hafrizal syandri <syandri_1960@bunghatta.ac.id> Thu, Jul 13, 2023 at 4:26 PM
To: Srimathi Anandan <srimathi.anandan@hindawi.com>

Dear,
Srimathi Anandan

Thank you for your email; We verify that the author Harfiandri with the email: d.harfiandri@bunghatta.ac.id, has changed to harfiandri@bunghatta.ac.id; besides that, we have changed the email d.harfiandri@bunghatta.ac.id to harfiandri@bunghatta.ac.id in the cover letter.

Best regards
Hafrijal Syandri

[Quoted text hidden]

Srimathi Anandan <srimathi.anandan@hindawi.com> Fri, Jul 14, 2023 at 12:47 PM
Reply-To: Srimathi Anandan <srimathi.anandan@hindawi.com>
To: syandri_1960@bunghatta.ac.id
Cc: syandri_1960@bunghatta.ac.id, deepanaa.rajadurai@hindawi.com

Dear Dr. Syandri,

Thank you for the response.

We will proceed with your manuscript for further processing.

Best Regards,
Srimathi Anandan

Srimathi Anandan
Editorial Screener

e. srimathi.anandan@hindawi.com

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Research Article

Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security

Azrita Azrita[1], Hafrijal Syandri[1*], Hazlina Ahamad Zakeri[2], Harfiandri Damanhuri[1], Netti Aryani[3]

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Abstract:

Fish has become an irreplaceable source of animal protein food, especially among households with low socioeconomic conditions in rural and urban areas in Indonesia. This study analyzes the nutrient composition of three local Bagridae fish species in Indonesia. The nutrient composition results of *Hemibagrus nemurus*, *Hemibagrus wyckii*, and *Mystus nigriceps* revealed that the protein content was 24.26%, 22.57%, and 21.39% (% of dry weight), respectively. The total lipid content varied between 6.64% and 7.75%, whereas the crude ash content ranged from 1.59% to 2.30%. Regarding mineral contents, the calcium levels ranged from 1.49 to 1.66 mg/g, iron levels varied between 28.35 and 40.36 µg/g, and zinc levels ranged from 24.03 to 54.46 µg/g. The predominant amino acids found in the three species of Bagridae fish were glutamic acid, aspartic acid, alanine, arginine, and lysine, with their concentrations ranging from 9.10% to 24.34%. Among the fatty acids, C16:0 (palmitic acid) was the most abundant in all three species, accounting for 25.59% to 30.70% of the total fatty acids. Additionally, significant amounts of C18:1 (oleic acid), C18:0 (stearic acid), and C20:4 (arachidonic acid) were also detected as primary fatty acids. The calculated AI (atherogenic index) values in the three species of Bagridae fish ranged from 0.73 to 0.99, while the TI (thrombogenic index) values varied between 0.54 and 0.75. These results indicate that consuming the meat of these three freshwater species of Bagridae fish caught in the wild does not pose any health risks to consumers. They can be considered a safe and suitable food source with good nutritional quality.

Keywords: Nutrient composition, Amino acids, Fatty acids, Freshwater fish, Kampar Kanan River,

1. Introduction

Fish serve as a high-quality protein source that is essential for satisfying dietary protein requirements, especially in areas where other protein sources could be few or difficult to get [1,2]. Their accessibility can aid in ensuring a steady supply of food, particularly for communities whose main sources of income are fishing or aquaculture [3]. Fish can contribute to a more varied selection of protein sources in communities, resulting in a diet that is more nutritious and balanced. Dietary fish can treat nutrient deficits and enhance general nutritional health. Fish are generally considered safe and offer a lower risk of contamination with harmful substances compared to certain land-based animal products. According to Ravichandran et al. [4], a reliable indicator of the fish's quality, nutritional value, physiological status, and environment is said to be its chemical makeup, which is found in fish flesh.

Hemibagrus nemurus, locally known as "baung", *Hemibagrus wyckii*, known as "geso" and *Mystus negriceps*, known as "ingir-ingir," are three species of catfish found in Kampar Kanan River, Indonesia [5,6]. Due to their high market value, these species have been identified as significant economic resources for the rural community [7]. Therefore, the nutritional quality of fish meat in the study area is very important for analysis that is beneficial to human health.

Knowing the composition of fatty acids and amino acids in fish meat is an essential factor that should not be ignored [8,9,10]. This information provides valuable insight into the fish's nutritional quality and values of more nutritious and healthy foods [11]. In addition, a better understanding of the composition of fatty acids and amino acids can assist in selecting a suitable feed [12], developing a balanced diet [13], and maintaining optimal fish meat nutritional [14].

Omega-3 polyunsaturated fatty acids, particularly DHA and EPA derived from fish oil, exhibit anti-inflammatory and anti-gastrointestinal cancer properties, making them crucial as immune-boosting nutrients [15,16]. Studies have demonstrated that ω-3 and ω-6 polyunsaturated fatty acids (PUFA) exhibit beneficial effects in the management of cardiovascular diseases and cancers [17,18]. The fatty acid composition of polyunsaturated fatty acids (PUFAs) can differ among different types of fish, including both freshwater and marine species, as noted in studies conducted by Rincón-Cervera et al. [19] and Sun et al. [20] . Amino acids (AAs) like cysteine, arginine, tyrosine, glycine, proline, and serine play a vital role in illness and stress situations [21], including the prevention of inflammation and the repair processes in fish intestines [22].

In addition, knowledge of the atherogenicity index (AI) and thrombogenicity (TI) of fatty acids in three local freshwater fish species of Bagridae can contribute to improving dietary guidelines. This information, as suggested by Wen et al. [23] and Duarte et al. [24], demonstrates that the value of AI and TI can be used to develop recommendations aimed at improving heart health. These recommendations may involve selecting fish with favorable fatty acid profiles, allowing individuals to choose the most suitable fish species based on their specific needs [25,19]. Therefore, this study aims to examine the nutritional composition profile, mineral content, amino acids, and fatty acids, including AI and TI indices of three freshwater fish species, namely *H. nemurus*, *H. wyckii*, and *M. nigriceps*. These three types of fish are generally consumed by people who live around the Kampar Kanan River in Kampar Regency, Riau Province, Indonesia.

2. Material and methods

2.1. Materials

In this study, a total of 27 Bagridae fish belonging to three distinct species (*H. nemurus*, *H. wyckii*, and *M. nigriceps*) were examined. The specimens were obtained from local fishermen operating in the upper stretches of the Kampar Kanan River in Kampar Regency, Riau Province (Figure 1). The sampling took place between June and August 2022. They were verified by the Fisheries Department, Faculty of Fisheries and Marine Science Universitas Bung Hatta, Indonesia. The samples were placed in plastic bags and transported to the laboratory in an insulated icebox. The samples were then grouped based on their respective sampling locations.

2.2. Biometric measurement

Upon reaching the laboratory within 10 hours, the fish samples were subjected to gutted and washing. Each specimen was weighed (TW) and measured to determine the standard length (SL) as well as the depth or maximum height (H). The length measurement was taken from the mouth's tip to the end of the upper lobe of the caudal fin, representing the total body length. The height measurement involved a vertical assessment of the body's maximum height, excluding the fins. The condition factor (CF) was calculated using the formula $CF = (TW/SL^3) \times 100$.

2.3. Proximate, amino acid, and mineral content analysis

The proximate carcass composition was assessed following the AOAC standard methods [26]. The samples were dried until a constant weight was achieved at 105°C. The crude protein content was analyzed using the standard Kjeldahl method, which involves multiplying the nitrogen content by a factor of 6.25. The Soxhlet method with ether extraction was employed to analyze crude lipids. The ash content was obtained by incinerating the samples at 550°C for 16 hours. The amino acid composition was determined using a high-performance liquid chromatography (HPLC) system, which consisted of a water 1525 binary HPLC pump, 717 autosamplers (water®), and water 2475 multi λ fluorescence detector optics (with excitation at 250 nm and emission at 395 nm). The samples were hydrolyzed in triplicate with 6 N hydrochloric acid for 24 hours at 11°C [27].

For mineral data composition (Na, Mg, Ca, K, P, Fe, Cu, Mn, and Zn), the ashed of feed sample and carcass were dissolved in 1 ml of hydrochloric acid (35% v/v Suprapur® Merck). Furthermore, it was filtered with cellulose filter paper (Watchman No 1, International Ltd; Maidstone, UK) and diluted to an appropriate concentration for each elemental mineral. P levels were analyzed with a Perkin-Elmer AA spectrophotometer mod 3110 (Norwalk, CT. USA).

2.4. Fatty acids analysis

The body meat of fish was examined utilizing the gas chromatography-mass spectrometry (GC-MS) method. The modified Folch *et al*. (1957) method, as described by Rajion [28], was employed to perform the total fat extraction. This involved utilizing a solvent system consisting of chloroform and methanol in a 2.1 (v/v) ratio. The process of transmethylation was conducted using a solution of 14% methanolic boron trifluoride. The fatty acid composition of the meat was then analyzed at the Laboratory Accredited Testing Laboratory-LP-184-IDN.

The nutritional quality of lipids AI and TI was calculated using the equations [29].

$$AI = \frac{[(C12:0\ + 4\ \times C14:0\ +\ C16:0)]}{\sum MUFA\ +\ \sum n-6\ +\ \sum n-3}$$

$$\mathrm{TI} = \frac{[(\mathrm{C14:0}\ +\ \mathrm{C16:0}\ + \mathrm{C18:0})]}{[(0.5 \times \sum \mathrm{MUFA}) + (0.5\ \times\ \sum \mathrm{n}-6) +\ (3 \times \sum \mathrm{n}-3) + (\sum \mathrm{n}-3/\sum \mathrm{n}-6)}$$

Where

AI = Atherogenic index

TI = Thrombogenic index

C12:0 = lauric acid

C14:0 = myristic acid

C16:0 = palmitic acid

C18:0 = stearic acid

∑MUFA = sum concentrations of all monosaturated fatty acid

∑n-6 = sum concentrations of n-6 polyunsaturated fatty acid

∑n-3 = sum concentrations of n-3 polyunsaturated fatty acid

2.5. Data analysis

Data analysis was performed using the SPSS 16.0 software package (SPSS; Chicago, IL). The homogeneity of the data was assessed using the Levine test. One-way ANOVA was carried out to determine the parameters of proximate and amino acid composition, including the composition of fatty acids and nutritional quality of lipids AI and TI for each species, followed by Duncan's multiple range test post hoc [30]. The results are reported as mean values ± standard errors for each parameter.

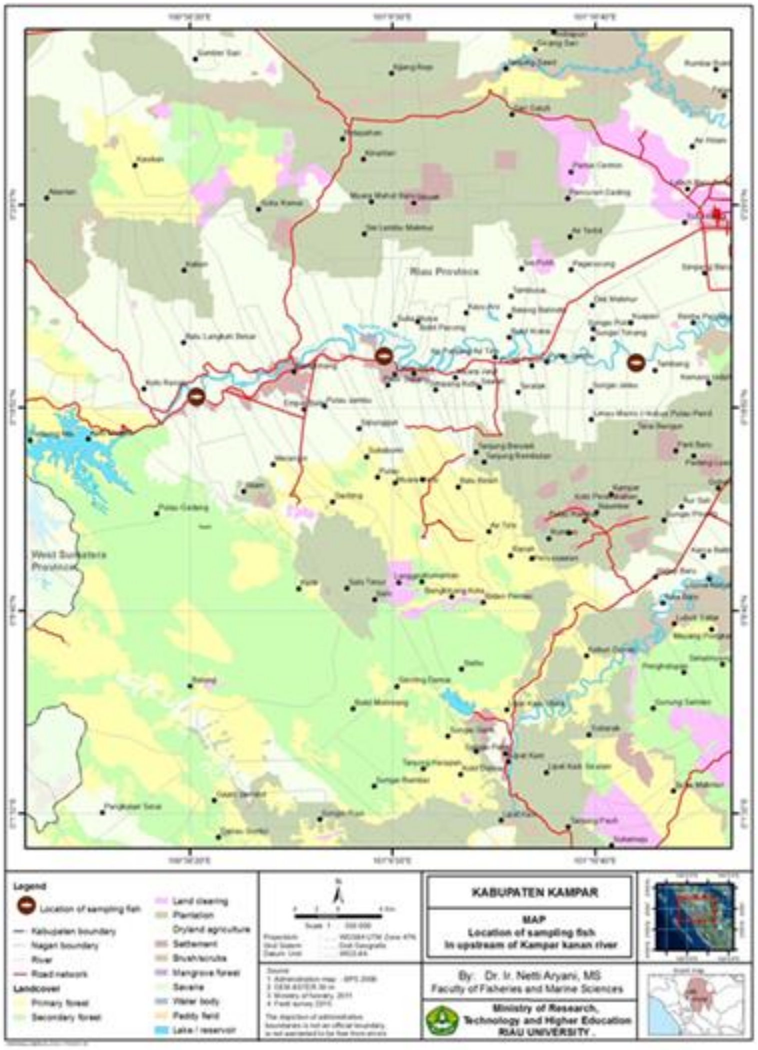

Figure 1. Map of Kampar Regency, Riau Province, and locations of three species of Bagridae fish sampling.

3. Results

Table 1 presents the average wet weight, standard length, width, and the results of meat nutritional composition analysis for three indigenous species of Indonesian freshwater Bagridae. The moisture content (% wet weight) ranges from 82.40% to 85.39%. Among the species examined, *M. nigriceps* exhibits the lowest protein content at 21.39%, while *H. nemurus* displays the highest value at 24.26%. However, *M. nigriceps* recorded has a higher mineral content such as iron and zinc.

Table 2 summarizes the fatty acid composition (% of total fatty acid) for the three species of Bagridae fish. C16:0 is the predominant fatty acid in the three species of Bagridae fish, with percentages ranging from 25.09% to 30.71%. The additional, prominent fatty acids found are C18:1, C18:0, and C22:6. *H. nemurus* exhibits a ω-6: ω-3 ratio below 1 (0.82), while *H. wyckii* and *M. nigriceps* have ratios of 1.11 and 1.02, respectively. The obtained PUFA/saturated (P/S) ratio varied between 0.61 and 0.76. In contrast, the AI values were 0.76 and 0.99, and the TI values were 0.54 and 0.75 for the respective cases (**Table 3**).

Table 4 presents the amino acid composition (% of total protein). Glutamic acid is the dominant amino acid, ranging from 19.29% to 24.34%, followed by aspartic acid, which ranges from 9.21% to 11.27%. Lysine content is consistent, ranging from 9.67% to 9.87%.In *H. nemurus*, the levels of various amino acids range from 0.86% to 24.35%. Similarly, in *H. wyckii*, the levels range from 0.76% to 21.58%, while in *M. nigriceps*, the levels range from 0.74% to 19.29%.

Table 1. Results of proximate analysis of three species of Bagridae fish

	Species		
	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
Biometric measurements			
Total weight (g)	389.99 ± 24.96^{a}	$1{,}390.33 \pm 168.29^{b}$	17.57 ± 1.53^{c}
Standard length (cm)	28.16 ± 0.53^{a}	44.14 ± 1.98^{b}	10.29 ± 0.15^{c}
Width (cm)	8.44 ± 0.16^{a}	8.82 ± 0.39^{b}	2.57 ± 0.03^{c}
Condition factor	1.63 ± 0.08	1.58 ± 0.07	1.56 ± 0.08
Proximate composition			
Crude protein (% DW)	24.26 ± 0.87^{a}	22.57 ± 0.37^{b}	21.39 ± 0.15^{c}
Crude fat (% DW)	6.64 ± 0.03^{a}	7.47 ± 0.02^{b}	7.75 ± 0.40^{c}
Crude ash (% DW)	1.94 ± 0.02^{a}	2.30 ± 0.09^{b}	1.59 ± 0.02^{c}
Moisture (% WW)	82.40 ± 2.51	85.39 ± 2.36	83.75 ± 2.21
Mineral composition			
Macromineral (mg/g)			
Sodium	0.99 ± 0.00^{a}	1.61 ± 0.01^{b}	1.61 ± 0.02^{c}
Magnesium	1.12 ± 0.01^{a}	0.57 ± 0.02^{b}	1.15 ± 0.01^{c}
Calcium	1.66 ± 0.00^{a}	1.55 ± 0.02^{b}	1.49 ± 0.04^{c}
Potassium	0.71 ± 0.00^{a}	0.55 ± 0.02^{b}	0.43 ± 0.01^{c}
Phosphorous	7.03 ± 0.03^{a}	2.74 ± 0.02^{b}	6.45 ± 0.07^{c}
Microminerals (µg/g)			
Iron	28.30 ± 0.11^{a}	28.73 ± 0.08^{b}	40.36 ± 0.55^{c}
Copper	8.93 ± 0.03^{a}	7.46 ± 0.09^{b}	6.21 ± 0.32^{c}

Manganese	1.64 ± 0.02[a]	2.64 ± 0.02[b]	2.84 ± 0.02[c]
Zinc	24.03 ± 0.45[a]	24.61 ± 0.19[b]	54.46 ± 0.17[c]

Values are % ± SE; *Values in the same row with a different superscript a significantly different ($p<0.05$)

Table 2. Fatty acid composition of three species of Bagridae fish

Fatty acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
C12:0 (lauric acid)	1.97 ± 0.05[a]	3.94 ± 0.01[b]	4.27 ± 0.01[c]
C14:0 (Meristic acid)	2.38 ± 0.03[a]	2.72 ± 0.08[b]	2.89 ± 0.01[c]
C16:0 (Palmitic acid)	27.23 ± 0.06[a]	30.70 ± 0.06[b]	25.59 ± 0.01[c]
C18:0 (Stearic acid)	16.17 ± 0.02[a]	13.54 ± 0.02[b]	10.64 ± 0.01[c]
C20:0 (Arachidic acid)	0.23 ± 0.01[a]	0.14 ± 0.01[b]	0.37 ± 0.01[c]
C16:1 (Palmitoleic acid)	1.78 ± 0.00[a]	1.27 ± 0.04[b]	4.93 ± 0.01[c]
C18:1(Oleic acid)	16.86 ± 0.01[a]	16.18 ± 0.01[b]	16.97 ± 0.01[c]
C18:2 (Linoleic acid)	3.24 ± 0.02[a]	3.84 ± 0.33[b]	4.55 ± 0.001[c]
C18:3 (Linolenic acid)	1.12 ± 0.01[a]	0.82 ± 0.01[b]	1.57 ± 000[c]
C20:4 (Arachidonic acid)	12.13 ± 0.01[a]	12.49 ± 0.09[b]	12.41 ± 0.02[c]
C20:5 (Eicosapentaenoic acid; EPA)	2.06 ± 0.08[a]	2.34 ± 0.04[b]	1.35 ± 0.01[c]
C22:6 (Docosahexaenoic acid; DHA)	15.65 ± 0.01[a]	11.56 ± 0.04[b]	13.64 ± 0.02[c]

Values are % ± SE; *Values in the same row with a different superscript a significantly different ($p<0.05$)

Table 3. Fatty acid ω-6/ω-3 and polyunsaturated/saturated fatty acid ratio of three species of Bagridae fish

	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
ω-6/ω-3	0.82 ± 0.00[a]	1.11 ± 0.02[b]	1.02 ± 0.01[c]
Ratio of P/S	0.69 ± 0.01[a]	0.61 ± 0.06[b]	0.76 ± 0.00[c]
AI	0.87 ± 0.01[a]	0.99 ± 0.06[b]	0.73 ± 0.00[c]
TI	0.63 ± 0.01[a]	0.75 ± 0.03[b]	0.54 ± 0.00[c]

P/S, polyunsaturated/saturated fatty acid; AI, Atherogenic index; TI, Thrombogenic index
Values are % ± SE; *Values in the same row with a different superscript a significantly different ($p<0.05$)

Table 4. Amino acid composition of three species of Bagridae fish

Amino acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
Aspartic acid	10.39 ± 0.01^{a}	9.61 ± 0.04^{b}	11.28 ± 0.02^{c}
Glutamic acid	24.34 ± 0.00^{a}	21.58 ± 0.41^{b}	19.29 ± 0.03^{c}
Serine	3.74 ± 0.00^{a}	5.40 ± 0.03^{b}	7.50 ± 0.06^{c}
Glycine	4.02 ± 0.00^{a}	5.77 ± 0.04^{b}	4.69 ± 0.02^{c}
Histidine	2.39 ± 0.00^{a}	2.90 ± 0.03^{b}	2.21 ± 0.02^{c}
Arginine	6.17 ± 0.01^{a}	8.27 ± 0.03^{b}	6.22 ± 0.03^{c}
Threonine	4.49 ± 0.01^{a}	4.19 ± 0.03^{b}	4.39 ± 0.04^{c}
Alanine	7.03 ± 0.00^{a}	6.04 ± 0.02^{b}	7.89 ± 0.01^{c}
Proline	2.40 ± 0.00^{a}	2.71 ± 0.01^{b}	2.21 ± 0.02^{c}
Tyrosine	3.91 ± 0.01^{a}	3.29 ± 0.06^{b}	3.82 ± 0.04^{c}
Valine	3.73 ± 0.00^{a}	4.02 ± 0.01^{b}	3.85 ± 0.04^{c}
Methionine	3.42 ± 0.00^{a}	1.96 ± 0.02^{b}	1.27 ± 0.03^{c}
Cystine	0.87 ± 0.00^{a}	0.76 ± 0.02^{b}	0.75 ± 0.03^{c}
Isoleucine	3.82 ± 0.001^{a}	3.96 ± 0.003^{b}	3.66 ± 0.002^{c}
Leucine	6.15 ± 0.000^{a}	6.69 ± 0.002^{b}	6.28 ± 0.004^{c}
Phenylalanine	5.13 ± 0.000^{a}	6.03 ± 0.005^{b}	5.18 ± 0.027^{c}
Lysine	9.61 ± 0.001^{a}	9.82 ± 0.026^{b}	9.87 ± 0.003^{c}

Values are % ± SE; *Values in the same row with a different superscript a significantly different ($p<0.05$)

4. Discussion

The results of this study provided significant new information about the nutritional makeup of the studied species of Bagridae fish. The fish's biometric measures yielded important information about its physical traits and health. Researchers are able to determine the average weight of fish at various lengths by examining the link between length and weight for a particular species. This knowledge is essential for understanding the trends in fish population growth, spotting potential shifts in growth rates over time, and assessing the general health and welfare of the fish [31]. A variety of factors, including sex, age, maturity level, size, level of stomach fullness, sampling strategies, sample sizes, and environmental circumstances, have an impact on fish health and the parameters that determine length-weight connections in fish [32]. However, none of these factors are considered in our study. In general, according to the theory put forth by Bagenal and Tesch [33], heavier fish of a given length are in better physiological condition. The condition factor is also used in fisheries science to compare the health, fatness, and condition of fish [34]. Ujjania et al. [35] stated that a condition factor of ≥ 1 is favourable, indicating a good level of nutrition and a suitable habitat. Thus, from the findings in this study, it may be said that the Kampar Kanan River provides a suitable habitat for the fish, ensuring their accessibility and availability for community consumption.

The fish samples exhibited good nutritional profiles, with high amounts of proteins and lipids as well as moisture content contributing to their overall nutritional value, according to the results of proximate analysis and minerals composition (Table 1). These results imply that the fish species studied may provide a possible source of nutrients to solve issues with food security. The study of the minerals composition revealed the existence of other critical minerals in the fish samples in addition to proteins and lipids. For total health and wellbeing, enough mineral consumption is required. Fish with a high level of crude ash can help increase dietary mineral intake and may even contain vital minerals including phosphorus (P), calcium (Ca), magnesium (Mg) and trace elements such as iron (Fe) and zinc (Zn). All the three Bagridae fish are significantly differ from each other in terms of their crude ash content and minerals profile (Table 1). However, in general, P and Ca are the two highest minerals found in all fish. Both these macrominerals are good for human's bone and teeth health, as key components of hydroxyapatitie, the mineral matrix that provides strength and structure to bones and teeth [36]. P also contributes to a number of activities that include the synthesis and utilisation of ATP, as well as the breakdown of carbs, proteins, and fats, helping the body's ability to produce and use energy [37]. Cellular communication, enzyme activation, and the control of cell membrane integrity are all affected by the presence of P [38]. Ca on the other hand, is crucial for muscle contraction and relaxation, nerve impulse transmission, and neurotransmitter release, enabling proper muscle function [39]. It also aids in the activation of clotting factors and the production of fibrin, a protein that forms a meshwork to halt bleeding from wounds or traumas [40].

In the current study, the meat of three species of Bagridae fish from the Kampar Kanan River Indonesia was found to contain abundance of microminerals such as Fe and Zn. Insufficient intake of Fe and Zn has been linked to major developmental health problems, such as Fe deficiency which is one of the major causes of anemia in pregnant and lactating women, especially in rural communities [41,42]. Lacking in Zn, on the other hand, can lead to numerous immunological disorders, such as metabolic and chronic illnesses, as well as infectious diseases including respiratory infections, malaria, HIV, or tuberculosis [43]. *M. nigriceps* that has been recorded exhibits higher mineral content, including iron and zinc. This species is categorized as a small indigenous fish (SIF) with a maximum standard length of approximately 10.29 cm. According to Mohanty et al. [44], SIFs, in general, are known to be rich in Ca, Fe, and manganese (Mn). The variation in mineral content among the three species of Bagridae fish is comparable to that of *Clarias gariepinus* and *Tilapia zilli* meat from the Owan River in Edo State, Nigeria [13].

In general, fish consists of 70-84% moisture [45] . High moisture content is often associated with freshness in fish. Compared to fish that has been processed or stored, fresh fish often has a higher moisture content, the factor that contributes to a moist and succulent texture. Fish with high moisture content may retain more water-soluble nutrients during cooking or processing as proven by Gupta et al. [46] with green leafy vegetables This can help preserve the nutritional value of the fish, ensuring that important vitamins and minerals are retained. However, due to the high moisture content in fish, a processing technique that changes the moisture content will also change the fish's properties, such as the texture and protein gelation [47].

The amount of crude fats in the fish is a good indicator of how much lipids or fats are present. In addition to acting as transporters for fat-soluble vitamins, fats offer a concentrated source of energy to the body. Additionally, they improve the fish's flavour, texture, and palatability [48]. Numerous health advantages, including improved cardiovascular health, improved brain function, and anti-inflammatory effects, have been linked to specific fatty acids present in fish, particularly omega fatty acids. So a fish with a high amount of crude fat might be good, especially if it has good fatty acids. From the findings, all three Bagridae fish had a total fat content of around 7-8% by weight (Table 1). According to Fuentes et al. [49], fish with lower fat content exhibit higher water content, which is also shown in our study. On the other hand, Nurnadia et al. [50] reported that the fish species can be grouped into different categories, including high-fat fish (>8%), medium-fat fish (4-8%), low-fat fish (2-4%), and lean fish (<2%). According to the established classification, the three indigenous Bagridae fish species are characterized as having a moderate level of fat content, which is reflected by the high levels of DHA and EPA in the meat of *H. nemurus*, *H. wyckii*, and *M. nigriceps* fish (Table 2). It is still unclear whether consuming the fish meat of these three species can indirectly help lower blood pressure, reduce inflammation in blood vessels, improve lipid profiles by increasing levels of good cholesterol (HDL) and decreasing levels of bad cholesterol (LDL), and reduce blood clotting in individuals. Nonetheless, the fat content of fish is determined by various factors, such as species, habitat ecosystems, feeding patterns, and other biological attributes, including the distinctive flavor characteristics of the fish [8,49,51,52].

Each of the three Bagridae fish species analyzed in the study contained arachidonic acid (C20:4), which serves as a precursor for synthesizing prostaglandins and leukotrienes [53]. Leukotrienes are crucial in allergic responses, inducing smooth muscle contraction and increasing vascular permeability [54]. In this study, the arachidonic acid content in H. nemurus, H. wyckii, and M. negriceps was determined to be 12.13%, 12.49%, and 12.41%, respectively. Conversely, the levels of arachidonic acid in *Channa striatus*, *Channa micropeltes*, and *Channa lucius* were reported as 19.02%, 4.71%, and 12.41%, respectively [55]. According to Carballo-Casla et al. [56], increased consumption of marine omega-3 fatty acids, such as EPA and DHA, has been linked to a decreased risk of pain development in older individuals. Additionally, DHA and EPA have demonstrated a preventive effect on human coronary arteries and Alzheimer's disease [57,58]. In this study, our hypothesis is that the levels of EPA and DHA found in the meat of three species of Bagridae fish in the Kampar Kanan River, Indonesia, may also have the potential in reducing muscle pain and inflammation. Additionally, as a primary food source, fish plays a role in the prevention and treatment of chronic pain [59]. As determined by the current study, the ω-6:ω-3 ratios of three Bagridae fish species ranged from 1:0.8 to 1:0.97. These varying ω-6:ω-3 ratios can have diverse implications for treating or preventing diseases [60]. It was found that all three fish species had ω-6:ω-3 ratios within the recommended range for a typical Indonesian diet. In contrast, a typical Western diet is characterized by a high ω-6:ω-3 ratio of 10:1 to 20:1, while a Mediterranean diet has a ratio of 4:1 to 5:1 [61]. The P/S ratio analysis revealed that all three Bagridae fish species were considered an average source of PUFA. Additionally, it has been reported that marine fish serve as a good source of PUFA [62].

The atherogenic index (AI) and thrombogenic index (TI) indices are directly influenced by the levels of C14:0, C16:0, and C18:0, all of which are known to promote thrombogenicity [24]. AI and TI indices indicate the potential to induce platelet aggregation. A lower value in AI and TI indicates a more significant protective potential against coronary artery disease [63]. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recommended AI and TI values ranging from 0.4 to 0.5 for promoting human health [64]. The AI and TI values of various marine fish species, such as Sardine (*Sardinella hualiensis*), being 0.60 and 0.20, respectively, and Mackerel (*Scomber japonicus*) having values of 0.48 and 0.24, respectively [65]. In the current study, the observed AI values in three freshwater species of Bagridae fish ranged from 0.73 to 0.99, while the TI values varied between 0.54 and 0.75. This finding is associated with a notable disparity in the values of saturated fatty acids (SFA) among the three species of Bagridae fish. Based on these findings, we certify that consuming the meat of three freshwater species of Bagridae fish caught in the wild does not endanger consumers' health and can serve as a suitable source of food safety and nutritional quality.

