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Research Article

Evaluation of Muscle Yield and Biochemical Properties of Several White Fleshed Fish from the Bay of Bengal for Nutraceutical Peptide Production

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ABSTRACT

Fish is recognized as an important functional food due to the presence of health promoting bioactive compounds. This study aimed to evaluate marine fish species with high muscle yield, low market value and year-round availability to be used as raw material in the production of nutraceutical compounds. A survey was conducted at Cox's Bazar Sadar and Teknaf upazila in Cox's Bazar district, Bangladesh targeting stakeholders involved in fish marketing and distribution through structured questionnaires. Nearly 100 fish species belonging to Ariidae, Sciaenidae, Leiognathidae, Nemipteridae, Trichiuridae, Carangidae, Scombridae, Clupeidae, Stromateidae, Mullidae, Harpadontidae, Synodontidae, Lutjanidae and Polynemidae landed at the artisanal landing centers. Of these, four croaker species were deemed suitable for muscle-derived fish peptide (FP) production. Accordingly, market-size Belanger's croaker (*Johnius belangerii*), blackspotted croaker (*Protonibeadia diacanthus*), panna croaker (*Panna microdon*) and pawak croaker (*Pennahia pawak*) were collected and analyzed for muscle yield and proximate composition. White the muscle yield ranged from 20.7% to 35.2% of total weight with the highest yield observed in *P. pawak* which had high protein (18.43±0.3%) and low lipid (0.53±0.1%). A test FP powder prepared from *P. microdon* using 0.02% (w/w) commercial papain, yielding a product with 95.00±1.20% protein, 3.20±0.10% lipid, 1.30±0.10% moisture, 1.70±0.20% ash and 409.1±5.2 kcal energy per 100 g edible raw material that is comparable to high quality hydrolysates prepared from other fish and meat sources. The findings highlight the significant potential of marine fisheries resources to contribute to the global nutraceutical markets and create new economic opportunities for further exploration.

Introduction

Fish is nutritious and rich in proteins, essential fatty acids, micronutrients and minerals. In recent years, the demand of fish has been increasing not only due to its nutritious value but also for its potential functional properties. Fish is known to be a valuable source of n-3 fatty acids, vitamins, minerals, gelatin, chitin, pigments and bioactive peptides (Kim and Mendis, 2006). The development of fish protein hydrolysates (FPH) and peptides as functional food ingredients is a relatively new technology. It has gained popularity for its diverse bioactive properties which include antioxidative, anticoagulative, antihypertensive, antidiabetic, antimicrobial, antiviral, antitumour and appetite-suppressing effects (Alasalvar et al. 2002; Klompong et al. 2007; Murray and FitzGerald, 2007; Cheung et al. 2015). Nowadays, these peptides are also incorporated into sports nutrition, weight control diets and dietary supplements (Mahmoud and Cordle, 2000).

Bioactive peptides are an important category of functional foods derived from fish consisting of naturally occurring components. They are typically produced through extraction or hydrolysis of proteins into the smaller fragments, usually 3–20 amino acid residues (Välimaa et al. 2019). The raw material for these valuable compounds can be derived not only from fish flesh but also from the by-products such as skins, heads, frames, viscera and fillet cut-offs (Abuine et al., 2019). Various methods have been developed to extract bioactive peptides including solvent extraction, chemical hydrolysis using acids or alkalis, enzymatic hydrolysis with proteolytic enzymes, microbial fermentation of proteins and techniques like precipitation and salting out of high-molecular weight compounds from decoctions or broths (Najafian and Babji, 2012; Urakova et al. 2012). Among these, enzymatic hydrolysis of fish muscle, particularly white muscle, is an important method that

