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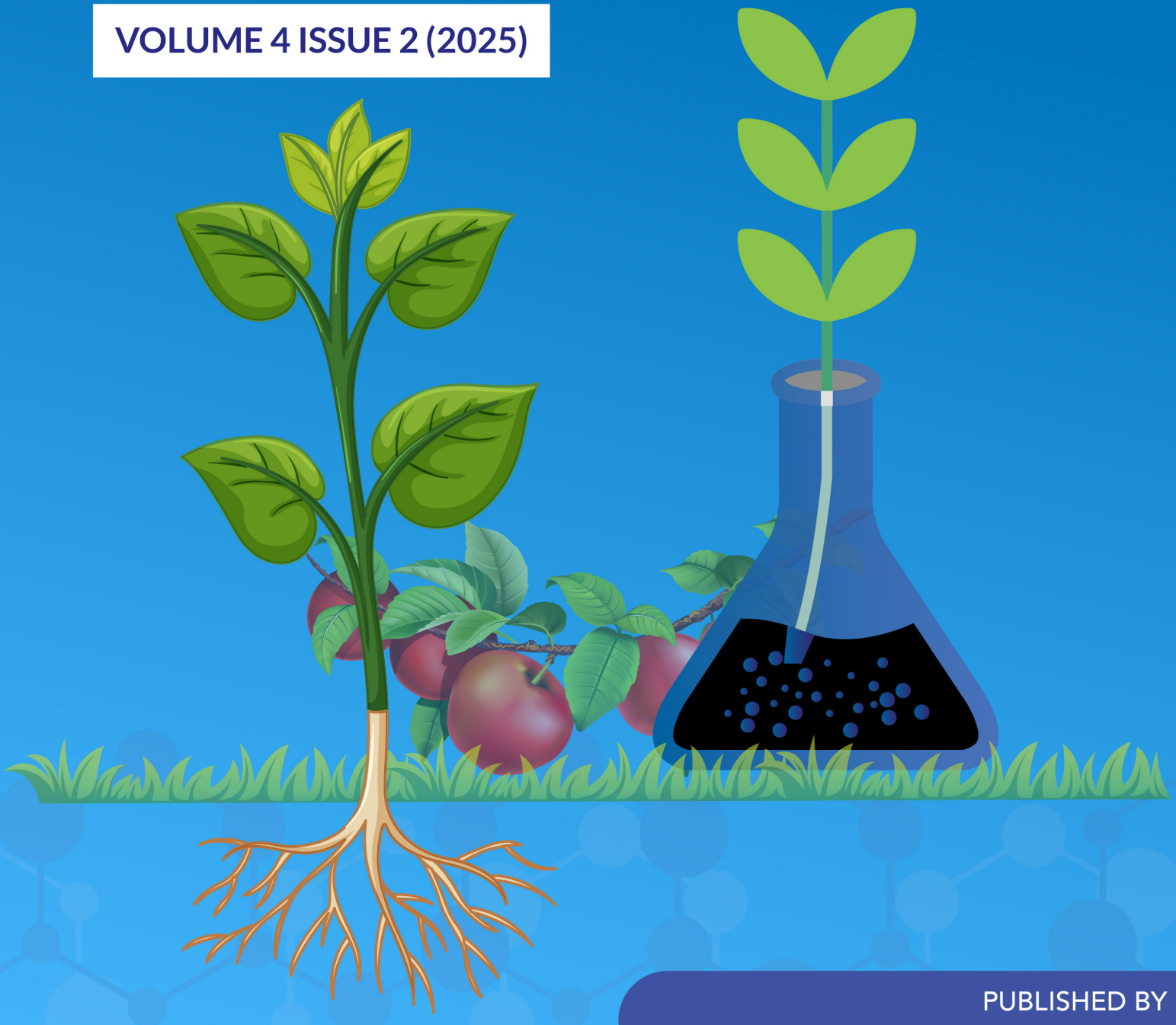

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Nutritional and Biochemical Evaluation of Wild Marine Fishes *Lates calcarifer* and *Alepes djedaba* from Cox's Bazar, Bangladesh

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ABSTRACT

Marine fish are crucial for human nutrition, as they include high-quality protein, necessary amino acids, polyunsaturated fatty acids (PUFAs), and accessible minerals. This study examined the nutritional and biochemical content of two economically important wild marine fish species, Asian seabass (*Lates calcarifer*) and shrimp scad (Alepes djedaba), obtained from artisanal landings in Cox's Bazar, Bangladesh, during the 2025 monsoon. Analyses were carried out using standard protocols and advanced instrumentation. *L. calcarifer* had somewhat less protein (21.1 ± 0.6%) and more lipid (2.5 ± 0.3%) than *A. djedaba* (22.0 ± 0.7% protein, 1.5 ± 0.2% lipid). The fatty acid profile revealed that *L. calcarifer* was high in polyunsaturated (53.0%) and monounsaturated (44.4%) fatty acids but low in saturated fatty acids (2.6%), resulting in minor index of atherogenicity (IA: 0.01) and index of thrombogenicity (IT: 0.01). In contrast, *A. djedaba* contained more saturated fatty acids (69.0%), as well as alpha-linolenic acid (4.2%) and eicosapentaenoic acid (4.6%), resulting in higher IA (2.03) and IT (1.01). Amino acid analysis revealed greater essential amino acids in *L. calcarifer* (~220 mg/g protein) than in *A. djedaba* (~135 mg/g protein). In contrast, mineral profiling showed *A. djedaba* contained high phosphorus (21,000 mg/100 g) and potassium (12,000 mg/100 g), and *L. calcarifer* had higher microminerals. Principal Component Analysis identified amino acids and minerals as the primary differentiating factors. Overall, *L. calcarifer* delivers superior amino acids and cardioprotective fatty acids, whereas *A. djedaba* provides rich macrominerals, implying that including a variety of marine fish species in diets can improve nutrition and food security.

INTRODUCTION

Fish is a vital component of human diets worldwide, particularly in regions where food insecurity, protein shortages, and micronutrient deficiencies are prevalent. In addition to providing almost 20% of the average amount of animal protein consumed by over 3.3 billion people worldwide, fish are an important source of essential amino acids (EAAs), long-chain omega-3 polyunsaturated fatty acids (PUFAs), and highly bioavailable micronutrients like calcium, zinc, iron, selenium, and iodine (FAO, 2020). According to Bogard *et al.* (2015) and Tacon & Metian (2013), these nutrients help prevent cardiovascular disease, promote neurological and cognitive development, boost immunity, and lessen the effects of micronutrient shortages or "hidden hunger." Marine fish both tiny pelagic and large demersal species are essential to public health and nutritional resilience in low- and middle-income countries (LMICs), such as Bangladesh, because they are frequently the most readily available and socially acceptable animal-source diets (Rifat *et al.*, 2023).

One of the highest rates of fish intake per capita among LMICs is seen in Bangladesh (Bogard *et al.*, 2015), a deltaic nation with abundant inland and marine water resources. Fish is deeply ingrained in the nation's socioeconomic, nutritional, and cultural systems, accounting for approximately 60% of the country's animal protein intake (DoF, 2023). The Bay of Bengal's most abundant marine and estuarine ecosystems may be found in the southeast coastal region, especially around Cox's Bazar. These ecosystems support a wide variety of finfish and shellfish species, which help artisanal fishing communities make a living (Manusher Jonno Foundation, 2021; Sadia *et al.*, 2022). Among the region's commercially important marine fish, *Lates calcarifer* (commonly known as barramundi or Asian seabass, locally "koral" or "red koral") and Alepes djedaba (shrimp scad, locally "pata kauya") hold substantial dietary and economic value (Belton *et al.*, 2011).

Large, carnivorous, and euryhaline, *L. calcarifer* is found in brackish, coastal, and estuary marine environments in the tropical Indo-West Pacific (Jerry, 2013). It commands premium market prices due to its big size, firm texture, and palatability. During the post-monsoon season in Bangladesh, when nutrient-rich runoff boosts primary productivity, its abundance peaks in estuarine ecosystems (Haque *et al.*, 2020). *A. djedaba*, on the other hand, is a small to medium-sized pelagic fish that is found in tropical and subtropical Indo-Pacific waters. It belongs to

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the Carangidae family (Majeed *et al.*, 2022). This species' flavor, tender flesh, and versatility in preparation make it reasonably priced, year-round, and widely consumed in both coastal and interior regions (Sajana & Nandan, 2019). Despite the widespread consumption of both species, little is known about their nutritional makeup, especially when it comes to populations that are wild-caught from Bangladesh's maritime seas. The majority of research on *L. calcarifer* to date has been conducted in aquaculture populations, where controlled conditions, stocking densities, and prepared diets affect nutrient profiles (Farhaduzzaman *et al.*, 2023; Mostofa *et al.*, 2023; Yasmin *et al.*, 2023; Seafood Network Bangladesh, 2024). Comparably, the majority of the research on *A. djedaba* that is currently available comes from other regions and is not very applicable to Bangladeshi stocks, which may have different biochemical compositions because of changes in prey availability, habitat-specific feeding ecology, and seasonal environmental variability (Sirot *et al.*, 2008; Ullah *et al.*, 2022). Compared to their farmed counterparts, wild marine fish typically have higher amounts of omega-3 fatty acids, better amino acid balance, and greater mineral diversity, highlighting the significance of region-specific assessments (Sarah *et al.*, 2020; Willer *et al.*, 2024).