A high value for crude protein shows that the fish contains a considerable amount of protein. Since fish protein is easier to digest than protein found in meat and includes less collagen fibre, the body can use its protein more effectively [66]. The body's tissues need protein to develop, mend, and remain healthy. The absence of amino acids and fatty acids elements will impede the recovery process [67]. Protein is a crucial ingredient for human health, contributing to a number of physiological functions like immunological function, muscular growth, and enzyme synthesis. Since protein is a crucial part of a balanced diet, fish with a high crude protein content, as also been shown by the three Bagridae fish studied (Table 1), are regarded as being nutritionally useful. According to Pawar and Sonaware [68], protein and amino acid content can directly indicate the nutritional quality of meat. In Table 4, *H. wykii* had higher quantities of essential amino acids (EAA) than *H. nemurus* and *M. nigriceps*. Since EAA cannot be synthesised by the body yet are necessary for physiologic function, they are significant for humans. They are thus derived through EAA-rich foods such as fish. Among the EAA, lysine (Lys) was found to be present in the highest amount in all three species. Lys is necessary for tissue growth and repair

[69]. Furthermore, Lys can reduced stress-induced anxiety [70] and has antiviral properties [71]. Lys also plays a role in metabolic activities, including the creation of carnitine for mitochondrial energy generation and the conversion of fatty acids into energy [72].

More than 60% of the amino acid composition in all three Brigade fish studied comes from the non-essential amino acids (NEAA), particularly glutamic acid (Glu) (Table 4). Watford [73] and Mohanty et al. [62] , however, classified Glu in addition to Arg, glycine (Gly), proline (Pro) and taurine as conditionally EAA, amino acids which are usually not essential except in times of illness and stress. Glu and its amine, glutamine (Gln) are highly abundant amino acids found in fish in the free and protein-bound forms [74]. As functional amino acids, Glu and Gln are significant metabolic fuels for fish tissues, such as the gut, liver, kidneys, and skeletal muscle, and they play crucial roles in protein synthesis as well as glutathione formation and anti-oxidative responses [75]. In humans, Glu functions as an excitatory neurotransmitter involved in memory, cognition and mood regulation [76]. Glu is also responsible for the “umami” or savory taste in protein-rich food such as fish [77]. The perception of this taste enhances food flavour and, when used as salt, such as monosodium glutamate, stands out for having only a third of the sodium found in table salt. This salt is therefore thought to be an option to help people consume less sodium [78]. Additionally, umami chemicals have been linked to the control of obesity and the post-meal feeling of satiety [79]. However, the association between the Glu content and umami taste in the three Bagridae fish studied has yet to be determined and proven. Other amino acids found abundant in the three fish also play an important physiologic as well biochemical functions. The NEAA, arginine (Arg), for example, are involved in protein synthesis, creatine formation, and various other biochemical processes within the body. The EAAs, leucine (Leu), phenylalanine (Phe) and methionine (Met), play important roles in the synthesis of nitric oxide (NO), a molecule that can expand blood vessels [75].

4. Conclusions

The present study offers insightful information about the fatty acid and amino acid compositions, biometric measurements, proximate analysis, and mineral composition of three local freshwater species of Indonesian Bagridae fish. The findings show their potential as a nutrient-dense, sustainable food source that can support efforts to increase food security. These fish species might be incorporated into the local diet to increase nutrient intake and alleviate nutritional inadequacies, which would ultimately improve Indonesia's overall food security status.

Data Availability

The data utilized in this research has not been previously released or published in any form. The data sets employed and/or analyzed during the present study can be obtained by contacting the corresponding author.

Conflicts of Interest

The authors confirm that they do not have any conflicting interests.

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Webmail Univ. Bung Hatta

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6639837: Revision requested

5 messages

International Journal of Food Science <ijfs@hindawi.com> Sat, Sep 16, 2023 at 8:53 PM
Reply-To: International Journal of Food Science <deepanaa.rajadurai@hindawi.com>
To: Hafrijal Syandri <syandri_1960@bunghatta.ac.id>

Hindawi

Dear Dr. Syandri,

In order for your submission "Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security " to "International Journal of Food Science" to proceed to the review process, there needs to be a revision.

Reason & Details:

> *Dear authors,*
> *We have received the reports from our advisers on your manuscript, "Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security". Based on the advice received, I have decided that your manuscript can be accepted for publication after a major revision, as suggested by the reviewer.*
> *Attached, please find the reviewers' comments for your perusal.*

For more information about what is required, please click the link below.

MANUSCRIPT DETAILS

Kind regards,
Deepanaa Rajadurai
on behalf of "International Journal of Food Science"

---

hafrizal syandri <syandri_1960@bunghatta.ac.id> Mon, Sep 18, 2023 at 6:41 AM
To: International Journal of Food Science <deepanaa.rajadurai@hindawi.com>

Dear
Deepanaa Rajadurai
on behalf of "International Journal of Food Science"

Thank you for your email on September 17, 2023. We have read the reviewer's report for manuscript No. 6639837. Five points need to be revised. Therefore, we ask for seven days to make edits to this manuscript. We will request assistance from American Journal Experts (AJE) to make edits for language and grammatical errors in some sections.

Best regards
Hafrijal Syandri
[Quoted text hidden]

Phenom Emails <phenom.emails@hindawi.com> Mon, Sep 18, 2023 at 3:19 PM
Reply-To: Phenom Emails <phenom.emails@hindawi.com>
To: syandri_1960@bunghatta.ac.id

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Hope you are good and well.

Thank you for your email and we are happy to grant your request for an extension during this uncertain time. Please note that you may receive some reminder emails from our system but please ignore these for the time being.

We hope to hear from you again soon.

Best Regards,

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Deepanaa Rajadurai
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hafrizal syandri <syandri_1960@bunghatta.ac.id> Thu, Sep 21, 2023 at 5:19 PM
To: Phenom Emails <phenom.emails@hindawi.com>

Dear
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Editorial Assistant

We want to inform you that we have made revisions to manuscript No. 6639837, as follows:
1. The manuscript has been thoroughly edited, including correcting language and grammatical errors by American Journal Experts (AJE) with an attached certificate.
2. We have reduced the number of references according to the revised manuscript.
3. The manuscript has been narrowed down based on research information that we have investigated.
We appreciate your attention and look forward to hearing good news from you. Thank You.

Best regards

Hafrijal Syandri
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Please be informed that for your manuscript 6639837, your revised manuscript has been successfully submitted. Once the decision is made you will be notified.

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On Mon, 18 Sep at 12:41 AM , hafrizal syandri <syandri_1960@bunghatta.ac.id> wrote:
Dear
Deepanaa Rajadurai
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Thank you for your email on September 17, 2023. We have read the reviewer's report for manuscript No. 6639837. Five points need to be revised. Therefore, we ask for seven days to make edits to this manuscript. We will request assistance from American Journal Experts (AJE) to make edits for language and grammatical errors in some sections.

Best regards
Hafrijal Syandri

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Research Article

Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security

Azrita Azrita[1], Hafrijal Syandri[1*], Hazlina Ahamad Zakeri[2], Harfiandri Damanhuri[1], Netti Aryani[3]

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Abstract:

Fish has become an irreplaceable source of animal protein food, especially among households with low socioeconomic conditions in rural and urban areas in Indonesia. This study analyzes the nutrient composition of three local Bagridae fish species in Indonesia. The nutrient composition results of *Hemibagrus nemurus*, *Hemibagrus wyckii*, and *Mystus nigriceps* revealed that the protein content was 24.26%, 22.57%, and 21.39% (% of dry weight), respectively. The total lipid content varied between 6.64% and 7.75%, whereas the crude ash content ranged from 1.59% to 2.30%. Regarding mineral contents, the calcium levels ranged from 1.49 to 1.66 mg/g, iron levels varied between 28.35 and 40.36 µg/g, and zinc levels ranged from 24.03 to 54.46 µg/g. The predominant amino acids found in the three species of Bagridae fish were glutamic acid, aspartic acid, alanine, arginine, and lysine, with their concentrations ranging from 9.10% to 24.34%. Among the fatty acids, C16:0 (palmitic acid) was the most abundant in all three species, accounting for 25.59% to 30.70% of the total fatty acids. Additionally, significant amounts of C18:1 (oleic acid), C18:0 (stearic acid), and C20:4 (arachidonic acid) were also detected as primary fatty acids. The calculated AI (atherogenic index) values in the three species of Bagridae fish ranged from 0.73 to 0.99, while the TI (thrombogenic index) values varied between 0.54 and 0.75. These results indicate that consuming the meat of these three freshwater species of Bagridae fish caught in the wild does not pose any health risks to consumers. They can be considered a safe and suitable food source with good nutritional quality.

Keywords: Nutrient composition, Amino acids, Fatty acids, Freshwater fish, Kampar Kanan River,

1. Introduction

Fish serve as a high-quality protein source that is essential for satisfying dietary protein requirements, especially in areas where other protein sources could be few or difficult to get [1,2]. Their accessibility can aid in ensuring a steady supply of food, particularly for communities whose main sources of income are fishing or aquaculture [3]. Fish can contribute to a more varied selection of protein sources in communities, resulting in a diet that is more nutritious and balanced. Dietary fish can treat nutrient deficits and enhance general nutritional health. Fish are generally considered safe and offer a lower risk of contamination with harmful substances compared to certain land-based animal products. According to Ravichandran et al. [4], a reliable indicator of the fish's quality, nutritional value, physiological status, and environment is said to be its chemical makeup, which is found in fish flesh.

Hemibagrus (H) nemurus, locally known as "baung", *Hemibagrus (H) wyckii*, known as "geso" and *Mystus (M) negriceps*, known as "ingir-ingir," are three species of catfish found in Kampar Kanan River, Indonesia [5,6]. Due to their high market value, these species have been identified as significant economic resources for the rural community [7]. Therefore, the nutritional quality of fish meat in the study area is very important for analysis that is beneficial to human health.

Knowing the composition of fatty acids and amino acids in fish meat is an essential factor that should not be ignored [8]. This information provides valuable insight into the fish's nutritional quality and values of more nutritious and healthy foods [9]. In addition, a better understanding of the composition of fatty acids and amino acids can assist in selecting a suitable feed [10], developing a balanced diet [11], and maintaining optimal fish meat nutritional [12].

Omega-3 polyunsaturated fatty acids, particularly DHA and EPA derived from fish oil, exhibit anti-inflammatory and anti-gastrointestinal cancer properties, making them crucial as immune-boosting nutrients [13,14]. Studies have demonstrated that ω-3 and ω-6 polyunsaturated fatty acids (PUFA) exhibit beneficial effects in the management of cardiovascular diseases and cancers [15,16]. The fatty acid composition of polyunsaturated fatty acids (PUFAs) can differ among different types of fish, including both freshwater and marine species [17, 18]. Amino acids (AAs) like cysteine, arginine, tyrosine, glycine, proline, and serine play a vital role in illness and stress situations and the prevention of inflammation and the repair processes in fish intestines [19, 20].

Furthermore, knowledge of the atherogenicity index (AI) and thrombogenicity (TI) of fatty acids in three local freshwater fish species of Bagridae can contribute to improving dietary guidelines. AI and TI indexes can be used to develop recommendations aimed at improving heart health [21,22]. These recommendations may involve selecting fish with favorable fatty acid profiles, allowing individuals to choose the most suitable fish species based on their specific needs [17, 23]. Therefore, this study aims to examine the nutritional composition profile, mineral content, amino acids, and fatty acids, including AI and TI indices of three freshwater fish species, namely *H. nemurus*, *H. wyckii*, and *M. nigriceps*. These three types of fish are generally consumed by people who live around the Kampar Kanan River in Kampar Regency, Riau Province, Indonesia.

2. Material and methods

2.1. Materials

In this study, a total of 27 Bagridae fish belonging to three distinct species (*H. nemurus*, *H. wyckii*, and *M. nigriceps*) were examined. The specimens were obtained from local fishermen operating in the upper stretches of the Kampar Kanan River in Kampar Regency, Riau Province (Figure 1). The sampling took place between June and August 2022. They were verified by the Fisheries Department, Faculty of Fisheries and Marine Science Universitas Bung Hatta, Indonesia. The samples were placed in plastic bags and transported to the laboratory in an insulated icebox. The samples were then grouped based on their respective sampling locations.

2.2. Biometry measurement

Upon reaching the laboratory within 10 hours, the fish samples were subjected to gutted and washing. Each specimen was weighed (TW) and measured to determine the standard length (SL) as well as the depth or maximum height (H). TW was measured using 600i-scales with a precision of 0.001 gram. The length measurement was taken from the mouth's tip to the end of the upper lobe of the caudal fin, representing the total body length using a meter ruler with an accuracy of 1 millimeter. The height measurement involved a vertical assessment of the body's maximum height measured using a Digital Sketmat Sigmat Vernier Caliper with an accuracy of 1 millimeter. The condition factor (CF) was calculated using the formula $CF = (TW/SL^3) \times 100$.

2.3. Proximate, amino acid, and mineral content analysis

The proximate carcass composition was assessed following the AOAC standard methods [24]. The samples were dried until a constant weight was achieved at 105°C. The crude protein content was analyzed using the standard Kjeldahl method, which involves multiplying the nitrogen content by a factor of 6.25. The Soxhlet method with ether extraction was employed to analyze crude lipids. The ash content was obtained by incinerating the samples at 550°C for 16 hours. The amino acid composition was determined using a high-performance liquid chromatography (HPLC) system, which consisted of a water 1525 binary HPLC pump, 717 autosamplers (water®), and water 2475 multi λ fluorescence detector optics (with excitation at 250 nm and emission at 395 nm). The samples were hydrolyzed in triplicate with 6 N hydrochloric acid for 24 hours at 11°C [25].

For mineral data composition (Na, Mg, Ca, K, P, Fe, Cu, Mn, and Zn), the ashed of feed sample and carcass were dissolved in 1 ml of hydrochloric acid (35% v/v Suprapur® Merck). Furthermore, it was filtered with cellulose filter paper (Watchman No 1, International Ltd; Maidstone, UK) and diluted to an appropriate concentration for each elemental mineral. P levels were analyzed with a Perkin-Elmer AA spectrophotometer mod 3110 (Norwalk, CT. USA).

2.4. Fatty acids analysis

The body meat of fish was examined utilizing the gas chromatography-mass spectrometry (GC-MS) method. The modified Folch *et al*. (1957) method, as described by Rajion [26], was employed to perform the total fat extraction. This involved utilizing a solvent system consisting of chloroform and methanol in a 2.1 (v/v) ratio. The process of transmethylation was conducted using a solution of 14% methanolic boron trifluoride. The fatty acid composition of the meat was then analyzed at the Laboratory Accredited Testing Laboratory-LP-184-IDN.

The nutritional quality of lipids AI and TI was calculated using the equations [27].

$$AI = \frac{[(C12:0\ + 4\ \times C14:0\ +\ C16:0)]}{\sum MUFA\ +\ \sum n-6\ +\ \sum n-3}$$

$$\mathrm{TI} = \frac{[(\mathrm{C14:0}\ +\ \mathrm{C16:0}\ + \mathrm{C18:0})]}{[(0.5 \times \sum \mathrm{MUFA}) + (0.5\ \times\ \sum \mathrm{n}-6) +\ (3 \times \sum \mathrm{n}-3) + (\sum \mathrm{n}-3/\sum \mathrm{n}-6)}$$

Where

AI = Atherogenic index
TI = Thrombogenic index
C12:0 = lauric acid
C14:0 = myristic acid
C16:0 = palmitic acid
C18:0 = stearic acid
∑MUFA = sum concentrations of all monosaturated fatty acid
∑n-6 = sum concentrations of n-6 polyunsaturated fatty acid
∑n-3 = sum concentrations of n-3 polyunsaturated fatty acid

2.5. Data analysis

Data analysis was performed using the SPSS 16.0 software package (SPSS; Chicago, IL). The homogeneity of the data was assessed using the Levine test. One-way ANOVA was carried out to determine the parameters of proximate and amino acid composition, including the composition of fatty acids and nutritional quality of lipids AI and TI for each species, followed by Duncan's multiple range test post hoc [28]. The results are reported as mean values ± standard errors for each parameter.

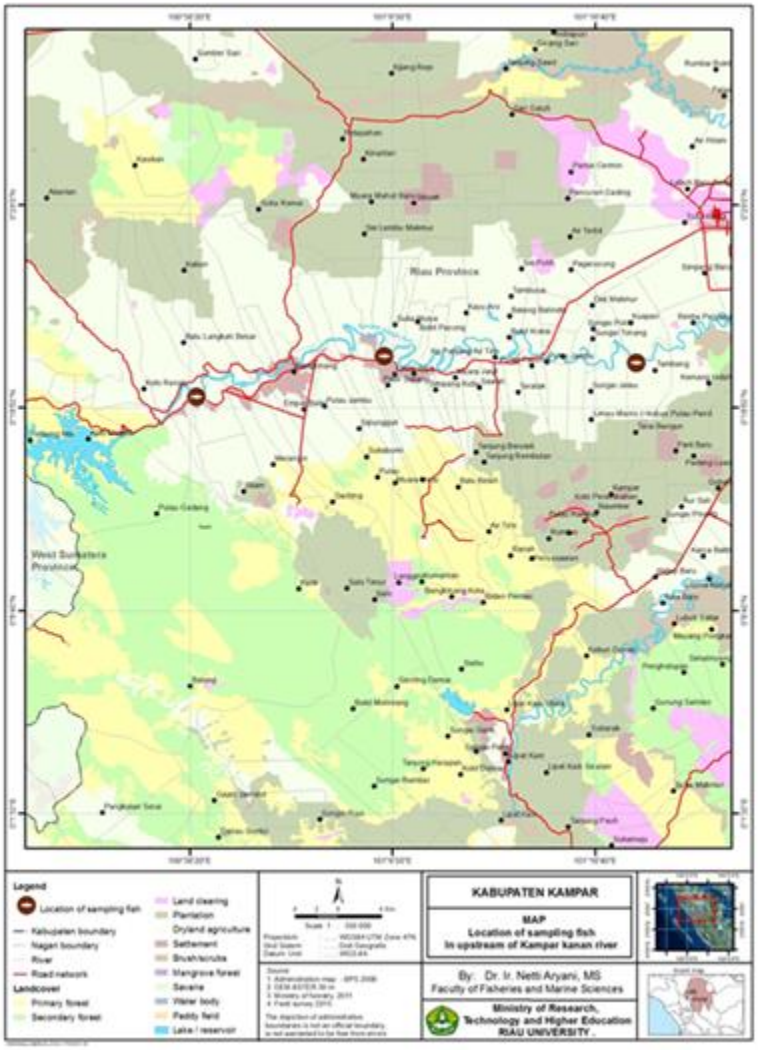

Figure 1. Map of Kampar Regency, Riau Province, and locations of three species of Bagridae fish sampling.

3. Results

Table 1 presents the average wet weight, standard length, width, and the results of meat nutritional composition analysis for three indigenous species of Indonesian freshwater Bagridae. The moisture content (% wet weight) ranges from 82.40% to 85.39%. Among the species examined, *M. nigriceps* exhibits the lowest protein content at 21.39%, while *H. nemurus* displays the highest value at 24.26%. However, *M. nigriceps* recorded has a higher mineral content such as iron and zinc.

Table 2 summarizes the fatty acid composition (% of total fatty acid) for the three species of Bagridae fish. C16:0 is the predominant fatty acid in the three species of Bagridae fish, with percentages ranging from 25.09% to 30.71%. The additional, prominent fatty acids found are C18:1, C18:0, and C22:6. *H. nemurus* exhibits a ω-6: ω-3 ratio below 1 (0.82), while *H. wyckii* and *M. nigriceps* have ratios of 1.11 and 1.02, respectively. The obtained PUFA/saturated (P/S) ratio varied between 0.61 and 0.76. In contrast, the AI values were 0.76 and 0.99, and the TI values were 0.54 and 0.75 for the respective cases (**Table 3**).

Table 4 presents the amino acid composition (% of total protein). Glutamic acid is the dominant amino acid, ranging from 19.29% to 24.34%, followed by aspartic acid, which ranges from 9.21% to 11.27%. Lysine content is consistent, ranging from 9.67% to 9.87%.In *H. nemurus*, the levels of various amino acids range from 0.86% to 24.35%. Similarly, in *H. wyckii*, the levels range from 0.76% to 21.58%, while in *M. nigriceps*, the levels range from 0.74% to 19.29%.

Table 1. Results of proximate analysis of three species of Bagridae fish

	Species		
	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
Biometric measurements			
Total weight (g)	389.99 ± 24.96^a	$1,390.33 \pm 168.29^b$	17.57 ± 1.53^c
Standard length (cm)	28.16 ± 0.53^a	44.14 ± 1.98^b	10.29 ± 0.15^c
Height (cm)	8.44 ± 0.16^a	8.82 ± 0.39^b	2.57 ± 0.03^c
Condition factor	1.63 ± 0.08	1.58 ± 0.07	1.56 ± 0.08
Proximate composition			
Crude protein (% DW)	24.26 ± 0.87^a	22.57 ± 0.37^b	21.39 ± 0.15^c
Crude fat (% DW)	6.64 ± 0.03^a	7.47 ± 0.02^b	7.75 ± 0.40^c
Crude ash (% DW)	1.94 ± 0.02^a	2.30 ± 0.09^b	1.59 ± 0.02^c
Moisture (% WW)	82.40 ± 2.51	85.39 ± 2.36	83.75 ± 2.21
Mineral composition			
Macromineral (mg/g)			
Sodium	0.99 ± 0.00^a	1.61 ± 0.01^b	1.61 ± 0.02^c
Magnesium	1.12 ± 0.01^a	0.57 ± 0.02^b	1.15 ± 0.01^c
Calcium	1.66 ± 0.00^a	1.55 ± 0.02^b	1.49 ± 0.04^c
Potassium	0.71 ± 0.00^a	0.55 ± 0.02^b	0.43 ± 0.01^c
Phosphorous	7.03 ± 0.03^a	2.74 ± 0.02^b	6.45 ± 0.07^c
Microminerals (µg/g)			
Iron	28.30 ± 0.11^a	28.73 ± 0.08^b	40.36 ± 0.55^c
Copper	8.93 ± 0.03^a	7.46 ± 0.09^b	6.21 ± 0.32^c
Manganese	1.64 ± 0.02^a	2.64 ± 0.02^b	2.84 ± 0.02^c

Zinc	24.03 ± 0.45[a]	24.61 ± 0.19[b]	54.46 ± 0.17[c]

Values are % ± SE; *Values in the same row with a different superscript a significantly different (p<0.05)

Table 2. Fatty acid composition of three species of Bagridae fish

Fatty acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
C12:0 (lauric acid)	1.97 ± 0.05[a]	3.94 ± 0.01[b]	4.27 ± 0.01[c]
C14:0 (Meristic acid)	2.38 ± 0.03[a]	2.72 ± 0.08[b]	2.89 ± 0.01[c]
C16:0 (Palmitic acid)	27.23 ± 0.06[a]	30.70 ± 0.06[b]	25.59 ± 0.01[c]
C18:0 (Stearic acid)	16.17 ± 0.02[a]	13.54 ± 0.02[b]	10.64 ± 0.01[c]
C20:0 (Arachidic acid)	0.23 ± 0.01[a]	0.14 ± 0.01[b]	0.37 ± 0.01[c]
C16:1 (Palmitoleic acid)	1.78 ± 0.00[a]	1.27 ± 0.04[b]	4.93 ± 0.01[c]
C18:1(Oleic acid)	16.86 ± 0.01[a]	16.18 ± 0.01[b]	16.97 ± 0.01[c]
C18:2 (Linoleic acid)	3.24 ± 0.02[a]	3.84 ± 0.33[b]	4.55 ± 0.001[c]
C18:3 (Linolenic acid)	1.12 ± 0.01[a]	0.82 ± 0.01[b]	1.57 ± 000[c]
C20:4 (Arachidonic acid)	12.13 ± 0.01[a]	12.49 ± 0.09[b]	12.41 ± 0.02[c]
C20:5 (Eicosapentaenoic acid; EPA)	2.06 ± 0.08[a]	2.34 ± 0.04[b]	1.35 ± 0.01[c]
C22:6 (Docosahexaenoic acid; DHA)	15.65 ± 0.01[a]	11.56 ± 0.04[b]	13.64 ± 0.02[c]

Values are % ± SE; *Values in the same row with a different superscript a significantly different (p<0.05)

Table 3. Fatty acid ω-6/ω-3 and polyunsaturated/saturated fatty acid ratio of three species of Bagridae fish

	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
ω-6/ω-3	0.82 ± 0.00[a]	1.11 ± 0.02[b]	1.02 ± 0.01[c]
Ratio of P/S	0.69 ± 0.01[a]	0.61 ± 0.06[b]	0.76 ± 0.00[c]
AI	0.87 ± 0.01[a]	0.99 ± 0.06[b]	0.73 ± 0.00[c]
TI	0.63 ± 0.01[a]	0.75 ± 0.03[b]	0.54 ± 0.00[c]

P/S, polyunsaturated/saturated fatty acid; AI, Atherogenic index; TI, Thrombogenic index
Values are % ± SE; *Values in the same row with a different superscript a significantly different (p<0.05)

Table 4. Amino acid composition of three species of Bagridae fish

Amino acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
Aspartic acid	10.39 ± 0.01[a]	9.61 ± 0.04[b]	11.28 ± 0.02[c]
Glutamic acid	24.34 ± 0.00[a]	21.58 ± 0.41[b]	19.29 ± 0.03[c]
Serine	3.74 ± 0.00[a]	5.40 ± 0.03[b]	7.50 ± 0.06[c]
Glycine	4.02 ± 0.00[a]	5.77 ± 0.04[b]	4.69 ± 0.02[c]
Histidine	2.39 ± 0.00[a]	2.90 ± 0.03[b]	2.21 ± 0.02[c]
Arginine	6.17 ± 0.01[a]	8.27 ± 0.03[b]	6.22 ± 0.03[c]
Threonine	4.49 ± 0.01[a]	4.19 ± 0.03[b]	4.39 ± 0.04[c]
Alanine	7.03 ± 0.00[a]	6.04 ± 0.02[b]	7.89 ± 0.01[c]
Proline	2.40 ± 0.00[a]	2.71 ± 0.01[b]	2.21 ± 0.02[c]
Tyrosine	3.91 ± 0.01[a]	3.29 ± 0.06[b]	3.82 ± 0.04[c]
Valine	3.73 ± 0.00[a]	4.02 ± 0.01[b]	3.85 ± 0.04[c]
Methionine	3.42 ± 0.00[a]	1.96 ± 0.02[b]	1.27 ± 0.03[c]
Cystine	0.87 ± 0.00[a]	0.76 ± 0.02[b]	0.75 ± 0.03[c]
Isoleucine	3.82 ± 0.001[a]	3.96 ± 0.003[b]	3.66 ± 0.002[c]
Leucine	6.15 ± 0.000[a]	6.69 ± 0.002[b]	6.28 ± 0.004[c]
Phenylalanine	5.13 ± 0.000[a]	6.03 ± 0.005[b]	5.18 ± 0.027[c]
Lysine	9.61 ± 0.001[a]	9.82 ± 0.026[b]	9.87 ± 0.003[c]

Values are % ± SE; *Values in the same row with a different superscript a significantly different ($p<0.05$)

4. Discussion

The results of this study provided significant new information about the nutritional makeup of the studied species of Bagridae fish. The fish's biometric measures yielded important information about its physical traits and health. Researchers are able to determine the average weight of fish at various lengths by examining the link between length and weight for a particular species. This knowledge is essential for understanding the trends in fish population growth, spotting potential shifts in growth rates over time, and assessing the general health and welfare of the fish [29]. A variety of factors, including sex, age, maturity level, size, level of stomach fullness, sampling strategies, sample sizes, and environmental circumstances, have an impact on fish health and the parameters that determine length-weight connections in fish [30]. However, none of these factors are considered in our study. In general, according to the theory put forth by Bagenal and Tesch [31], heavier fish of a given length are in better physiological condition. The condition factor is also used in fisheries science to compare the health, fatness, and condition of fish [32]. A condition factor of > 1 is favorable, indicating a good level of feed nutrition and suitable habitat for living [33). Thus, from the findings in this study, it may be said that the Kampar Kanan River provides a suitable habitat for the fish, ensuring their accessibility and availability for community consumption.

The fish samples exhibited good nutritional profiles, with high amounts of proteins and lipids as well as moisture content contributing to their overall nutritional value, according to the results of proximate analysis and minerals composition (see Table 1). These results imply that the fish species studied may provide a possible source of nutrients to solve issues with food security. The study of the mineral's composition revealed the existence of critical minerals such as phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) in the fish samples in addition to proteins and lipids. All three Bagridae fish significantly differ from each other in terms of their crude ash content and minerals profile (see Table 1). However, in general, P and Ca are the two highest minerals found in all fish. Both these macro minerals are good for human bone and teeth health, as key components of hydroxyapatites, the mineral matrix that provides strength and structure to bones and teeth [34].

In the current study, the meat of three species of Bagridae fish from the Kampar Kanan River in Indonesia was found to contain an abundance of microminerals such as Fe and Zn. M. nigriceps which has been recorded to exhibit higher mineral content, including Fe and Zn. This species is categorized as a small indigenous fish (SIF) with a maximum standard length of approximately 10.29 cm. According to [35], SIFs, in general, are known to be rich in Ca, Fe, and Mn.