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results in yields high quality fish peptide (FP). Such FP has been successfully isolated from various fish and shrimp species including tuna and salmon muscle, dried bonito and shrimp (Yokoyama et al. 1992; Matsufuji et al. 1994; Yu and Ahmed 1998; Ono et al. 2003; Hai-Lun et al. 2006; Qian et al. 2007). This simple biotechnological approach has been developed in Japan and yields FP with multiple health benefits such as lowering blood lipids, reducing hypertension, increasing serum albumin, enhancing total protein levels and improving bone density (Yoshino et al. 2011). They also exhibit an extended shelf life when dried and do not require refrigeration. This makes them highly versatile. However, the production of FP is not without challenges. One significant issue is the bitter taste resulting from the enzyme used for hydrolysis, hydrophobic nature of certain peptides, degree of hydrolysis, low water solubility and amino acid sequence (Umestu and Ichishima, 1985; Yokoyama et al. 1992; Matsufuji et al. 1994; Fu et al. 2018; Partanen et al. 2023). Additionally, FP often possesses a strong fishy odor (Yokoyama et al. 1992) which can limit its commercial appeal as a food ingredient or nutraceutical. The scalability and efficiency of the extraction processes, particularly in developing countries, also pose significant challenges. Issues such as the high cost of enzyme preparations, variability in the raw material quality and optimization of processing conditions to ensure consistent bioactivity further complicate FP production. Despite these challenges, the introduction of FP production in developing countries like Bangladesh holds great potential. Bangladesh is endowed with vast aquatic resources including some 475 marine fish species (DoF, 2024), many of which could be sustainably utilized for FP production.

The coastal and marine environment of Bangladesh is blessed with a warm tropical climate and high rainfall, enriched with nutrients from the land, creating one of the world's most productive ecosystems. The country has established sovereign rights on more than 118,813 km^2 area of territorial sea and 200 nautical miles of Exclusive Economic Zone (EEZ) in the Bay of Bengal, including rights over all living and non-living resources within the continental shelf extending up to 354 nautical miles (DoF, 2024). Most marine fish in Bangladesh are harvested by the artisanal sector that catches relatively small sized fishes and lower market value (Funge-Smith et al. 2005; UNIDO, 2009). These species could be effectively used for FP production. Currently, the marine fish species harvested consist mainly of the demersal fishes, shallow-water estuarine species and several pelagic species. Off the approximately 100 commercially important species, about 20 families contribute to 82-87% of the total demersal fish catch (Barua, 2019). The three most commercially important families are Ariidae (catfish) contributing 11.99%; Sciaenidae (croakers) contributing 10.37%; Nemipteridae (threadfin breams) contributing 9% of the total while mixed fish and trash represented 0.001% and 4.95% respectively (Mustafa, 2003; Barua, 2019). However, not all species are equally suitable for FP processing. Fish muscle types whether ordinary or dark muscle along with their chemical and protein composition are the key factors that determine the quality of FP (Yu and Ahmad, 1998). Generally, fishes having high amount of white muscles and lower fat content are suitable for the production of muscle-derived FP. To date, little or no work has been done in this region to identify suitable low-value marine fish species for producing FP. In this study, we aim to identify such species from marine artisanal sector that could serve as raw materials for locally producing FP.

Materials and Methods

Ethics statement

The experimental procedures and protocols in this study were approved by the Director, Bangladesh Agricultural University Research System, Bangladesh Agricultural University, Mymensingh, Bangladesh. No specific permits were required for the collection and use of fish samples as they are neither endangered nor protected by national law.

Selection of study area

Cox's Bazar Sadar and Teknaf upazila in Cox's Bazar district are the two artisanal fishing sites where large quantities of commercially important marine fishes land round the year. Supply chain has developed in this region consisting of fishermen, commission agents (locally called *Bepari*, *Aratdar*, *Paiker*), wholesaler, retailer, exporting agency and processing plant. Fish are caught by beach seine net (*Char Ber Jal*), drift gillnet (Vasha Jal), set bagnet (*Behundi Jal*) or longline (*Chhora Barshi*). The major fish marketing places in these two upazila including BFDC Fish Landing Center, Nazirtek Landing Center, Baharchara Bazar, Baroa Bagar, Kalor Dukan Bazar, Kattoli Bazar, Sonarpara Bazar, Linkroad Bazar, Upazila Bazar, Kharuilla Bazar, Ramu Bazar, Samitipara Bazar, PTI School Bazar, Ali Zahar Bazar and Moheshkhali Bazar at Cox's Bazar Sadar and Teknaf Bazar Fish Market, Teknaf Station Fish Market, Sabrung Bazar, Noyapara Bazar, Shaparirdip Fish Market and Teknaf Beach Landing at Teknaf upazila in Cox's Bazar district were selected for the study.

Sample size and sampling techniques

Sample size and sampling design for taking interview from various stakeholders are important parts of the study. Total sample size of the study was 110 comprising of 50 fishermen, 30 commission agents (wholesaler / *Aratdar* / *Paiker*) and 30 retailers at Cox's Bazar Sadar and Teknaf upazila in Cox's Bazar district.

