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Research Article

PIGMENT COMPOSITION AND BIOCHEMICAL PROFILES IN SOME FRESHWATER FISHES OF ASSAM, INDIA

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ABSTRACT

The state of Assam is diverse, with many indigenous fish species commonly found in riverine and wetland ecosystems. The current study is to unravel the nutritional and pigment profiles in the skin of 11 locally available and popular fish species collected from the local market of Nalbari district of Assam, India during February, 2024 to May, 2025. The study shows variations in their pigment profiles and biochemical profiles. Carbohydrates were maximum in *Mystus vittatus* and minimum in *Channa punctata*. The variations in proteins, lipids, carotenes, astaxanthins, pteridines, melanin and moisture contents are significantly different. Overall, the study interprets the highly valued nutritional profiles of the indigenous fish of Assam.

Keywords: Assam, Pigment, Nutritional, Biochemical, *Channa punctata.*

INTRODUCTION

Assam is well-known for its freshwater bodies. Most commonly, rivers, wetlands, shallow lands and other artificial water bodies are diverse in the state. The abundance of freshwater resources has made fish an integral part of the region's dietary culture, livelihood, and ecological balance. The study of fish pigmentation is a fascinating part of fisheries biology. Pigmentation in fish is an engaging topic of research. Fish exhibit a multitude of colours due to the presence of specialized pigment-bearing cells called chromatophores. Fish are found not only in the skin but also in the eyes and internally, such as around various organs (Nilsson Sköld *et al.,* 2013). Fish can have six types of chromatophores. The most common ones include melanophores (black and brown), xanthophores (yellow), erythrophores (reddish pigment), iridophores (metallic shades like blue, silver, or gold), leucophores (whitish), and cyanophores (vivid blue) (Fuji, 2000; Kelsh, 2004). Fishes can alter their skin colour as an adaptive response and consequently change in response to environmental fluctuations. These changes can happen quickly (physiological colour change), by moving pigments inside the cells or adjusting crystal spacing to reflect different colours. Colour change in fish is important for survival and communication. It helps them hide from predators (camouflage), trick others (mimicry), or attract mates. Fish can also change colour as they grow from young to adult (Sköld *et al.,* 2016). Unravelling the pigmentation pattern in fish is crucial in understanding species-specific adaptations, homeostatic balance and colourations. Studies show that blood astaxanthin levels in rainbow trout are influenced by dietary fat (Barbosa *et al.,* 1999). Dietary fat affected astaxanthin in fillets, especially in tail tissue, but increasing fat did not reduce colour variation across fillet regions (Nickell & Bromage, 1998). Tyrosine also produces melanin from the Tyrosinase enzyme (Sugimoto,2002). Another pigment, called carotenoids, is obtained from various diets, which are metabolized and transported by lipoproteins, reflecting fish's dietary and bodily condition. (Torrissen *et al*.,1989; Bjerkeng, 2000).

Fish play a vital role as a component of nutrition for Assamese people. The dietary value of fish is quite apparent, as inferred from various research. Recently, many studies have deciphered the importance of fish as a complementary source of protein, lipids, carbohydrates, essential micronutrients, vitamins and moisture content. Indigenous fish are a common culinary item for local

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people. Worldwide, the fish production is 167.2 million tons, of which 146.3 million tons are used for human consumption. The demand for high-quality fish increases yearly for nutritional value and health benefits. (Pal *et al.,* 2018). Freshwater fish constitute a vital source of animal protein in numerous regions globally. Moreover, they are a remarkable source of lipids, carbohydrates, essential minerals and vitamins (Steffens, 2006). Fish are also rich in bioactive compounds, such as bioactive lipids. Particularlyomega-3 fatty acids, which have been extensively studied for their role in supporting cardiovascular health, brain development, anti-inflammatory processes, etc. Biochemical profiling of fish is a key aspect of fishery science, as it provides valuable insight into the nutritional content of a fish along with their physiological status and systemic health condition. Based on all the main aims and objective of the present study are to investigate the pigmentation and biochemical composition of eleven selected freshwater fishes of Assam, India.