Therefore, generating robust, species- and habitat-specific nutritional data is critical for several reasons: (i) to guide consumer education and encourage the consumption of nutrient-rich marine fish; (ii) to support nutrition-sensitive fisheries management and sustainable exploitation strategies; and (iii) to inform dietary planning and public health nutrition interventions in coastal and inland communities. These findings also offer a scientific foundation for assessing these species' capacity to satisfy the 0.8 g of protein per kilogram of body weight that the World Health Organization (WHO) recommends adults consume daily, with higher needs for children, pregnant women, and physically active people (Joint WHO/FAO/UNU Expert Consultation, 2007). Given the great biological value of fish protein, even moderate consumption of these species might significantly improve Bangladesh's food quality and meet the country's necessary amino acid demands.

Thus, the present study was undertaken to evaluate the proximate composition, amino acid and fatty acid profiles, and mineral content of wild-caught *L. calcarifer* and *A. djedaba* from the Cox's Bazar coast, Bangladesh. The results will set baseline nutritional information for these species, evaluate how well they contribute to achieving recommended protein intakes, and offer proof of their contribution to improving food and nutrition security at the national and regional levels.

MATERIALS AND METHODS

Sample Collection and Preparation

Fifteen adult fish of each species (*Lates calcarifer* and *Alepes djedaba*) were collected from artisanal landings at Cox's Bazar Sadar coast, Bangladesh, in July-August 2025 (monsoon season). Fish were cleansed of any surface material as soon as they were collected, put on ice in insulated styrofoam crates, and then taken to the Hatchery of Chattogram Veterinary and Animal Sciences University (CVASU) Cox's Bazar campus, for primary processing within 4 hours. Biometric traits of samples were recorded at the Hatchery lab immediately. The fish sample of each species was split into three groups, each having five fish. A pool sample of each group was collected and used as a replicate sample. The fish samples were cleaned in distilled water and filleted, and the meat was chopped before being dried to a consistent weight in an oven with heated air at 60^0 C. Before micronutrient analysis, the dried samples were crushed into a fine powder and preserved in sealed plastic bags at 4 ◦C. Proximate compositions of the powdered samples were analyzed at the Nutrition Lab of CVASU, Chittagong, while fatty acid, amino acid, and mineral analyses were conducted at the Institute of Technology Transfer and Innovation of the Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh, using established protocols and advanced instrumentation.

Biometric Traits and Proximate Composition

Every specimen's total body weight (g) and length (cm) were measured at the lab and recorded to the closest 0.01 g and 0.1 cm, respectively. The results were then displayed as mean ± standard deviation.

The AOAC technique (1995) was used to determine the proximate compositions (protein, lipid, ash, carbohydrate, and moisture) of collected koral and shrimp scad fish samples. To summarize, moisture content (5 g each sample) was evaluated by drying the sample at 105°C overnight until a consistent weight was achieved. The Kjeldahl method (N × 6.25) was used to quantify crude protein concentration in homogenized samples (0.5 g) following acid digestion, distillation, and titration. To measure lipid content, 2 g of wet homogenized samples were placed in a crucible thimble and extracted with petroleum ether (boiling point 100° C) for 1 hour using a Soxhlet apparatus (LSFA-A10, Labtron, UK). After lipid extraction, the solvent was evaporated, and the extracted lipid was dried in a hot oven at 105 °C, cooled in a desiccator, and weighed. Lipids were measured gravimetrically, and lipid content was estimated as the fat percentage relative to the initial dry sample weight. The ash content of samples (4 g each) was tested using a Muffle furnace at 550 °C for 4 hours. The carbohydrate content of each sample was calculated by subtracting the protein, fat, ash, and moisture content from 100. All analyses were performed in triplicate from three pooled samples of each fish species, and the results were expressed on a wet weight basis and on average:

Moisture (%) = [(wet sample weight – dried sample weight)/ wet sample weight] × 100

Crude protein (%) = % nitrogen (N) × 6.25

% nitrogen = [milliequivalent of nitrogen (0.014) × titrant value (ml) × strength of HCl / sample weight] × 100

Crude lipid (%) = (weight of lipid/ weight of sample) × 100

Ash (%) = (weight of ash/ weight of sample) × 100
Carbohydrates (%) = 100 - (moisture – lipids – proteins - ash)

Fatty Acids Measure

Fatty acid composition was determined using gas chromatography with a flame ionization detector (GC-FID, GC6000, SciencePower, China). The fat content of each dried powdered sample was extracted in a combination of methanol (CH_3OH) and chloroform ($CHCl_3$) (v/v = 1:2 ratio) with 0.1 mg per 100 g of butylated hydroxytoluene. Next, 200 mg of fat sample was added to each 10 ml test tube, followed by 3.5 ml of 0.5 M sodium methoxide (CH_3ONa). Following that, the mixtures were heated on the burner to remove bubbles before adding 1.5 ml of n-hexane and homogenizing consistently with the vortex mixture. To speed up the phase separation of fat content, 5 ml of deionized water was gently added to the mixtures. After giving appropriate time for phase separation, the superior layer was used to analyze fatty acids. The data were identified, quantified, and processed by comparing the withhold times to known fatty acid standards.

Amino Acids Measure

The amino acid content of each sample was evaluated using an automatic amino acid analyzer (Sykam S4300, GmBH, Germany). The powder samples were first treated with 25 ml of 7N HCl, homogenized uniformly, and filtered to remove insoluble materials before being hydrolyzed in the hydrolyzer for 24 hours. After the hydrolysis, leftover HCl was neutralized with 7.5 N NaOH and measured using a pH meter (Sension TM 156, HACH, USA). The sample volumes were increased to 250 ml in calibrated volumetric flasks using a buffer solution with a pH of 3.4. After filtration via a 0.45 µm pore-sized filter paper, 1 ml of the prepared sample, consisting of 100 µL sample solution and 900 µL of pH 3.4 buffer solution, was serially analyzed to detect amino acids. A standard amino acid solution was also evaluated at the same time for data comparison, quantity accuracy, and quality assurance purposes.

Minerals Measure

Mineral composition analysis was performed using the Agilent AA240FS Fast Sequential Atomic Absorption Spectrometer (Agilent Technologies, USA). Approximately 0.5 to 1.0 g of dried powdered sample was precisely weighed and placed in a Teflon digesting vessel. The sample was digested with 10 mL of concentrated nitric acid (HNO_3) and 2-3 mL of hydrogen peroxide (H_2O_2) using controlled microwave digestion (ramped to 180°C over 15 minutes and held for 30 minutes). After cooling, the digested solution was diluted with 50 mL of deionized water. Calibration standards with known concentrations (0.1 to 10 mg/L) were prepared for each target mineral element. The AA240FS was outfitted with element-specific hollow cathode lamps, and appropriate flame and nebulizer settings were used. Approximately 10 mL of each sample solution was aspirated, and absorbance was measured in triplicate at characteristic wavelengths for each mineral. Blanks, verified reference materials, and replication samples were analyzed to guarantee quality control, with relative standard deviations of less than 5%. Mineral concentrations were estimated using interpolation from calibration curves and represented in mg per 100 g dry weight.

Statistical Analyses

The biometric traits (length and weight) of *L. calcarifer* and *A. djedaba* were analyzed using descriptive statistics, including means and standard deviations (SD). Variations in proximate composition of fish were analyzed using one-way ANOVA followed by Tukey's HSD post hoc for multiple comparisons, with statistical significance set at $P < 0.05$. Comparative figures on the fatty acid composition, amino acid composition, and mineral contents between two species were generated using R software. Principal Component Analysis (PCA) was applied to investigate multivariate patterns in the key nutrient groups (fatty acids, amino acids, and minerals), as well as to visually analyze species-specific variations in nutritional composition. The first two principal components (PC1 and PC2) explained the majority of the variation, enabling qualitative differentiation between *L. calcarifer* and *A. djedaba*.

RESULTS AND DISCUSSION

Biometric Traits and Proximate Composition

The biometric measurements of the harvested *L. calcarifer* and *A. djedaba* fish species are shown in Table 1. The mean total length and weight of *L. calcarifer* were 42.2 ± 4.20 cm and 900 ± 20 g, respectively, while *A. djedaba* specimens measured 33.2 ± 1.08 cm in length and 500 ± 10 g in weight. All measurements represent mean values ± standard deviation (SD).

These observations are consistent with previous research highlighting *L. calcarifer* as a fast-growing predatory species widely farmed for its adaptability to aquaculture systems (Jerry, 2013; Venkatachalam *et al.*, 2018), whereas *A. djedaba* plays a significant ecological role as a mid-trophic species with lower per-individual economic importance (Sivakami, 1990).