Questionnaire interview

A questionnaire was prepared for pre-testing, finalized subsequently after refinement and used to gather information on the suitability of fish based on factors such as size, seasonality, abundance, price and related details including fishing location, harvesting methods and daily catch volume. The questionnaire primarily consisted of structured questions, supplemented by some open-ended ones. Initially drafted in English, it was translated into Bengali during face-to-face interviews with the respondents. The survey was conducted in November and December 2017 in collaboration with the scientists of Marine Fisheries and Technology Station (MFTS), Bangladesh Fisheries Research Institute (BFRI), Cox's Bazar. Data were then recorded through direct interviews with different stakeholders involved in fishing and fish marketing activities. Before starting the interview, the purpose of the study was explained to the respondents to ensure clarity and avoid any misunderstanding regarding the nature of the survey. The answers to the questions of the respondents were immediately recorded by the survey team. Each item of questionnaire was carefully reviewed and verified to ensure that all the responses were accurately recorded.

Selection of suitable fish species

After the survey, suitable fish species having large quantities of white ordinary muscle, low price and round-the-year availability were identified. Information was also obtained about their sizes and prices at different stages of marketing chain.

Muscle yield analysis

Muscle-derived FP was prepared from fish species with predominantly white muscle, low fat content and minimal dark muscle. Based on these criteria, eleven fish species including four croaker species were initially selected. However, only croaker species were considered for further study due to their year-round availability. The fish were purchased in 10 kg batches from local markets and transported to the Laboratory of Fish Processing and Quality Control, Department of Fisheries Technology, Bangladesh Agricultural University, Mymensingh, Bangladesh. They were kept in iced condition during transportation in an insulated box. The samples were then divided into two portions: one for determining muscle yield and proximate composition while other portion was stored into a deep freezer at -20℃ for the subsequent FP processing. Before determining muscle yield, the length and weight of each sample were recorded. Yield was then estimated by weighing different parts of the fish including (a) muscle, (b) skin, (c) viscera, (d) head + vertebral column + fins and scales. Yield percentages were calculated as previously described (Öksüz, 2010; Islami et al. 2014).

Enzymatic hydrolysis of P. microdon protein

For the hydrolysis of fish muscle, we followed the protocol suggested by Ueki et al. (2008) where they used 1/2000 papain (w/w) at 70℃ for 2 h to achieve optimal hydrolysis and preserve the bioactive properties like angiotenstin I enzyme inhibitory and antioxidant activities. Ghosh et al. (2017) previously prepared fish peptide powder through enzymatic hydrolysis using 5% papain at 45℃ for 2 h and reported a product containing 89.12% protein but with relatively low foaming property (60%) even at 1% concentration. Therefore, we adopted Ueki et al. (2008) protocol for this study to preserve the bioactive properties. In brief, frozen *P. microdon* samples were thawed under running tap water, gutted, skinned and deboned. The white muscle was carefully separated from dark muscle, and the recovered white muscle was ground in a pre-cooled (4°C±1) mechanical meat grinder (Model MK-G20NR, National Co. Ltd., Tokyo, Japan) to produce mince. To remove sarcoplasmic proteins, lipid droplets, pigments and other low molecular weight compounds, the fish mince was washed twice with chilled salt water containing 0.2% NaCl using a mince to water ratio of 1:3 (w/v). The mixture was then decanted and excess water was removed by squeezing through a piece of fine cloth. Then 0.02% (w/w) papain / papaya proteinase I (Parchem Inc., New Rochelle, NY, USA) at pH 6.5 was mixed with fish mince and heated at 60°C for 2 h in a thermostatic water bath (Jiangsu, Medical Instrument Factory, China) to produce hydrolyzed peptide suspension. The suspension was heated at 95°C for 1 h to inactivate the enzyme and dried in a hot air oven (Gallenkamp, HOTBOX OVB-360, Manchester, UK) at 80°C for 6 h. The dried product was ground using a blender (Panasonic, Model MX-AC210S, Japan) and passed through a fine mesh sieve. Finally, the dry FP was kept in desiccator for 6 h to complete the drying process.