~~In the current study, the meat of three species of Bagridae fish from the Kampar Kanan River Indonesia was found to contain abundance of microminerals such as Fe and Zn. Insufficient intake of Fe and Zn has been linked to major developmental health problems, such as~~

~~Fe deficiency which is one of the major causes of anemia in pregnant and lactating women, especially in rural communities [41,42]. Lacking in Zn, on the other hand, can lead to numerous immunological disorders, such as metabolic and chronic illnesses, as well as infectious diseases including respiratory infections, malaria, HIV, or tuberculosis [43]. M. nigriceps that has been recorded exhibits higher mineral content, including iron and zinc. This species is categorized as a small indigenous fish (SIF) with a maximum standard length of approximately 10.29 cm. According to Mohanty et al. [44], SIFs, in general, are known to be rich in Ca, Fe, and manganese (Mn). The variation in mineral content among the three species of Bagridae fish is comparable to that of Clarias gariepinus and Tilapia zilli meat from the Owan River in Edo State, Nigeria [13].~~

~~In general, fish consists of 70% to 84% moisture [45] . High moisture content is often associated with freshness in fish. Compared to fish that has been processed or stored, fresh fish often has a higher moisture content, the factor that contributes to a moist and succulent texture. Fish with high moisture content may retain more water-soluble nutrients during cooking or processing as proven by Gupta et al. [46] with green leafy vegetables This can help preserve the nutritional value of the fish, ensuring that important vitamins and minerals are retained. However, due to the high moisture content in fish, a processing technique that changes the moisture content will also change the fish's properties, such as the texture and protein gelation [47].~~

~~The amount of crude fats in the fish is a good indicator of how much lipids or fats are present. In addition to acting as transporters for fat-soluble vitamins, fats offer a concentrated source of energy to the body. Additionally, they improve the fish's flavour, texture, and palatability [48]. Numerous health advantages, including improved cardiovascular health, improved brain function, and anti-inflammatory effects, have been linked to specific fatty acids present in fish, particularly omega fatty acids. So a fish with a high amount of crude fat might be good, especially if it has good fatty acids.~~ From the findings, all three Bagridae fish had a total fat content of around 7-8% by weight (Table 1). According to Fuentes et al. [49], fish with lower fat content exhibit higher water content, which is also shown in our study. On the other hand, Nurnadia et al. [50] reported that the fish species can be grouped into different categories, including high-fat fish (>8%), medium-fat fish (4-8%), low-fat fish (2-4%), and lean fish (<2%). According to the established classification, the three indigenous Bagridae fish species are characterized as having a moderate level of fat content, which is reflected by the high levels of DHA and EPA in the meat of *H. nemurus*, *H. wyckii*, and *M. nigriceps* fish (Table 2). It is still unclear whether consuming the fish meat of these three species can indirectly help lower blood pressure, reduce inflammation in blood vessels, improve lipid profiles by increasing levels of good cholesterol (HDL) and decreasing levels of bad cholesterol (LDL), and reduce blood clotting in individuals. Nonetheless, the fat content of fish is determined by various factors, such as species, habitat ecosystems, feeding patterns, and other biological attributes, including the distinctive flavor characteristics of the fish [8,49,51,52].

In this study, all three Bagridae fish had a total fat content of around 7% to 8% by weight, with a higher water content ranging from 82.40% to 85.39% (Table 1). Similarly, for wild and cultured Sea bass, Dicentrarchus labrax [36]. ~~49~~]. Additionally, the fish species can be grouped into different categories, including high-fat fish (>8%), medium-fat fish (4-8%), low-fat fish (2-4%), and lean fish (<2%) [37].- ~~49~~]. According to the established classification by [37] 49], the three indigenous Bagridae fish species are characterized as having a moderate level of fat content, which is reflected by the high levels of DHA and EPA in the meat of *H. nemurus*, *H. wyckii*, and M. nigriceps (Table 2). Therefore, we hav recommended consuming the fish meat of these three species can indirectly help for food security in rural and urban communities.

Each of the three Bagridae fish species analyzed in the study contained arachidonic acid (C20:4) 12.13% for *H.nemerus*, 12.49 % for *H. wyckii*, and 12.41% for *M. nigriceps*. Arachidonic acid serves as a precursor for synthesizing prostaglandins and leukotrienes [38, ~~53~~]. Leukotrienes are crucial in allergic responses, inducing smooth muscle contraction and increasing vascular permeability [39, ~~54~~]. Additionally, all three species also contained EPA ranging from 1.35% and 2.34%, and DHA ranging from 11.56% to 15.65%. The increased consumption of omega-3 fatty acids, such as EPA and DHA, has been linked to a decreased risk of pain development in older individuals and preventive Alzheimer's disease [40,41, ~~55,56~~].

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increasing vascular permeability [54]. In this study, the arachidonic acid content in H. nemurus, H. wyckii, and M. negriceps was determined to be 12.13%, 12.49%, and 12.41%, respectively. Conversely, the levels of arachidonic acid in *Channa striatus*, *Channa micropeltes*, and *Channa lucius* were reported as 19.02%, 4.71%, and 12.41%, respectively [55]. According to Carballo-Casla et al. [56], increased consumption of marine omega-3 fatty acids, such as EPA and DHA, has been linked to a decreased risk of pain development in older individuals. Additionally, DHA and EPA have demonstrated a preventive effect on human coronary arteries and Alzheimer's disease [57,58].

As determined by the current study, the ω-6:ω-3 ratios of three Bagridae fish species ranged from 1:0.8 to 1:0.97. It was found that all three fish species had ω-6: ω-3 ratios within the recommended range for a typical Indonesian diet. In contrast, a typical Western diet is characterized by a high ω-6:ω-3 ratio of 10:1 to 20:1, while a Mediterranean diet has a ratio of 4:1 to 5:1 [42, 61]. On the other hand, P/S ratio analysis shows that the three Bagridae fish species are contained sources of PUFA that meet the requirements for food safety.

In this study, our hypothesis is that the levels of EPA and DHA found in the meat of three species of Bagridae fish in the Kampar Kanan River, Indonesia, may also have the potential in reducing muscle pain and inflammation. Additionally, as a primary food source, fish plays a role in the prevention and treatment of chronic pain [59]. As determined by the current study, the ω-6:ω-3 ratios of three Bagridae fish species ranged from 1:0.8 to 1:0.97. These varying ω-6:ω-3 ratios can have diverse implications for treating or preventing diseases [60]. It was found that all three fish species had ω-6: ω-3 ratios within the recommended range for a typical Indonesian diet. In contrast, a typical Western diet is characterized by a high ω-6:ω-3 ratio of 10:1 to 20:1, while a Mediterranean diet has a ratio of 4:1 to 5:1 [61]. The P/S ratio analysis revealed that all three Bagridae fish species were considered an average source of PUFA. Additionally, it has been reported that marine fish serve as a good source of PUFA [62].

The atherogenic index (AI) and thrombogenic index (TI) indices are directly influenced by the levels of C14:0, C16:0, and C18:0, all of which are known to promote thrombogenicity [24]. AI and TI indices indicate the potential to induce platelet aggregation. A lower value in AI and TI indicates a more significant protective potential against coronary artery disease [63]. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recommended AI and TI values ranging from 0.4 to 0.5 for promoting human health [64]. The AI and TI values of various marine fish species, such as Sardine (*Sardinella hualiensis*), being 0.60 and 0.20, respectively, and Mackerel (*Scomber japonicus*) having values of 0.48 and 0.24, respectively [65]. In the current study, the observed AI values in three freshwater species of Bagridae fish ranged from 0.73 to 0.99, while the TI values varied between 0.54 and 0.75. This finding is associated with a notable disparity in the values of saturated fatty acids (SFA) among the three species of Bagridae fish. Based on these findings, we certify that consuming the meat of three freshwater species of Bagridae fish caught in the wild does not endanger consumers' health and can serve as a suitable source of food safety and nutritional quality.

The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recommended AI and TI values ranging from 0.4 to 0.5 for promoting human health [43, 64]. In the current study, the observed AI values in three freshwater species of Bagridae fish ranged from 0.73 to 0.99, while the TI values varied between 0.54 and 0.75. This finding is associated with a notable disparity in the values of saturated fatty acids (SFA) among the three species of Bagridae fish. Based on these findings, we certify that consuming the meat of three freshwater species of Bagridae fish caught in the wild does not endanger consumers' health and can serve as a suitable source of food safety and nutritional quality.

Fish with a high crude protein content, as also shown by the three Bagridae fish studied (Table 1), are regarded as being nutritionally useful for human health. According to Pawar and Sonaware [44, 68], protein and amino acid content can directly indicate the nutritional quality of meat. In Table 4, H. wykii had higher content of essential amino acids (EAA) than H. nemurus and M. nigriceps. Among the EAA, lysine (Lys) was found to be present in the highest amount in all three species. Lys is necessary for tissue growth and repair, reduced stress-induced anxiety, and the conversion of fatty acids into energy [45-47, 69,71,72].

A high value for crude protein shows that the fish contains a considerable amount of protein. Since fish protein is easier to digest than protein found in meat and includes less collagen fibre, the body can use its protein more effectively [66]. The body's tissues need protein to develop, mend, and remain healthy. The absence of amino acids and fatty acids elements will impede the recovery process [67]. Protein is a crucial ingredient for human health, contributing to a number of physiological functions like immunological function, muscular growth, and enzyme synthesis. Since protein is a crucial part of a balanced diet, fish with a high crude protein content, as also been shown by the three Bagridae fish studied (Table 1), are regarded as being nutritionally useful. According to Pawar and Sonaware [68], protein and amino acid content can directly indicate the nutritional quality of meat. In Table 4, *H. wykii* had higher quantities of essential amino acids (EAA) than *H. nemurus* and *M. nigriceps*. Since EAA cannot be synthesised by the body yet are necessary for physiologic function, they are significant for humans. They are thus derived through EAA-rich foods such as fish. Among the EAA, lysine (Lys) was found to be present in the highest amount in all three species. Lys is necessary for tissue growth and repair [69]. Furthermore, Lys can reduced stress-induced anxiety [70] and has antiviral properties [71]. Lys also plays a role in metabolic activities, including the creation of carnitine for mitochondrial energy generation and the conversion of fatty acids into energy [72].

More than 60% of the amino acid composition in all three Brigade fish studied comes from the non-essential amino acids (NEAA), particularly glutamic acid (Table 4). Glutamic and its amine, glutamine are highly abundant amino acids found in fish in the free and protein-bound forms [48,74]. Other amino acids found abundant in the three fish also play important physiologic as well as biochemical functions. The NEAA, arginine, for example, is involved in protein synthesis, creatine formation, and various other biochemical processes within the body. The EAAs, leucine, phenylalanine, and methionine, play important roles in the synthesis of nitric oxide, a molecule that can expand blood vessels [49, 75].

4. Conclusions

The present study offers insightful information about the fatty acid and amino acid compositions, biometric measurements, proximate analysis, and mineral composition of three local freshwater species of Indonesian Bagridae fish. The findings show their potential as a nutrient-dense, sustainable food source that can support efforts to increase food security. These fish species might be incorporated into the local diet to increase nutrient intake and alleviate nutritional inadequacies, which would ultimately improve Indonesia's overall food security status.

Data Availability

The data utilized in this research has not been previously released or published in any form. The data sets employed and/or analyzed during the present study can be obtained by contacting the corresponding author.

Conflicts of Interest

The authors confirm that they do not have any conflicting interests.

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Research Article

Analysis of Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security

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Abstract

Fish have become an irreplaceable dietary source of animal protein, especially among households with low socioeconomic status in rural and urban areas of Indonesia. This study analysed the nutrient composition of three local Bagridae fish species in Indonesia. The nutrient composition results of *Hemibagrus nemurus*, *Hemibagrus wyckii*, and *Mystus nigriceps* revealed that the protein content was 24.26%, 22.57%, and 21.39% (%dry weight), respectively. The total lipid content varied between 6.64–7.75%, whereas the crude ash content ranged from 1.59–2.30%. Regarding mineral contents, the calcium levels ranged from 1.49–1.66 mg/g, iron levels from 28.35–40.36 µg/g, and zinc levels from 24.03–54.46 µg/g. The predominant amino acids found in the three species of Bagridae fish were glutamic acid, aspartic acid, alanine, arginine, and lysine, with their concentrations ranging from 9.10–24.34%. Among the fatty acids, C16:0 (palmitic acid) was the most abundant in all three species, accounting for 25.59–30.70% of the total fatty acids. Additionally, significant amounts of C18:1 (oleic acid), C18:0 (stearic acid), and C20:4 (arachidonic acid) were also detected as primary fatty acids. The calculated atherogenic index values in the three species of Bagridae fish ranged from 0.73–0.99, while the thrombogenic index values varied between 0.54–0.75. These results indicate that consuming the meat of these three freshwater Bagridae fish species caught in the wild does not pose any health risks to consumers. They can be considered a safe and suitable food source with good nutritional quality.

Keywords: Nutrient composition, Amino acids, Fatty acids, Freshwater fish, Kampar Kanan River of Indonesia

1. Introduction

Fish serve as a high-quality protein source that is essential for satisfying dietary protein requirements, especially in areas where other protein sources are few or difficult to obtain [1,2]. Their accessibility can aid in ensuring a steady supply of food, particularly for communities whose main source of income is fishing or aquaculture [3]. Fish can contribute to a more varied selection of protein sources in communities, resulting in a diet that is more nutritious and balanced. Dietary fish can treat nutrient deficits and enhance general nutritional health. Fish are generally considered safe and offer a lower risk of contamination with harmful substances compared to some land-based animal products. A reliable indicator of a fish's quality, nutritional value, physiological status, and environment is its chemical makeup, which is found in fish flesh [4].

Hemibagrus nemurus, locally known as "baung", *Hemibagrus wyckii*, known as "geso" and *Mystus nigriceps,* known as "ingir-ingir," are three species of catfish found in the Kampar Kanan River, Indonesia [5,6]. Due to their high market value, these species have been identified as significant economic resources for rural communities [7]. Therefore, the analysis of the nutritional quality of fish meat in the study area is very important to determine whether it is beneficial to human health.

Knowing the composition of fatty acids and amino acids in fish meat is an essential factor that should not be ignored [8]. This information provides valuable insight into the nutritional quality of fish and the values of more nutritious and healthy foods [9]. In addition, a better understanding of the composition of fatty acids and amino acids can assist in selecting a suitable feed [10], developing a balanced diet [11], and maintaining optimal fish meat nutrition [12].

Omega-3 polyunsaturated fatty acids (PUFAs), particularly docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) derived from fish oil, exhibit anti-inflammatory and anti-gastrointestinal cancer properties, making them crucial as immune-boosting nutrients [13,14]. Studies have demonstrated that ω-3 and ω-6 PUFAs exhibit beneficial effects in the management of cardiovascular diseases and cancers [15,16]. The fatty acid composition of PUFAs can differ among different types of fish, including both freshwater and marine species [17, 18]. Amino acids (AAs), such as cysteine, arginine, tyrosine, glycine, proline, and serine, play a vital role in illness and stress situations and in the prevention of inflammation and repair processes in fish intestines [19, 20].

Furthermore, knowledge of the atherogenicity index (AI) and thrombogenicity index (TI) of fatty acids in the three local freshwater fish species of Bagridae can contribute to improving dietary guidelines. The AI and TI can be used to develop recommendations aimed at improving heart health [21,22]. These recommendations may involve selecting fish with favourable fatty acid profiles, allowing individuals to choose the most suitable fish species based on their specific needs [17, 23]. Therefore, this study aims to examine the nutritional composition profile, mineral content, amino acids, and fatty acids, and AI and TI of three freshwater fish species, namely, *H. nemurus*, *H. wyckii*, and *M. nigriceps*. These three fish species are generally consumed by people who live around the Kampar Kanan River in Kampar Regency, Riau Province, Indonesia.

2. Material and methods

2.1. Materials

In this study, a total of 27 Bagridae fish belonging to three distinct species (*H. nemurus*, *H. wyckii*, and *M. nigriceps*) were examined. The specimens were obtained from local fishers operating in the upper stretches of the Kampar Kanan River in Kampar Regency, Riau Province (Figure 1). Sampling took place between June and August 2022 and was verified by the Fisheries Department, Faculty of Fisheries and Marine Science, Universitas Bung Hatta, Indonesia. The samples were placed in plastic bags and transported to the laboratory in an insulated icebox. The samples were then grouped based on their respective sampling locations.

2.2. Biometry measurement

Upon reaching the laboratory within 10 hours, the fish samples were subjected to gutting and washing. Each specimen was weighed (TW) and measured to determine the standard length (SL) as well as the depth or maximum height (H). TW was measured using balance scale (OHAUS Model CT 6000 USA) with a precision of 0.01 g. The length measurement was taken from the tip of the mouth to the end of the upper lobe of the caudal fin, representing the total body length, using a metre ruler with an accuracy of 1 mm. The height measurement involved a vertical assessment of the body's maximum height measured using a

Digital Sekhmet Sigma Vernier calliper with an accuracy of 1 mm. The condition factor (CF) was calculated using the formula CF = $(TW/SL^3) \times 100$.

2.3. Proximate, amino acid, and mineral content analysis

The proximate carcass composition was assessed following the AOAC standard methods [24]. The samples were dried to a constant weight at 105 °C. The crude protein content was analysed using the standard Kjeldahl method, which involves multiplying the nitrogen content by a factor of 6.25. The Soxhlet method with ether extraction was employed to analyse crude lipids. The ash content was obtained by incinerating the samples at 550 °C for 16 h. The amino acid composition was determined using a high-performance liquid chromatography (HPLC) system, which consisted of a Waters® 1525 binary HPLC pump, Waters® 717 autosamplers, and Waters® 2475 multi-λ fluorescence detector (with excitation at 250 nm and emission at 395 nm). The samples were hydrolysed in triplicate with 6 N hydrochloric acid for 24 h at 11 °C [25].

For mineral data composition (Na, Mg, Ca, K, P, Fe, Cu, Mn, and Zn), the ashed feed sample and carcass were dissolved in 1 ml of hydrochloric acid (35% v/v Suprapur®, Merck) and then filtered with cellulose filter paper (Watchman No 1, International Ltd; Maidstone, UK) and diluted to an appropriate concentration for each elemental mineral. P levels were analysed with a Perkin-Elmer AA spectrophotometer mod 3110 (Norwalk, CT, USA).

2.4. Fatty acid analysis

The fish meat was examined utilizing the gas chromatography–mass spectrometry (GC–MS) method. The method of Folch et al. (1957) modified by Rajion et al. [26] was employed to perform the total fat extraction. This involved using a solvent system consisting of chloroform and methanol at a 2:1 (v/v) ratio. The process of transmethylation was conducted using a solution of 14% methanolic boron trifluoride. The fatty acid composition of the meat was then analysed at the SIG Laboratory, Accredited Testing Laboratory-LP-184-IDN.

The nutritional quality of lipids (AI and TI) was calculated using the following equations [27]:

$$AI = \frac{[(C12{:}0\ + 4\ \times C14{:}0\ +\ C16{:}0)]}{\sum MUFA\ +\ \sum n-6\ +\ \sum n-3}$$

$$TI = \frac{[(C14:0 + C16:0 + C18:0)]}{[(0.5 \times \sum MUFA) + (0.5 \times \sum n-6) + (3 \times \sum n-3) + (\sum n-3/\sum n-6)}$$

where:

AI = Atherogenic index
TI = Thrombogenic index
C12:0 = lauric acid
C14:0 = myristic acid
C16:0 = palmitic acid
C18:0 = stearic acid
∑MUFA = sum of the concentrations of all monosaturated fatty acids
∑n-6 = sum of the concentrations of n-6 polyunsaturated fatty acids
∑n-3 = sum of the concentrations of n-3 polyunsaturated fatty acids

2.5. Data analysis

Data analysis was performed using the SPSS 16.0 software package (SPSS; Chicago, IL). The homogeneity of variances was assessed using Levene's test. One-way ANOVA was carried out to determine the parameters of proximate and amino acid composition, including the composition of fatty acids and nutritional quality of lipids (AI and TI) for each species, followed by the post hoc Duncan's multiple range test [28]. The results are reported as the mean values ± standard errors for each parameter.

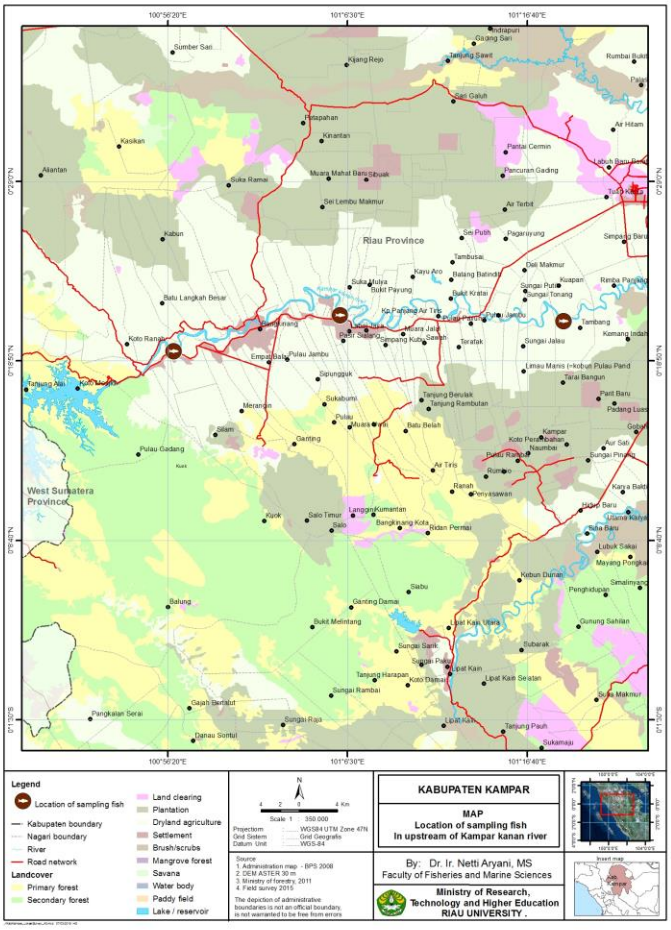

Figure 1. Map of Kampar Regency, Riau Province, and sampling locations of the three species of Bagridae fish.

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3. Results

Table 1 presents the average wet weight, standard length, height, and the results of meat nutritional composition analysis for three indigenous Indonesian freshwater Bagridae species. The moisture content (% wet weight) ranged from 82.40– 85.39%. Among the species examined, *M. nigriceps* exhibited the lowest protein content at 21.39%, while *H. nemurus* displayed the highest value at 24.26%. However, *M. nigriceps* had a higher mineral content, including of iron and zinc.

Table 2 summarizes the fatty acid composition (%total fatty acid) for the three Bagridae fish species. C16:0 was the predominant fatty acid in the three species of Bagridae fish, with percentages ranging from 25.09–30.71%. The additional prominent fatty acids found were C18:1, C18:0, and C22:6. *H. nemurus* exhibited a ω-6/ω-3 ratio below 1 (0.82), while *H. wyckii* and *M. nigriceps* had ratios of 1.11 and 1.02, respectively. The obtained PUFA/saturated fatty acid (SFA) (P/S) ratio varied between 0.61 and 0.76. The AI values varied between 0.76 and 0.99 and the TI between 0.54 and 0.75 (**Table 3**).

Table 4 presents the amino acid composition (% of total protein) of the three Bagridae species. Glutamic acid was the dominant amino acid, ranging from 19.29–24.34%, followed by aspartic acid, which ranged from 9.21–11.27%. The lysine content was consistent, ranging from 9.67–9.87%. In *H. nemurus*, the levels of various amino acids ranged from 0.86–24.35%. Similarly, in *H. wyckii*, the amino acid levels ranged from 0.76–21.58%, while in *M. nigriceps*, the levels ranged from 0.74–19.29%.

Table 1. Results of biometric, proximate and mineral composition of three species of Bagridae fish

	Species		
	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
Biometric measurements			
Total weight (g)	389.99 ± 24.96^{a}	1,390.33 ± 168.29^{b}	17.57 ± 1.53^{c}
Standard length (cm)	28.16 ± 0.53^{a}	44.14 ± 1.98^{b}	10.29 ± 0.15^{c}
Height (cm)	8.44 ± 0.16^{a}	8.82 ± 0.39^{b}	2.57 ± 0.03^{c}
Condition factor	1.63 ± 0.08	1.58 ± 0.07	1.56 ± 0.08
Proximate composition			
Crude protein (% DW)	24.26 ± 0.87^{a}	22.57 ± 0.37^{b}	21.39 ± 0.15^{c}
Crude fat (% DW)	6.64 ± 0.03^{a}	7.47 ± 0.02^{b}	7.75 ± 0.40^{c}
Crude ash (% DW)	1.94 ± 0.02^{a}	2.30 ± 0.09^{b}	1.59 ± 0.02^{c}
Moisture (% WW)	82.40 ± 2.51	85.39 ± 2.36	83.75 ± 2.21
Mineral composition			
Macrominerals (mg/g)			
Sodium	0.99 ± 0.00^{a}	1.61 ± 0.01^{b}	1.61 ± 0.02^{c}
Magnesium	1.12 ± 0.01^{a}	0.57 ± 0.02^{b}	1.15 ± 0.01^{c}
Calcium	1.66 ± 0.00^{a}	1.55 ± 0.02^{b}	1.49 ± 0.04^{c}
Potassium	0.71 ± 0.00^{a}	0.55 ± 0.02^{b}	0.43 ± 0.01^{c}
Phosphorous	7.03 ± 0.03^{a}	2.74 ± 0.02^{b}	6.45 ± 0.07^{c}
Microminerals (µg/g)			
Iron	28.30 ± 0.11^{a}	28.73 ± 0.08^{b}	40.36±0.55^{c}
Copper	8.93 ± 0.03^{a}	7.46 ± 0.09^{b}	6.21 ± 0.32^{c}

Manganese	1.64 ± 0.02[a]	2.64 ± 0.02[b]	2.84 ± 0.02[c]
Zinc	24.03 ± 0.45[a]	24.61 ± 0.19[b]	54.46 ± 0.17[c]

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

Table 2. Fatty acid composition of three species of Bagridae fish

Fatty acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
C12:0 (lauric acid)	1.97 ± 0.05[a]	3.94 ± 0.01[b]	4.27 ± 0.01[c]
C14:0 (Meristic acid)	2.38 ± 0.03[a]	2.72 ± 0.08[b]	2.89 ± 0.01[c]
C16:0 (Palmitic acid)	27.23 ± 0.06[a]	30.70 ± 0.06[b]	25.59 ± 0.01[c]
C18:0 (Stearic acid)	16.17 ± 0.02[a]	13.54 ± 0.02[b]	10.64 ± 0.01[c]
C20:0 (Arachidic acid)	0.23 ± 0.01[a]	0.14 ± 0.01[b]	0.37 ± 0.01[c]
C16:1 (Palmitoleic acid)	1.78 ± 0.00[a]	1.27 ± 0.04[b]	4.93 ± 0.01[c]
C18:1(Oleic acid)	16.86 ± 0.01[a]	16.18 ± 0.01[b]	16.97 ± 0.01[c]
C18:2 (Linoleic acid)	3.24 ± 0.02[a]	3.84 ± 0.33[b]	4.55 ± 0.001[c]
C18:3 (Linolenic acid)	1.12 ± 0.01[a]	0.82 ± 0.01[b]	1.57 ± 000[c]
C20:4 (Arachidonic acid)	12.13 ± 0.01[a]	12.49 ± 0.09[b]	12.41 ± 0.02[c]
C20:5 (Eicosapentaenoic acid; EPA)	2.06 ± 0.08[a]	2.34 ± 0.04[b]	1.35 ± 0.01[c]
C22:6 (Docosahexaenoic acid; DHA)	15.65 ± 0.01[a]	11.56 ± 0.04[b]	13.64 ± 0.02[c]

Values are mean % ± SE; *Values in the same row with a different superscript are significantly different ($p<0.05$).

Table 3. Fatty acid ω-6/ω-3 and polyunsaturated/saturated fatty acid ratio of three species of Bagridae fish

	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
ω-6/ω-3 ratio	0.82 ± 0.00[a]	1.11 ± 0.02[b]	1.02 ± 0.01[c]
P/S ratio	0.69 ± 0.01[a]	0.61 ± 0.06[b]	0.76 ± 0.00[c]
AI	0.87 ± 0.01[a]	0.99 ± 0.06[b]	0.73 ± 0.00[c]
TI	0.63 ± 0.01[a]	0.75 ± 0.03[b]	0.54 ± 0.00[c]

P/S, polyunsaturated/saturated fatty acid; AI, atherogenic index; TI, thrombogenic index
Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

Table 4. Amino acid composition of three species of Bagridae fish

Amino acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
Aspartic acid	10.39 ± 0.01[a]	9.61 ± 0.04[b]	11.28 ± 0.02[c]
Glutamic acid	24.34 ± 0.00[a]	21.58 ± 0.41[b]	19.29 ± 0.03[c]
Serine	3.74 ± 0.00[a]	5.40 ± 0.03[b]	7.50 ± 0.06[c]
Glycine	4.02 ± 0.00[a]	5.77 ± 0.04[b]	4.69 ± 0.02[c]
Histidine	2.39 ± 0.00[a]	2.90 ± 0.03[b]	2.21 ± 0.02[c]
Arginine	6.17 ± 0.01[a]	8.27 ± 0.03[b]	6.22 ± 0.03[c]
Threonine	4.49 ± 0.01[a]	4.19 ± 0.03[b]	4.39 ± 0.04[c]
Alanine	7.03 ± 0.00[a]	6.04 ± 0.02[b]	7.89 ± 0.01[c]
Proline	2.40 ± 0.00[a]	2.71 ± 0.01[b]	2.21 ± 0.02[c]
Tyrosine	3.91 ± 0.01[a]	3.29 ± 0.06[b]	3.82 ± 0.04[c]
Valine	3.73 ± 0.00[a]	4.02 ± 0.01[b]	3.85 ± 0.04[c]
Methionine	3.42 ± 0.00[a]	1.96 ± 0.02[b]	1.27 ± 0.03[c]
Cystine	0.87 ± 0.00[a]	0.76 ± 0.02[b]	0.75 ± 0.03[c]
Isoleucine	3.82 ± 0.001[a]	3.96 ± 0.003[b]	3.66 ± 0.002[c]
Leucine	6.15 ± 0.000[a]	6.69 ± 0.002[b]	6.28 ± 0.004[c]
Phenylalanine	5.13 ± 0.000[a]	6.03 ± 0.005[b]	5.18 ± 0.027[c]
Lysine	9.61 ± 0.001[a]	9.82 ± 0.026[b]	9.87 ± 0.003[c]

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

4. Discussion

The results of this study provide important new information about the nutritional makeup of the studied species of Bagridae fish. The biometric measures of the fish yielded important information about their physical traits and health. Researchers are able to determine the average weight of fish at various lengths by examining the link between length and weight for a particular species. This knowledge is essential for understanding the trends in fish population growth, identifying potential shifts in growth rates over time, and assessing the general health and welfare of fish [29]. A variety of factors, including sex, age, maturity level, size, stomach fullness level, sampling strategies, sample sizes, and environmental circumstances, have an impact on fish health and the parameters that determine length–weight connections in fish [30]. However, none of these factors were considered in our study. In general, according to the theory put forth by Bagenal and Tesch [31], heavier fish of a given length are in better physiological condition. The condition factor is also used in fisheries science to compare the health, fatness, and condition of fish [32]. A condition factor of > 1 is favourable, indicating a good feed nutrition level and suitable living habitat [33]. Thus, based on the findings in this study, the Kampar Kanan River provides a suitable habitat for the fish, ensuring their accessibility and availability for community consumption.