Table 1: Biometric traits of the two fish species

English name	Local Name	Scientific Name	Length (cm)	Weight (g)
Barramundi/ Asian seabass	Koral	*Lates calcarifer*	42.2 ± 4.20	900 ± 20
Shrimp scad	Icha mouri/Pata kauya	*Alepes djedaba*	33.2 ± 1.08	500 ± 10

Values are mean ± standard deviation; n = 15 fish per species

The proximate composition analysis revealed notable biochemical differences between the two species (Table 2), reflecting distinct nutritional profiles. *A. djedaba* had substantially greater moisture content (74.4 ± 1.8%) than *L. calcarifer* (71.4 ± 1.5%) ($P < 0.05$), suggesting that the former had leaner muscular tissue. This finding is consistent with that of Sajana and Nandan (2019), who found that leaner species tend to have higher water percentages in their muscle tissue, which are inversely correlated with lipid content. Protein content was marginally higher in *A. djedaba* (22.0 ± 0.7%) than in *L. calcarifer* (21.08 ± 0.6%), with both species representing high-quality protein sources enriched in essential amino acids (FAO/WHO, 1991; FAO, 2019; Sajana and Nandan, 2019). These findings demonstrate both species' capacity to significantly increase dietary protein intake, especially in areas where malnutrition is still a problem. A considerable difference was found in the amount of lipids, with *L. calcarifer* having far greater quantities (2.5 ± 0.3%) than *A. djedaba* (1.5 ± 0.2%) ($P < 0.05$). *L. calcarifer*'s lipid-rich profile indicates that it is a nutritious dietary source that is high in important fatty acids, particularly omega-3 polyunsaturated fatty acids (PUFAs), which are well known for their cardioprotective qualities (Pervin *et al.*, 2012; Sikder *et al.*, 2025). As a result, customers looking for dietary fat sources may favor *L. calcarifer*, whereas low-fat diets may benefit from the leaner *A. djedaba* (Sajana and Nandan, 2019).

Ash content, reflecting mineral composition, was comparable in both species (1.2 ± 0.1% in *L. calcarifer* and 1.1 ± 0.1% in *A. djedaba*), consistent with findings by Islam *et al.* (2012), which emphasized the relatively uniform mineral content in marine fish species. Carbohydrate content was below 1% in both species, as expected for fish muscle predominantly relying on proteins and lipids for energy metabolism (Wilson, 2003).

Table 2: Proximate Composition (% of wet weight basis) of the two fish species

Fish species	Moisture	Protein	Lipid	Ash	Carbohydrate
Barramundi	71.4 ± 1.5[b]	21.08 ± 0.6[a]	2.5 ± 0.3[a]	1.2 ± 0.1[a]	0.82 ± 0.05[a]
Shrimp Scad	74.4 ± 1.8[a]	22.00 ± 0.7[a]	1.5 ± 0.2 [b]	1.1 ± 0.1[a]	0.9 ± 0.05[a]

Values are mean ± standard deviation of three pooled samples. Different superscripts under each column indicate significant differences ($P < 0.05$).

Fatty Acid Composition

L. calcarifer and *A. djedaba*'s mean fatty acid composition differed significantly across individual fatty acids, major fatty acid groups, and lipid quality metrics (Figure 1-3).

Individual Fatty Acids

A thorough analysis of fatty acid profiles (Figure 1) highlighted the nutritional variations between species. Linoleic acid (C18:2, LA; 34.5%), oleic acid (C18:1; 19.0%), and gamma-linolenic acid (C18:3 n-6, GLA; 16.5%) dominated the lipid profile of *L. calcarifer*. These three acids are essential precursors in PUFA biosynthesis, supporting physiological processes like inflammation regulation and cell membrane integrity (Simopoulos, 2002). Conversely, *A. djedaba* showed comparatively larger amounts of saturated fatty acids (SFAs), including stearic acid (C18:0; 8.5%) and tetracosanoic acid (C24:0; 7.6%), but very low concentrations of LA (0.2%), oleic acid (1.3%), and GLA (0.2%). Essential omega-3 fatty acids, alpha-linolenic acid (C18:3 n-3, ALA; 4.2%) and eicosapentaenoic acid (C20:5, EPA; 4.6%), were significantly more abundant in *A. djedaba* than in *L. calcarifer* (<0.5%), aligning with prior studies that report species-specific fatty acid profiles influenced by dietary habits and environmental conditions (Sajana & Nandan, 2019; Gladyshev *et al.*, 2009). Interestingly, no docosahexaenoic acid (DHA) was found, which could be explained by trophic level, species-specific lipid metabolism, or the fatty acid makeup of the prey (Tocher, 2003).

Although polyunsaturated fatty acids (PUFAs) are necessary for many physiological processes, the n-6/n-3 ratio in *L. calcarifer* that was found in this study (93.84) was very high, indicating a possible nutritional imbalance if it is not supplemented with sufficient consumption of n-3 PUFAs from other sources (Simopoulos, 2002). Alpha-linolenic acid (18:3n-3; 0.39%) and eicosapentaenoic acid (20:5n-3, EPA; 0.16%) were among the n-3 PUFAs that were comparatively low in content in *L. calcarifer* (Figure 1). If *L. calcarifer* is ingested as the only or main source of dietary PUFA, the unbalanced n-6/n-3 ratio may provide a nutritional risk (Scaioli *et al.*, 2017). Excessive levels of n-6 fatty acids are already common in modern diets, and a higher ratio has been linked to non-communicable diseases and inflammatory conditions (Simopoulos, 2002; Hilton *et al.*, 2019; Mariamenatu *et al.*, 2021). Therefore, increasing the n-3 content and optimizing the nutritional profile may be achieved by changing the feeding schedules of fish to incorporate n-3-rich oils (such as fish oil or algae) or by diversifying the sources of PUFA.