Biochemical analyses of raw materials and FP

Moisture content was determined by air drying of a given sample in a thermostat oven (Gallenkamp, Manchester, UK) at 105ºC for 24 h until constant weight (Reza et al. 2006). Ash content was determined by igniting the sample in a muffle furnace at a temperature of 550ºC for 6 h. Crude protein was determined by the Macro Kjeldahl method by determining total nitrogen and applying the protein conversion factor of 6.25 to the results to convert total nitrogen into total protein, assuming that fish protein contained 16% nitrogen, and lipid content was determined by extracting required quantity of samples with petroleum ether for 16 to 18 h in a ground joint Soxhlet apparatus. The oil obtained by evaporation of the solvent on a steam bath was weighed in a sensitive balance and percent lipid was calculated (Reza et al. 2006). All analyses were conducted in triplicate.

Energy content

Energy content of the fish species was quantified based on their crude protein, lipid, and carbohydrate contents according to Crisan and Sands (1978).

Statistical analysis

The collected data were tabulated and analyzed using SPSS version 20.0 (IBM SPSS Inc., Chicago, IL). Analysis of Variance (ANOVA) was performed to assess the differences in yield and biochemical composition among groups to determine specific group differences. Additionally, t-test ($p < 0.05$) was applied to compare data between two groups.

Results and Discussion

Overview of fish harvesting and marketing system in artisanal fisheries

Different types of fishing gears are operated up to 40 m depth in the artisanal fisheries sector of Bangladesh. Major types of gears used are: (i) gillnet such as drift gillnet (*Vasha Jal*), fixed gillnet, bottom set gillnet, mullet gillnet (*Bata Jal*), (ii) different types of set bagnet such as estuarine set bagnet (*Behundi Jal*), marine set bagnet (*Sagor Behundi Jal*) and large mesh set bagnet, (iii) trammel net, (iv) set longline (*Chhora Barshi*) and (v) beach seine net (*Char Ber Jal*) (Kamal et al. 2024). A large number of people are engaged in different activities as fishermen, assemblers, traders, intermediaries and transporters. The study revealed that four levels of marketing systems are observed in the distribution channel of fish in the marine artisanal sector of Bangladesh. These are primary, secondary, higher secondary and consuming markets. Primary market is a place located at the catching point, close to the landing area of the marine artisanal fishes. Fishermen usually sell their catch at the landing places (primary markets) to the middlemen (locally known as *Baperies* or *Paikers*) (Ahmed, 1997; Nayeem et al. 2010). In Cox's Bazar, the fishermen often sell their fish in the boats at the fish landing stations. The *Beparies* bring the fish from the primary market to the nearest market or at a place well linked by rivers, road or rail transport to the local retailers. The retailers perform post-harvest tasks including cleaning, sorting, grading and icing before selling to the consumers. Sometimes, they purchase fish from the fishermen in landing centres and transport them to different centres / depot for sale. The *Aratdar* is a commission agent who has a fixed establishment (depot) and assists the *Beparies* in selling their fish lots to the retailers. On purchasing the fish from the higher secondary market, they sell the fish to the local wholesaler or directly to the retailers. The wholesalers also sell their fish to the retailers (Ahmed, 1997; Kamal et al. 2024). Majority of fish from artisanal sector is consumed locally in fresh and transported to different parts of the country in iced condition while some are exported.

Identification of suitable fish species

The fish species usually landed in the artisanal sector in Cox's Bazar and Teknaf area are Ariidae (catfish), Sciaenidae (croakers), Leiognathidae (silver bellies/pony fish), Nemipteridae (threadfin bream), Trichiuridae (ribbonfish), Carangidae (jacks, scads), Scombridae (mackerel, tuna), Clupeidae (sardine, shad), Stromateidae (pomfrets), Mullidae (goatfish), Harpadontidae (Bombay duck), Synodontidae (lizardfish), Lutjanidae (snapper) and Polynemidae (threadfin) (Khan et al. 1989; Barua, 2019). More than 100 species of commercially important fishes, their size distribution and market prices were identified of which 11 were white-fleshed fish (Table 1). They were gagora catfish (*Arius gagora*), whipfin silver-biddy (*Gerres filamentosus*), John's snapper (*Lutjanus johnii*), Belanger's croaker (*Johnius belangerii*), blackspotted croaker (*Protonibeadia diacanthus*), Panna croaker (*Panna microdon*), Pawak croaker (*Pennahia pawak*), Malabar blood snapper (*Lutjanus malabaricus*), humphead snapper (*Lutjanus sanguineus*), Japanese threadfin bream (*Nemipterus japonicus*) and silver grunt (*Pomadasys argenteus*). Of these 11 species, some were abundant in a particular season while others were available round the year. Four croaker species viz., *J. belangerii*, *P. diacanthus*, *P. microdon* and *P. pawak* were found to be available round the year and relatively cheap compared to other fishes.