The fish samples exhibited good nutritional profiles, with high amounts of proteins and lipids as well as moisture content contributing to their overall nutritional value, according to the results of proximate analysis and mineral composition (see Table 1). These results imply that the fish species studied provide a possible source of nutrients to solve issues with food security. The study of the mineral composition revealed the existence of critical minerals such as phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) in the fish samples in addition to proteins and lipids. All three Bagridae fish significantly differed from each other in terms of their crude ash content and mineral profile (see Table 1). However, in general, P and Ca are the two highest minerals found in all fish. Both of these macro minerals are good for human bone and tooth health, as key components of hydroxyapatite, the mineral matrix that provides strength and structure to bones and teeth [34].

In the current study, the meat of three species of Bagridae fish from the Kampar Kanan River in Indonesia was found to contain an abundance of microminerals such as Fe and Zn. *M. nigriceps* has been reported to exhibit higher mineral content, including of Fe and Zn. This species is categorized as a small indigenous fish (SIF) with a maximum standard length of approximately 10.29 cm. According to [35], SIFs are generally known to be rich in Ca, Fe, and Mn.

In this study, all three Bagridae fish had a total fat content of approximately 7–8% by weight, with a higher water content ranging from 82.40–85.39% (Table 1). These values are similar to those found in wild and cultured sea bass *Dicentrarchus labrax* [36]. Additionally, the fish species can be grouped into different categories, including high-fat fish (>8%), medium-fat fish (4–8%), low-fat fish (2–4%), and lean fish (<2%) [37]. According to the classification established by [37], the three indigenous Bagridae fish species are characterized as having a moderate fat content level, which is reflected by the high levels of DHA and EPA in the meat of *H. nemurus*, *H. wyckii*, and *M. nigriceps* (Table 2). Therefore, we recommend that consuming the meat of these three fish species can indirectly boost food security in rural and urban communities.

All three Bagridae fish species analysed in the study contained arachidonic acid (C20:4), at 12.13% for *H. nemurus*, 12.49% for *H. wyckii*, and 12.41% for *M. nigriceps*. Arachidonic acid serves as a precursor for synthesizing prostaglandins and leukotrienes [38]. Leukotrienes are crucial in allergic responses, inducing smooth muscle contraction and increasing vascular permeability [39]. Additionally, all three species also contained EPA ranging from 1.35–2.34% and DHA ranging from 11.56–15.65%. The increased consumption of omega-3 fatty acids, such as EPA and DHA, has been linked to a decreased risk of pain development in older individuals and to the prevention of Alzheimer's disease [40,41].

As determined by the current study, the ω-6/ω-3 ratios of the three Bagridae fish species ranged from 1:0.8 to 1:0.97. It was found that all three fish species had ω-6/ω-3 ratios within the recommended range for a typical Indonesian diet. In contrast, a typical Western diet is characterized by a high ω-6/ω-3 ratio of 10:1 to 20:1, while a Mediterranean diet has a ratio of 4:1 to 5:1 [42]. Additionally, the P/S ratio analysis showed that the three Bagridae fish species are sources of PUFAs that meet the requirements for food safety.

The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recommended AI and TI values ranging from 0.4 to 0.5 for promoting human health [43]. In the current study, the observed AI values in the three freshwater species of Bagridae ranged from 0.73 to 0.99, while the TI values varied between 0.54 and 0.75. This finding is associated with a notable disparity in the values of SFAs among the three Bagridae fish species. Based on these findings, we confirm that consuming the meat of the three freshwater species of Bagridae fish caught in the wild does not endanger consumer health and can serve as a suitable source of food safety and nutritional quality.

Fish with a high crude protein content, as shown by the three studied Bagridae fish (Table 1), are regarded as being nutritionally useful for human health. The protein and amino acid contents can directly indicate the nutritional quality of meat [44]. As shown in Table 4, *H. wyckii* had a higher content of essential amino acids (EAAs) than *H. nemurus* and *M. nigriceps*. Among the EAAs, lysine (Lys) was found to be present in the highest amount in all three species. Lys is necessary for tissue growth and repair, reduced stress-induced anxiety, and the conversion of fatty acids into energy [45-47].

More than 60% of the amino acid composition in all three Brigade fish studied comes from nonessential amino acids (NEAAs), particularly glutamic acid (Table 4). Glutamic acid and its amine, glutamine, are highly abundant amino acids found in fish in the free and protein-bound forms [48]. Other amino acids found at abundant levels in the three fish also play important physiological and biochemical functions. The NEAA arginine, for example, is involved in protein synthesis, creatine formation, and various other biochemical processes within the body. The EAAs leucine, phenylalanine, and methionine play important roles in the synthesis of nitric oxide, a molecule that can expand blood vessels [48].

4. Conclusions

The present study provides insightful information about the fatty acid and amino acid compositions, biometric measurements, proximate analysis, and mineral composition of three local freshwater species of Indonesian Bagridae fish. The findings show their potential as a nutrient-dense, sustainable food source that can support efforts to increase food security. These fish species might be incorporated into the local diet to increase nutrient intake and alleviate nutritional inadequacies, which would ultimately improve Indonesia's overall food security status.

Data Availability

The data utilized in this research has not been previously released or published in any form. The datasets employed and/or analysed during the present study can be obtained by contacting the corresponding author.

Conflicts of Interest

The authors confirm that they do not have any conflicting interests.

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3 messages

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To: Hafrijal Syandri <syandri_1960@bunghatta.ac.id>

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>
> > *The idea to study the nutritional value of Local Freshwater Species is excellent and interesting. and deserves to be published in the International Journal of Food Science. There are some problems inredaction style and should be checked by an English speaker.*
> > *Abstract*
> > *- The objective should be described;*
> > *Keywords*
> > *- Abbreviations must be written in alphabetical order.*
> > *MM*
> > *- Animal material not Materials.*
> > *- TI : Stearic acid is a fatty acid that is neutral concerning cardiovascular disease. Normally you should not take it as a proatherogenic fatty acid in your calculations.*
> > *- Figure 1 : invisible, need to improve the resolution*

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hafrizal syandri <syandri_1960@bunghatta.ac.id> Wed, Nov 15, 2023 at 4:04 PM
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Hafrijal Syandri
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Phenom Emails <phenom.emails@hindawi.com> Wed, Nov 15, 2023 at 6:44 PM
Reply-To: Phenom Emails <phenom.emails@hindawi.com>
To: syandri_1960@bunghatta.ac.id

Dear Dr. Syandri,

Thank you so much for your revised manuscript.

Please do not hesitate to get back in touch if you have any further questions.

Best Regards,

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Deepanaa Rajadurai
Editorial Assistant

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, hafrizal syandri <syandri_1960@bunghatta.ac.id> wrote:
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Research Article

Analysis of Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security

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Abstract

Fish have become an irreplaceable dietary source of animal protein, especially among households with low socioeconomic status in rural and urban areas of Indonesia. This study aimed to analyse the proximate composition, minerals, fatty acids, and amino acids of three local Bagridae fish species in Indonesia. The standard AOAC method was employed to examine the proximate composition of the carcass, and the analysis of amino acids and fatty acids was conducted through HPLC and GC-MS, respectively. The mineral content was determined using AAS. The nutrient composition results of *Hemibagrus nemurus*, *Hemibagrus wyckii*, and *Mystus nigriceps* revealed that the protein content was 24.26%, 22.57%, and 21.39% (%dry weight), whereas the total lipid content was 6.64%, 7.47% and 7.75%, respectively. Regarding mineral contents, the calcium levels ranged from 1.49–1.66 mg/g, iron levels from 28.35–40.36 µg/g, and zinc levels from 24.03–54.46 µg/g. Among the fatty acids, palmitic acid was the most abundant in all three species, accounting for 25.59–30.70% of the total fatty acids. Additionally, significant amounts of C18:1 (oleic acid), C18:0 (stearic acid), and C20:4 (arachidonic acid) were also detected as primary fatty acids.The calculated atherogenic index values in the three species of Bagridae fish ranged from 0.73–0.99, while the thrombogenic index values varied between 0.54–0.75. The predominant amino acids found in the three species of Bagridae fish were glutamic acid with their concentrations ranging from 9.10–24.34%. These results indicate that consuming the meat of these three freshwater Bagridae fish species caught in the wild does not pose any health risks to consumers. They can be considered a safe and suitable food source with good nutritional quality.

Keywords: Amino acids, Fatty acids, Indonesia, Kampar Kanan River, Minerals

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1. Introduction

Fish serve as a high-quality protein source that is essential for satisfying dietary protein requirements, especially in areas where other protein sources are few or difficult to obtain [1,2]. Their accessibility can aid in ensuring a steady supply of food, particularly for communities whose main source of income is fishing or aquaculture [3]. Fish can contribute to a more varied selection of protein sources in communities, resulting in a diet that is more nutritious and balanced. Dietary fish can treat nutrient deficits and enhance general nutritional health. Fish are generally considered safe and offer a lower risk of contamination with harmful substances compared to some land-based animal products. A reliable indicator of a fish's quality, nutritional value, physiological status, and environment is its chemical makeup, which is found in fish flesh [4].

Hemibagrus nemurus, locally known as "baung", *Hemibagrus wyckii*, known as "geso" and *Mystus nigriceps*, known as "ingir-ingir," are three species of catfish found in the Kampar Kanan River, Indonesia [5,6]. Due to their high market value, these species have been identified as significant economic resources for rural communities [7]. Therefore, the analysis of the nutritional quality of fish meat in the study area is very important to determine whether it is beneficial to human health.

Knowing the composition of fatty acids and amino acids in fish meat is an essential factor that should not be ignored [8]. This information provides valuable insight into the nutritional quality of fish and the values of more nutritious and healthy foods [9]. In addition, a better understanding of the composition of fatty acids and amino acids can assist in selecting a suitable feed [10], developing a balanced diet [11], and maintaining optimal fish meat nutrition [12].

Omega-3 polyunsaturated fatty acids (PUFAs), particularly docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) derived from fish oil, exhibit anti-inflammatory and anti-gastrointestinal cancer properties, making them crucial as immune-boosting nutrients [13,14]. Studies have demonstrated that ω-3 and ω-6 PUFAs exhibit beneficial effects in the management of cardiovascular diseases and cancers [15,16]. The fatty acid composition of PUFAs can differ among different types of fish, including both freshwater and marine species

[17, 18]. Amino acids (AAs), such as cysteine, arginine, tyrosine, glycine, proline, and serine, play a vital role in illness and stress situations and in the prevention of inflammation and repair processes in fish intestines [19, 20].

Furthermore, knowledge of the atherogenicity index (AI) and thrombogenicity index (TI) of fatty acids in the three local freshwater fish species of Bagridae can contribute to improving dietary guidelines. The AI and TI can be used to develop recommendations aimed at improving heart health [21,22]. These recommendations may involve selecting fish with favourable fatty acid profiles, allowing individuals to choose the most suitable fish species based on their specific needs [17, 23]. Therefore, this study aims to examine the nutritional composition profile, mineral content, amino acids, and fatty acids, and AI and TI of three freshwater fish species, namely, *H. nemurus*, *H. wyckii*, and *M. nigriceps*. These three fish species are generally consumed by people who live around the Kampar Kanan River in Kampar Regency, Riau Province, Indonesia.

2. Material and methods

2.1. Animal material

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In this study, a total of 27 Bagridae fish belonging to three distinct species (*H. nemurus*, *H. wyckii*, and *M. nigriceps*) were examined. The specimens were obtained from local fishers operating in the upper stretches of the Kampar Kanan River in Kampar Regency, Riau Province (Figure 1). Sampling took place between June and August 2022 and was verified by the Fisheries Department, Faculty of Fisheries and Marine Science, Universitas Bung Hatta, Indonesia. The samples were placed in plastic bags and transported to the laboratory in an insulated icebox. The samples were then grouped based on their respective sampling locations.

2.2. Biometry measurement

Upon reaching the laboratory within 10 hours, the fish samples were subjected to gutting and washing. Each specimen was weighed (TW) and measured to determine the standard length (SL) as well as the depth or maximum height (H). TW was measured using balance scale (OHAUS Model CT 6000 USA) with a precision of 0.01 g. The length measurement was taken from the tip of the mouth to the end of the upper lobe of the caudal fin, representing the total body length, using a metre ruler with an accuracy of 1 mm. The height measurement involved a vertical assessment of the body's maximum height measured using a

Digital Sekhmet Sigma Vernier calliper with an accuracy of 1 mm. The condition factor (CF) was calculated using the formula CF = $(TW/SL^3) \times 100$.

2.3. Proximate, amino acid, and mineral content analysis

The proximate carcass composition was assessed following the AOAC standard methods [24]. The samples were dried to a constant weight at 105 °C. The crude protein content was analysed using the standard Kjeldahl method, which involves multiplying the nitrogen content by a factor of 6.25. The Soxhlet method with ether extraction was employed to analyse crude lipids. The ash content was obtained by incinerating the samples at 550 °C for 16 h. The amino acid composition was determined using a high-performance liquid chromatography (HPLC) system, which consisted of a Waters® 1525 binary HPLC pump, Waters® 717 autosamplers, and Waters® 2475 multi-λ fluorescence detector (with excitation at 250 nm and emission at 395 nm). The samples were hydrolysed in triplicate with 6 N hydrochloric acid for 24 h at 11 °C [25].

For mineral data composition (Na, Mg, Ca, K, P, Fe, Cu, Mn, and Zn), the ashed feed sample and carcass were dissolved in 1 ml of hydrochloric acid (35% v/v Suprapur®, Merck) and then filtered with cellulose filter paper (Watchman No 1, International Ltd; Maidstone, UK) and diluted to an appropriate concentration for each elemental mineral. P levels were analysed with a Perkin-Elmer AA spectrophotometer mod 3110 (Norwalk, CT, USA).

2.4. Fatty acid analysis

The fish meat was examined utilizing the gas chromatography–mass spectrometry (GC–MS) method. The method of Folch et al. (1957) modified by Rajion et al. [26] was employed to perform the total fat extraction. This involved using a solvent system consisting of chloroform and methanol at a 2:1 (v/v) ratio. The process of transmethylation was conducted using a solution of 14% methanolic boron trifluoride. The fatty acid composition of the meat was then analysed at the SIG Laboratory, Accredited Testing Laboratory-LP-184-IDN.

The nutritional quality of lipids (AI and TI) was calculated using the following equations [27]:

$$AI = \frac{[(C12{:}0 + 4 \times C14{:}0 + C16{:}0)]}{\sum MUFA + \sum n-6 + \sum n-3}$$

$$TI = \frac{[(C14:0 + C16:0 + C18:0)]}{[(0.5 \times \sum MUFA) + (0.5 \times \sum n-6) + (3 \times \sum n-3) + (\sum n-3/\sum n-6)}$$

where:

AI = Atherogenic index

TI = Thrombogenic index

C12:0 = lauric acid

C14:0 = myristic acid

C16:0 = palmitic acid

C18:0 = stearic acid

∑MUFA = sum of the concentrations of all monosaturated fatty acids

∑n-6 = sum of the concentrations of n-6 polyunsaturated fatty acids

∑n-3 = sum of the concentrations of n-3 polyunsaturated fatty acids

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2.5. Data analysis

Data analysis was performed using the SPSS 16.0 software package (SPSS; Chicago, IL). The homogeneity of variances was assessed using Levene's test. One-way ANOVA was carried out to determine the parameters of proximate and amino acid composition, including the composition of fatty acids and nutritional quality of lipids (AI and TI) for each species, followed by the post hoc Duncan's multiple range test [28]. The results are reported as the mean values ± standard errors for each parameter.

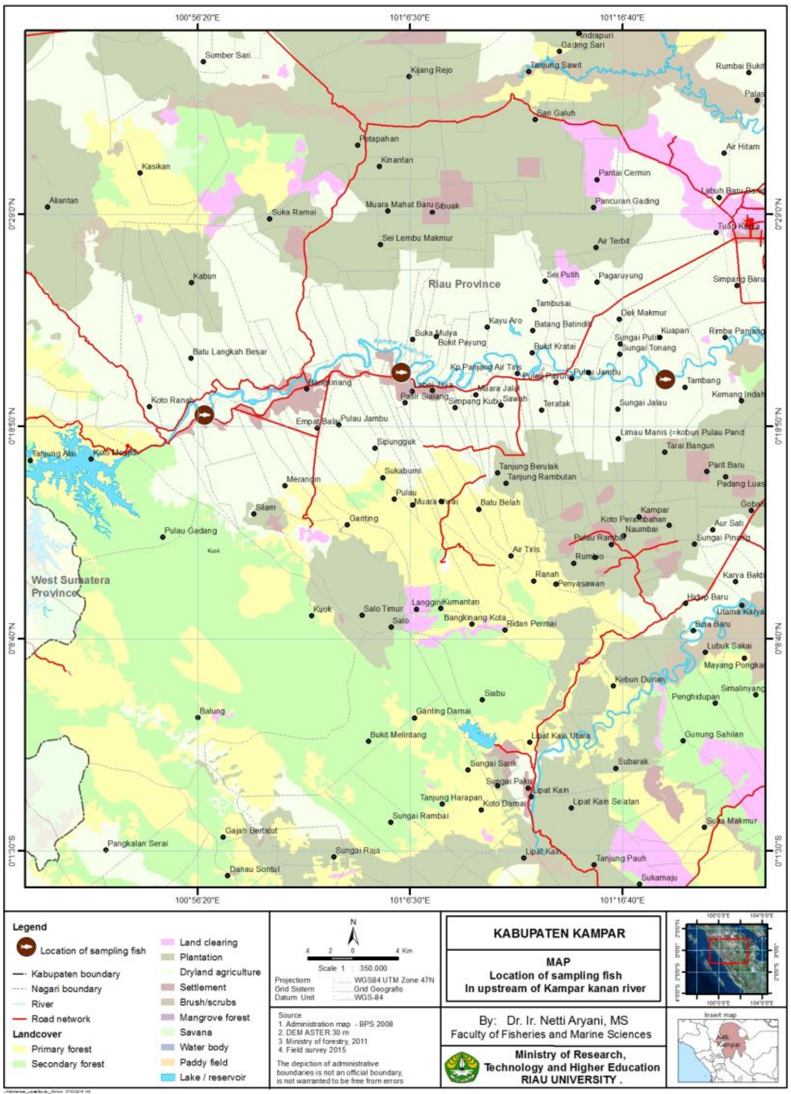

Figure 1. Map of Kampar Regency, Riau Province, and sampling locations of the three species of Bagridae fish.

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3. Results

Table 1 presents the average wet weight, standard length, height, and the results of meat nutritional composition analysis for three indigenous Indonesian freshwater Bagridae species. The moisture content (% wet weight) ranged from 82.40– 85.39%. Among the species examined, *M. nigriceps* exhibited the lowest protein content at 21.39%, while *H. nemurus* displayed the highest value at 24.26%. However, *M. nigriceps* had a higher mineral content, including of iron and zinc.

Table 2 summarizes the fatty acid composition (%total fatty acid) for the three Bagridae fish species. C16:0 was the predominant fatty acid in the three species of Bagridae fish, with percentages ranging from 25.09–30.71%. The additional prominent fatty acids found were C18:1, C18:0, and C22:6. *H. nemurus* exhibited a ω-6/ω-3 ratio below 1 (0.82), while *H. wyckii* and *M. nigriceps* had ratios of 1.11 and 1.02, respectively. The obtained PUFA/saturated fatty acid (SFA) (P/S) ratio varied between 0.61 and 0.76. The AI values varied between 0.76 and 0.99 and the TI between 0.54 and 0.75 (**Table 3**).

Table 4 presents the amino acid composition (% of total protein) of the three Bagridae species. Glutamic acid was the dominant amino acid, ranging from 19.29–24.34%, followed by aspartic acid, which ranged from 9.21–11.27%. The lysine content was consistent, ranging from 9.67–9.87%. In *H. nemurus*, the levels of various amino acids ranged from 0.86–24.35%. Similarly, in *H. wyckii*, the amino acid levels ranged from 0.76–21.58%, while in *M. nigriceps*, the levels ranged from 0.74–19.29%.

Table 1. Results of biometric, proximate and mineral composition of three species of Bagridae fish

	Species		
	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
Biometric measurements			
Total weight (g)	389.99 ± 24.96^{a}	$1,390.33 \pm 168.29^{b}$	17.57 ± 1.53^{c}
Standard length (cm)	28.16 ± 0.53^{a}	44.14 ± 1.98^{b}	10.29 ± 0.15^{c}
Height (cm)	8.44 ± 0.16^{a}	8.82 ± 0.39^{b}	2.57 ± 0.03^{c}
Condition factor	1.63 ± 0.08	1.58 ± 0.07	1.56 ± 0.08
Proximate composition			
Crude protein (% DW)	24.26 ± 0.87^{a}	22.57 ± 0.37^{b}	21.39 ± 0.15^{c}
Crude fat (% DW)	6.64 ± 0.03^{a}	7.47 ± 0.02^{b}	7.75 ± 0.40^{c}
Crude ash (% DW)	1.94 ± 0.02^{a}	2.30 ± 0.09^{b}	1.59 ± 0.02^{c}
Moisture (% WW)	82.40 ± 2.51	85.39 ± 2.36	83.75 ± 2.21

Mineral composition			
Macrominerals (mg/g)			
Sodium	0.99 ± 0.00^{a}	1.61 ± 0.01^{b}	1.61 ± 0.02^{c}
Magnesium	1.12 ± 0.01^{a}	0.57 ± 0.02^{b}	1.15 ± 0.01^{c}
Calcium	1.66 ± 0.00^{a}	1.55 ± 0.02^{b}	1.49 ± 0.04^{c}
Potassium	0.71 ± 0.00^{a}	0.55 ± 0.02^{b}	0.43 ± 0.01^{c}
Phosphorous	7.03 ± 0.03^{a}	2.74 ± 0.02^{b}	6.45 ± 0.07^{c}
Microminerals (µg/g)			
Iron	28.30 ± 0.11^{a}	28.73 ± 0.08^{b}	40.36±0.55^{c}
Copper	8.93 ± 0.03^{a}	7.46 ± 0.09^{b}	6.21 ± 0.32^{c}
Manganese	1.64 ± 0.02^{a}	2.64 ± 0.02^{b}	2.84 ± 0.02^{c}
Zinc	24.03 ± 0.45^{a}	24.61 ± 0.19^{b}	54.46 ± 0.17^{c}

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different (p<0.05).

Table 2. Fatty acid composition of three species of Bagridae fish

Fatty acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
C12:0 (lauric acid)	1.97 ± 0.05^{a}	3.94 ± 0.01^{b}	4.27 ± 0.01^{c}
C14:0 (Meristic acid)	2.38 ± 0.03^{a}	2.72 ± 0.08^{b}	2.89 ± 0.01^{c}
C16:0 (Palmitic acid)	27.23 ± 0.06^{a}	30.70 ± 0.06^{b}	25.59 ± 0.01^{c}
C18:0 (Stearic acid)	16.17 ± 0.02^{a}	13.54 ± 0.02^{b}	10.64 ± 0.01^{c}
C20:0 (Arachidic acid)	0.23 ± 0.01^{a}	0.14 ± 0.01^{b}	0.37 ± 0.01^{c}
C16:1 (Palmitoleic acid)	1.78 ± 0.00^{a}	1.27 ± 0.04^{b}	4.93 ± 0.01^{c}
C18:1(Oleic acid)	16.86 ± 0.01^{a}	16.18 ± 0.01^{b}	16.97 ± 0.01^{c}
C18:2 (Linoleic acid)	3.24 ± 0.02^{a}	3.84 ± 0.33^{b}	4.55 ± 0.001^{c}
C18:3 (Linolenic acid)	1.12 ± 0.01^{a}	0.82 ± 0.01^{b}	1.57 ± 000^{c}
C20:4 (Arachidonic acid)	12.13 ± 0.01^{a}	12.49 ± 0.09^{b}	12.41 ± 0.02^{c}
C20:5 (Eicosapentaenoic acid; EPA)	2.06 ± 0.08^{a}	2.34 ± 0.04^{b}	1.35 ± 0.01^{c}
C22:6 (Docosahexaenoic acid; DHA)	15.65 ± 0.01^{a}	11.56 ± 0.04^{b}	13.64 ± 0.02^{c}

Values are mean % ± SE; *Values in the same row with a different superscript are significantly different (p<0.05).

Table 3. Fatty acid ω-6/ω-3 and polyunsaturated/saturated fatty acid ratio of three species of Bagridae fish

	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
ω-6/ω-3 ratio	0.82 ± 0.00^{a}	1.11 ± 0.02^{b}	1.02 ± 0.01^{c}

P/S ratio	0.69 ± 0.01^{a}	0.61 ± 0.06^{b}	0.76 ± 0.00^{c}
AI	0.87 ± 0.01^{a}	0.99 ± 0.06^{b}	0.73 ± 0.00^{c}
TI	0.63 ± 0.01^{a}	0.75 ± 0.03^{b}	0.54 ± 0.00^{c}

P/S, polyunsaturated/saturated fatty acid; AI, atherogenic index; TI, thrombogenic index
Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

Table 4. Amino acid composition of three species of Bagridae fish

Amino acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
Aspartic acid	10.39 ± 0.01^{a}	9.61 ± 0.04^{b}	11.28 ± 0.02^{c}
Glutamic acid	24.34 ± 0.00^{a}	21.58 ± 0.41^{b}	19.29 ± 0.03^{c}
Serine	3.74 ± 0.00^{a}	5.40 ± 0.03^{b}	7.50 ± 0.06^{c}
Glycine	4.02 ± 0.00^{a}	5.77 ± 0.04^{b}	4.69 ± 0.02^{c}
Histidine	2.39 ± 0.00^{a}	2.90 ± 0.03^{b}	2.21 ± 0.02^{c}
Arginine	6.17 ± 0.01^{a}	8.27 ± 0.03^{b}	6.22 ± 0.03^{c}
Threonine	4.49 ± 0.01^{a}	4.19 ± 0.03^{b}	4.39 ± 0.04^{c}
Alanine	7.03 ± 0.00^{a}	6.04 ± 0.02^{b}	7.89 ± 0.01^{c}
Proline	2.40 ± 0.00^{a}	2.71 ± 0.01^{b}	2.21 ± 0.02^{c}
Tyrosine	3.91 ± 0.01^{a}	3.29 ± 0.06^{b}	3.82 ± 0.04^{c}
Valine	3.73 ± 0.00^{a}	4.02 ± 0.01^{b}	3.85 ± 0.04^{c}
Methionine	3.42 ± 0.00^{a}	1.96 ± 0.02^{b}	1.27 ± 0.03^{c}
Cystine	0.87 ± 0.00^{a}	0.76 ± 0.02^{b}	0.75 ± 0.03^{c}
Isoleucine	3.82 ± 0.001^{a}	3.96 ± 0.003^{b}	3.66 ± 0.002^{c}
Leucine	6.15 ± 0.000^{a}	6.69 ± 0.002^{b}	6.28 ± 0.004^{c}
Phenylalanine	5.13 ± 0.000^{a}	6.03 ± 0.005^{b}	5.18 ± 0.027^{c}
Lysine	9.61 ± 0.001^{a}	9.82 ± 0.026^{b}	9.87 ± 0.003^{c}

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

4. Discussion

The results of this study provide important new information about the nutritional makeup of the studied species of Bagridae fish. The biometric measures of the fish yielded important information about their physical traits and health. Researchers are able to determine the average weight of fish at various lengths by examining the link between length and weight for a particular species. This knowledge is essential for understanding the trends in fish population growth, identifying potential shifts in growth rates over time, and assessing the general health and welfare of fish [29]. A variety of factors, including sex, age, maturity level, size, stomach fullness level, sampling strategies, sample sizes, and environmental circumstances, have an impact on fish health and the parameters that determine length–weight connections in fish [30]. However, none of these factors were considered in our study. In general, according to the theory put forth by Bagenal and Tesch [31], heavier fish of a given length are in better physiological condition. The condition factor is also used in fisheries science to compare the health, fatness, and condition of fish [32]. A condition factor of > 1 is favourable, indicating a good feed nutrition level and suitable living habitat [33]. Thus, based on the findings in this study, the Kampar Kanan River provides a suitable habitat for the fish, ensuring their accessibility and availability for community consumption.

The fish samples exhibited good nutritional profiles, with high amounts of proteins and lipids as well as moisture content contributing to their overall nutritional value, according to the results of proximate analysis and mineral composition (see Table 1). These results imply that the fish species studied provide a possible source of nutrients to solve issues with food security. The study of the mineral composition revealed the existence of critical minerals such as phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) in the fish samples in addition to proteins and lipids. All three Bagridae fish significantly differed from each other in terms of their crude ash content and mineral profile (see Table 1). However, in general, P and Ca are the two highest minerals found in all fish. Both of these macro minerals are good for human bone and tooth health, as key components of hydroxyapatite, the mineral matrix that provides strength and structure to bones and teeth [34].

In the current study, the meat of three species of Bagridae fish from the Kampar Kanan River in Indonesia was found to contain an abundance of microminerals such as Fe and Zn. *M. nigriceps* has been reported to exhibit higher mineral content, including of Fe and Zn. This species is categorized as a small indigenous fish (SIF) with a maximum standard length

of approximately 10.29 cm. According to [35], SIFs are generally known to be rich in Ca, Fe, and Mn.