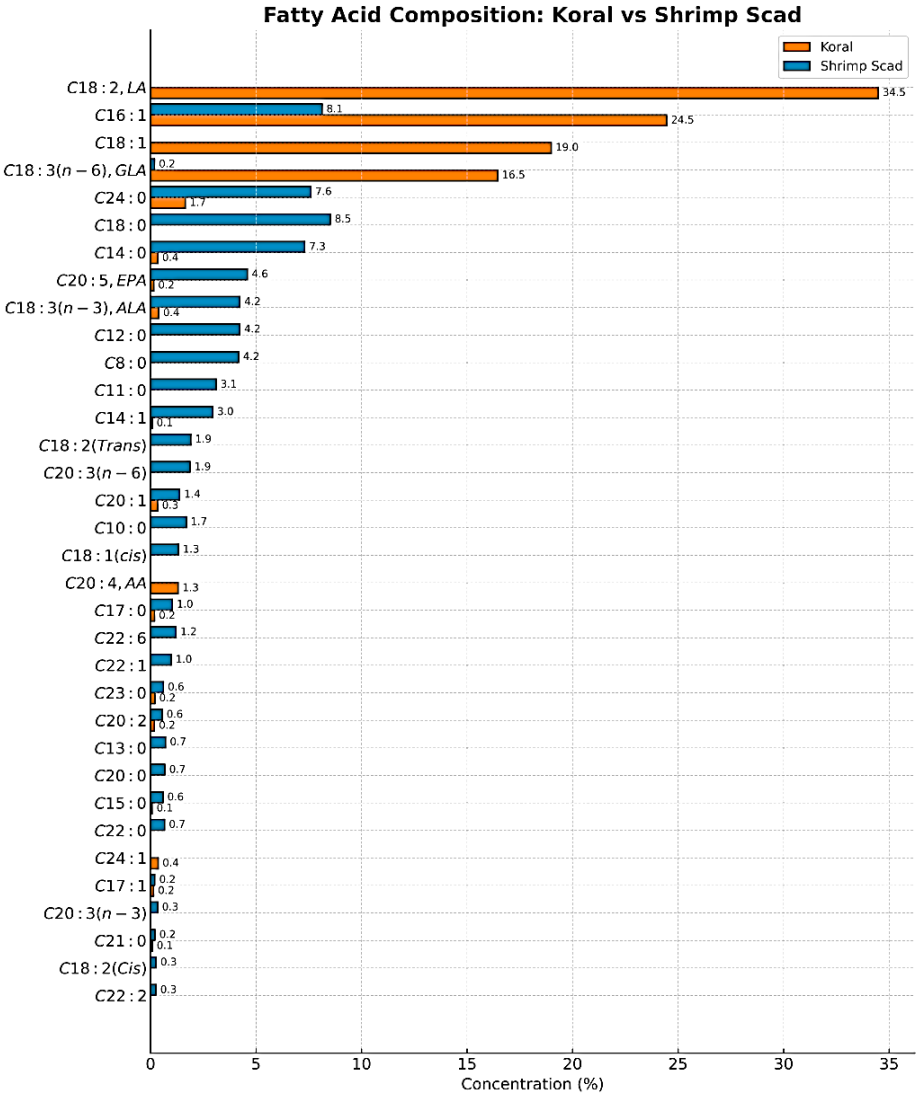

Figure 1: Fatty acid composition (% of total fat) in the muscle of koral and shrimp scad fish species. Values represent the mean of three pooled samples. Here, C8:0 = caprylic acid; C10:0 = capric acid; C11:0 = undecanoic acid; C12:0 = lauric acid; C13:0 = tridecanoic acid; C14:0 = myristic acid; C15:0 = pentadecanoic acid; C17:0 = heptadecanoic acid; C18:0 = stearic acid/octadecanoic acid; C20:0 = arachidic acid /eicosanoic acid; C21:0 = heneicosanoic acid; C22:0 = docosanoic acid; C23:0 = tricosanoic acid; C24:0 = tetracosanoic acid; C14:1 = myristoleic acid; C16:1 = palmitoleic acid; C17:1 = heptadecenoic acid; C18:1/C18:1(cis) = oleic acid; C20:1 = gondoic acid; C22:1 = erucic acid; C24:1 = nervonic acid; C18:2, LA = linoleic acid; C18:2 (Trans) = trans-linoleic acid; C18:2 (Cis) = cis-linoleic acid; C18:3 (n-6) = gamma linolenic acid (GLA); C18:3 (n-3) = alpha linolenic acid (ALA); C20:2 = eicosadienoic acid (EDA); C20:3 (n-6) = dihomo-gamma-linolenic acid (DGLA); C20:3 (n-3) = eicosatrienoic acid (ETE); C20:4, AA = arachidonic acid (AA); C20:5 = eicosapentaenoic acid (EPA); C22:2 = docosadienoic acid; C22:6, DHA = docosahexaenoic acid (DHA)

Fatty Acid Group

At the fatty acid group level, SFAs made up 69.0% of the total fatty acid content in *A. djedaba*, while they only made up 2.6% in *L. calcarifer*. According to Kris-Etherton *et al.* (2002), *L. calcarifer*'s low total SFA concentration supports a lower risk of cardiovascular illnesses by contributing to a good lipid quality index. In contrast, *L. calcarifer* exhibited considerably higher polyunsaturated (53.0%) and monounsaturated fatty acids (44.4%) than *A. djedaba* (15.5% and 15.0%, respectively) (Figure 2). It is well known that these MUFAs have anti-inflammatory and hypocholesterolemic properties, which help to improve metabolic profiles and regulate plasma lipid levels (Gillingham *et al.*, 2011; Coniglio *et al.*, 2023). The high 16:1 ratio is in line with findings for carnivorous marine finfish, which are frequently connected to endogenous synthesis pathways and dietary lipid sources (Bruno *et al.*, 2016). These results highlight the nutritional superiority of *L. calcarifer* in delivering unsaturated fatty acids, which are widely known to promote cardiovascular health (Brenna *et al.*, 2009; Mozaffarian & Wu, 2011; Calder, 2015).

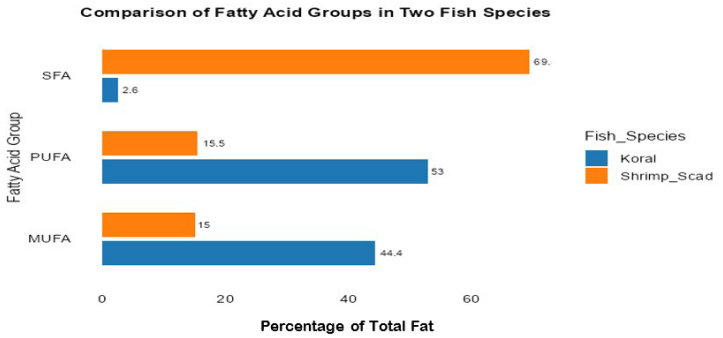

Figure 2: SFA, MUFA, PUFA comparison of fishes. Values represent the mean of three pooled samples. Here, SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids

Lipid Quality Indices (LQI)

Lipid quality indices mirrored the two species' distinct nutritional consequences (Figure 3). In *A. djedaba*, the index of atherogenicity (IA) and thrombogenicity (IT) were significantly higher (IA: 2.03; IT: 1.01), whereas in *L. calcarifer*, they were remarkably low (IA: 0.01; IT: 0.01) (Figure 3). The idea that *L. calcarifer* is a healthy food choice is supported by low IA and IT values, which indicate a lipid profile that presents little danger of encouraging atherogenesis and thrombosis (Ulbricht & Southgate, 1991). In contrast, the higher IA and IT in *A. djedaba* are consistent with its elevated SFA content, which is associated with an increased risk of cardiovascular disease when consumed in excess (Siri-Tarino *et al.*, 2010; Baum *et al.*, 2012).

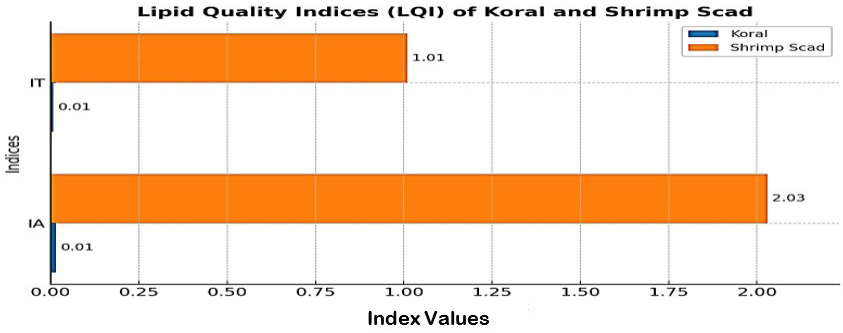

Figure 3: Lipid quality indices of two fish species. Values represent the mean of three pooled samples Here, IA = index of atherogenicity; IT = index of thrombogenicity

Collectively, the findings show that *L. calcarifer* is a good source of healthy fatty acids, especially PUFAs and MUFAs, which help to regulate lipid metabolism and have anti-inflammatory properties (Simopoulos, 2002; Pervin *et al.*, 2012). Despite having important polyunsaturated fats (PUFAs) like ALA and EPA, *A. djedaba*'s high SFA content and poor lipid quality indices indicate that it may offer limited health benefits if consumed in large quantities over extended periods (Sajana & Nandan, 2019).

Amino Acid Composition

The amino acid profiles in the muscle tissue of *L. calcarifer* and *A. djedaba* are thoroughly compared in this work (Figure 4-5). Amino acid composition plays a pivotal role in evaluating the nutritional and functional quality of fish proteins, which are increasingly valued as high-quality dietary protein sources (FAO, 2013; Ghosh *et al.*, 2017; Zhang *et al.*, 2021).

Individual Amino Acids

Non-essential amino acids (NEAAs), especially glutamic acid and aspartic acid, which are known to contribute to the taste and umami qualities of fish flesh (Misako *et al.*, 2002; Özden, 2005; Golam *et al.*, 2012), dominated the qualitative profiles of both species. According to quantitative analysis, *L. calcarifer* had somewhat more aspartic acid (67.148 mg/g protein) and substantially more glutamic acid (111.063 mg/g protein) than *A. djedaba* (66.399 mg/g protein and 100.650 mg/g protein, respectively) (Figure 4). These variations point to a possibly higher organoleptic quality in *L. calcarifer*, which is consistent with earlier findings that emphasize the function of glutamic acid in flavor improvement (Golam *et al.*, 2012; Sikder *et al.*, 2025). Aromatic amino acids, especially tyrosine, were higher in *L. calcarifer* (17.67 mg/g) than in *A. djedaba* (12.50 mg/g), aligning with the view that marine fish often provide substantial precursors for neurotransmitter synthesis (Fernstrom & Fernstrom, 2007). Notably, *A. djedaba* had significantly greater levels of cystine and proline (26.564 mg/g protein and 25.884 mg/g protein, respectively) than *L. calcarifer* (5.715 mg/g and 17.394 mg/g) (Figure 4). Given that cystine is a precursor of glutathione, a crucial cellular antioxidant, *A. djedaba*'s high cystine content may help explain its antioxidant potential (Wu *et al.*, 2014). Increased amounts of proline and cystine also suggest possible functional

advantages in specific dietary applications, such as promoting skin health or serving as an additional source of amino acids in food formulations (Wu, 2010; Zhang *et al.*, 2021).

In terms of essential amino acids (EAAs), Leucine (40.996 mg/g protein), lysine (56.887 mg/g protein), and threonine (28.547 mg/g protein) concentrations were consistently greater in *L. calcarifer* than in *A. djedaba* (27.037 mg/g, 36.335 mg/g, and 20.178 mg/g, respectively) (Figure 4). These amino acids are essential for human nutrition because they support immunological response, metabolic homeostasis, and muscle protein synthesis (FAO/WHO, 2013; Wu, 2016). *L. calcarifer* had nearly twice as much methionine (19.28 mg/g) as *A. djedaba* (9.13 mg/g), indicating that it offers a more balanced sulfur amino acid profile that is crucial for methylation and antioxidant defense (Li *et al.*, 2009). Overall, *L. calcarifer*'s EAA content scored well against FAO/WHO reference amino acid scoring patterns, suggesting a complete protein profile appropriate for people of all ages, including young children, the elderly, and those with higher protein needs (Harper, 1981).