MATERIALS AND METHODS

Study areas and sample collection

In the present study some indigenous fishes were use as material for the study. The fishes i.e. *Puntius sophore* (Hamilton, 1822), *Wallago attu* (Bloch & Schneider, 1801), *Channa stewarii* (Playfair,1867), *Channa punctata* (Bloch, 1793), *Channa gachua* (Hamilton, 1822), *Anabas testudineus* (Bloch, 1792), *Clarias magur* (Hamilton, 1822), *Heteropneustes fossilis* (Bloch, 1794), *Monopterus cuchia* (Hamilton, 1822), *Mystus vittatus* (Bloch, 1794), *Channa striata* (Bloch, 1793) are collected from the local fish market of Nalbari district (Latitude: 26°26'14.48"N; Longitude :91°25'39.87"E), Assam, India. For each species, 20 Samples were freshly collected using polythene begs from the various vendors of the study areas.

Sample preparation

Freshly dissect the fish skin with a scalpel. Wash the sample with distilled water to remove any dirt or blood. Weigh approximately 1 g of skin sample and crush to powder in liquid nitrogen with a chilled mortar and pestle. Add chilled buffer to the ground powder—vortex the sample extract and spin at 10000 rpm for 15 minutes at 4ºC. Collect the supernatant and discard the solid debris.

Melanin extraction

Melanin was extracted from Bai *et al.* (2025) with modifications. Add 5ml of 1N NaOH to 0.5 g of skin powder for the extraction. Vortex and heat the sample in a water bath maintained at 60ºC for 30 minutes. Cool the sample and spin at 10000 rpm for 15 minutes at 4ºC. Collect the supernatant in an Eppendorf tube and measure the absorbance at 470 nm with a DU 800 UV-visible spectrophotometer (Beckman Coulter, USA). Keep 1N NaOH as a blank. Prepare a standard curve for synthetic melanin (Albatross Healthcare). Dissolve 1 mg of melanin in 1 ml of ddH_2O and dilute to 50 µg/ml, 100 µg/ml, 150 µg/ml, 200 µg/ml, 250 µg/ml.

Extraction of carotenoids

With minor modifications, the β-carotene and astaxanthin from skin powder were quantified from Hagos *et al.* (2022) and Yeguang *et al*. (2012). To 0.5 g of fish skin powder, add 5ml of acetone. Vigorously shake the sample and vortex in between. Incubate the sample in the dark for 30 minutes. Centrifuge the sample at 10000 rpm for 15 minutes at 4ºC. Collect the supernatant in an Eppendorf tube and measure the absorbance at 453 (for β-carotene). Keep acetone as a blank. A calibration curve was prepared from a standard concentration of β-carotene. For the standard solution of Astaxanthin, 1 mg of the sample was dissolved in 5 mL of DMSO. A series of dilutions of 10 µg/mL, 20 µg/mL, 30 µg/mL, 40 µg/mL, and 50 µg/mL was prepared, and absorbance at 530 nm was taken, considering DMSO as blank. Five milliliters of DMSO were added to 0.5 g of skin powder. The sample was vortexes vigorously and incubated at 70ºC for 5 minutes. The sample was spun at 4000×g for 5 minutes, and the supernatant was collected to measure the absorbance at 530 nm.

Extraction of pteridines

Pteridine content was determined from Liao et al. (2023) with slight modifications. To about 0.5 g of skin powder, 2mL of MTBE was added and the sample was centrifuged at 3000 rpm for 5 minutes at 4ºC. The extract was transferred to a centrifuge tube, and 2 ml of 1% NH_4OH solution was added, shaken for 1 minute, and centrifuged at 3000 rpm for 5 minutes at 4ºC. Absorbance at 490 nm was measured with a 1% NH_4OH solution as a blank.

Extraction and quantification of total carbohydrates

Total carbohydrate was extracted from Carol *et al.* (1956) with modifications. Before quantification of total carbohydrates from fish samples, a standard curve of glucose at various concentrations was prepared using Anthrone reagent, and absorbance was measured. The concentration of unknown samples was calculated from the standard graph.

Extraction and quantification of total Proteins

The total amount of protein was quantified from Kruger N. J. (2002) with modifications. A standard curve of known concentration (0, 5, 10, 20, 30, 40, 50, 100 µg/mL) of Bovine serum albumin was plotted against the absorbance measured at 595 nm. Briefly, 0.5 g of sample is extracted with 0.5 mL of protein extraction buffer. To the above 1 mL sample, add 4 mL of Bradford reagent and mix well by vortexing. Calculate the protein concentration of the extract (1 mL) from the equation obtained from the standard curve.