In this study, all three Bagridae fish had a total fat content of approximately 7–8% by weight, with a higher water content ranging from 82.40–85.39% (Table 1). These values are similar to those found in wild and cultured sea bass *Dicentrarchus labrax* [36]. Additionally, the fish species can be grouped into different categories, including high-fat fish (>8%), medium-fat fish (4–8%), low-fat fish (2–4%), and lean fish (<2%) [37]. According to the classification established by [37], the three indigenous Bagridae fish species are characterized as having a moderate fat content level, which is reflected by the high levels of DHA and EPA in the meat of *H. nemurus*, *H. wyckii*, and *M. nigriceps* (Table 2). Therefore, we recommend that consuming the meat of these three fish species can indirectly boost food security in rural and urban communities.

All three Bagridae fish species analysed in the study contained arachidonic acid (C20:4), at 12.13% for *H. nemurus*, 12.49% for *H. wyckii*, and 12.41% for *M. nigriceps*. Arachidonic acid serves as a precursor for synthesizing prostaglandins and leukotrienes [38]. Leukotrienes are crucial in allergic responses, inducing smooth muscle contraction and increasing vascular permeability [39]. Additionally, all three species also contained EPA ranging from 1.35–2.34% and DHA ranging from 11.56–15.65%. The increased consumption of omega-3 fatty acids, such as EPA and DHA, has been linked to a decreased risk of pain development in older individuals and to the prevention of Alzheimer's disease [40,41].

As determined by the current study, the ω-6/ω-3 ratios of the three Bagridae fish species ranged from 1:0.8 to 1:0.97. It was found that all three fish species had ω-6/ω-3 ratios within the recommended range for a typical Indonesian diet. In contrast, a typical Western diet is characterized by a high ω-6/ω-3 ratio of 10:1 to 20:1, while a Mediterranean diet has a ratio of 4:1 to 5:1 [42]. Additionally, the P/S ratio analysis showed that the three Bagridae fish species are sources of PUFAs that meet the requirements for food safety.

The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recommended AI and TI values ranging from 0.4 to 0.5 for promoting human health [43]. In the current study, the observed AI values in the three freshwater species of Bagridae ranged from 0.73 to 0.99, while the TI values varied between 0.54 and 0.75. This finding is associated with a notable disparity in the values of SFAs among the three Bagridae

fish species. Based on these findings, we confirm that consuming the meat of the three freshwater species of Bagridae fish caught in the wild does not endanger consumer health and can serve as a suitable source of food safety and nutritional quality.

Fish with a high crude protein content, as shown by the three studied Bagridae fish (Table 1), are regarded as being nutritionally useful for human health. The protein and amino acid contents can directly indicate the nutritional quality of meat [44]. As shown in Table 4, *H. wyckii* had a higher content of essential amino acids (EAAs) than *H. nemurus* and *M. nigriceps*. Among the EAAs, lysine (Lys) was found to be present in the highest amount in all three species. Lys is necessary for tissue growth and repair, reduced stress-induced anxiety, and the conversion of fatty acids into energy [45-47].

More than 60% of the amino acid composition in all three Brigade fish studied comes from nonessential amino acids (NEAAs), particularly glutamic acid (Table 4). Glutamic acid and its amine, glutamine, are highly abundant amino acids found in fish in the free and protein-bound forms [48]. Other amino acids found at abundant levels in the three fish also play important physiological and biochemical functions. The NEAA arginine, for example, is involved in protein synthesis, creatine formation, and various other biochemical processes within the body. The EAAs leucine, phenylalanine, and methionine play important roles in the synthesis of nitric oxide, a molecule that can expand blood vessels [48].

4. Conclusions

The present study provides insightful information about the fatty acid and amino acid compositions, biometric measurements, proximate analysis, and mineral composition of three local freshwater species of Indonesian Bagridae fish. The findings show their potential as a nutrient-dense, sustainable food source that can support efforts to increase food security. These fish species might be incorporated into the local diet to increase nutrient intake and alleviate nutritional inadequacies, which would ultimately improve Indonesia's overall food security status.

Data Availability

The data utilized in this research has not been previously released or published in any form. The datasets employed and/or analysed during the present study can be obtained by contacting the corresponding author.

Conflicts of Interest

The authors confirm that they do not have any conflicting interests.

Acknowledgements

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6639837: Revision requested

4 messages

International Journal of Food Science <ijfs@hindawi.com> Fri, Dec 1, 2023 at 6:35 PM
Reply-To: International Journal of Food Science <drajadurai@wiley.com>
To: Hafrijal Syandri <syandri_1960@bunghatta.ac.id>

WILEY

Dear Dr. Hafrijal Syandri,

In order for your submission "Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security " to "International Journal of Food Science" to proceed further in the review process, you will need to revise your manuscript.

Reason & Details:

> *The reviewer suggests a few remarks before the acceptance of the manuscript.*

When you have finished revising, follow the link below to submit your revision:

MANUSCRIPT DETAILS

Kind regards,
Deepanaa Rajadurai
International Journal of Food Science

Reviewer Comments:

> ***Reviewer 1 Comments to the Author***
>
> > *The article is very much improved. The author has made a considerable effort but a few remarks are mentioned below.*
> >
> > *animal material not animal materials*
> >
> > *TI : I know that this is the formula proposed by*
> > *Ulbricht, D.A. Southgate. I wanted to warn you that C18:0 should not be considered a pro-atherogenic fatty acid.*
> > *The principle of lipid health indices is to make the relationship between protherogens and antiatherogens.*

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hafrizal syandri <syandri_1960@bunghatta.ac.id> Sat, Dec 9, 2023 at 4:40 AM
To: International Journal of Food Science <drajadurai@wiley.com>

Dear
Deepanaa Rajadurai
International Journal of Food Science

Thank you for your email on December 1, 2023. The author has revised manuscript No. 6639837. We appreciate the reviewer's contribution that C18:0 should not be considered a pro-atherogenic fatty acid. However, to ensure alignment with the Thrombogenic Index analysis, we request further clarification on whether the reviewer expected to remove C18:0 from our data (green highlight in the manuscript). We are delighted to get this information.

Best regards

Hafrijal Syandri

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Deepanaa Rajadurai <deepanaa.rajadurai@hindawi.com> Sat, Dec 9, 2023 at 12:06 PM
Reply-To: Deepanaa Rajadurai <deepanaa.rajadurai@hindawi.com>
To: syandri_1960@bunghatta.ac.id

Dear Dr. Syandri,

Thank you for your email regarding your manuscript.

Please be informed I have contacted the reviewer regarding your concern. Once I receive a response, I will get back to you shortly.

Please do not hesitate to get back in touch, if you have any further questions.

Best Regards,

Deepanaa

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, hafrizal syandri <syandri_1960@bunghatta.ac.id> wrote:

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Deepanaa Rajadurai <deepanaa.rajadurai@hindawi.com> Mon, Dec 11, 2023 at 7:47 PM
Reply-To: Deepanaa Rajadurai <deepanaa.rajadurai@hindawi.com>
To: syandri_1960@bunghatta.ac.id

Dear Dr. Syandri,

Hope you are good and well.

Please be informed that the reviewer has conveyed as follows "Regarding my remark about C18:0, it is preferable to recalculate the TI without using stearic fatty acid (C18:0) as a proatherogenic fatty acid".

Please do not hesitate to get back in touch, if you have any further questions.

Best Regards,

Deepanaa

Deepanaa Rajadurai
Editorial Assistant

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On Sat, 9 Dec at 5:06 AM , Deepanaa Rajadurai <deepanaa.rajadurai@hindawi.com> wrote:
Dear Dr. Syandri,

Thank you for your email regarding your manuscript.

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Please do not hesitate to get back in touch, if you have any further questions.

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On Fri, 8 Dec at 9:40 PM , hafrizal syandri <syandri_1960@bunghatta.ac.id> wrote:
[Quoted text hidden]

Research Article

Analysis of Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security

Azrita Azrita[1], Hafrijal Syandri[1*], Hazlina Ahamad Zakeri[2], Harfiandri Damanhuri[1], Netti Aryani[3]

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Abstract

Fish have become an irreplaceable dietary source of animal protein, especially among households with low socioeconomic status in rural and urban areas of Indonesia. This study aimed to analyse the proximate composition, minerals, fatty acids, and amino acids of three local Bagridae fish species in Indonesia. The standard AOAC method was employed to examine the proximate composition of the carcass, and the analysis of amino acids and fatty acids was conducted through HPLC and GC-MS, respectively. The mineral content was determined using AAS. The nutrient composition results of *Hemibagrus nemurus*, *Hemibagrus wyckii*, and *Mystus nigriceps* revealed that the protein content was 24.26%, 22.57%, and 21.39% (%dry weight), whereas the total lipid content was 6.64%, 7.47% and 7.75%, respectively. Regarding mineral contents, the calcium levels ranged from 1.49–1.66 mg/g, iron levels from 28.35–40.36 µg/g, and zinc levels from 24.03–54.46 µg/g. Among the fatty acids, palmitic acid was the most abundant in all three species, accounting for 25.59–30.70% of the total fatty acids. Additionally, significant amounts of C18:1 (oleic acid), C18:0 (stearic acid), and C20:4 (arachidonic acid) were also detected as primary fatty acids.The calculated atherogenic index values in the three species of Bagridae fish ranged from 0.73–0.99, while the thrombogenic index values varied between 0.54–0.75. The predominant amino acids found in the three species of Bagridae fish were glutamic acid with their concentrations ranging from 9.10–24.34%. These results indicate that consuming the meat of these three freshwater Bagridae fish species caught in the wild does not pose any health risks to consumers. They can be considered a safe and suitable food source with good nutritional quality.

Keywords: Amino acids, Fatty acids, Indonesia, Kampar Kanan River, Minerals

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1. Introduction

Fish serve as a high-quality protein source that is essential for satisfying dietary protein requirements, especially in areas where other protein sources are few or difficult to obtain [1,2]. Their accessibility can aid in ensuring a steady supply of food, particularly for communities whose main source of income is fishing or aquaculture [3]. Fish can contribute to a more varied selection of protein sources in communities, resulting in a diet that is more nutritious and balanced. Dietary fish can treat nutrient deficits and enhance general nutritional health. Fish are generally considered safe and offer a lower risk of contamination with harmful substances compared to some land-based animal products. A reliable indicator of a fish's quality, nutritional value, physiological status, and environment is its chemical makeup, which is found in fish flesh [4].

Hemibagrus nemurus, locally known as "baung", *Hemibagrus wyckii*, known as "geso" and *Mystus nigriceps*, known as "ingir-ingir," are three species of catfish found in the Kampar Kanan River, Indonesia [5,6]. Due to their high market value, these species have been identified as significant economic resources for rural communities [7]. Therefore, the analysis of the nutritional quality of fish meat in the study area is very important to determine whether it is beneficial to human health.

Knowing the composition of fatty acids and amino acids in fish meat is an essential factor that should not be ignored [8]. This information provides valuable insight into the nutritional quality of fish and the values of more nutritious and healthy foods [9]. In addition, a better understanding of the composition of fatty acids and amino acids can assist in selecting a suitable feed [10], developing a balanced diet [11], and maintaining optimal fish meat nutrition [12].

Omega-3 polyunsaturated fatty acids (PUFAs), particularly docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) derived from fish oil, exhibit anti-inflammatory and anti-gastrointestinal cancer properties, making them crucial as immune-boosting nutrients [13,14]. Studies have demonstrated that ω-3 and ω-6 PUFAs exhibit beneficial effects in the management of cardiovascular diseases and cancers [15,16]. The fatty acid composition of PUFAs can differ among different types of fish, including both freshwater and marine species

[17, 18]. Amino acids (AAs), such as cysteine, arginine, tyrosine, glycine, proline, and serine, play a vital role in illness and stress situations and in the prevention of inflammation and repair processes in fish intestines [19, 20].

Furthermore, knowledge of the atherogenicity index (AI) and thrombogenicity index (TI) of fatty acids in the three local freshwater fish species of Bagridae can contribute to improving dietary guidelines. The AI and TI can be used to develop recommendations aimed at improving heart health [21,22]. These recommendations may involve selecting fish with favourable fatty acid profiles, allowing individuals to choose the most suitable fish species based on their specific needs [17, 23]. Therefore, this study aims to examine the nutritional composition profile, mineral content, amino acids, and fatty acids, and AI and TI of three freshwater fish species, namely, *H. nemurus*, *H. wyckii*, and *M. nigriceps*. These three fish species are generally consumed by people who live around the Kampar Kanan River in Kampar Regency, Riau Province, Indonesia.

2. Material and methods

2.1. Animal material

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In this study, a total of 27 Bagridae fish belonging to three distinct species (*H. nemurus*, *H. wyckii*, and *M. nigriceps*) were examined. The specimens were obtained from local fishers operating in the upper stretches of the Kampar Kanan River in Kampar Regency, Riau Province (Figure 1). Sampling took place between June and August 2022 and was verified by the Fisheries Department, Faculty of Fisheries and Marine Science, Universitas Bung Hatta, Indonesia. The samples were placed in plastic bags and transported to the laboratory in an insulated icebox. The samples were then grouped based on their respective sampling locations.

2.2. Biometry measurement

Upon reaching the laboratory within 10 hours, the fish samples were subjected to gutting and washing. Each specimen was weighed (TW) and measured to determine the standard length (SL) as well as the depth or maximum height (H). TW was measured using balance scale (OHAUS Model CT 6000 USA) with a precision of 0.01 g. The length measurement was taken from the tip of the mouth to the end of the upper lobe of the caudal fin, representing the total body length, using a metre ruler with an accuracy of 1 mm. The height measurement involved a vertical assessment of the body's maximum height measured using a Digital Sekhmet Sigma

Vernier calliper with an accuracy of 1 mm. The condition factor (CF) was calculated using the formula CF = $(TW/SL^3) \times 100$.

2.3. Proximate, amino acid, and mineral content analysis

The proximate carcass composition was assessed following the AOAC standard methods [24]. The samples were dried to a constant weight at 105 °C. The crude protein content was analysed using the standard Kjeldahl method, which involves multiplying the nitrogen content by a factor of 6.25. The Soxhlet method with ether extraction was employed to analyse crude lipids. The ash content was obtained by incinerating the samples at 550 °C for 16 h. The amino acid composition was determined using a high-performance liquid chromatography (HPLC) system, which consisted of a Waters® 1525 binary HPLC pump, Waters® 717 autosamplers, and Waters® 2475 multi-λ fluorescence detector (with excitation at 250 nm and emission at 395 nm). The samples were hydrolysed in triplicate with 6 N hydrochloric acid for 24 h at 11 °C [25].

For mineral data composition (Na, Mg, Ca, K, P, Fe, Cu, Mn, and Zn), the ashed feed sample and carcass were dissolved in 1 ml of hydrochloric acid (35% v/v Suprapur®, Merck) and then filtered with cellulose filter paper (Watchman No 1, International Ltd; Maidstone, UK) and diluted to an appropriate concentration for each elemental mineral. P levels were analysed with a Perkin-Elmer AA spectrophotometer mod 3110 (Norwalk, CT, USA).

2.4. Fatty acid analysis

The fish meat was examined utilizing the gas chromatography–mass spectrometry (GC–MS) method. The method of Folch et al. (1957) modified by Rajion et al. [26] was employed to perform the total fat extraction. This involved using a solvent system consisting of chloroform and methanol at a 2:1 (v/v) ratio. The process of transmethylation was conducted using a solution of 14% methanolic boron trifluoride. The fatty acid composition of the meat was then analysed at the SIG Laboratory, Accredited Testing Laboratory-LP-184-IDN.

The nutritional quality of lipids (AI and TI) was calculated using the following equations [27]:

$$AI = \frac{[(C12{:}0 + 4 \times C14{:}0 + C16{:}0)]}{\sum MUFA + \sum n-6 + \sum n-3}$$

$$\mathrm{TI} = \frac{[(\mathrm{C14{:}0} + \mathrm{C16{:}0} + \mathrm{C18{:}0})]}{[(0.5 \times \sum \mathrm{MUFA}) + (0.5 \times \sum \mathrm{n}-6) + (3 \times \sum \mathrm{n}-3) + (\sum \mathrm{n}-3/\sum \mathrm{n}-6)}$$

where:

AI = Atherogenic index

TI = Thrombogenic index

C12:0 = lauric acid

C14:0 = myristic acid

C16:0 = palmitic acid

C18:0 = stearic acid

∑MUFA = sum of the concentrations of all monosaturated fatty acids

∑n-6 = sum of the concentrations of n-6 polyunsaturated fatty acids

∑n-3 = sum of the concentrations of n-3 polyunsaturated fatty acids

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2.5. Data analysis

Data analysis was performed using the SPSS 16.0 software package (SPSS; Chicago, IL). The homogeneity of variances was assessed using Levene's test. One-way ANOVA was carried out to determine the parameters of proximate and amino acid composition, including the composition of fatty acids and nutritional quality of lipids (AI and TI) for each species, followed by the post hoc Duncan's multiple range test [28]. The results are reported as the mean values ± standard errors for each parameter.

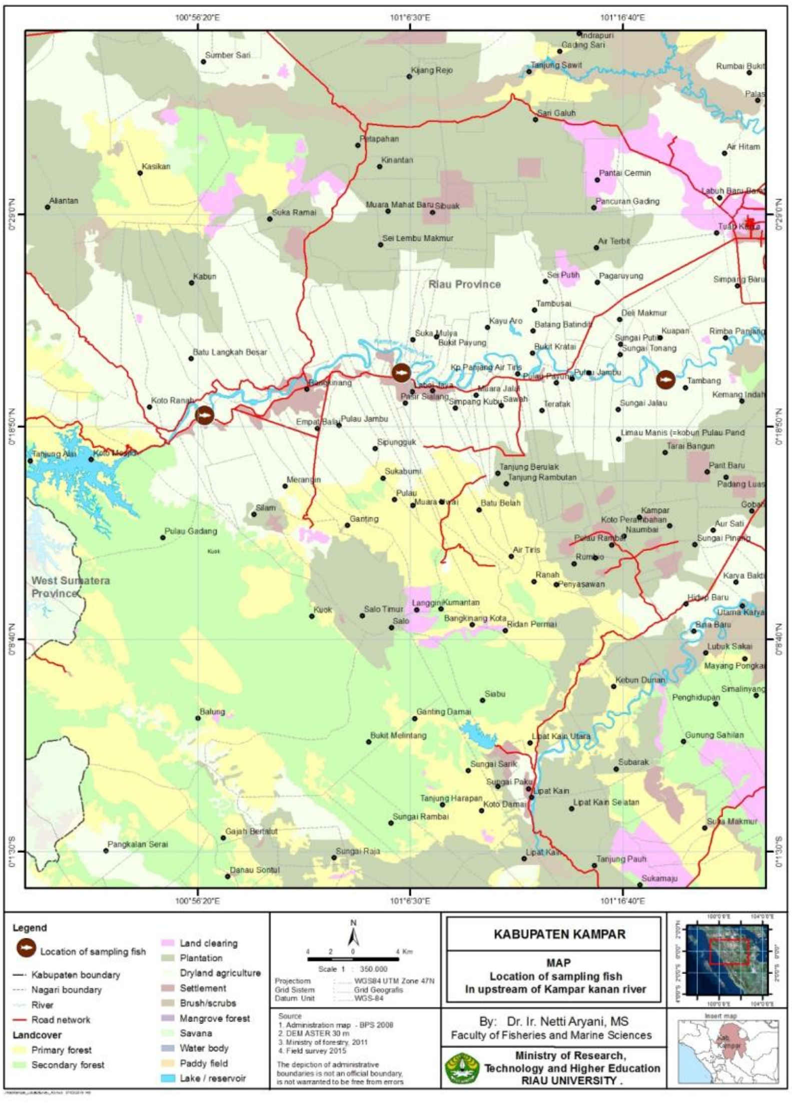

Figure 1. Map of Kampar Regency, Riau Province, and sampling locations of the three species of Bagridae fish.

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3. Results

Table 1 presents the average wet weight, standard length, height, and the results of meat nutritional composition analysis for three indigenous Indonesian freshwater Bagridae species. The moisture content (% wet weight) ranged from 82.40– 85.39%. Among the species examined, *M. nigriceps* exhibited the lowest protein content at 21.39%, while *H. nemurus* displayed the highest value at 24.26%. However, *M. nigriceps* had a higher mineral content, including of iron and zinc.

Table 2 summarizes the fatty acid composition (%total fatty acid) for the three Bagridae fish species. C16:0 was the predominant fatty acid in the three species of Bagridae fish, with percentages ranging from 25.09–30.71%. The additional prominent fatty acids found were C18:1, C18:0, and C22:6. *H. nemurus* exhibited a ω-6/ω-3 ratio below 1 (0.82), while *H. wyckii* and *M. nigriceps* had ratios of 1.11 and 1.02, respectively. The obtained PUFA/saturated fatty acid (SFA) (P/S) ratio varied between 0.61 and 0.76. The AI values varied between 0.76 and 0.99 and the TI between 0.54 and 0.75 (**Table 3**).

Table 4 presents the amino acid composition (% of total protein) of the three Bagridae species. Glutamic acid was the dominant amino acid, ranging from 19.29–24.34%, followed by aspartic acid, which ranged from 9.21–11.27%. The lysine content was consistent, ranging from 9.67–9.87%. In *H. nemurus*, the levels of various amino acids ranged from 0.86– 24.35%. Similarly, in *H. wyckii*, the amino acid levels ranged from 0.76–21.58%, while in *M. nigriceps*, the levels ranged from 0.74–19.29%.

Table 1. Results of biometric, proximate and mineral composition of three species of Bagridae fish

	Species		
	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
Biometric measurements			
Total weight (g)	389.99 ± 24.96[a]	1,390.33 ± 168.29[b]	17.57 ± 1.53[c]
Standard length (cm)	28.16 ± 0.53[a]	44.14 ± 1.98[b]	10.29 ± 0.15[c]
Height (cm)	8.44 ± 0.16[a]	8.82 ± 0.39[b]	2.57 ± 0.03[c]
Condition factor	1.63 ± 0.08	1.58 ± 0.07	1.56 ± 0.08
Proximate composition			
Crude protein (% DW)	24.26 ± 0.87[a]	22.57 ± 0.37[b]	21.39 ± 0.15[c]
Crude fat (% DW)	6.64 ± 0.03[a]	7.47 ± 0.02[b]	7.75 ± 0.40[c]
Crude ash (% DW)	1.94 ± 0.02[a]	2.30 ± 0.09[b]	1.59 ± 0.02[c]

Moisture (% WW)	82.40 ± 2.51	85.39 ± 2.36	83.75 ± 2.21
Mineral composition			
Macrominerals (mg/g)			
Sodium	0.99 ± 0.00[a]	1.61 ± 0.01[b]	1.61 ± 0.02[c]
Magnesium	1.12 ± 0.01[a]	0.57 ± 0.02[b]	1.15 ± 0.01[c]
Calcium	1.66 ± 0.00[a]	1.55 ± 0.02[b]	1.49 ± 0.04[c]
Potassium	0.71 ± 0.00[a]	0.55 ± 0.02[b]	0.43 ± 0.01[c]
Phosphorous	7.03 ± 0.03[a]	2.74 ± 0.02[b]	6.45 ± 0.07[c]
Microminerals (µg/g)			
Iron	28.30 ± 0.11[a]	28.73 ± 0.08[b]	40.36±0.55[c]
Copper	8.93 ± 0.03[a]	7.46 ± 0.09[b]	6.21 ± 0.32[c]
Manganese	1.64 ± 0.02[a]	2.64 ± 0.02[b]	2.84 ± 0.02[c]
Zinc	24.03 ± 0.45[a]	24.61 ± 0.19[b]	54.46 ± 0.17[c]

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

Table 2. Fatty acid composition of three species of Bagridae fish

Fatty acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
C12:0 (lauric acid)	1.97 ± 0.05[a]	3.94 ± 0.01[b]	4.27 ± 0.01[c]
C14:0 (Meristic acid)	2.38 ± 0.03[a]	2.72 ± 0.08[b]	2.89 ± 0.01[c]
C16:0 (Palmitic acid)	27.23 ± 0.06[a]	30.70 ± 0.06[b]	25.59 ± 0.01[c]
C18:0 (Stearic acid)	16.17 ± 0.02[a]	13.54 ± 0.02[b]	10.64 ± 0.01[c]
C20:0 (Arachidic acid)	0.23 ± 0.01[a]	0.14 ± 0.01[b]	0.37 ± 0.01[c]
C16:1 (Palmitoleic acid)	1.78 ± 0.00[a]	1.27 ± 0.04[b]	4.93 ± 0.01[c]
C18:1(Oleic acid)	16.86 ± 0.01[a]	16.18 ± 0.01[b]	16.97 ± 0.01[c]
C18:2 (Linoleic acid)	3.24 ± 0.02[a]	3.84 ± 0.33[b]	4.55 ± 0.001[c]
C18:3 (Linolenic acid)	1.12 ± 0.01[a]	0.82 ± 0.01[b]	1.57 ± 000[c]
C20:4 (Arachidonic acid)	12.13 ± 0.01[a]	12.49 ± 0.09[b]	12.41 ± 0.02[c]
C20:5 (Eicosapentaenoic acid; EPA)	2.06 ± 0.08[a]	2.34 ± 0.04[b]	1.35 ± 0.01[c]
C22:6 (Docosahexaenoic acid; DHA)	15.65 ± 0.01[a]	11.56 ± 0.04[b]	13.64 ± 0.02[c]

Values are mean % ± SE; *Values in the same row with a different superscript are significantly different ($p<0.05$).

Table 3. Fatty acid ω-6/ω-3 and polyunsaturated/saturated fatty acid ratio of three species of Bagridae fish

	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*

ω-6/ω-3 ratio	0.82 ± 0.00[a]	1.11 ± 0.02[b]	1.02 ± 0.01[c]
P/S ratio	0.69 ± 0.01[a]	0.61 ± 0.06[b]	0.76 ± 0.00[c]
AI	0.87 ± 0.01[a]	0.99 ± 0.06[b]	0.73 ± 0.00[c]
TI	0.63 ± 0.01[a]	0.75 ± 0.03[b]	0.54 ± 0.00[c]

P/S, polyunsaturated/saturated fatty acid; AI, atherogenic index; TI, thrombogenic index
Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

Table 4. Amino acid composition of three species of Bagridae fish

Amino acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
Aspartic acid	10.39 ± 0.01[a]	9.61 ± 0.04[b]	11.28 ± 0.02[c]
Glutamic acid	24.34 ± 0.00[a]	21.58 ± 0.41[b]	19.29 ± 0.03[c]
Serine	3.74 ± 0.00[a]	5.40 ± 0.03[b]	7.50 ± 0.06[c]
Glycine	4.02 ± 0.00[a]	5.77 ± 0.04[b]	4.69 ± 0.02[c]
Histidine	2.39 ± 0.00[a]	2.90 ± 0.03[b]	2.21 ± 0.02[c]
Arginine	6.17 ± 0.01[a]	8.27 ± 0.03[b]	6.22 ± 0.03[c]
Threonine	4.49 ± 0.01[a]	4.19 ± 0.03[b]	4.39 ± 0.04[c]
Alanine	7.03 ± 0.00[a]	6.04 ± 0.02[b]	7.89 ± 0.01[c]
Proline	2.40 ± 0.00[a]	2.71 ± 0.01[b]	2.21 ± 0.02[c]
Tyrosine	3.91 ± 0.01[a]	3.29 ± 0.06[b]	3.82 ± 0.04[c]
Valine	3.73 ± 0.00[a]	4.02 ± 0.01[b]	3.85 ± 0.04[c]
Methionine	3.42 ± 0.00[a]	1.96 ± 0.02[b]	1.27 ± 0.03[c]
Cystine	0.87 ± 0.00[a]	0.76 ± 0.02[b]	0.75 ± 0.03[c]
Isoleucine	3.82 ± 0.001[a]	3.96 ± 0.003[b]	3.66 ± 0.002[c]
Leucine	6.15 ± 0.000[a]	6.69 ± 0.002[b]	6.28 ± 0.004[c]
Phenylalanine	5.13 ± 0.000[a]	6.03 ± 0.005[b]	5.18 ± 0.027[c]
Lysine	9.61 ± 0.001[a]	9.82 ± 0.026[b]	9.87 ± 0.003[c]

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

4. Discussion

The results of this study provide important new information about the nutritional makeup of the studied species of Bagridae fish. The biometric measures of the fish yielded important information about their physical traits and health. Researchers are able to determine the average weight of fish at various lengths by examining the link between length and weight for a particular species. This knowledge is essential for understanding the trends in fish population growth, identifying potential shifts in growth rates over time, and assessing the general health and welfare of fish [29]. A variety of factors, including sex, age, maturity level, size, stomach fullness level, sampling strategies, sample sizes, and environmental circumstances, have an impact on fish health and the parameters that determine length–weight connections in fish [30]. However, none of these factors were considered in our study. In general, according to the theory put forth by Bagenal and Tesch [31], heavier fish of a given length are in better physiological condition. The condition factor is also used in fisheries science to compare the health, fatness, and condition of fish [32]. A condition factor of > 1 is favourable, indicating a good feed nutrition level and suitable living habitat [33]. Thus, based on the findings in this study, the Kampar Kanan River provides a suitable habitat for the fish, ensuring their accessibility and availability for community consumption.

The fish samples exhibited good nutritional profiles, with high amounts of proteins and lipids as well as moisture content contributing to their overall nutritional value, according to the results of proximate analysis and mineral composition (see Table 1). These results imply that the fish species studied provide a possible source of nutrients to solve issues with food security. The study of the mineral composition revealed the existence of critical minerals such as phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) in the fish samples in addition to proteins and lipids. All three Bagridae fish significantly differed from each other in terms of their crude ash content and mineral profile (see Table 1). However, in general, P and Ca are the two highest minerals found in all fish. Both of these macro minerals are good for human bone and tooth health, as key components of hydroxyapatite, the mineral matrix that provides strength and structure to bones and teeth [34].

In the current study, the meat of three species of Bagridae fish from the Kampar Kanan River in Indonesia was found to contain an abundance of microminerals such as Fe and Zn. *M. nigriceps* has been reported to exhibit higher mineral content, including of Fe and Zn. This species is categorized as a small indigenous fish (SIF) with a maximum standard length of approximately 10.29 cm. According to [35], SIFs are generally known to be rich in Ca, Fe, and Mn.