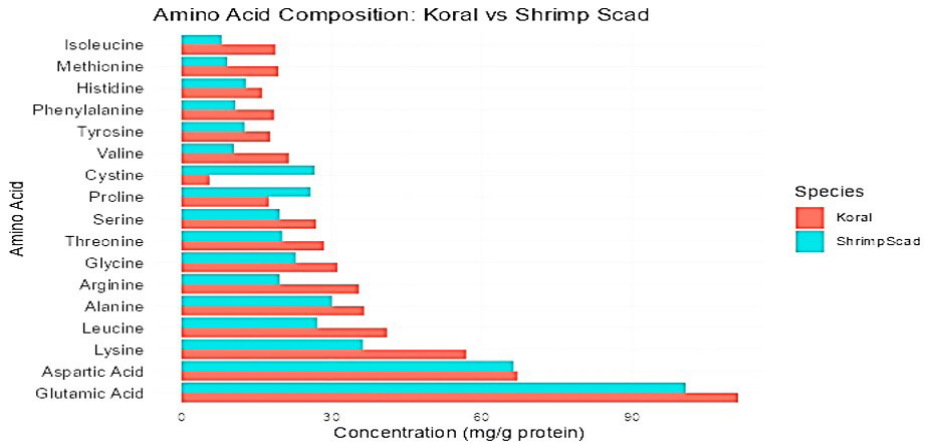

Figure 4: Amino acid composition (mg/g protein) in the muscle of koral and shrimp scad fish species. Values represent the mean of three pooled samples

Essential vs. Non-Essential Amino Acids

At the aggregated level (Figure 5), the *L. calcarifer* muscle had a total EAA content of around 220.847 mg/g protein, which was significantly higher than that of *A. djedaba* (134.859 mg/g protein). In a similar vein, *L. calcarifer* had a greater NEAA content (349.359 mg/g protein) than *A. djedaba* (324.481 mg/g protein) (Figure 5). The overall balance of EAAs to NEAAs in *L. calcarifer* was superior, consistent with the amino acid scoring pattern proposed by WHO/FAO for evaluating protein quality (FAO/WHO, 2013). This elevated EAA and NEAA content suggests a higher biological value of *L. calcarifer* protein, rendering it a more balanced and nutritionally favorable option for human consumption (FAO/WHO, 1991; Reddy *et al.*, 2019).

These findings collectively imply that although both species provide valuable amino acids, *L. calcarifer* has a more nutritionally favorable profile with higher EAA content, especially leucine, lysine, and methionine, while *A. djedaba* stands out for having higher cystine and proline, which may have an impact on connective tissue integrity and collagen metabolism (Karna *et al.*, 2020). These results are consistent with other research on tropical marine fish that shows species-specific variations in amino acids related to diet, metabolic physiology, and environment (Venugopal & Shahidi, 1996; Syed *et al.*, 2020; Kumar *et al.*, 2024; Traina *et al.*, 2024).

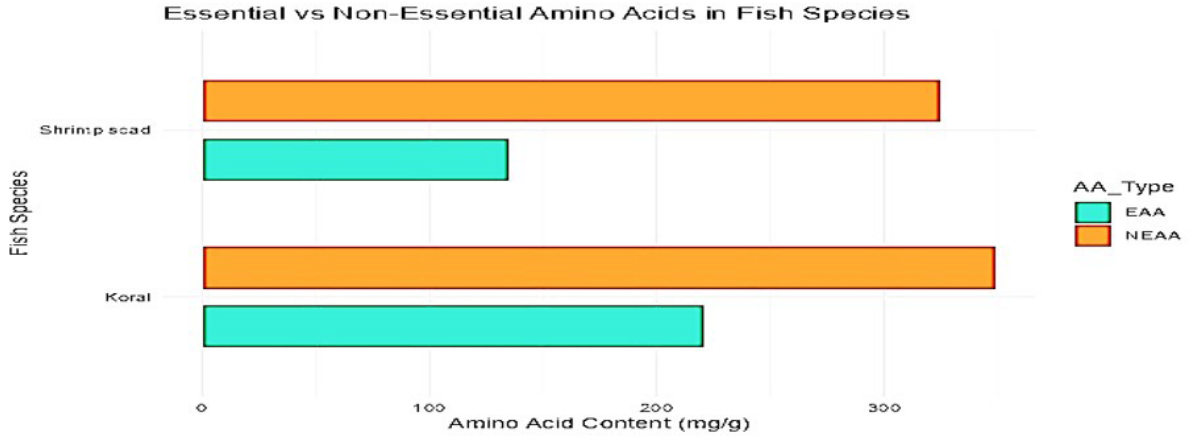

Figure 5: Essential amino acids (EAA) and non-essential amino acids (NEAA) (mg/g protein) in koral and shrimp scad fish species. Values represent the mean of three pooled samples.

Mineral Composition

The mean mineral composition of muscle tissues from *L. calcarifer* and *A. djedaba* fish species is presented in Figure 6. Mineral concentrations were determined on a dry weight basis (mg/100 g) and plotted using a log10 scale to accommodate the wide range of concentration values and enable clearer comparison.

The result demonstrated significant interspecific differences in both macromineral and micromineral concentrations between two species (Figure 6). In *L. calcarifer*, micromineral contents were higher than *A. djedaba*, with Fe recorded at 22.18 mg/100 g, Cu at 16.11 mg/100 g, K at 20.37 mg/100 g, P at 10.91 mg/100 g, Zn at 10.70 mg/100 g, and Mn at 1.45 mg/100 g. According to earlier research on the mineral profiles of marine fish species, these microminerals are necessary for metabolic processes like hemoglobin synthesis (Fe), antioxidant enzymes (Zn and Mn), and enzymatic reactions (Cu) (FAO/WHO, 2001; FAO, 2019; Lall *et al.*, 2021; Frydrych *et al.*, 2023).

As opposed to *L. calcarifer*, *A. djedaba* showed a remarkably distinct profile with extraordinarily high macromineral concentrations, including P at 21,000 mg/100 g and K at 12,000 mg/100 g, which were roughly three orders of magnitude higher. *A. djedaba*'s high P and K levels may be an indication of adaptation to particular environmental factors, such as sediment composition or brackish water environments, which are known to affect mineral bioavailability (Scott *et al.*, 2001; Hamza *et al.*, 2019). Similarly, eutrophication and environmental deterioration in aquatic ecosystems are associated with excessive phosphorus discharge, according to Kuldeep *et al.* (2015) and Hamza *et al.* (2019). Even though these high macromineral concentrations might be essential for energy metabolism, osmotic control, or skeletal growth, the possible physiological and environmental effects of such high P levels call for more research (Graham Sustainability Institute, 2025). Conversely, the micromineral levels were lower: Cu (11 mg/100 g), Fe (4.15 mg/100 g), Zn (1.5 mg/100 g), and Mn (0.8 mg/100 g). This discrepancy likely reflects species-specific differences in mineral accumulation due to dietary choices, environmental conditions, or physiological adaptations (Bayissa *et al.*, 2021; Lall *et al.*, 2021; Rodrigues *et al.*, 2021; Khawar *et al.*, 2024).

These findings scientifically validate *L. calcarifer* as a valuable dietary source of key microminerals such as Fe, Zn, Cu, and Mn, all of which play important roles in human metabolic processes. The relatively greater micromineral concentrations observed in *L. calcarifer* compared to *A. djedaba* highlight its nutritional significance, consistent with previous reports (Kamruzzaman *et al.*, 2015; Rahman *et al.*, 2019; Rifat *et al.*, 2023; Ghosh *et al.*, 2024; Kanij *et al.*, 2025). This underscores the potential of *L. calcarifer* as a key component in correcting micronutrient deficiencies in human diets.

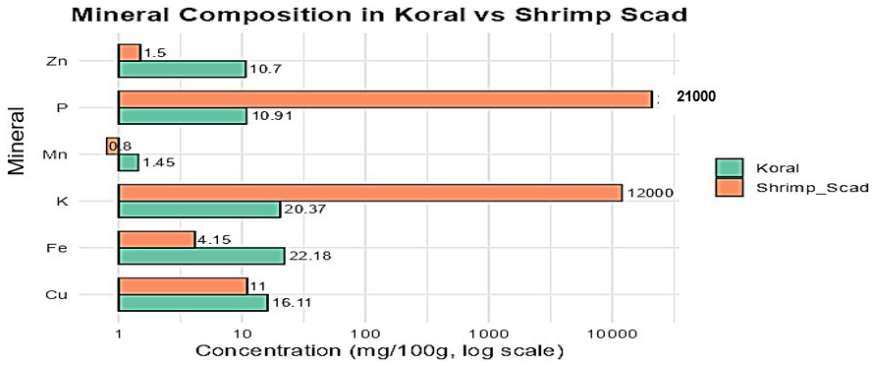

Figure 6: Mineral composition (mg/100 g dry weight) in the muscle of koral and shrimp scad fish species. Values represent the mean of three pooled samples and were converted to log10 scale for improved visualization of the wide concentration range. Here, Cu = Copper; Fe = Iron; Zn = Zinc; Mn = Manganese; P = Phosphorus; K = Potassium

Correlation of Major Amino Acid Groups, Fatty Acid Groups, and Vital Minerals between Species

A principal Component Analysis (PCA) was conducted to compare the patterns of variation in main nutritional groups—amino acids, fatty acids, and minerals—between the *L. calcarifer* and *A. djedaba* fish species (Figure 7). The PCA intended to reduce dimensionality and identify critical variables that contributed to species differences based on nutritional profiles. The first principal component (PC1) accounted for 60.8% of the overall variance, showing that it captured the majority of the variation in nutritional content among species. The second main component (PC2) accounted for 39.2% of the variation, further separating the nutritional groups (Figure 7).