In the marine fish marketing channel, some fishes were sold in the local market in fresh condition with or without ice, some were sold to the distant markets while a small portion was exported in refrigerated or iced condition. In the present study, 11 fish species having large quantities of white ordinary muscles, their sizes and market prices were identified. Except the 4 croaker species, others were seasonal i.e., not available round the year. Therefore, value chain of the croakers was analyzed according to Reza et al. (2005) and the results are shown in Table 2. In the primary market, the average purchasing and selling price of croaker was 92.50 and 135.00 BDT/kg, respectively. Considering cost associated with marketing of fishes, the share of marketing profit in the primary markets stood to 33.50 BDT/kg. Marketing costs involved costs for the use of ice, packaging materials and labour. Similarly, the purchase price of the secondary market was 135.00 BDT/kg and selling price was 172.50 BDT/kg. The share of marketing profit including cost associated in marketing was 29.5 BDT/kg. Similarly, at the consumer market, marketing profit stood to 51.50 BDT/kg. With the increment of fish price at every step of the marketing chain, the highest share of marketing profit stood to 44.98% in the consuming market.

Marketing margin as well as marketing profit is relatively higher in consumer market followed by primary and secondary markets. This observation is in agreement with Islam (2006) reported for croaker where marketing margin was between 25% or 30% of the consumer purchase price. It indicated that for production of any value-added fish products like FP, it is important to find a supplier from the primary markets to make the products profitable.

Table 1. White-fleshed marine fish species identified in the study area

English name	Scientific name	Local name	Size		Season	Price (BDT/ kg)
			Length (cm)	Weight (g)		
Gagora catfish	*Arius gagora*	*Guijja / Ghora*	30-70	400-4500	D/W	130-400
Whipfin silver-biddy	*Gerres filamentosus*	*Dhommach*	15-20	50-200	D/W	130-150
John's snapper	*Lutjanus johnii*	*Rangga koi*	20-50	200-3000	D/W	200-350
Belanger's croaker	*Johnius belangerii*	*Rupali Poa*	15-30	50-200	All year round	100-200
Blackspotted croaker	*Protonibeadia diacanthus*	*Kala Poa*	15-40	50-450	All year round	100-250
Panna croaker	*Panna microdon*	*Leijja Poa*	15-30	50-350	All year round	130-300
Pawak croaker	*Pennahia pawak*	*Datta Poa*	15-30	50-200	All year round	100-250
Malabar blood snapper	*Lutjanus malabaricus*	*Lalpansa*	20-50	200-2500	D/W	200-350
Humphead snapper	*Lutjanus sanguineus*	*Rangga chowkka*	20-50	200-3500	D/W	200-350
Japanese threadfin bream	*Nemipterus japonicus*	*Rupban*	10-20	100-200	W	120-150
Silver grunt	*Pomadasys argenteus*	*Sadadatina*	20-30	300-700	D	250-350

Season: D=December to February, W=June to October
1 USD = Approximately 125 BDT (Bangladeshi Taka)

Table 2. Average marketing margin and profitability for croaker in the domestic market.

Marketing stage	Purchase price (PP)	Sales price (SP)	Marketing margin (MM=SP-PP)	Marketing cost (MC)	Marketing profit (MP=MM-MC)	Total Marketing profit	Share to total marketing profit (%)
Primary	85-100 (92.5)	120-150 (135)	35-50 (42.5)	8-10 (9)	33.5		29.26
Secondary	120-150 (135)	145-200 (172.5)	25-50 (37.5)	6-10 (8)	29.5	114.5	25.76
Consumer	145-200 (172.5)	220-250 (235)	50-75 (62.5)	10-12 (11)	51.5		44.98

Values in the parentheses indicate average price.
Units are (BDT/kg)
Marketing margin (MM) = Sales price (SP) - Purchase price (PP)
Marketing profit (MP) = Marketing margin (MM) - Marketing cost (MC)