In this study, all three Bagridae fish had a total fat content of approximately 7–8% by weight, with a higher water content ranging from 82.40–85.39% (Table 1). These values are similar to those found in wild and cultured sea bass *Dicentrarchus labrax* [36]. Additionally, the fish species can be grouped into different categories, including high-fat fish (>8%), medium-fat fish (4–8%), low-fat fish (2–4%), and lean fish (<2%) [37]. According to the classification established by [37], the three indigenous Bagridae fish species are characterized as having a moderate fat content level, which is reflected by the high levels of DHA and EPA in the meat of *H. nemurus*, *H. wyckii*, and *M. nigriceps* (Table 2). Therefore, we recommend that consuming the meat of these three fish species can indirectly boost food security in rural and urban communities.

All three Bagridae fish species analysed in the study contained arachidonic acid (C20:4), at 12.13% for *H. nemurus*, 12.49% for *H. wyckii*, and 12.41% for *M. nigriceps*. Arachidonic acid serves as a precursor for synthesizing prostaglandins and leukotrienes [38]. Leukotrienes are crucial in allergic responses, inducing smooth muscle contraction and increasing vascular permeability [39]. Additionally, all three species also contained EPA ranging from 1.35–2.34% and DHA ranging from 11.56–15.65%. The increased consumption of omega-3 fatty acids, such as EPA and DHA, has been linked to a decreased risk of pain development in older individuals and to the prevention of Alzheimer's disease [40,41].

As determined by the current study, the ω-6/ω-3 ratios of the three Bagridae fish species ranged from 1:0.8 to 1:0.97. It was found that all three fish species had ω-6/ω-3 ratios within the recommended range for a typical Indonesian diet. In contrast, a typical Western diet is characterized by a high ω-6/ω-3 ratio of 10:1 to 20:1, while a Mediterranean diet has a ratio of 4:1 to 5:1 [42]. Additionally, the P/S ratio analysis showed that the three Bagridae fish species are sources of PUFAs that meet the requirements for food safety.

The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recommended AI and TI values ranging from 0.4 to 0.5 for promoting human health [43]. In the current study, the observed AI values in the three freshwater species of Bagridae ranged from 0.73 to 0.99, while the TI values varied between 0.54 and 0.75. This finding is associated with a notable disparity in the values of SFAs among the three Bagridae fish species. Based on these findings, we confirm that consuming the meat of the three freshwater species of Bagridae fish caught in the wild does not endanger consumer health and can serve as a suitable source of food safety and nutritional quality.

Fish with a high crude protein content, as shown by the three studied Bagridae fish (Table 1), are regarded as being nutritionally useful for human health. The protein and amino acid contents can directly indicate the nutritional quality of meat [44]. As shown in Table 4, *H. wyckii* had a higher content of essential amino acids (EAAs) than *H. nemurus* and *M. nigriceps*. Among the EAAs, lysine (Lys) was found to be present in the highest amount in all three species. Lys is necessary for tissue growth and repair, reduced stress-induced anxiety, and the conversion of fatty acids into energy [45-47].

More than 60% of the amino acid composition in all three Brigade fish studied comes from nonessential amino acids (NEAAs), particularly glutamic acid (Table 4). Glutamic acid and its amine, glutamine, are highly abundant amino acids found in fish in the free and protein-bound forms [48]. Other amino acids found at abundant levels in the three fish also play important physiological and biochemical functions. The NEAA arginine, for example, is involved in protein synthesis, creatine formation, and various other biochemical processes within the body. The EAAs leucine, phenylalanine, and methionine play important roles in the synthesis of nitric oxide, a molecule that can expand blood vessels [48].

4. Conclusions

The present study provides insightful information about the fatty acid and amino acid compositions, biometric measurements, proximate analysis, and mineral composition of three local freshwater species of Indonesian Bagridae fish. The findings show their potential as a nutrient-dense, sustainable food source that can support efforts to increase food security. These fish species might be incorporated into the local diet to increase nutrient intake and alleviate nutritional inadequacies, which would ultimately improve Indonesia's overall food security status.

Data Availability

The data utilized in this research has not been previously released or published in any form. The datasets employed and/or analysed during the present study can be obtained by contacting the corresponding author.

Conflicts of Interest

The authors confirm that they do not have any conflicting interests.

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6639837: Revision requested

Deepanaa Rajadurai <deepanaa.rajadurai@hindawi.com>
Reply-To: Deepanaa Rajadurai <deepanaa.rajadurai@hindawi.com>
To: syandri_1960@bunghatta.ac.id

Mon, Dec 11, 2023 at 7:47 PM

Dear Dr. Syandri,

Hope you are good and well.

Please be informed that the reviewer has conveyed as follows "Regarding my remark about C18:0, it is preferable to recalculate the TI without using stearic fatty acid (C18:0) as a proatherogenic fatty acid".

Please do not hesitate to get back in touch, if you have any further questions.

Best Regards,

Deepanaa

Deepanaa Rajadurai
Editorial Assistant

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> On Sat, 9 Dec at 5:06 AM , Deepanaa Rajadurai <deepanaa.rajadurai@hindawi.com> wrote:
> Dear Dr. Syandri,
>
> Thank you for your email regarding your manuscript.
>
> Please be informed I have contacted the reviewer regarding your concern. Once I receive a response, I will get back to you shortly.
>
> Please do not hesitate to get back in touch, if you have any further questions.
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> Best Regards,
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On Fri, 8 Dec at 9:40 PM , hafrizal syandri <syandri_1960@bunghatta.ac.id> wrote:
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Research Article

Analysis of Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security

Azrita Azrita[1], Hafrijal Syandri[1*], Hazlina Ahamad Zakeri[2], Harfiandri Damanhuri[1], Netti Aryani[3]

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Abstract

Fish have become an irreplaceable dietary source of animal protein, especially among households with low socioeconomic status in rural and urban areas of Indonesia. This study aimed to analyse the proximate composition, minerals, fatty acids, and amino acids of three local Bagridae fish species in Indonesia. The standard AOAC method was employed to examine the proximate composition of the carcass, and the analysis of amino acids and fatty acids was conducted through HPLC and GC-MS, respectively. The mineral content was determined using AAS. The nutrient composition results of *Hemibagrus nemurus*, *Hemibagrus wyckii*, and *Mystus nigriceps* revealed that the protein content was 24.26%, 22.57%, and 21.39% (%dry weight), whereas the total lipid content was 6.64%, 7.47% and 7.75%, respectively. Regarding mineral contents, the calcium levels ranged from 1.49–1.66 mg/g, iron levels from 28.35–40.36 µg/g, and zinc levels from 24.03–54.46 µg/g. Among the fatty acids, palmitic acid was the most abundant in all three species, accounting for 25.59–30.70% of the total fatty acids. Additionally, significant amounts of C18:1 (oleic acid), C18:0 (stearic acid), and C20:4 (arachidonic acid) were also detected as primary fatty acids.The calculated atherogenic index values in the three species of Bagridae fish ranged from 0.73–0.99, while the thrombogenic index values varied between 0.54–0.75. The predominant amino acids found in the three species of Bagridae fish were glutamic acid with their concentrations ranging from 9.10–24.34%. These results indicate that consuming the meat of these three freshwater Bagridae fish species caught in the wild does not pose any health risks to consumers. They can be considered a safe and suitable food source with good nutritional quality.

Keywords: Amino acids, Fatty acids, Indonesia, Kampar Kanan River, Minerals

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1. Introduction

Fish serve as a high-quality protein source that is essential for satisfying dietary protein requirements, especially in areas where other protein sources are few or difficult to obtain [1,2]. Their accessibility can aid in ensuring a steady supply of food, particularly for communities whose main source of income is fishing or aquaculture [3]. Fish can contribute to a more varied selection of protein sources in communities, resulting in a diet that is more nutritious and balanced. Dietary fish can treat nutrient deficits and enhance general nutritional health. Fish are generally considered safe and offer a lower risk of contamination with harmful substances compared to some land-based animal products. A reliable indicator of a fish's quality, nutritional value, physiological status, and environment is its chemical makeup, which is found in fish flesh [4].

Hemibagrus nemurus, locally known as "baung", *Hemibagrus wyckii*, known as "geso" and *Mystus nigriceps*, known as "ingir-ingir," are three species of catfish found in the Kampar Kanan River, Indonesia [5,6]. Due to their high market value, these species have been identified as significant economic resources for rural communities [7]. Therefore, the analysis of the nutritional quality of fish meat in the study area is very important to determine whether it is beneficial to human health.

Knowing the composition of fatty acids and amino acids in fish meat is an essential factor that should not be ignored [8]. This information provides valuable insight into the nutritional quality of fish and the values of more nutritious and healthy foods [9]. In addition, a better understanding of the composition of fatty acids and amino acids can assist in selecting a suitable feed [10], developing a balanced diet [11], and maintaining optimal fish meat nutrition [12].

Omega-3 polyunsaturated fatty acids (PUFAs), particularly docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) derived from fish oil, exhibit anti-inflammatory and anti-gastrointestinal cancer properties, making them crucial as immune-boosting nutrients [13,14]. Studies have demonstrated that ω-3 and ω-6 PUFAs exhibit beneficial effects in the management of cardiovascular diseases and cancers [15,16]. The fatty acid composition of PUFAs can differ among different types of fish, including both freshwater and marine species

[17, 18]. Amino acids (AAs), such as cysteine, arginine, tyrosine, glycine, proline, and serine, play a vital role in illness and stress situations and in the prevention of inflammation and repair processes in fish intestines [19, 20].

Furthermore, knowledge of the atherogenicity index (AI) and thrombogenicity index (TI) of fatty acids in the three local freshwater fish species of Bagridae can contribute to improving dietary guidelines. The AI and TI can be used to develop recommendations aimed at improving heart health [21,22]. These recommendations may involve selecting fish with favourable fatty acid profiles, allowing individuals to choose the most suitable fish species based on their specific needs [17, 23]. Therefore, this study aims to examine the nutritional composition profile, mineral content, amino acids, and fatty acids, and AI and TI of three freshwater fish species, namely, *H. nemurus*, *H. wyckii*, and *M. nigriceps*. These three fish species are generally consumed by people who live around the Kampar Kanan River in Kampar Regency, Riau Province, Indonesia.

2. Material and methods

2.1. Animal material

In this study, a total of 27 Bagridae fish belonging to three distinct species (*H. nemurus*, *H. wyckii*, and *M. nigriceps*) were examined. The specimens were obtained from local fishers operating in the upper stretches of the Kampar Kanan River in Kampar Regency, Riau Province (Figure 1). Sampling took place between June and August 2022 and was verified by the Fisheries Department, Faculty of Fisheries and Marine Science, Universitas Bung Hatta, Indonesia. The samples were placed in plastic bags and transported to the laboratory in an insulated icebox. The samples were then grouped based on their respective sampling locations.

2.2. Biometry measurement

Upon reaching the laboratory within 10 hours, the fish samples were subjected to gutting and washing. Each specimen was weighed (TW) and measured to determine the standard length (SL) as well as the depth or maximum height (H). TW was measured using balance scale (OHAUS Model CT 6000 USA) with a precision of 0.01 g. The length measurement was taken from the tip of the mouth to the end of the upper lobe of the caudal fin, representing the total body length, using a metre ruler with an accuracy of 1 mm. The height measurement involved a vertical assessment of the body's maximum height measured using a

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Digital Sekhmet Sigma Vernier calliper with an accuracy of 1 mm. The condition factor (CF) was calculated using the formula CF = $(TW/SL^3) \times 100$.

2.3. Proximate, amino acid, and mineral content analysis

The proximate carcass composition was assessed following the AOAC standard methods [24]. The samples were dried to a constant weight at 105 °C. The crude protein content was analysed using the standard Kjeldahl method, which involves multiplying the nitrogen content by a factor of 6.25. The Soxhlet method with ether extraction was employed to analyse crude lipids. The ash content was obtained by incinerating the samples at 550 °C for 16 h. The amino acid composition was determined using a high-performance liquid chromatography (HPLC) system, which consisted of a Waters® 1525 binary HPLC pump, Waters® 717 autosamplers, and Waters® 2475 multi-λ fluorescence detector (with excitation at 250 nm and emission at 395 nm). The samples were hydrolysed in triplicate with 6 N hydrochloric acid for 24 h at 11 °C [25].

For mineral data composition (Na, Mg, Ca, K, P, Fe, Cu, Mn, and Zn), the ashed feed sample and carcass were dissolved in 1 ml of hydrochloric acid (35% v/v Suprapur®, Merck) and then filtered with cellulose filter paper (Watchman No 1, International Ltd; Maidstone, UK) and diluted to an appropriate concentration for each elemental mineral. P levels were analysed with a Perkin-Elmer AA spectrophotometer mod 3110 (Norwalk, CT, USA).

2.4. Fatty acid analysis

The fish meat was examined utilizing the gas chromatography–mass spectrometry (GC–MS) method. The method of Folch et al. (1957) modified by Rajion et al. [26] was employed to perform the total fat extraction. This involved using a solvent system consisting of chloroform and methanol at a 2:1 (v/v) ratio. The process of transmethylation was conducted using a solution of 14% methanolic boron trifluoride. The fatty acid composition of the meat was then analysed at the SIG Laboratory, Accredited Testing Laboratory-LP-184-IDN.

The nutritional quality of lipids (AI and TI) was calculated using the following equations [27]:

$$AI = \frac{[(C12{:}0 + 4 \times C14{:}0 + C16{:}0)]}{\sum MUFA + \sum n-6 + \sum n-3}$$

$$TI = \frac{[(C14{:}0 + C16{:}0)]}{[(0.5 \times \sum MUFA) + (0.5 \times \sum n-6) + (3 \times \sum n-3) + (\sum n-3/\sum n-6)}$$

where:

AI = Atherogenic index
TI = Thrombogenic index
C12:0 = lauric acid
C14:0 = myristic acid
C16:0 = palmitic acid

Commented [S3]: We appreciate the reviewer's contribution regarding the perspective that C18:0 should not be considered a pro-atherogenic fatty acid. However, to ensure alignment with the Thrombogenic Index analysis, we would like to request further clarification as to whether the authors expected to remove C18:0 from our data

The author has recalculated the Thrombogenic Index (TI) without using stearic fatty acid (C18:0).

∑MUFA = sum of the concentrations of all monosaturated fatty acids
∑n-6 = sum of the concentrations of n-6 polyunsaturated fatty acids
∑n-3 = sum of the concentrations of n-3 polyunsaturated fatty acids

2.5. Data analysis

Data analysis was performed using the SPSS 16.0 software package (SPSS; Chicago, IL). The homogeneity of variances was assessed using Levene's test. One-way ANOVA was carried out to determine the parameters of proximate and amino acid composition, including the composition of fatty acids and nutritional quality of lipids (AI and TI) for each species, followed by the post hoc Duncan's multiple range test [28]. The results are reported as the mean values ± standard errors for each parameter.

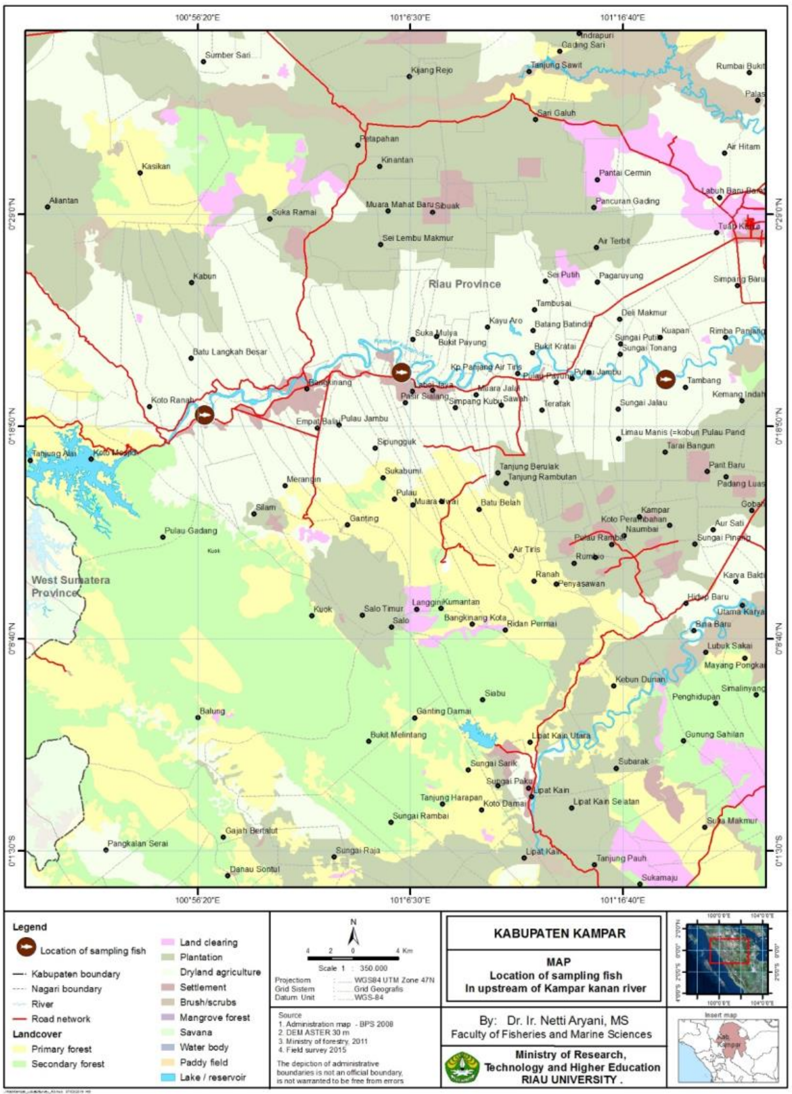

Figure 1. Map of Kampar Regency, Riau Province, and sampling locations of the three species of Bagridae fish.

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3. Results

Table 1 presents the average wet weight, standard length, height, and the results of meat nutritional composition analysis for three indigenous Indonesian freshwater Bagridae species. The moisture content (% wet weight) ranged from 82.40– 85.39%. Among the species examined, *M. nigriceps* exhibited the lowest protein content at 21.39%, while *H. nemurus* displayed the highest value at 24.26%. However, *M. nigriceps* had a higher mineral content, including of iron and zinc.

Table 2 summarizes the fatty acid composition (%total fatty acid) for the three Bagridae fish species. C16:0 was the predominant fatty acid in the three species of Bagridae fish, with percentages ranging from 25.09–30.71%. The additional prominent fatty acids found were C18:1, C18:0, and C22:6. *H. nemurus* exhibited a ω-6/ω-3 ratio below 1 (0.82), while *H. wyckii* and *M. nigriceps* had ratios of 1.11 and 1.02, respectively. The obtained PUFA/saturated fatty acid (SFA) (P/S) ratio varied between 0.61 and 0.76. The AI values varied between 0.76 and 0.99 and the TI between 0.40 and 0.63 (**Table 3**).

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Table 4 presents the amino acid composition (% of total protein) of the three Bagridae species. Glutamic acid was the dominant amino acid, ranging from 19.29–24.34%, followed by aspartic acid, which ranged from 9.21–11.27%. The lysine content was consistent, ranging from 9.67–9.87%. In *H. nemurus*, the levels of various amino acids ranged from 0.86–24.35%. Similarly, in *H. wyckii*, the amino acid levels ranged from 0.76–21.58%, while in *M. nigriceps*, the levels ranged from 0.74–19.29%.

Table 1. Results of biometric, proximate and mineral composition of three species of Bagridae fish

	Species		
	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
Biometric measurements			
Total weight (g)	389.99 ± 24.96[a]	1,390.33 ± 168.29[b]	17.57 ± 1.53[c]
Standard length (cm)	28.16 ± 0.53[a]	44.14 ± 1.98[b]	10.29 ± 0.15[c]
Height (cm)	8.44 ± 0.16[a]	8.82 ± 0.39[b]	2.57 ± 0.03[c]
Condition factor	1.63 ± 0.08	1.58 ± 0.07	1.56 ± 0.08
Proximate composition			
Crude protein (% DW)	24.26 ± 0.87[a]	22.57 ± 0.37[b]	21.39 ± 0.15[c]
Crude fat (% DW)	6.64 ± 0.03[a]	7.47 ± 0.02[b]	7.75 ± 0.40[c]
Crude ash (% DW)	1.94 ± 0.02[a]	2.30 ± 0.09[b]	1.59 ± 0.02[c]
Moisture (% WW)	82.40 ± 2.51	85.39 ± 2.36	83.75 ± 2.21

Mineral composition			
Macrominerals (mg/g)			
Sodium	0.99 ± 0.00[a]	1.61 ± 0.01[b]	1.61 ± 0.02[c]
Magnesium	1.12 ± 0.01[a]	0.57 ± 0.02[b]	1.15 ± 0.01[c]
Calcium	1.66 ± 0.00[a]	1.55 ± 0.02[b]	1.49 ± 0.04[c]
Potassium	0.71 ± 0.00[a]	0.55 ± 0.02[b]	0.43 ± 0.01[c]
Phosphorous	7.03 ± 0.03[a]	2.74 ± 0.02[b]	6.45 ± 0.07[c]
Microminerals (µg/g)			
Iron	28.30 ± 0.11[a]	28.73 ± 0.08[b]	40.36±0.55[c]
Copper	8.93 ± 0.03[a]	7.46 ± 0.09[b]	6.21 ± 0.32[c]
Manganese	1.64 ± 0.02[a]	2.64 ± 0.02[b]	2.84 ± 0.02[c]
Zinc	24.03 ± 0.45[a]	24.61 ± 0.19[b]	54.46 ± 0.17[c]

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

Table 2. Fatty acid composition of three species of Bagridae fish

Fatty acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
C12:0 (lauric acid)	1.97 ± 0.05[a]	3.94 ± 0.01[b]	4.27 ± 0.01[c]
C14:0 (Meristic acid)	2.38 ± 0.03[a]	2.72 ± 0.08[b]	2.89 ± 0.01[c]
C16:0 (Palmitic acid)	27.23 ± 0.06[a]	30.70 ± 0.06[b]	25.59 ± 0.01[c]
C18:0 (Stearic acid)	16.17 ± 0.02[a]	13.54 ± 0.02[b]	10.64 ± 0.01[c]
C20:0 (Arachidic acid)	0.23 ± 0.01[a]	0.14 ± 0.01[b]	0.37 ± 0.01[c]
C16:1 (Palmitoleic acid)	1.78 ± 0.00[a]	1.27 ± 0.04[b]	4.93 ± 0.01[c]
C18:1(Oleic acid)	16.86 ± 0.01[a]	16.18 ± 0.01[b]	16.97 ± 0.01[c]
C18:2 (Linoleic acid)	3.24 ± 0.02[a]	3.84 ± 0.33[b]	4.55 ± 0.001[c]
C18:3 (Linolenic acid)	1.12 ± 0.01[a]	0.82 ± 0.01[b]	1.57 ± 000[c]
C20:4 (Arachidonic acid)	12.13 ± 0.01[a]	12.49 ± 0.09[b]	12.41 ± 0.02[c]
C20:5 (Eicosapentaenoic acid; EPA)	2.06 ± 0.08[a]	2.34 ± 0.04[b]	1.35 ± 0.01[c]
C22:6 (Docosahexaenoic acid; DHA)	15.65 ± 0.01[a]	11.56 ± 0.04[b]	13.64 ± 0.02[c]

Values are mean % ± SE; *Values in the same row with a different superscript are significantly different ($p<0.05$).

Table 3. Fatty acid ω-6/ω-3 and polyunsaturated/saturated fatty acid ratio of three species of Bagridae fish

	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
ω-6/ω-3 ratio	0.82 ± 0.00[a]	1.11 ± 0.02[b]	1.02 ± 0.01[c]

P/S ratio	0.69 ± 0.01[a]	0.61 ± 0.06[b]	0.76 ± 0.00[c]
AI	0.87 ± 0.01[a]	0.99 ± 0.06[b]	0.73 ± 0.00[c]
TI	0.40 ± 0.01[a]	0.63 ± 0.01[b]	0.43 ± 0.00[c]

P/S, polyunsaturated/saturated fatty acid; AI, atherogenic index; TI, thrombogenic index
Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

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Table 4. Amino acid composition of three species of Bagridae fish

Amino acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
Aspartic acid	10.39 ± 0.01[a]	9.61 ± 0.04[b]	11.28 ± 0.02[c]
Glutamic acid	24.34 ± 0.00[a]	21.58 ± 0.41[b]	19.29 ± 0.03[c]
Serine	3.74 ± 0.00[a]	5.40 ± 0.03[b]	7.50 ± 0.06[c]
Glycine	4.02 ± 0.00[a]	5.77 ± 0.04[b]	4.69 ± 0.02[c]
Histidine	2.39 ± 0.00[a]	2.90 ± 0.03[b]	2.21 ± 0.02[c]
Arginine	6.17 ± 0.01[a]	8.27 ± 0.03[b]	6.22 ± 0.03[c]
Threonine	4.49 ± 0.01[a]	4.19 ± 0.03[b]	4.39 ± 0.04[c]
Alanine	7.03 ± 0.00[a]	6.04 ± 0.02[b]	7.89 ± 0.01[c]
Proline	2.40 ± 0.00[a]	2.71 ± 0.01[b]	2.21 ± 0.02[c]
Tyrosine	3.91 ± 0.01[a]	3.29 ± 0.06[b]	3.82 ± 0.04[c]
Valine	3.73 ± 0.00[a]	4.02 ± 0.01[b]	3.85 ± 0.04[c]
Methionine	3.42 ± 0.00[a]	1.96 ± 0.02[b]	1.27 ± 0.03[c]
Cystine	0.87 ± 0.00[a]	0.76 ± 0.02[b]	0.75 ± 0.03[c]
Isoleucine	3.82 ± 0.001[a]	3.96 ± 0.003[b]	3.66 ± 0.002[c]
Leucine	6.15 ± 0.000[a]	6.69 ± 0.002[b]	6.28 ± 0.004[c]
Phenylalanine	5.13 ± 0.000[a]	6.03 ± 0.005[b]	5.18 ± 0.027[c]
Lysine	9.61 ± 0.001[a]	9.82 ± 0.026[b]	9.87 ± 0.003[c]

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

4. Discussion

The results of this study provide important new information about the nutritional makeup of the studied species of Bagridae fish. The biometric measures of the fish yielded important information about their physical traits and health. Researchers are able to determine the average weight of fish at various lengths by examining the link between length and weight for a particular species. This knowledge is essential for understanding the trends in fish population growth, identifying potential shifts in growth rates over time, and assessing the general health and welfare of fish [29]. A variety of factors, including sex, age, maturity level, size, stomach fullness level, sampling strategies, sample sizes, and environmental circumstances, have an impact on fish health and the parameters that determine length–weight connections in fish [30]. However, none of these factors were considered in our study. In general, according to the theory put forth by Bagenal and Tesch [31], heavier fish of a given length are in better physiological condition. The condition factor is also used in fisheries science to compare the health, fatness, and condition of fish [32]. A condition factor of > 1 is favourable, indicating a good feed nutrition level and suitable living habitat [33]. Thus, based on the findings in this study, the Kampar Kanan River provides a suitable habitat for the fish, ensuring their accessibility and availability for community consumption.

The fish samples exhibited good nutritional profiles, with high amounts of proteins and lipids as well as moisture content contributing to their overall nutritional value, according to the results of proximate analysis and mineral composition (see Table 1). These results imply that the fish species studied provide a possible source of nutrients to solve issues with food security. The study of the mineral composition revealed the existence of critical minerals such as phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) in the fish samples in addition to proteins and lipids. All three Bagridae fish significantly differed from each other in terms of their crude ash content and mineral profile (see Table 1). However, in general, P and Ca are the two highest minerals found in all fish. Both of these macro minerals are good for human bone and tooth health, as key components of hydroxyapatite, the mineral matrix that provides strength and structure to bones and teeth [34].

In the current study, the meat of three species of Bagridae fish from the Kampar Kanan River in Indonesia was found to contain an abundance of microminerals such as Fe and Zn. *M. nigriceps* has been reported to exhibit higher mineral content, including of Fe and Zn. This species is categorized as a small indigenous fish (SIF) with a maximum standard length

of approximately 10.29 cm. According to [35], SIFs are generally known to be rich in Ca, Fe, and Mn.

In this study, all three Bagridae fish had a total fat content of approximately 7–8% by weight, with a higher water content ranging from 82.40–85.39% (Table 1). These values are similar to those found in wild and cultured sea bass *Dicentrarchus labrax* [36]. Additionally, the fish species can be grouped into different categories, including high-fat fish (>8%), medium-fat fish (4–8%), low-fat fish (2–4%), and lean fish (<2%) [37]. According to the classification established by [37], the three indigenous Bagridae fish species are characterized as having a moderate fat content level, which is reflected by the high levels of DHA and EPA in the meat of *H. nemurus*, *H. wyckii*, and *M. nigriceps* (Table 2). Therefore, we recommend that consuming the meat of these three fish species can indirectly boost food security in rural and urban communities.

All three Bagridae fish species analysed in the study contained arachidonic acid (C20:4), at 12.13% for *H. nemurus*, 12.49% for *H. wyckii*, and 12.41% for *M. nigriceps*. Arachidonic acid serves as a precursor for synthesizing prostaglandins and leukotrienes [38]. Leukotrienes are crucial in allergic responses, inducing smooth muscle contraction and increasing vascular permeability [39]. Additionally, all three species also contained EPA ranging from 1.35–2.34% and DHA ranging from 11.56–15.65%. The increased consumption of omega-3 fatty acids, such as EPA and DHA, has been linked to a decreased risk of pain development in older individuals and to the prevention of Alzheimer's disease [40,41].

As determined by the current study, the ω-6/ω-3 ratios of the three Bagridae fish species ranged from 1:0.8 to 1:0.97. It was found that all three fish species had ω-6/ω-3 ratios within the recommended range for a typical Indonesian diet. In contrast, a typical Western diet is characterized by a high ω-6/ω-3 ratio of 10:1 to 20:1, while a Mediterranean diet has a ratio of 4:1 to 5:1 [42]. Additionally, the P/S ratio analysis showed that the three Bagridae fish species are sources of PUFAs that meet the requirements for food safety.