Essential Amino Acids (EAA) and non-essential Amino Acids (NEAA) had significant positive loadings along PC1 and PC2, clustering together and showing a high correlation. These amino acids made a major contribution to species differentiation, particularly promoting separation along the positive axis of PC1 and PC2. *L. calcarifer* and *A. djedaba* both showed significant quantities of amino acids; however, the PCA indicated that *L. calcarifer* had a greater amino acid content, which contributed to this pattern. This aligns with the finding by Kamruzzaman *et al.* (2015), who reported high amounts of essential amino acids in muscles of *L. calcarifer*.

Conversely, monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) clustered together

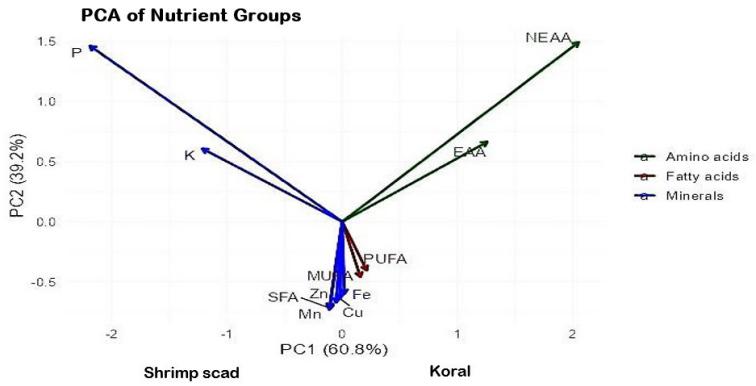

Figure 7: PCA plot of major amino acid groups, fatty acid groups, and vital minerals of koral and shrimp scad fish species. Here, SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; EAA = essential amino acids; NEAA = non-essential amino acids; Cu = Copper; Fe = Iron; Zn = Zinc; Mn = Manganese; P = Phosphorus; K = Potassium

and had moderate loadings on PC1 and slightly negative loadings on PC2. These fatty acids mostly contributed to differentiation along PC1, although their impact was less substantial when compared to amino acids and minerals. The PCA suggested that *L. calcarifer* had slightly higher MUFA and PUFA content than *A. djedaba*, as indicated by the direction of the vectors. These results are consistent with the findings of Chan *et al.* (2021), who reported that the tissue oil of *L. calcarifer* contained high levels of monounsaturated fatty acids (MUFA), particularly oleic acid. In contrast, Purushothaman *et al.* (2024) found a different result in their experiment that koral fish muscle contained less PUFA and SFA than another marine fish malabar red snapper (Lutjanus malabaricus).

Vital minerals such as P, K, Fe, Zn, Mn, and Cu were tightly clustered with high negative loadings along PC1 and PC2. Phosphorus and potassium had very high loadings along PC2, indicating a considerable contribution to differentiation along this axis. The PCA indicated that *A. djedaba* was more enriched in vital minerals than *L. calcarifer*, particularly with higher P and K content, which drove the separation toward the negative side of PC1 and positive PC2. A similar finding was also reported by Sajana and Nandan (2019) that *A. djedaba*, regardless of their sexes, was enriched with important minerals, especially P and K.

Overall, the comparative investigation revealed that amino acids and minerals played key roles in the differentiation of *L. calcarifer* and *A. djedaba* species. *L. calcarifer* contained more amino acids (NEAA and EAA) and minerals, whereas *A. djedaba* had a higher concentration of saturated fatty acids (SFA). This nutrient profiling using PCA highlights species-specific nutritional advantages, with implications for dietary recommendations and aquaculture strategies.

Limitation of the Study

This investigation was hampered by seasonal and logistical constraints. All specimens were obtained during a single monsoon season, and financial constraints precluded multi-seasonal sampling, limiting the research to a snapshot of biochemical composition. Future studies should encompass multiple seasons to capture temporal fluctuations in proximate composition, fatty acids, amino acids, and mineral profiles, resulting in a more complete understanding of these species' nutritional dynamics.

CONCLUSION

This study revealed significant nutritional differences between *L. calcarifer* and *A. djedaba*, two major wild marine fish species of Bangladesh's Cox's Bazar coast. *L. calcarifer* was discovered to have a healthier lipid profile, including higher levels of unsaturated fatty acids and necessary amino acids, making it an excellent source of protein and lipids for human health. In contrast, *A. djedaba* had a lipid composition dominated by saturated fats and very high concentrations of phosphorus and potassium, as well as considerable levels of cystine and proline, contributing to mineral intake and particular metabolic functions. Based on these findings, *L. calcarifer* should be included in diets regularly to support protein sufficiency and cardiovascular health, while *A. djedaba* can be used as a supplement to important minerals, particularly phosphorus and potassium, to help address macronutrient deficiencies in coastal and inland populations. Together, these species can play an important role in increasing dietary diversity and boosting nutrition security in vulnerable communities. However, further research exploring seasonal dynamics in the biochemical composition of these fish is needed to inform sustainable harvesting practices and nutritional assessment strategies.

REFERENCES

Aberoumand, A. (2012). Proximate and mineral composition of fish and shellfish. *Food Science and Quality Management, 7,* 33-36.

AOAC. (1995). *Official methods of analysis* (16th ed.). Association of Official Analytical Chemists. https://www.scirp.org/reference/referencespapers?referenceid=2720214

Bayissa, T. N., Gobena, S., Vanhauteghem, D., Du, L. G., Kabeta, M. W., & Janssens, G. P. J. (2021). The impact of lake ecosystems on mineral concentrations

in tissues of Nile tilapia (Oreochromis niloticus). *Animals, 11*(4), 1000. https://doi.org/10.3390/ani11041000

Baum, S. J., Kris-Etherton, P. M., Willett, W. C., Lichtenstein, A. H., Rudel, L. L., Maki, K. C., Whelan, J., Ramsden, C. E., & Block, R. C. (2012). Fatty acids in cardiovascular health and disease: a comprehensive update. *J Clin Lipidol., 6*(3), 216-34. https://doi.org/10.1016/j.jacl.2012.04.077. Epub 2012 Apr 13. PMID: 22658146; PMCID: PMC9398216.

Belton, B., Karim, M., Thilsted, S., Murshed-e-Jahan, K., Collis, W., & Phillips, M. (2011). *Review of aquaculture and fish consumption in Bangladesh* (Studies and Reviews 2011-53). The WorldFish Center.

Bogard, J. R., Thilsted, S. H., Marks, G. C., Wahab, M. A., Hossain, M. A. R., Jakobsen, J., & Stangoulis, J. (2015). Nutrient composition of important fish species in Bangladesh and potential contribution to recommended nutrient intakes. *Journal of Food Composition and Analysis, 42,* 120-133. https://doi.org/10.1016/j.jfca.2015.03.002

Brenna, J. T., Salem, N., Sinclair, A., & Cunnane, S. C. (2009). α-Linolenic acid supplementation and conversion to n-3 long-chain polyunsaturated fatty acids in humans. *Prostaglandins, Leukotrienes and Essential Fatty Acids, 80*(2-3), 8591, https://doi.org/10.1016/j.plefa.2009.01.004

Bruno, A., Michael, S., Brett, G., & Nicholas, W. (2016). The influence of dietary fatty acids and fasting on the hepatic lipid metabolism of barramundi (Lates calcarifer). *Aquaculture Research, 48*(7). 10.1111/are.13215

Calder, P. C. (2015). *Marine omega-3 fatty acids and inflammatory processes: Effects, mechanisms, and clinical relevance. Biochimica et Biophysica Acta (BBA) - Molecular and Cell Biology of Lipids, 1851*(4), 469–484.

Chan, Y. B., Loh, S. H., Ibrahim, Y. S., Bachok, Z., & Tuan Anuar, S. (2021). Dynamic fatty acid profiles of Asian sea bass (Lates calcarifer) from Setiu Wetlands, East Coast Peninsular Malaysia. *Malaysian Journal of Analytical Sciences, 25*(1), 53-61. https://doi.org/10.17576/mjas-2021-2501-05

Coniglio, S., Shumskaya, M., & Vassiliou, E. (2023). Unsaturated Fatty Acids and Their Immunomodulatory Properties. *Biology (Basel), 12*(2), 279. https://doi.org/10.3390/biology12020279. PMID: 36829556; PMCID: PMC9953405.

Department of Fisheries. (2023). *Yearbook of fisheries statistics of Bangladesh 2021–2022*. Ministry of Fisheries and Livestock (MoFL), Bangladesh.

Food and Agriculture Organization of the United Nations & World Health Organization. (1991). *Protein quality evaluation: Report of the Joint FAO/WHO Expert Consultation* (FAO Food and Nutrition Paper No. 51).