Muscle yield for different species of croaker

For muscle yield studies, a total of 40 croaker samples, 10 from each species were taken and their length and weight were measured. The fish samples used in this study were in the range of 13.0±1.3 to 22.2±2.1 cm in length and 35.2±2.1 to 151.6±2.3 g in weight. Although their length did not vary significantly, except the smallest sized *J. belangerii* ($p > 0.05$), the yielded muscle weight did vary across croaker samples ($p < 0.01$). *P. pawak* and *P. diacanthus* were comparatively larger in size (Table 3). However, *P. diacanthus* was very seasonal and not abundantly available round the year. This seasonal variation in coastal fishes occurs due to feeding, environmental temperature, salinity, migration and breeding. Other species of croaker were available round the year and their market prices varied from 100-250 BDT/kg depending on season and sizes. Since fish muscles are used for the production of muscle-derived FP, muscle yields of the fish were taken into consideration. The white muscle yields of the 4 croaker species varied from 20.67 to 35.19% of the total weight. The highest yield was obtained in *P. pawak* and the lowest for *J. belangerii*. The muscles of these two species individually or together in one to two species can be used for the production of FP.

Table 3. Muscle yield of different species of croaker

English name	Scientific name	Local name	Length (cm)	Weight (g)	Carcass (g)	Muscle (g)	Skin (g)	Roe (g)	Muscle yield (%)
Belanger's croaker	*Johnius belangerii*	*Rupali Poa*	13.0±1.3^{a}	35.2±2.1^{a}	15.3±0.4^{a}	7.3±0.6^{a}	8.1±0.1^{a}	-	20.7±0.8^{a}
Blackspotted croaker	*Protonibeadia diacanthus*	*Kala Poa*	21.2±1.7^{b}	151.6±2.3^{b}	52.4±0.7^{c}	35.90±0.6^{c}	20.2±0.1^{c}	9.1±0.1^{a}	23.7±0.3^{b}
Panna croaker	*Panna microdon*	*Leijja Poa*	19.8±1.2^{b}	79.5±2.2^{c}	29.3±0.9^{b}	11.2±0.4^{b}	11.2±0.6^{b}	2.7±0.4^{b}	29.4±0.3^{c}
Pawak croaker	*Pennahia pawak*	*Datta Poa*	22.2±2.1^{b}	137.2±2.3^{d}	42.5±0.4^{d}	48.3±0.1^{d}	23.7±0.2^{d}	3.3±0.6^{b}	35.2±0.5^{d}

Different superscripts within each column indicate significant differences ($p < 0.01$) between different values for two species

Proximate composition analyses of fresh croaker

Major chemical components of the fish are water, crude protein and lipid. Together they constitute about 98% of the total mass (Reza et al. 2009; Islami et al. 2014). These components significantly influence the nutritive value, functional properties, sensory quality, and stability of fish meats. These factors, in turn, are affected by species, feed intake, migratory behaviour and physiological changes associated with spawning. In this study, moisture content among croaker species ranged from 78.36±0.1 to 80.42±0.0%, lipid content from 0.53±0.1 to 1.87±0.2%, crude protein from 18.18±0.4 to 18.43±0.3% and ash content from 0.12±0.1 to 0.97±0.1%, all on a wet weight basis (Table 4). On dry weight basis, lipid content ranged from 2.54±0.0 to 8.66±0.1%, crude protein from 84.44±0.6 to 92.87±0.8% and ash content from 2.76±0.1 to 6.40±0.2%. According to Ackman (1973), lean fish contains < 2% fat, low fatty fish 2-4% fat, medium fatty fish 4-8% and fatty fish > 8% fat. Similarly, fish can be categorized based on crude protein into four groups: below 10%, 10-15%, 15-20%, and over 20% (Zdzislaw, 1994*).* So, the fish species analyzed in this study fall into the category of high protein and low lipid content. These findings are also consistent with previous reports (Reza et al. 2009; Bogard et al. 2015).

FP from P. microdon

Among the 4 croaker species, *P. microdon* was chosen for test production of FP because of its high muscle yield and high protein content. Another reason was that the raw material is abundantly available round the year in the coastal areas of Cox's Bazar and Teknaf at a relatively lower price compared to the other commercially important species. The prepared FP was found to be slightly brownish color with slight bitterness (Fig. 1). It was reported that majority of the FP tasted bitter produced by neutral proteases, alkaline proteases, papain, flavourzyme, and animal proteases (Maehashi and Huang, 2009; Fan et al. 2019). FP in the present study was prepared using papain, a cysteine protease enzyme present in papaya. So it may possibly have a bitter taste. The odor, on the other hand, was like dry fish. This initial fish odor and off-flavor generated during the protein hydrolysis may be masked using different methods including promoting Maillard reaction through addition of sugar (Kouakou et al. 2014).