The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recommended AI and TI values ranging from 0.4 to 0.5 for promoting human health [43]. In the current study, the observed AI values in the three freshwater species of Bagridae ranged from 0.73 to 0.99, while the TI values varied between 0.40 and 0.63. This finding is associated with a notable disparity in the values of SFAs among the three Bagridae

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fish species. Based on these findings, we confirm that consuming the meat of the three freshwater species of Bagridae fish caught in the wild does not endanger consumer health and can serve as a suitable source of food safety and nutritional quality.

Fish with a high crude protein content, as shown by the three studied Bagridae fish (Table 1), are regarded as being nutritionally useful for human health. The protein and amino acid contents can directly indicate the nutritional quality of meat [44]. As shown in Table 4, *H. wyckii* had a higher content of essential amino acids (EAAs) than *H. nemurus* and *M. nigriceps*. Among the EAAs, lysine (Lys) was found to be present in the highest amount in all three species. Lys is necessary for tissue growth and repair, reduced stress-induced anxiety, and the conversion of fatty acids into energy [45-47].

More than 60% of the amino acid composition in all three Brigade fish studied comes from nonessential amino acids (NEAAs), particularly glutamic acid (Table 4). Glutamic acid and its amine, glutamine, are highly abundant amino acids found in fish in the free and protein-bound forms [48]. Other amino acids found at abundant levels in the three fish also play important physiological and biochemical functions. The NEAA arginine, for example, is involved in protein synthesis, creatine formation, and various other biochemical processes within the body. The EAAs leucine, phenylalanine, and methionine play important roles in the synthesis of nitric oxide, a molecule that can expand blood vessels [48].

4. Conclusions

The present study provides insightful information about the fatty acid and amino acid compositions, biometric measurements, proximate analysis, and mineral composition of three local freshwater species of Indonesian Bagridae fish. The findings show their potential as a nutrient-dense, sustainable food source that can support efforts to increase food security. These fish species might be incorporated into the local diet to increase nutrient intake and alleviate nutritional inadequacies, which would ultimately improve Indonesia's overall food security status.

Data Availability

The data utilized in this research has not been previously released or published in any form. The datasets employed and/or analysed during the present study can be obtained by contacting the corresponding author.

Conflicts of Interest

The authors confirm that they do not have any conflicting interests.

Acknowledgements

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3 messages

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Kind regards,
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International Journal of Food Science

Reviewer Comments:

> ***Reviewer 1 Comments to the Author***
>
> > *Regarding my remark about C18:0, it is preferable to recalculate the TI without using stearic fatty acid (C18:0) as a proatherogenic fatty acid*

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hafrizal syandri <syandri_1960@bunghatta.ac.id> Fri, Dec 15, 2023 at 9:26 AM
To: International Journal of Food Science <drajadurai@wiley.com>

Dear
Deepanaa Rajadurai
International Journal of Food Science

Based on the reviewer's recommendation, the authors have recalculated the Thrombogenic Index (TI) without using stearic fatty acid (C18:0), and the TI value changed, highlighted in pink.

Best Regards

Hafrijal Syandri

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Phenom Emails <phenom.emails@hindawi.com> Fri, Dec 15, 2023 at 4:41 PM
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Thank you so much for your response.

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Best Regards,

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Research Article

Analysis of Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security

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Abstract

Fish have become an irreplaceable dietary source of animal protein, especially among households with low socioeconomic status in rural and urban areas of Indonesia. This study aimed to analyse the proximate composition, minerals, fatty acids, and amino acids of three local Bagridae fish species in Indonesia. The standard AOAC method was employed to examine the proximate composition of the carcass, and the analysis of amino acids and fatty acids was conducted through HPLC and GC-MS, respectively. The mineral content was determined using AAS. The nutrient composition results of *Hemibagrus nemurus*, *Hemibagrus wyckii*, and *Mystus nigriceps* revealed that the protein content was 24.26%, 22.57%, and 21.39% (%dry weight), whereas the total lipid content was 6.64%, 7.47% and 7.75%, respectively. Regarding mineral contents, the calcium levels ranged from 1.49–1.66 mg/g, iron levels from 28.35–40.36 µg/g, and zinc levels from 24.03–54.46 µg/g. Among the fatty acids, palmitic acid was the most abundant in all three species, accounting for 25.59–30.70% of the total fatty acids. Additionally, significant amounts of C18:1 (oleic acid), C18:0 (stearic acid), and C20:4 (arachidonic acid) were also detected as primary fatty acids.The calculated atherogenic index values in the three species of Bagridae fish ranged from 0.73–0.99, while the thrombogenic index values varied between 0.54–0.75. The predominant amino acids found in the three species of Bagridae fish were glutamic acid with their concentrations ranging from 9.10–24.34%. These results indicate that consuming the meat of these three freshwater Bagridae fish species caught in the wild does not pose any health risks to consumers. They can be considered a safe and suitable food source with good nutritional quality.

Keywords: Amino acids, Fatty acids, Indonesia, Kampar Kanan River, Minerals

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1. Introduction

Fish serve as a high-quality protein source that is essential for satisfying dietary protein requirements, especially in areas where other protein sources are few or difficult to obtain [1,2]. Their accessibility can aid in ensuring a steady supply of food, particularly for communities whose main source of income is fishing or aquaculture [3]. Fish can contribute to a more varied selection of protein sources in communities, resulting in a diet that is more nutritious and balanced. Dietary fish can treat nutrient deficits and enhance general nutritional health. Fish are generally considered safe and offer a lower risk of contamination with harmful substances compared to some land-based animal products. A reliable indicator of a fish's quality, nutritional value, physiological status, and environment is its chemical makeup, which is found in fish flesh [4].

Hemibagrus nemurus, locally known as "baung", *Hemibagrus wyckii*, known as "geso" and *Mystus nigriceps*, known as "ingir-ingir," are three species of catfish found in the Kampar Kanan River, Indonesia [5,6]. Due to their high market value, these species have been identified as significant economic resources for rural communities [7]. Therefore, the analysis of the nutritional quality of fish meat in the study area is very important to determine whether it is beneficial to human health.

Knowing the composition of fatty acids and amino acids in fish meat is an essential factor that should not be ignored [8]. This information provides valuable insight into the nutritional quality of fish and the values of more nutritious and healthy foods [9]. In addition, a better understanding of the composition of fatty acids and amino acids can assist in selecting a suitable feed [10], developing a balanced diet [11], and maintaining optimal fish meat nutrition [12].

Omega-3 polyunsaturated fatty acids (PUFAs), particularly docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) derived from fish oil, exhibit anti-inflammatory and anti-gastrointestinal cancer properties, making them crucial as immune-boosting nutrients [13,14]. Studies have demonstrated that ω-3 and ω-6 PUFAs exhibit beneficial effects in the management of cardiovascular diseases and cancers [15,16]. The fatty acid composition of PUFAs can differ among different types of fish, including both freshwater and marine species

[17, 18]. Amino acids (AAs), such as cysteine, arginine, tyrosine, glycine, proline, and serine, play a vital role in illness and stress situations and in the prevention of inflammation and repair processes in fish intestines [19, 20].

Furthermore, knowledge of the atherogenicity index (AI) and thrombogenicity index (TI) of fatty acids in the three local freshwater fish species of Bagridae can contribute to improving dietary guidelines. The AI and TI can be used to develop recommendations aimed at improving heart health [21,22]. These recommendations may involve selecting fish with favourable fatty acid profiles, allowing individuals to choose the most suitable fish species based on their specific needs [17, 23]. Therefore, this study aims to examine the nutritional composition profile, mineral content, amino acids, and fatty acids, and AI and TI of three freshwater fish species, namely, *H. nemurus*, *H. wyckii*, and *M. nigriceps*. These three fish species are generally consumed by people who live around the Kampar Kanan River in Kampar Regency, Riau Province, Indonesia.

2. Material and methods

2.1. Animal material

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In this study, a total of 27 Bagridae fish belonging to three distinct species (*H. nemurus*, *H. wyckii*, and *M. nigriceps*) were examined. The specimens were obtained from local fishers operating in the upper stretches of the Kampar Kanan River in Kampar Regency, Riau Province (Figure 1). Sampling took place between June and August 2022 and was verified by the Fisheries Department, Faculty of Fisheries and Marine Science, Universitas Bung Hatta, Indonesia. The samples were placed in plastic bags and transported to the laboratory in an insulated icebox. The samples were then grouped based on their respective sampling locations.

2.2. Biometry measurement

Upon reaching the laboratory within 10 hours, the fish samples were subjected to gutting and washing. Each specimen was weighed (TW) and measured to determine the standard length (SL) as well as the depth or maximum height (H). TW was measured using balance scale (OHAUS Model CT 6000 USA) with a precision of 0.01 g. The length measurement was taken from the tip of the mouth to the end of the upper lobe of the caudal fin, representing the total body length, using a metre ruler with an accuracy of 1 mm. The height measurement involved a vertical assessment of the body's maximum height measured using a

Digital Sekhmet Sigma Vernier calliper with an accuracy of 1 mm. The condition factor (CF) was calculated using the formula CF = $(TW/SL^3) \times 100$.

2.3. Proximate, amino acid, and mineral content analysis

The proximate carcass composition was assessed following the AOAC standard methods [24]. The samples were dried to a constant weight at 105 °C. The crude protein content was analysed using the standard Kjeldahl method, which involves multiplying the nitrogen content by a factor of 6.25. The Soxhlet method with ether extraction was employed to analyse crude lipids. The ash content was obtained by incinerating the samples at 550 °C for 16 h. The amino acid composition was determined using a high-performance liquid chromatography (HPLC) system, which consisted of a Waters® 1525 binary HPLC pump, Waters® 717 autosamplers, and Waters® 2475 multi-λ fluorescence detector (with excitation at 250 nm and emission at 395 nm). The samples were hydrolysed in triplicate with 6 N hydrochloric acid for 24 h at 11 °C [25].

For mineral data composition (Na, Mg, Ca, K, P, Fe, Cu, Mn, and Zn), the ashed feed sample and carcass were dissolved in 1 ml of hydrochloric acid (35% v/v Suprapur®, Merck) and then filtered with cellulose filter paper (Watchman No 1, International Ltd; Maidstone, UK) and diluted to an appropriate concentration for each elemental mineral. P levels were analysed with a Perkin-Elmer AA spectrophotometer mod 3110 (Norwalk, CT, USA).

2.4. Fatty acid analysis

The fish meat was examined utilizing the gas chromatography–mass spectrometry (GC–MS) method. The method of Folch et al. (1957) modified by Rajion et al. [26] was employed to perform the total fat extraction. This involved using a solvent system consisting of chloroform and methanol at a 2:1 (v/v) ratio. The process of transmethylation was conducted using a solution of 14% methanolic boron trifluoride. The fatty acid composition of the meat was then analysed at the SIG Laboratory, Accredited Testing Laboratory-LP-184-IDN.

The nutritional quality of lipids (AI and TI) was calculated using the following equations [27]:

$$AI = \frac{[(C12{:}0 + 4 \times C14{:}0 + C16{:}0)]}{\sum MUFA + \sum n-6 + \sum n-3}$$

$$TI = \frac{[(C14:0\ +\ C16:0\ )]}{[(0.5 \times \sum MUFA) + (0.5\ \times\ \sum n-6) +\ (3 \times \sum n-3) + (\sum n-3/\sum n-6)}$$

where:

AI = Atherogenic index
TI = Thrombogenic index
C12:0 = lauric acid
C14:0 = myristic acid
C16:0 = palmitic acid

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The author has recalculated the Thrombogenic Index (TI) without using stearic fatty acid (C18:0).

∑MUFA = sum of the concentrations of all monosaturated fatty acids
∑n-6 = sum of the concentrations of n-6 polyunsaturated fatty acids
∑n-3 = sum of the concentrations of n-3 polyunsaturated fatty acids

2.5. Data analysis

Data analysis was performed using the SPSS 16.0 software package (SPSS; Chicago, IL). The homogeneity of variances was assessed using Levene’s test. One-way ANOVA was carried out to determine the parameters of proximate and amino acid composition, including the composition of fatty acids and nutritional quality of lipids (AI and TI) for each species, followed by the post hoc Duncan's multiple range test [28]. The results are reported as the mean values ± standard errors for each parameter.

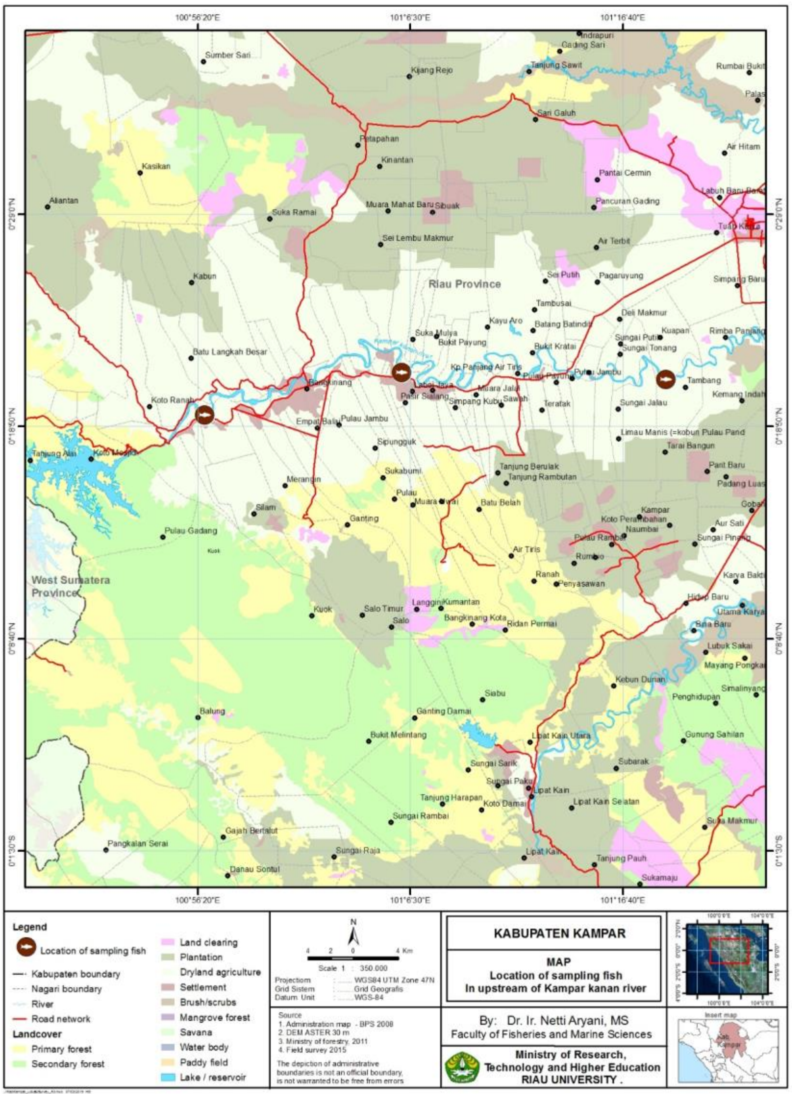

Figure 1. Map of Kampar Regency, Riau Province, and sampling locations of the three species of Bagridae fish.

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3. Results

Table 1 presents the average wet weight, standard length, height, and the results of meat nutritional composition analysis for three indigenous Indonesian freshwater Bagridae species. The moisture content (% wet weight) ranged from 82.40– 85.39%. Among the species examined, *M. nigriceps* exhibited the lowest protein content at 21.39%, while *H. nemurus* displayed the highest value at 24.26%. However, *M. nigriceps* had a higher mineral content, including of iron and zinc.

Table 2 summarizes the fatty acid composition (%total fatty acid) for the three Bagridae fish species. C16:0 was the predominant fatty acid in the three species of Bagridae fish, with percentages ranging from 25.09–30.71%. The additional prominent fatty acids found were C18:1, C18:0, and C22:6. *H. nemurus* exhibited a ω-6/ω-3 ratio below 1 (0.82), while *H. wyckii* and *M. nigriceps* had ratios of 1.11 and 1.02, respectively. The obtained PUFA/saturated fatty acid (SFA) (P/S) ratio varied between 0.61 and 0.76. The AI values varied between 0.76 and 0.99 and the TI between 0.40 and 0.63 (**Table 3**).

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Table 4 presents the amino acid composition (% of total protein) of the three Bagridae species. Glutamic acid was the dominant amino acid, ranging from 19.29–24.34%, followed by aspartic acid, which ranged from 9.21–11.27%. The lysine content was consistent, ranging from 9.67–9.87%. In *H. nemurus*, the levels of various amino acids ranged from 0.86–24.35%. Similarly, in *H. wyckii*, the amino acid levels ranged from 0.76–21.58%, while in *M. nigriceps*, the levels ranged from 0.74–19.29%.

Table 1. Results of biometric, proximate and mineral composition of three species of Bagridae fish

	Species		
	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
Biometric measurements			
Total weight (g)	389.99 ± 24.96[a]	1,390.33 ± 168.29[b]	17.57 ± 1.53[c]
Standard length (cm)	28.16 ± 0.53[a]	44.14 ± 1.98[b]	10.29 ± 0.15[c]
Height (cm)	8.44 ± 0.16[a]	8.82 ± 0.39[b]	2.57 ± 0.03[c]
Condition factor	1.63 ± 0.08	1.58 ± 0.07	1.56 ± 0.08
Proximate composition			
Crude protein (% DW)	24.26 ± 0.87[a]	22.57 ± 0.37[b]	21.39 ± 0.15[c]
Crude fat (% DW)	6.64 ± 0.03[a]	7.47 ± 0.02[b]	7.75 ± 0.40[c]
Crude ash (% DW)	1.94 ± 0.02[a]	2.30 ± 0.09[b]	1.59 ± 0.02[c]
Moisture (% WW)	82.40 ± 2.51	85.39 ± 2.36	83.75 ± 2.21

Mineral composition			
Macrominerals (mg/g)			
Sodium	0.99 ± 0.00[a]	1.61 ± 0.01[b]	1.61 ± 0.02[c]
Magnesium	1.12 ± 0.01[a]	0.57 ± 0.02[b]	1.15 ± 0.01[c]
Calcium	1.66 ± 0.00[a]	1.55 ± 0.02[b]	1.49 ± 0.04[c]
Potassium	0.71 ± 0.00[a]	0.55 ± 0.02[b]	0.43 ± 0.01[c]
Phosphorous	7.03 ± 0.03[a]	2.74 ± 0.02[b]	6.45 ± 0.07[c]
Microminerals (μg/g)			
Iron	28.30 ± 0.11[a]	28.73 ± 0.08[b]	40.36±0.55[c]
Copper	8.93 ± 0.03[a]	7.46 ± 0.09[b]	6.21 ± 0.32[c]
Manganese	1.64 ± 0.02[a]	2.64 ± 0.02[b]	2.84 ± 0.02[c]
Zinc	24.03 ± 0.45[a]	24.61 ± 0.19[b]	54.46 ± 0.17[c]

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

Table 2. Fatty acid composition of three species of Bagridae fish

Fatty acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
C12:0 (lauric acid)	1.97 ± 0.05[a]	3.94 ± 0.01[b]	4.27 ± 0.01[c]
C14:0 (Meristic acid)	2.38 ± 0.03[a]	2.72 ± 0.08[b]	2.89 ± 0.01[c]
C16:0 (Palmitic acid)	27.23 ± 0.06[a]	30.70 ± 0.06[b]	25.59 ± 0.01[c]
C18:0 (Stearic acid)	16.17 ± 0.02[a]	13.54 ± 0.02[b]	10.64 ± 0.01[c]
C20:0 (Arachidic acid)	0.23 ± 0.01[a]	0.14 ± 0.01[b]	0.37 ± 0.01[c]
C16:1 (Palmitoleic acid)	1.78 ± 0.00[a]	1.27 ± 0.04[b]	4.93 ± 0.01[c]
C18:1(Oleic acid)	16.86 ± 0.01[a]	16.18 ± 0.01[b]	16.97 ± 0.01[c]
C18:2 (Linoleic acid)	3.24 ± 0.02[a]	3.84 ± 0.33[b]	4.55 ± 0.001[c]
C18:3 (Linolenic acid)	1.12 ± 0.01[a]	0.82 ± 0.01[b]	1.57 ± 000[c]
C20:4 (Arachidonic acid)	12.13 ± 0.01[a]	12.49 ± 0.09[b]	12.41 ± 0.02[c]
C20:5 (Eicosapentaenoic acid; EPA)	2.06 ± 0.08[a]	2.34 ± 0.04[b]	1.35 ± 0.01[c]
C22:6 (Docosahexaenoic acid; DHA)	15.65 ± 0.01[a]	11.56 ± 0.04[b]	13.64 ± 0.02[c]

Values are mean % ± SE; *Values in the same row with a different superscript are significantly different ($p<0.05$).

Table 3. Fatty acid ω-6/ω-3 and polyunsaturated/saturated fatty acid ratio of three species of Bagridae fish

	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
ω-6/ω-3 ratio	0.82 ± 0.00[a]	1.11 ± 0.02[b]	1.02 ± 0.01[c]

P/S ratio	0.69 ± 0.01[a]	0.61 ± 0.06[b]	0.76 ± 0.00[c]
AI	0.87 ± 0.01[a]	0.99 ± 0.06[b]	0.73 ± 0.00[c]
TI	0.40 ± 0.01[a]	0.63 ± 0.01[b]	0.43 ± 0.00[c]

P/S, polyunsaturated/saturated fatty acid; AI, atherogenic index; TI, thrombogenic index
Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

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Table 4. Amino acid composition of three species of Bagridae fish

Amino acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
Aspartic acid	10.39 ± 0.01[a]	9.61 ± 0.04[b]	11.28 ± 0.02[c]
Glutamic acid	24.34 ± 0.00[a]	21.58 ± 0.41[b]	19.29 ± 0.03[c]
Serine	3.74 ± 0.00[a]	5.40 ± 0.03[b]	7.50 ± 0.06[c]
Glycine	4.02 ± 0.00[a]	5.77 ± 0.04[b]	4.69 ± 0.02[c]
Histidine	2.39 ± 0.00[a]	2.90 ± 0.03[b]	2.21 ± 0.02[c]
Arginine	6.17 ± 0.01[a]	8.27 ± 0.03[b]	6.22 ± 0.03[c]
Threonine	4.49 ± 0.01[a]	4.19 ± 0.03[b]	4.39 ± 0.04[c]
Alanine	7.03 ± 0.00[a]	6.04 ± 0.02[b]	7.89 ± 0.01[c]
Proline	2.40 ± 0.00[a]	2.71 ± 0.01[b]	2.21 ± 0.02[c]
Tyrosine	3.91 ± 0.01[a]	3.29 ± 0.06[b]	3.82 ± 0.04[c]
Valine	3.73 ± 0.00[a]	4.02 ± 0.01[b]	3.85 ± 0.04[c]
Methionine	3.42 ± 0.00[a]	1.96 ± 0.02[b]	1.27 ± 0.03[c]
Cystine	0.87 ± 0.00[a]	0.76 ± 0.02[b]	0.75 ± 0.03[c]
Isoleucine	3.82 ± 0.001[a]	3.96 ± 0.003[b]	3.66 ± 0.002[c]
Leucine	6.15 ± 0.000[a]	6.69 ± 0.002[b]	6.28 ± 0.004[c]
Phenylalanine	5.13 ± 0.000[a]	6.03 ± 0.005[b]	5.18 ± 0.027[c]
Lysine	9.61 ± 0.001[a]	9.82 ± 0.026[b]	9.87 ± 0.003[c]

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

4. Discussion

The results of this study provide important new information about the nutritional makeup of the studied species of Bagridae fish. The biometric measures of the fish yielded important information about their physical traits and health. Researchers are able to determine the average weight of fish at various lengths by examining the link between length and weight for a particular species. This knowledge is essential for understanding the trends in fish population growth, identifying potential shifts in growth rates over time, and assessing the general health and welfare of fish [29]. A variety of factors, including sex, age, maturity level, size, stomach fullness level, sampling strategies, sample sizes, and environmental circumstances, have an impact on fish health and the parameters that determine length–weight connections in fish [30]. However, none of these factors were considered in our study. In general, according to the theory put forth by Bagenal and Tesch [31], heavier fish of a given length are in better physiological condition. The condition factor is also used in fisheries science to compare the health, fatness, and condition of fish [32]. A condition factor of > 1 is favourable, indicating a good feed nutrition level and suitable living habitat [33]. Thus, based on the findings in this study, the Kampar Kanan River provides a suitable habitat for the fish, ensuring their accessibility and availability for community consumption.

The fish samples exhibited good nutritional profiles, with high amounts of proteins and lipids as well as moisture content contributing to their overall nutritional value, according to the results of proximate analysis and mineral composition (see Table 1). These results imply that the fish species studied provide a possible source of nutrients to solve issues with food security. The study of the mineral composition revealed the existence of critical minerals such as phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) in the fish samples in addition to proteins and lipids. All three Bagridae fish significantly differed from each other in terms of their crude ash content and mineral profile (see Table 1). However, in general, P and Ca are the two highest minerals found in all fish. Both of these macro minerals are good for human bone and tooth health, as key components of hydroxyapatite, the mineral matrix that provides strength and structure to bones and teeth [34].

In the current study, the meat of three species of Bagridae fish from the Kampar Kanan River in Indonesia was found to contain an abundance of microminerals such as Fe and Zn. *M. nigriceps* has been reported to exhibit higher mineral content, including of Fe and Zn. This species is categorized as a small indigenous fish (SIF) with a maximum standard length

of approximately 10.29 cm. According to [35], SIFs are generally known to be rich in Ca, Fe, and Mn.

In this study, all three Bagridae fish had a total fat content of approximately 7–8% by weight, with a higher water content ranging from 82.40–85.39% (Table 1). These values are similar to those found in wild and cultured sea bass *Dicentrarchus labrax* [36]. Additionally, the fish species can be grouped into different categories, including high-fat fish (>8%), medium-fat fish (4–8%), low-fat fish (2–4%), and lean fish (<2%) [37]. According to the classification established by [37], the three indigenous Bagridae fish species are characterized as having a moderate fat content level, which is reflected by the high levels of DHA and EPA in the meat of *H. nemurus*, *H. wyckii*, and *M. nigriceps* (Table 2). Therefore, we recommend that consuming the meat of these three fish species can indirectly boost food security in rural and urban communities.

All three Bagridae fish species analysed in the study contained arachidonic acid (C20:4), at 12.13% for *H. nemurus*, 12.49% for *H. wyckii*, and 12.41% for *M. nigriceps*. Arachidonic acid serves as a precursor for synthesizing prostaglandins and leukotrienes [38]. Leukotrienes are crucial in allergic responses, inducing smooth muscle contraction and increasing vascular permeability [39]. Additionally, all three species also contained EPA ranging from 1.35–2.34% and DHA ranging from 11.56–15.65%. The increased consumption of omega-3 fatty acids, such as EPA and DHA, has been linked to a decreased risk of pain development in older individuals and to the prevention of Alzheimer's disease [40,41].

As determined by the current study, the ω-6/ω-3 ratios of the three Bagridae fish species ranged from 1:0.8 to 1:0.97. It was found that all three fish species had ω-6/ω-3 ratios within the recommended range for a typical Indonesian diet. In contrast, a typical Western diet is characterized by a high ω-6/ω-3 ratio of 10:1 to 20:1, while a Mediterranean diet has a ratio of 4:1 to 5:1 [42]. Additionally, the P/S ratio analysis showed that the three Bagridae fish species are sources of PUFAs that meet the requirements for food safety.

The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recommended AI and TI values ranging from 0.4 to 0.5 for promoting human health [43]. In the current study, the observed AI values in the three freshwater species of Bagridae ranged from 0.73 to 0.99, while the TI values varied between 0.40 and 0.63. This finding is associated with a notable disparity in the values of SFAs among the three Bagridae

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fish species. Based on these findings, we confirm that consuming the meat of the three freshwater species of Bagridae fish caught in the wild does not endanger consumer health and can serve as a suitable source of food safety and nutritional quality.

Fish with a high crude protein content, as shown by the three studied Bagridae fish (Table 1), are regarded as being nutritionally useful for human health. The protein and amino acid contents can directly indicate the nutritional quality of meat [44]. As shown in Table 4, *H. wyckii* had a higher content of essential amino acids (EAAs) than *H. nemurus* and *M. nigriceps*. Among the EAAs, lysine (Lys) was found to be present in the highest amount in all three species. Lys is necessary for tissue growth and repair, reduced stress-induced anxiety, and the conversion of fatty acids into energy [45-47].

More than 60% of the amino acid composition in all three Brigade fish studied comes from nonessential amino acids (NEAAs), particularly glutamic acid (Table 4). Glutamic acid and its amine, glutamine, are highly abundant amino acids found in fish in the free and protein-bound forms [48]. Other amino acids found at abundant levels in the three fish also play important physiological and biochemical functions. The NEAA arginine, for example, is involved in protein synthesis, creatine formation, and various other biochemical processes within the body. The EAAs leucine, phenylalanine, and methionine play important roles in the synthesis of nitric oxide, a molecule that can expand blood vessels [48].

4. Conclusions

The present study provides insightful information about the fatty acid and amino acid compositions, biometric measurements, proximate analysis, and mineral composition of three local freshwater species of Indonesian Bagridae fish. The findings show their potential as a nutrient-dense, sustainable food source that can support efforts to increase food security. These fish species might be incorporated into the local diet to increase nutrient intake and alleviate nutritional inadequacies, which would ultimately improve Indonesia's overall food security status.

Data Availability

The data utilized in this research has not been previously released or published in any form. The datasets employed and/or analysed during the present study can be obtained by contacting the corresponding author.

Conflicts of Interest

The authors confirm that they do not have any conflicting interests.

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3 messages

Chandrika Harikrishnan <chandrika.harikrishnan@hindawi.com> Sat, Dec 16, 2023 at 11:53 AM
Reply-To: Chandrika Harikrishnan <chandrika.harikrishnan@hindawi.com>
To: syandri_1960@bunghatta.ac.id

Dear Dr. Syandri,

This is regarding the manuscript "**6639837**" titled "**Fatty Acids and Amino Acids of Three Local Freshwater Species of Indonesian Bagridae Fish for Food Security**" has been submitted to "**International Journal of Food Science".**

During our routine quality checks, we found that the manuscript consists of many et al references. Kindly update the reference section and provide a detailed reference list that includes all authors names ***(explain et al.,), title, journal name, and published year*** in the final manuscript and send us the file in document format via email in order to proceed further.