Food and Agriculture Organization of the United Nations & World Health Organization. (2001). *Human vitamin and mineral requirements: Report of a joint FAO/WHO expert consultation, Bangkok, Thailand.* https://www.fao.org/3/y2809e/y2809e03.htm

FAO/WHO. (2013). *Dietary protein quality evaluation in human nutrition: Report of an FAO Expert Consultation* (FAO Food and Nutrition Paper No. 92). Food and Agriculture Organization of the United Nations.

FAO. (2019). *The state of world fisheries and aquaculture 2018 – Meeting the Sustainable Development Goals.* Food and Agriculture Organization of the United Nations. http://www.fao.org/3/i9540en/i9540en.pdf

FAO. (2020). *The state of world fisheries and aquaculture 2020: Sustainability in action.* Food and Agriculture Organization of the United Nations.

Farhaduzzaman, A. M., Khan, M. S., Osman, M. H., Shovon, M. N. H., Azam, M., & Makhdum, N. (2023). Progress of seabass, Lates calcarifer (Bloch, 1970) culture in Bangladesh: Field-level updates from the Bhola and Satkhira Districts. *International Journal of Agricultural Research, Innovation and Technology, 12*(2), 117-125. https://doi.org/10.3329/ijarit.v12i2.64097

Fernstrom, J. D., & Fernstrom, M. H. (2007). Tyrosine, phenylalanine, and catecholamine synthesis and function in the brain. *Journal of Nutrition, 137*(6 Suppl 1), 1539S-1547S. https://doi.org/10.1093/jn/137.6.1539S

Frydrych, A., Krośniak, M., & Jurowski, K. (2023). The role of chosen essential elements (Zn, Cu, Se, Fe, Mn) in food for special medical purposes (FSMPs) dedicated to oncology patients—critical review: State-of-the-art. *Nutrients, 15*(4), 1012. https://doi.org/10.3390/nu15041012

Gillingham, L. G., Harris-Janz, S., & Jones, P. J. (2011). Dietary monounsaturated fatty acids are protective against metabolic syndrome and cardiovascular disease risk factors. *Lipids, 46*(3), 209-28. https://doi.org/10.1007/s11745-010-3524-y, PMID: 21308420.

Gladyshev, M. I., Arts, M. T., & Sushchik, N. N. (2009). Preliminary estimates of the export of omega-3 highly unsaturated fatty acids (EPA + DHA) from aquatic to terrestrial ecosystems. In: Lipids in Aquatic Ecosystems. Springer, 179-209, http://dx.doi.org/10.1007/978-0-387-89366-2_8

Golam, S., Abul, H., Bhabananda, B., & Hiroki, A. (2012). Taste-producing components in fish and fisheries products: A review. *International Journal of Food and Fermentation Technology, 2,* 113-121.

Ghosh, A., Ray, S., Roy, B., Shahid, R., Rahman, M., Kumar, R., & Sarower, G. (2024). Heavy metals, trace elements, and biochemical composition of Asian seabass (Lates calcarifer) in coastal areas of Bangladesh. *AACL Bioflux, 16*(6), 3461-3469.

Graham Sustainability Institute (2025). Impacts of excess phosphorus. *University of Michigan, Retrieved September 13,* 2025, from https://graham.umich.edu/wleb/phosphorus/impacts

Hamza, B., Muhammad, N. Y., Ali, I., & Iliyasu, A. B. (2019). Impacts of Phosphates on Water Quality and Aquatic Life. *Chemistry Research Journal, 4*(3), 124-133.

Haque, M., Hossain, I., Uddin, S., & Dey, P. (2020). Review on distribution, culture practices, food and

feeding, brood development, and artificial breeding of Seabass, Lates calcarifer (BLOCH 1790): Bangladesh perspective. *Research in Agriculture Livestock and Fisheries, 6,* 405-414. 10.3329/ralf.v6i3.44806

Harper, A. (1981). *Amino Acid Scoring Patterns.* Joint FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements, Rome, https://www.fao.org/4/m3013e/m3013e00.htm

Hilton, C., Ram, S., Shairy, K., Agnieszka, W., & Toru, T. (2019). High Omega-6/Omega-3 Fatty Acid Ratio Diets and Risk of Noncommunicable Diseases. In: *The Role of Functional Food Security in Global Health*. https://doi.org/10.1016/B978-0-12-813148-0.00014-1

Islam, R., Kamruzzaman, P. T., Rahman, A., & Sattar, A. (2012). Studies on nutritional composition and characterization of lipids of Lates calcarifer (Bhetki). *Bangladesh Journal of Scientific and Industrial Research, 47*(4), 393–400.

Jerry, D. R. (Ed.) (2013). *Biology and culture of Asian seabass Lates calcarifer*. CRC Press. file:///C:/Users/khmeh/Downloads/Dean_R._Jerry_Biology_and_Culture_of_Asian_SeabaBook4You.pdf

Joint WHO/FAO/UNU Expert Consultation. (2007). Protein and amino acid requirements in human nutrition. *World Health Organization Technical Report Series, 935,* 1–265. https://pubmed.ncbi.nlm.nih.gov/18330140

Kamruzzaman, S., Hossain, M. D., Jewel, M. A. S., Khanom, D. A., Mustary, S., & Khatun, M. M. (2015). Proximate composition and nutritional value of different life stages of Lates calcarifer (Bloch, 1790). *University Journal of Zoology, Rajshahi University, 34,* 21–24. http://journals.sfu.ca/bd/index.php/UJZRU

Kanij, R. S., Tania, A., Moriom, A., Sakeb, A. P., & Hasan, M. R. (2025). A first analytical report on nutritional profiling of wild and cultured Asian sea bass (Lates calcarifer). *Applied Food Research, 5*(1), 100932, https://doi.org/10.1016/j.afres.2025.100932

Karna, E., Szoka, L., Huynh, T. Y. L., & Palka, J. A. (2020). Proline-dependent regulation of collagen metabolism. *Cellular and Molecular Life Sciences, 77*(10), 1911–1918. https://doi.org/10.1007/s00018-019-03363-3

Khawar, M., Masood, Z., & Hasan, H. (2024). Trace metals and nutrient analysis of marine fish species from the Gwadar coast. *Scientific Reports, 14,* 6548. https://doi.org/10.1038/s41598-024-57335-0

Kris-Etherton, P. M., Harris, W. S., & Appel, L. J. (2002). Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease. *Circulation, 106*(21), 2747-2757. https://doi.org/10.1161/01.CIR.0000038493.65177.94

Kuldeep, V., Ashwani, W., Srikanta, S., Subhendu, A., & Muralidhar, M. (2015). Phosphorus dynamics, eutrophication and fisheries in the aquatic ecosystems in India. *Current science, 108*(7), 1306 -1314.

Kumar, D. B., Kajal, K., Kumar, T. A., Archisman, R., Subhamoy, D., & Barsha, B. (2024). Unlocking the nutritional potential: amino acid profile of eight Indian food fishes and their role in meeting recommended dietary allowances. *Frontiers in Sustainable Food Systems, 8,* 10.3389/fsufs.2024.1432034

Lall, S. P., & Kaushik, S. J. (2021). Nutrition and Metabolism of Minerals in Fish. *Animals (Basel), 11*(9), 2711. https://doi.org/10.3390/ani11092711

Li, P., Mai, K., Trushenski, J., & Wu, G. (2009). New developments in fish amino acid nutrition: Towards functional and environmentally oriented aquafeeds. *Amino Acids, 37*(1), 43-53. https://doi.org/10.1007/s00726-008-0171-1

Manusher Jonno Foundation (2021). Policy Brief 2: Standard of Living of Small-Scale Artisanal Fishing Communities of Bangladesh. Retrieved from https://www.manusherjonno.org/wp-content/uploads/2021/07/Policy-Brief-2-Standard-of-Living-of-small-scale-artisanal-fishing-communities-of-Bangladesh.pdf

Mariamenatu, A. H., & Abdu, E. M. (2021). Overconsumption of omega-6 polyunsaturated fatty acids (PUFAs) versus deficiency of omega-3 PUFAs in modern-day diets: The disturbing factor for their "balanced antagonistic metabolic functions" in the human body. *Journal of Lipids, 2021,* 8848161. https://doi.org/10.1155/2021/8848161

Majeed, A., Liang, Z., Zhu, L., Liu, C., Kalhoro, M. A., & Saeed, F. (2022). Stock analysis of shrimp scads (Alepes djedaba) fishery from Northern Arabian Sea, Balochistan coast, Pakistan. *Pakistan Journal of Zoology, 54*(5), 2203–2212. https://doi.org/10.17582/journal.pjz/20210329070315

Misako, K., Atsushi, O., & Yoichi, U. (2002). Taste enhancements between various amino acids and IMP. *Chemical senses, 27*(8), 739-45.

Mostofa, M., Rahman, S., Sonia, S., Sobuj, M. K., Islam, Z., & Hasan, S. (2023). Cage culture of seabass (Lates calcarifer) in Cox's Bazar coast of the Bay of Bengal: A pilot study. *Bangladesh Journal of Fisheries, 21-22,* 127-134.