Table 4. Proximate composition of different species of fresh croaker and FP prepared from Panna croaker

English name	Scientific name	Local name	Component					Total energy (Kcal per 100 g)
			Moisture (%)	Lipid (%)	Crude protein (%)	Ash (%)	Carbohydrate (%)	
Fresh fish sample								
Belanger's croaker	*Johnius belangerii*	*Rupali Poa*	78.36±0.1	1.87±0.2 (8.66±0.1)	18.27±0.3 (84.44±0.6)	1.38±0.1 (6.40±0.2)	0.12±0.1 (0.55±0.1)	90.6±2.9
Blackspotted croaker	*Protonibeadia diacanthus*	*Kala Poa*	80.42±0.0	0.57±0.0 (2.89±0.1)	18.18±0.4 (92.87±0.8)	0.54±0.0 (2.76±0.1)	0.29±0.1 (1.48±0.4)	79.1±1.5
Panna croaker	*Panna microdon*	*Leijja Poa*	79.68±0.5	0.53±0.0 (2.60±0.4)	18.27±0.6 (89.90±0.9)	1.30±0.0 (6.39±0.1)	0.22±0.0 (1.08±0.4)	78.8±1.2
Pawak croaker	*Pennahia pawak*	*Datta Poa*	79.06±0.2	0.53±0.1 (2.54±0.0)	18.43±0.3 (88.02±0.6)	1.01±0.0 (4.84±0.2)	0.97±0.1 (4.63±0.5)	82.6±3.1
p - value			ns	ns	ns	ns	ns	ns
Fish peptide sample								
Panna croaker	*Panna microdon*	*Leijja Poa*	1.30±0.1	3.20±0.1	95.0±1.2	1.70±0.2	-	409.1±5.2

Data are mean ± SD (n = 3),
ns = not significant.
Values in the parentheses are on dry matter basis.

A

B

Fig. 1. Panna croaker (*Panna microdon*) collected from the Bay of Bengal (A) and FP powder prepared from the fish (B).

Proximate composition of P. microdon FP

The results are shown in Table 4. The table shows that peptide contains moisture 1.30±0.1%, protein 95.0±1.2%, lipid 3.20±0.1% and ash 1.70±0.2%. It is generally accepted that fish is an important source of quality animal protein and possess greater satiety effect than other sources of animal proteins (Uhe et al. 1992). The results of the proximate composition revealed that FP obtained from *P. microdon* could be a good source of protein. Although the color dried FP was slight brown and low whiteness, it may be attributed to lipid oxidation caused during the drying phase inside of the hot air oven. Such discoloration may be prevented by minimizing lipid oxidation (Partanen et al. 2023).

Energy content

The study revealed that the energy content of the fresh fish samples did not vary significantly (Table 4). The values ranged from 78.8±1.2 to 90.6±2.9 Kcal per 100 g with lowest in Panna croaker and the highest in Belanger's croaker. These values are relatively lower than those reported by Ullah et al. (2022) where they reported total energy was 132.99±5.67 Kcal per 100 g for Bigeye snapper. This may be linked to relatively low amount of lipid content obtained for the croaker fish species used in this study, and they are known to vary according to the nutritional state, growth, and stress variables of the fish species (Roy et al., 2020; Mansur et al., 2022). Interestingly, the energy content was significantly high at 409.1±5.2 Kcal per 100 g in FP sample prepared from *P. microdon*. This is linked to the very low moisture content (1.30±0.1%) with high protein content (95.0±1.2%) of the FP samples (Kabir et al. 2022; Nusrat et al. 2024).

Conclusion

With the year- round availability and low-cost of locally available white-fleshed marine croakers in the coastal region of Bangladesh, this study demonstrates the feasibility of domestically producing fish peptide (FP) for nutraceutical use. This natural product can supplement protein for women and children as well as act as pharmaceutical and nutraceutical products to support different aspects of human health. It is concluded that there is good potential for marine fisheries resources of Bangladesh to contribute to the global nutraceutical markets, which may improve public health outcomes and create new economic opportunities within the coastal region.

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