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Best regards,
Chandrika

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hafrizal syandri <syandri_1960@bunghatta.ac.id> Sun, Dec 17, 2023 at 5:51 PM
To: Chandrika Harikrishnan <chandrika.harikrishnan@hindawi.com>

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Chandrika Harikrishnan
Quality Checker of International Journal of Food Science

Thank you for your email on December 16, 2023; The authors have revised the manuscript consisting of many et al on the references (attached).

Best Regards
Hafrijal Syandri
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Chandrika Harikrishnan <chandrika.harikrishnan@hindawi.com> Mon, Dec 18, 2023 at 3:18 PM
Reply-To: Chandrika Harikrishnan <chandrika.harikrishnan@hindawi.com>
To: syandri_1960@bunghatta.ac.id

Dear Dr. Syandri,

Thank you for your email. We will check this and get back to you incase of any queries.

Best regards,
Chandrika

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Analysis of Fatty Acids and Amino Acids of Three Local Freshwater Bagridae Fish Species in the Kampar Kanan River, Indonesia for Food Security

Azrita Azrita[1], Hafrijal Syandri[1*], Hazlina Ahamad Zakeri[2], Harfiandri Damanhuri[1], Netti Aryani[3]

[1]*Faculty of Fisheries and Marine Science, Bung Hatta University, 25131, Padang-West Sumatra Province, Indonesia*
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Abstract

Fish have become an irreplaceable dietary source of animal protein, especially among households with low socioeconomic status in rural and urban areas of Indonesia. This study aimed to analyse the proximate composition, minerals, fatty acids, and amino acids of three local Bagridae fish species in Indonesia. The standard AOAC method was employed to examine the proximate composition of the carcass, and the analysis of amino acids and fatty acids was conducted through HPLC and GC-MS, respectively. The mineral content was determined using AAS. The nutrient composition results of *Hemibagrus nemurus*, *Hemibagrus wyckii*, and *Mystus nigriceps* revealed that the protein content was 24.26%, 22.57%, and 21.39% (%dry weight), whereas the total lipid content was 6.64%, 7.47% and 7.75%, respectively. Regarding mineral contents, the calcium levels ranged from 1.49–1.66 mg/g, iron levels from 28.35–40.36 µg/g, and zinc levels from 24.03–54.46 µg/g. Among the fatty acids, palmitic acid was the most abundant in all three species, accounting for 25.59–30.70% of the total fatty acids. Additionally, significant amounts of C18:1 (oleic acid), C18:0 (stearic acid), and C20:4 (arachidonic acid) were also detected as primary fatty acids.The calculated atherogenic index values in the three species of Bagridae fish ranged from 0.73–0.99, while the thrombogenic index values varied between 0.54–0.75. The predominant amino acids found in the three species of Bagridae fish were glutamic acid with their concentrations ranging from 9.10–24.34%. These results indicate that consuming the meat of these three freshwater Bagridae fish species caught in the wild does not pose any health risks to consumers. They can be considered a safe and suitable food source with good nutritional quality.

Keywords: Amino acids, Fatty acids, Indonesia, Kampar Kanan River, Minerals

1. Introduction

Fish serve as a high-quality protein source that is essential for satisfying dietary protein requirements, especially in areas where other protein sources are few or difficult to obtain [1,2]. Their accessibility can aid in ensuring a steady supply of food, particularly for communities whose main source of income is fishing or aquaculture [3]. Fish can contribute to a more varied selection of protein sources in communities, resulting in a diet that is more nutritious and balanced. Dietary fish can treat nutrient deficits and enhance general nutritional health. Fish are generally considered safe and offer a lower risk of contamination with harmful substances compared to some land-based animal products. A reliable indicator of a fish's quality, nutritional value, physiological status, and environment is its chemical makeup, which is found in fish flesh [4].

Hemibagrus nemurus, locally known as "baung", *Hemibagrus wyckii*, known as "geso" and *Mystus nigriceps*, known as "ingir-ingir," are three species of catfish found in the Kampar Kanan River, Indonesia [5,6]. Due to their high market value, these species have been identified as significant economic resources for rural communities [7]. Therefore, the analysis of the nutritional quality of fish meat in the study area is very important to determine whether it is beneficial to human health.

Knowing the composition of fatty acids and amino acids in fish meat is an essential factor that should not be ignored [8]. This information provides valuable insight into the nutritional quality of fish and the values of more nutritious and healthy foods [9]. In addition, a better understanding of the composition of fatty acids and amino acids can assist in selecting a suitable feed [10], developing a balanced diet [11], and maintaining optimal fish meat nutrition [12].

Omega-3 polyunsaturated fatty acids (PUFAs), particularly docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) derived from fish oil, exhibit anti-inflammatory and anti-gastrointestinal cancer properties, making them crucial as immune-boosting nutrients [13,14]. Studies have demonstrated that ω-3 and ω-6 PUFAs exhibit beneficial effects in the management of cardiovascular diseases and cancers [15,16]. The fatty acid composition of PUFAs can differ among different types of fish, including both freshwater and marine species [17, 18]. Amino acids (AAs), such as cysteine, arginine, tyrosine, glycine, proline, and serine, play a vital role in illness and stress situations and in the prevention of inflammation and repair processes in fish intestines [19, 20].

Furthermore, knowledge of the atherogenicity index (AI) and thrombogenicity index (TI) of fatty acids in the three local freshwater fish species of Bagridae can contribute to improving dietary guidelines. The AI and TI can be used to develop recommendations aimed at improving heart health [21,22]. These recommendations may involve selecting fish with favourable fatty acid profiles, allowing individuals to choose the most suitable fish species based on their specific needs [17, 23]. Therefore, this study aims to examine the nutritional composition profile, mineral content, amino acids, and fatty acids, and AI and TI of three freshwater fish species, namely, *H. nemurus*, *H. wyckii*, and *M. nigriceps*. These three fish species are generally consumed by people who live around the Kampar Kanan River in Kampar Regency, Riau Province, Indonesia.

2. Material and methods

2.1. Animal material

In this study, a total of 27 Bagridae fish belonging to three distinct species (*H. nemurus*, *H. wyckii*, and *M. nigriceps*) were examined. The specimens were obtained from local fishers operating in the upper stretches of the Kampar Kanan River in Kampar Regency, Riau Province (Figure 1). Sampling took place between June and August 2022 and was verified by the Fisheries Department, Faculty of Fisheries and Marine Science, Bung Hatta University, Indonesia. The samples were placed in plastic bags and transported to the laboratory in an insulated icebox. The samples were then grouped based on their respective sampling locations.

2.2. Biometry measurement

Upon reaching the laboratory within 10 hours, the fish samples were subjected to gutting and washing. Each specimen was weighed (TW) and measured to determine the standard length (SL) as well as the depth or maximum height (H). TW was measured using balance scale (OHAUS Model CT 6000 USA) with a precision of 0.01 g. The length measurement was taken from the tip of the mouth to the end of the upper lobe of the caudal fin, representing the total body length, using a metre ruler with an accuracy of 1 mm. The height measurement involved a vertical assessment of the body's maximum height measured using a Digital Sekhmet Sigma Vernier calliper with an accuracy of 1 mm. The condition factor (CF) was calculated using the formula $CF = (TW/SL^3) \times 100$.

2.3. Proximate, amino acid, and mineral content analysis

The proximate carcass composition was assessed following the AOAC standard methods [24]. The samples were dried to a constant weight at 105 °C. The crude protein content was analysed using the standard Kjeldahl method, which involves multiplying the nitrogen content by a factor of 6.25. The Soxhlet method with ether extraction was employed to analyse crude lipids. The ash content was obtained by incinerating the samples at 550 °C for 16 h. The amino acid composition was determined using a high-performance liquid chromatography (HPLC) system, which consisted of a Waters® 1525 binary HPLC pump, Waters® 717 autosamplers, and Waters® 2475 multi-λ fluorescence detector (with excitation at 250 nm and emission at 395 nm). The samples were hydrolysed in triplicate with 6 N hydrochloric acid for 24 h at 11 °C [25].

For mineral data composition (Na, Mg, Ca, K, P, Fe, Cu, Mn, and Zn), the ashed feed sample and carcass were dissolved in 1 ml of hydrochloric acid (35% v/v Suprapur®, Merck) and then filtered with cellulose filter paper (Watchman No 1, International Ltd; Maidstone, UK) and diluted to an appropriate concentration for each elemental mineral. P levels were analysed with a Perkin-Elmer AA spectrophotometer mod 3110 (Norwalk, CT, USA).

2.4. Fatty acid analysis

The fish meat was examined utilizing the gas chromatography–mass spectrometry (GC–MS) method. The method of Folch et al. (1957) modified by Rajion et al. [26] was employed to perform the total fat extraction. This involved using a solvent system consisting of chloroform and methanol at a 2:1 (v/v) ratio. The process of transmethylation was conducted using a solution of 14% methanolic boron trifluoride. The fatty acid composition of the meat was then analysed at the SIG Laboratory, Accredited Testing Laboratory-LP-184-IDN.

The nutritional quality of lipids (AI and TI) was calculated using the following equations [27]:

$$AI = \frac{[(C12:0\ + 4\ \times C14:0\ +\ C16:0)]}{[(\sum MUFA\ +\ \sum n-6\ +\ \sum n-3)]}$$

$$TI = \frac{[(C14:0\ +\ C16:0\ )]}{[(0.5 \times \sum MUFA) + (0.5\ \times\ \sum n-6) +\ (3 \times \sum n-3) + (\sum n-3/\sum n-6)]}$$

where:

AI = Atherogenic index
TI = Thrombogenic index
C12:0 = lauric acid
C14:0 = myristic acid
C16:0 = palmitic acid
∑MUFA = sum of the concentrations of all monosaturated fatty acids
∑n-6 = sum of the concentrations of n-6 polyunsaturated fatty acids
∑n-3 = sum of the concentrations of n-3 polyunsaturated fatty acids

2.5. Data analysis

Data analysis was performed using the SPSS 16.0 software package (SPSS; Chicago, IL). The homogeneity of variances was assessed using Levene’s test. One-way ANOVA was carried out to determine the parameters of proximate and amino acid composition, including the composition of fatty acids and nutritional quality of lipids (AI and TI) for each species, followed by the post hoc Duncan's multiple range test [28]. The results are reported as the mean values ± standard errors for each parameter.

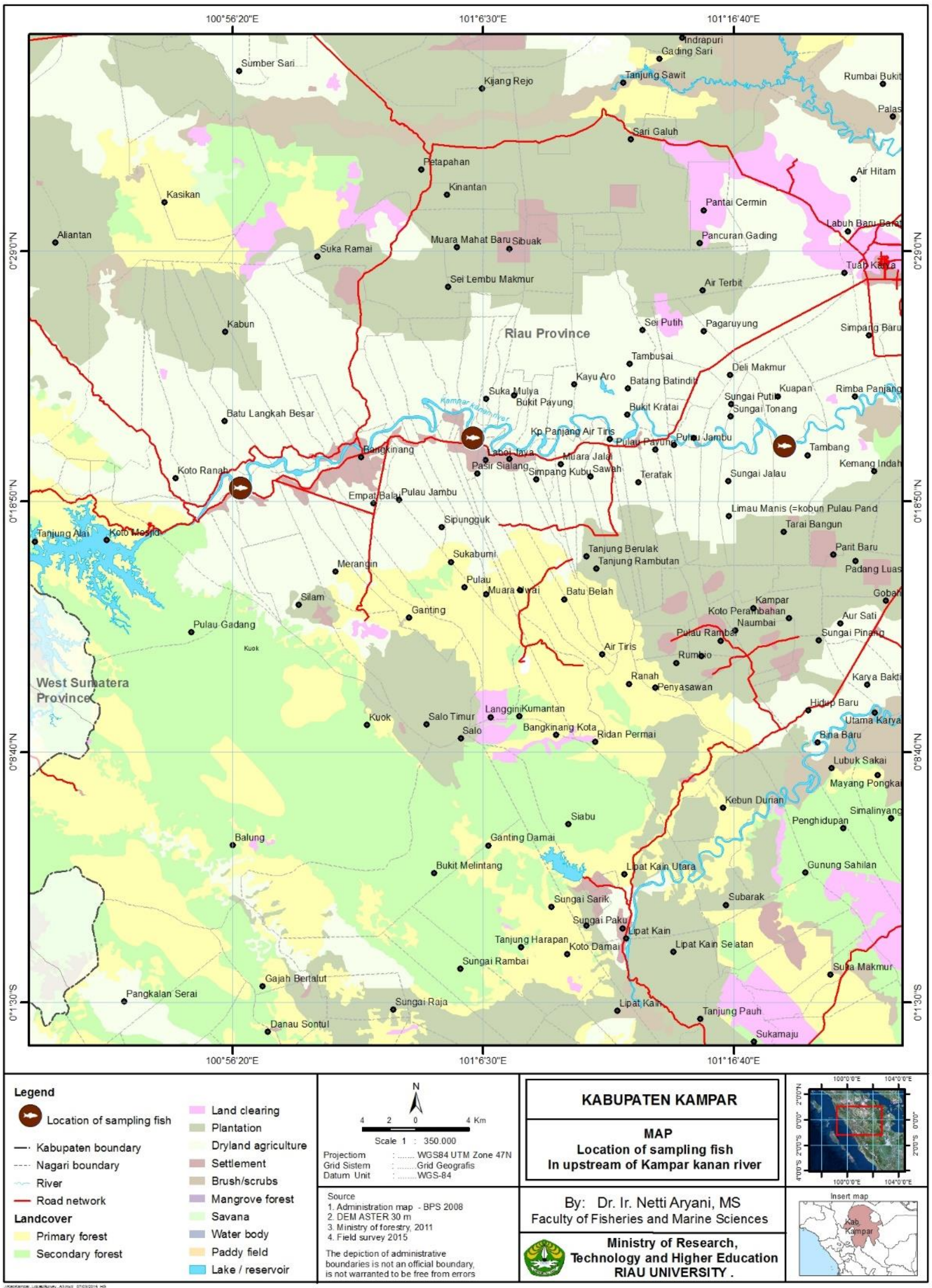

Figure 1. Map of Kampar Regency, Riau Province, and sampling locations of the three species of Bagridae fish.

3. Results

Table 1 presents the average wet weight, standard length, height, and the results of meat nutritional composition analysis for three indigenous Indonesian freshwater Bagridae species. The moisture content (% wet weight) ranged from 82.40– 85.39%. Among the species examined, *M. nigriceps* exhibited the lowest protein content at 21.39%, while *H. nemurus* displayed the highest value at 24.26%. However, *M. nigriceps* had a higher mineral content, including of iron and zinc.

Table 2 summarizes the fatty acid composition (%total fatty acid) for the three Bagridae fish species. C16:0 was the predominant fatty acid in the three species of Bagridae fish, with percentages ranging from 25.09–30.71%. The additional prominent fatty acids found were C18:1, C18:0, and C22:6. *H. nemurus* exhibited a ω-6/ω-3 ratio below 1 (0.82), while *H. wyckii* and *M. nigriceps* had ratios of 1.11 and 1.02, respectively. The obtained PUFA/saturated fatty acid (SFA) (P/S) ratio varied between 0.61 and 0.76. The AI values varied between 0.76 and 0.99 and the TI between 0.40 and 0.63 (**Table 3**).

Table 4 presents the amino acid composition (% of total protein) of the three Bagridae species. Glutamic acid was the dominant amino acid, ranging from 19.29–24.34%, followed by aspartic acid, which ranged from 9.21–11.27%. The lysine content was consistent, ranging from 9.67–9.87%. In *H. nemurus*, the levels of various amino acids ranged from 0.86– 24.35%. Similarly, in *H. wyckii*, the amino acid levels ranged from 0.76–21.58%, while in *M. nigriceps*, the levels ranged from 0.74–19.29%.

Table 1. Results of biometric, proximate and mineral composition of three species of Bagridae fish

	Species		
	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*
Biometric measurements			
Total weight (g)	389.99 ± 24.96[a]	1,390.33 ± 168.29[b]	17.57 ± 1.53[c]
Standard length (cm)	28.16 ± 0.53[a]	44.14 ± 1.98[b]	10.29 ± 0.15[c]
Height (cm)	8.44 ± 0.16[a]	8.82 ± 0.39[b]	2.57 ± 0.03[c]
Condition factor	1.63 ± 0.08	1.58 ± 0.07	1.56 ± 0.08
Proximate composition			
Crude protein (% DW)	24.26 ± 0.87[a]	22.57 ± 0.37[b]	21.39 ± 0.15[c]
Crude fat (% DW)	6.64 ± 0.03[a]	7.47 ± 0.02[b]	7.75 ± 0.40[c]
Crude ash (% DW)	1.94 ± 0.02[a]	2.30 ± 0.09[b]	1.59 ± 0.02[c]

Moisture (% WW)	82.40 ± 2.51	85.39 ± 2.36	83.75 ± 2.21
Mineral composition			
Macrominerals (mg/g)			
Sodium	0.99 ± 0.00[a]	1.61 ± 0.01[b]	1.61 ± 0.02[c]
Magnesium	1.12 ± 0.01[a]	0.57 ± 0.02[b]	1.15 ± 0.01[c]
Calcium	1.66 ± 0.00[a]	1.55 ± 0.02[b]	1.49 ± 0.04[c]
Potassium	0.71 ± 0.00[a]	0.55 ± 0.02[b]	0.43 ± 0.01[c]
Phosphorous	7.03 ± 0.03[a]	2.74 ± 0.02[b]	6.45 ± 0.07[c]
Microminerals (µg/g)			
Iron	28.30 ± 0.11[a]	28.73 ± 0.08[b]	40.36±0.55[c]
Copper	8.93 ± 0.03[a]	7.46 ± 0.09[b]	6.21 ± 0.32[c]
Manganese	1.64 ± 0.02[a]	2.64 ± 0.02[b]	2.84 ± 0.02[c]
Zinc	24.03 ± 0.45[a]	24.61 ± 0.19[b]	54.46 ± 0.17[c]

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

Table 2. Fatty acid composition of three species of Bagridae fish

Fatty acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
C12:0 (lauric acid)	1.97 ± 0.05[a]	3.94 ± 0.01[b]	4.27 ± 0.01[c]
C14:0 (Meristic acid)	2.38 ± 0.03[a]	2.72 ± 0.08[b]	2.89 ± 0.01[c]
C16:0 (Palmitic acid)	27.23 ± 0.06[a]	30.70 ± 0.06[b]	25.59 ± 0.01[c]
C18:0 (Stearic acid)	16.17 ± 0.02[a]	13.54 ± 0.02[b]	10.64 ± 0.01[c]
C20:0 (Arachidic acid)	0.23 ± 0.01[a]	0.14 ± 0.01[b]	0.37 ± 0.01[c]
C16:1 (Palmitoleic acid)	1.78 ± 0.00[a]	1.27 ± 0.04[b]	4.93 ± 0.01[c]
C18:1(Oleic acid)	16.86 ± 0.01[a]	16.18 ± 0.01[b]	16.97 ± 0.01[c]
C18:2 (Linoleic acid)	3.24 ± 0.02[a]	3.84 ± 0.33[b]	4.55 ± 0.001[c]
C18:3 (Linolenic acid)	1.12 ± 0.01[a]	0.82 ± 0.01[b]	1.57 ± 000[c]
C20:4 (Arachidonic acid)	12.13 ± 0.01[a]	12.49 ± 0.09[b]	12.41 ± 0.02[c]
C20:5 (Eicosapentaenoic acid; EPA)	2.06 ± 0.08[a]	2.34 ± 0.04[b]	1.35 ± 0.01[c]
C22:6 (Docosahexaenoic acid; DHA)	15.65 ± 0.01[a]	11.56 ± 0.04[b]	13.64 ± 0.02[c]

Values are mean % ± SE; *Values in the same row with a different superscript are significantly different ($p<0.05$).

Table 3. Fatty acid ω-6/ω-3 and polyunsaturated/saturated fatty acid ratio of three species of Bagridae fish

	Hemibagrus nemurus	*Hemibagrus wyckii*	*Mystus nigriceps*

ω-6/ω-3 ratio	0.82 ± 0.00[a]	1.11 ± 0.02[b]	1.02 ± 0.01[c]
P/S ratio	0.69 ± 0.01[a]	0.61 ± 0.06[b]	0.76 ± 0.00[c]
AI	0.87 ± 0.01[a]	0.99 ± 0.06[b]	0.73 ± 0.00[c]
TI	0.40 ± 0.01[a]	0.63 ± 0.01[b]	0.43 ± 0.00[c]

P/S, polyunsaturated/saturated fatty acid; AI, atherogenic index; TI, thrombogenic index
Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

Table 4. Amino acid composition of three species of Bagridae fish

Amino acid	*Hemibagrus nemurus*	*Hemibagrus wyckii*	*Mystus nigriceps*
Aspartic acid	10.39 ± 0.01[a]	9.61 ± 0.04[b]	11.28 ± 0.02[c]
Glutamic acid	24.34 ± 0.00[a]	21.58 ± 0.41[b]	19.29 ± 0.03[c]
Serine	3.74 ± 0.00[a]	5.40 ± 0.03[b]	7.50 ± 0.06[c]
Glycine	4.02 ± 0.00[a]	5.77 ± 0.04[b]	4.69 ± 0.02[c]
Histidine	2.39 ± 0.00[a]	2.90 ± 0.03[b]	2.21 ± 0.02[c]
Arginine	6.17 ± 0.01[a]	8.27 ± 0.03[b]	6.22 ± 0.03[c]
Threonine	4.49 ± 0.01[a]	4.19 ± 0.03[b]	4.39 ± 0.04[c]
Alanine	7.03 ± 0.00[a]	6.04 ± 0.02[b]	7.89 ± 0.01[c]
Proline	2.40 ± 0.00[a]	2.71 ± 0.01[b]	2.21 ± 0.02[c]
Tyrosine	3.91 ± 0.01[a]	3.29 ± 0.06[b]	3.82 ± 0.04[c]
Valine	3.73 ± 0.00[a]	4.02 ± 0.01[b]	3.85 ± 0.04[c]
Methionine	3.42 ± 0.00[a]	1.96 ± 0.02[b]	1.27 ± 0.03[c]
Cystine	0.87 ± 0.00[a]	0.76 ± 0.02[b]	0.75 ± 0.03[c]
Isoleucine	3.82 ± 0.001[a]	3.96 ± 0.003[b]	3.66 ± 0.002[c]
Leucine	6.15 ± 0.000[a]	6.69 ± 0.002[b]	6.28 ± 0.004[c]
Phenylalanine	5.13 ± 0.000[a]	6.03 ± 0.005[b]	5.18 ± 0.027[c]
Lysine	9.61 ± 0.001[a]	9.82 ± 0.026[b]	9.87 ± 0.003[c]

Values are mean % ± SE; *Values in the same row followed by different letters are significantly different ($p<0.05$).

4. Discussion

The results of this study provide important new information about the nutritional makeup of the studied species of Bagridae fish. The biometric measures of the fish yielded important information about their physical traits and health. Researchers are able to determine the average weight of fish at various lengths by examining the link between length and weight for a particular species. This knowledge is essential for understanding the trends in fish population growth, identifying potential shifts in growth rates over time, and assessing the general health and welfare of fish [29]. A variety of factors, including sex, age, maturity level, size, stomach fullness level, sampling strategies, sample sizes, and environmental circumstances, have an impact on fish health and the parameters that determine length–weight connections in fish [30]. However, none of these factors were considered in our study. In general, according to the theory put forth by Bagenal and Tesch [31], heavier fish of a given length are in better physiological condition. The condition factor is also used in fisheries science to compare the health, fatness, and condition of fish [32]. A condition factor of > 1 is favourable, indicating a good feed nutrition level and suitable living habitat [33]. Thus, based on the findings in this study, the Kampar Kanan River provides a suitable habitat for the fish, ensuring their accessibility and availability for community consumption.

The fish samples exhibited good nutritional profiles, with high amounts of proteins and lipids as well as moisture content contributing to their overall nutritional value, according to the results of proximate analysis and mineral composition (see Table 1). These results imply that the fish species studied provide a possible source of nutrients to solve issues with food security. The study of the mineral composition revealed the existence of critical minerals such as phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) in the fish samples in addition to proteins and lipids. All three Bagridae fish significantly differed from each other in terms of their crude ash content and mineral profile (see Table 1). However, in general, P and Ca are the two highest minerals found in all fish. Both of these macro minerals are good for human bone and tooth health, as key components of hydroxyapatite, the mineral matrix that provides strength and structure to bones and teeth [34].

In the current study, the meat of three species of Bagridae fish from the Kampar Kanan River in Indonesia was found to contain an abundance of microminerals such as Fe and Zn. *M. nigriceps* has been reported to exhibit higher mineral content, including of Fe and Zn. This species is categorized as a small indigenous fish (SIF) with a maximum standard length of approximately 10.29 cm. According to [35], SIFs are generally known to be rich in Ca, Fe, and Mn. On the other hand, scale flour from three species of freshwater fish, such as *Osphronemus goramy*, *Cyprinus carpio*, and *Oreochromis niloticus*, also contains high levels of macrominerals and microminerals [36].

In this study, all three Bagridae fish had a total fat content of approximately 7–8% by weight, with a higher water content ranging from 82.40–85.39% (Table 1). These values are similar to those found in wild and cultured sea bass *Dicentrarchus labrax* [37]. Additionally, the fish species can be grouped into different categories, including high-fat fish (>8%), medium-fat fish (4–8%), low-fat fish (2–4%), and lean fish (<2%) [38]. According to the classification established by [38], the three indigenous Bagridae fish species are characterized as having a moderate fat content level, which is reflected by the high levels of DHA and EPA in the meat of *H. nemurus*, *H. wyckii*, and *M. nigriceps* (Table 2). Therefore, we recommend that consuming the meat of these three fish species can indirectly boost food security in rural and urban communities.

All three Bagridae fish species analysed in the study contained arachidonic acid (C20:4), at 12.13% for *H. nemurus*, 12.49% for *H. wyckii*, and 12.41% for *M. nigriceps*. Arachidonic acid serves as a precursor for synthesizing prostaglandins and leukotrienes [39]. Leukotrienes are crucial in allergic responses, inducing smooth muscle contraction and increasing vascular permeability [40]. Additionally, all three species also contained EPA ranging from 1.35–2.34% and DHA ranging from 11.56–15.65%. The increased consumption of omega-3 fatty acids, such as EPA and DHA, has been linked to a decreased risk of pain development in older individuals and to the prevention of Alzheimer's disease [41,42].

As determined by the current study, the ω-6/ω-3 ratios of the three Bagridae fish species ranged from 1:0.8 to 1:0.97. It was found that all three fish species had ω-6/ω-3 ratios within the recommended range for a typical Indonesian diet. In contrast, a typical Western diet is characterized by a high ω-6/ω-3 ratio of 10:1 to 20:1, while a Mediterranean diet has a ratio of 4:1 to 5:1 [43]. Additionally, the P/S ratio analysis showed that the three Bagridae fish species are sources of PUFAs that meet the requirements for food safety.

The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have recommended AI and TI values ranging from 0.4 to 0.5 for promoting human health [44].

In the current study, the observed AI values in the three freshwater species of Bagridae ranged from 0.73 to 0.99, while the TI values varied between 0.40 and 0.63. This finding is associated with a notable disparity in the values of SFAs among the three Bagridae fish species. Based on these findings, we confirm that consuming the meat of the three freshwater species of Bagridae fish caught in the wild does not endanger consumer health and can serve as a suitable source of food safety and nutritional quality.

Fish with a high crude protein content, as shown by the three studied Bagridae fish (Table 1), are regarded as being nutritionally useful for human health. The protein and amino acid contents can directly indicate the nutritional quality of meat [45]. As shown in Table 4, *H. wyckii* had a higher content of essential amino acids (EAAs) than *H. nemurus* and *M. nigriceps*. Among the EAAs, lysine (Lys) was found to be present in the highest amount in all three species. Lys is necessary for tissue growth and repair, reduced stress-induced anxiety, and the conversion of fatty acids into energy [46-48].

More than 60% of the amino acid composition in all three Brigade fish studied comes from nonessential amino acids (NEAAs), particularly glutamic acid (Table 4). Glutamic acid and its amine, glutamine, are highly abundant amino acids found in fish in the free and protein-bound forms [49]. Other amino acids found at abundant levels in the three fish also play important physiological and biochemical functions. The NEAA arginine, for example, is involved in protein synthesis, creatine formation, and various other biochemical processes within the body. The EAAs leucine, phenylalanine, and methionine play important roles in the synthesis of nitric oxide, a molecule that can expand blood vessels [49].

4. Conclusions

The present study provides insightful information about the fatty acid and amino acid compositions, biometric measurements, proximate analysis, and mineral composition of three local freshwater species of Indonesian Bagridae fish. The findings show their potential as a nutrient-dense, sustainable food source that can support efforts to increase food security. These fish species might be incorporated into the local diet to increase nutrient intake and alleviate nutritional inadequacies, which would ultimately improve Indonesia's overall food security status.

Data Availability

The data utilized in this research has not been previously released or published in any form. The datasets employed and/or analysed during the present study can be obtained by contacting the corresponding author.

Conflicts of Interest

The authors confirm that they do not have any conflicting interests.

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Dear Dr. Hafrijal,

I am pleased to let you know that the first set of galley proofs of your Research Article 6639837 titled "Analysis of Fatty Acids and Amino Acids of Three Local Freshwater Bagridae Fish Species in the Kampar Kanan River, Indonesia for Food Security," is ready. You can apply your corrections directly to the manuscript with the Online Proofing System (OPS).

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Best regards,

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hafrizal syandri <syandri_1960@bunghatta.ac.id> Fri, Dec 29, 2023 at 10:26 AM
To: International Journal of Food Science <production.a@hindawi.com>

Dear,
Hindawi Production Team
Thank you for your email on Dec 27, 2023. The author has checked the galley proofs Manuscript no. 6639837 and agree to publish.

Best regards
Hafrijal Syandri

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