Mozaffarian, D., & Wu, J. H. Y. (2011). Omega-3 fatty acids and cardiovascular disease: effects on risk factors, molecular pathways, and clinical events. *Journal of the American College of Cardiology, 58*(20), 2047-2067, https://doi.org/10.1016/j.jacc.2011.06.063

Özden, Ö. (2005). Changes in amino acid and fatty acid composition during the shelf-life of marinated fish. *Journal of the Science of Food and Agriculture, 85*(12), 2015–2020, http://dx.doi.org/10.1002/jsfa.2207

Pervin, T., Yeasmin, S., Islam, R., Kamruzzaman, M., Rahman, M. A., & Sattar, M. (2012). Studies on nutritional composition and characterization of lipids of Lates calcarifer (Bhetki). *Bangladesh Journal of Scientific and Industrial Research, 47*(4), 393. 10.3329/bjsir.v47i4.14068

Purushothaman, K., Ho Jia Wen, R., bin Mohamed, M. H., Rwei Qing, S. D. T., Heng Wuan, L., Liang, B., Thanh Vu, N., Voigtmann, M., Loo, G., & Vij, S. (2024). Comparative nutritional and histological analysis

of Malabar red snapper (Lutjanus malabaricus) and Asian seabass (Lates calcarifer). *Animals, 14*(12), 1803. https://doi.org/10.3390/ani14121803

Rahman, R., Chowdhury, M. M., Sultana, N., & Saha, B. (2019). Proximate and major mineral composition of commercially important marine fishes of Bangladesh. *IOSR Journal of Agriculture and Veterinary Science, 11*(1) 18-25.

Rifat, M., Wahab, M., Rahman, M., Nahiduzzaman, M., & Mamun, A. (2023). Nutritional value of the marine fish in Bangladesh and their potential to address malnutrition: A review. *Heliyon, 9,* e13385. https://doi.org/10.1016/j.heliyon.2023.e13385

Rodrigues, M. J., Franco, F., Martinho, F., Pereira, M. E., Coelho, J. P., & Pardal, M. A. (2021). Essential mineral content variations in commercial marine species induced by ecological and taxonomical attributes. *Journal of Food Composition and Analysis, 103,* 104118, https://doi.org/10.1016/j.jfca.2021.104118

Sadia, A. K., Chad, M., Hossain, J., Ferdous, A., & Jahan, R. (2022). Availability of marine fishes in Cox's Bazar, Bangladesh: A case study on the BFDC Landing Center. *Croatian Journal of Fisheries, 80*(3). https://doi.org/10.2478/cjf-2022-0014

Sajana, N., & Nandan, S. B. (2019). Proximate composition and nutritive value of shrimp scad, Alpes djedaba (Forsskal, 1775) off Cochin coast. *International Journal for Research in Engineering Application & Management, 5*(1), https://ijream.org/papers/IJREAMV05I0149073.pdf

Sarah, A., Afnan, F., & Simone, P. (2020). Farmed versus wild fish consumption in relation to fatty acid composition in the Kingdom of Bahrain. *Egyptian Journal of Aquatic Biology and Fisheries, 24,* 803-816. https://doi.org/10.21608/ejabf.2020.151489

Seafood Network Bangladesh (2024). *Culture techniques of coral/vetki or seabass fish in Bangladesh.* https://seafoodnetworkbd.com/culture-techniques-of-coral-vetki-or-seabass-fish-in-bangladesh

Scaioli, E., Liverani, E., & Belluzzi, A. (2017). The imbalance between n-6/n-3 polyunsaturated fatty acids and inflammatory bowel disease: A comprehensive review and future therapeutic perspectives. *Int J Mol Sci., 18*(12), 2619. https://doi.org/10.3390/ijms18122619.

Scott, M., Paul, B., Graeme, B., Simon, A., & Jenny, S. (2001). Incorporating metal speciation and bioavailability into water quality guidelines for protecting aquatic ecosystems. *Australasian Journal of Ecotoxicology, 7*(2), 109-122.

Sikder, R., Haque, M., Das, S., Shaon, M. A., & Islam, M. (2025). Investigating the nutritional composition of cultured Asian seabass Lates calcarifer in Bangladesh's Khulna-Satkhira region: A focus on fatty acids and amino acids (preprint). 10.21203/rs.3.rs-5750226/v1

Simopoulos, A. P. (2002). Omega-3 fatty acids in inflammation and autoimmune diseases. *Journal of the American College of Nutrition, 21*(6), 495-505. https://doi.org/10.1080/07315724.2002.10719248

Siri-Tarino, P. W., Sun, Q., Hu, F. B., & Krauss, R. M. (2010). Meta-analysis of prospective cohort studies evaluating the association of saturated fat with cardiovascular disease. *The American Journal of Clinical Nutrition, 91*(3), 535-546, https://doi.org/10.3945/ajcn.2009.27725

Sirot, V., Oseredczuk, M., Bemrah-Aouachria, N., Volatier, J. L., & Leblanc, J. C. (2008). Lipid and fatty acid composition of fish and seafood consumed in France. *Journal of Food Composition and Analysis, 21*(1), 8-16.

Sivakami, S. (1990). Observations on some aspects of the biology of Alepes djedaba (Forsskal) from Cochin. *Journal of the Marine Biological Association of India, 32* (1&2), 107-118. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/http://eprints.cmfri.org.in/1109/1/Siva_107-118.pdf

Syed, R., Abdhakir, E., & Muthukkaruppan, R. (2020). Proximate and mineral composition of commercially important marine fin fishes from the Kasimedu fish landing centre, Chennai. *Journal of Fisheries and Life Sciences, 5*(1). https://www.fishlifesciencejournal.com/archives/2020/5/1/JUNE/134Tacon, A. G. J., & Metian, M. (2013). Fish nutrition and feeding. Aquaculture, 412-413, 1-4.

Tocher, D. R. (2003). Metabolism and functions of lipids and fatty acids in teleost fish. *Reviews in Fisheries Science, 11*(2), 107-184. https://doi.org/10.1080/713610925

Traina, A. Quinci, E. M., Sabatino, N., Del Core, M., Bellante, A., Bono, G., Giuga, M., Avellone, G., Sprovieri, M., & D'Agostino, F. (2024). Protein, essential amino acid, and fatty acid composition of five target fishery species of the Central Mediterranean sea. *Animals, 14*(15), 2158. https://doi.org/10.3390/ani14152158

Ulbricht, T. L. V., & Southgate, D. A. T. (1991). Coronary heart disease: seven dietary factors. *The Lancet, 338*(8773), 985-992. https://doi.org/10.1016/0140-6736(91)91846-M

Ullah, M. R., Rahman, M. A., Haque, M. N., Sharker, M. R., Islam, M. M., & Alam, M. A. (2022). Nutritional profiling of some selected commercially important freshwater and marine water fishes of Bangladesh. *Heliyon, 8*(10), e10825, https://doi.org/10.1016/j.heliyon.2022.e10825

Venkatachalam, S., Kandasamy, K., Krishnamoorthy, I., & Narayanasamy, R. (2018). Survival and growth of fish (Lates calcarifer) under integrated mangrove-aquaculture and open-aquaculture systems. *Aquaculture Reports, 9,* 18-24. https://doi.org/10.1016/j.aqrep.2017.11.004

Venugopal, V., & Shahidi, F. (1996). Structure and composition of fish muscle. *Food Reviews International, 12*(2), 175-197. https://doi.org/10.1080/87559129609541074

Willer, D. F., Newton, R., Malcorps, W., Kok, B., Little, D., Lofstedt, A., de Roos, B., & Robinson, J. P. W. (2024).

Wild fish consumption can balance nutrient retention in farmed fish. *Nat Food, 5*(3), 221-229. https://doi.org/10.1038/s43016-024-00932-z.

Wilson, R. P. (2003). Utilization of dietary carbohydrate by fish. *Aquaculture, 124,* 67-80. https://doi.org/10.1016/0044-8486(94)90363-8

Wu, G. (2010). Functional amino acids in growth, reproduction, and health. *Advances in Nutrition, 1*(1), 31-37, https://doi.org/10.3945/an.110.1008

Wu, G., Bazer, F. W., & Davis, T. A. (2014). Amino acid nutrition in animals: Protein synthesis and beyond. *Annual Review of Animal Biosciences, 2*(1), 387-417. https://doi.org/10.1146/annurev-animal-022513-114113

Wu, G. (2016). Dietary requirements of synthesizable amino acids by animals: A paradigm shift in protein nutrition. *Journal of Animal Science and Biotechnology, 5,* 34. https://doi.org/10.1186/2049-1891-5-34

Yasmin, F., Bosu, A., Ullah, M., Khan, A., Akhter, M., Karim, E., Hasan, K., & Mahmud, Y. (2023). Assessment of growth performance and survivability of Asian seabass (Lates calcarifer) under different stocking densities in brackish water ponds of the south-west coast of Bangladesh. *Sustainable Aquatic Research, 2*(2), 92-100. https://doi.org/10.5281/zenodo.8296609