Extraction and quantification of total Lipids

The total lipid was quantified spectrophotometrically using the Sulfophosphovanillin (SPV) method, by Abdullah *et al.* (2018) with modifications. A standard curve was prepared from a known Soybean oil concentration (1 mg/mL). A series of dilutions from 0, 5, 10, 20, 40, 80 and 160 µg/mL was diluted in methanol: Chloroform (1:1) and made up to 2.5 mL with Vanillin reagent. Incubate the sample for -10 minutes and take the absorbance at 525 nm. To 0.5 g of sample, add 0.5 ml of chloroform-methanol (1:1) and shake gently. 0.25 ml of sample was heated at 100°Cto evaporate off the solvent. Add 0.1 mL H2SO4 to the tube and heat again at the same temperature. After cooling, 2.5 ml of vanillin reagent was added, and absorbance was recorded at 525 nm.

Determination of moisture content

The collected fish samples were washed with tap water to remove any dirt. The fresh weight of each sample (n=10) was calculated in an analytical balance (Shimadzu, Japan). After that, the samples were dried in a hot air oven set at 80°C till a constant weight was found. The moisture contents were determined from the formula

% Moisture content (Fresh Weight-Dry Weight)/Fresh weight×100%

RESULTS AND DISCUSSION

The analysis of melanin concentration in the skin of various freshwater fish species revealed significant interspecific variation. Among the sampled species, *Channa punctata* (CP) exhibited the highest melanin content at 129.56 µg/g, closely followed by *Channa stewartii (S)* with 117.06 µg/g and *Heteropneustes fossilis* (HF) with 110.81 µg/g. Moderate levels were recorded in *Monopterus cuchia* (MC), *Channa striata* (SC), and *Clarias magur* (CM), with values of 93.36 µg/g, 93.62 µg/g, and 87.89 µg/g, respectively. In contrast, *Channa gachua* (CG) and *Mystus vittatus* (MV) showed comparatively lower melanin concentrations of 55.60 µg/g and 30.60 µg/g, while *Anabas testudineus* (AT) registered 20.73 µg/g. The lowest melanin contents were observed in *Wallago attu* (WA) and *Puntius sophore* (PS), with values of 6.82 µg/g and 7.50 µg/g, respectively.

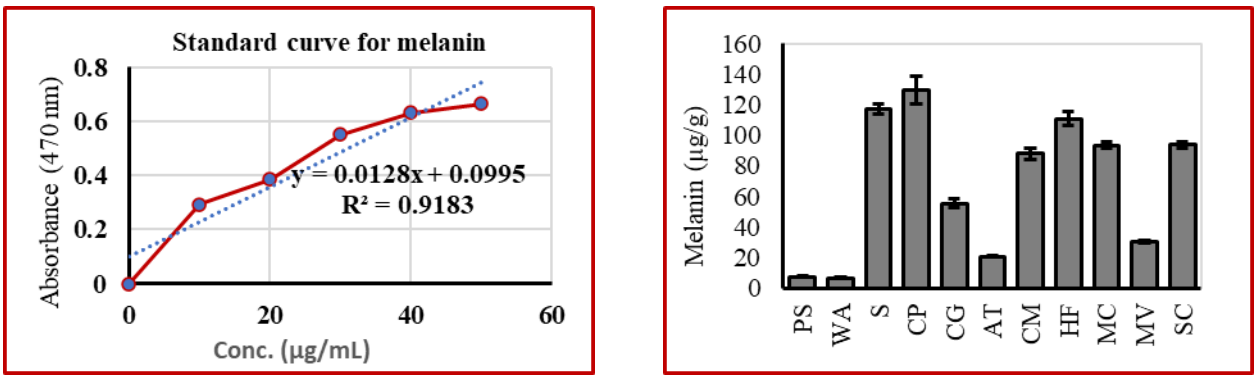

Figure 1. Standard curve of Melanin (left panel) and Melanin content (right panel) of various fish species considered for the study.

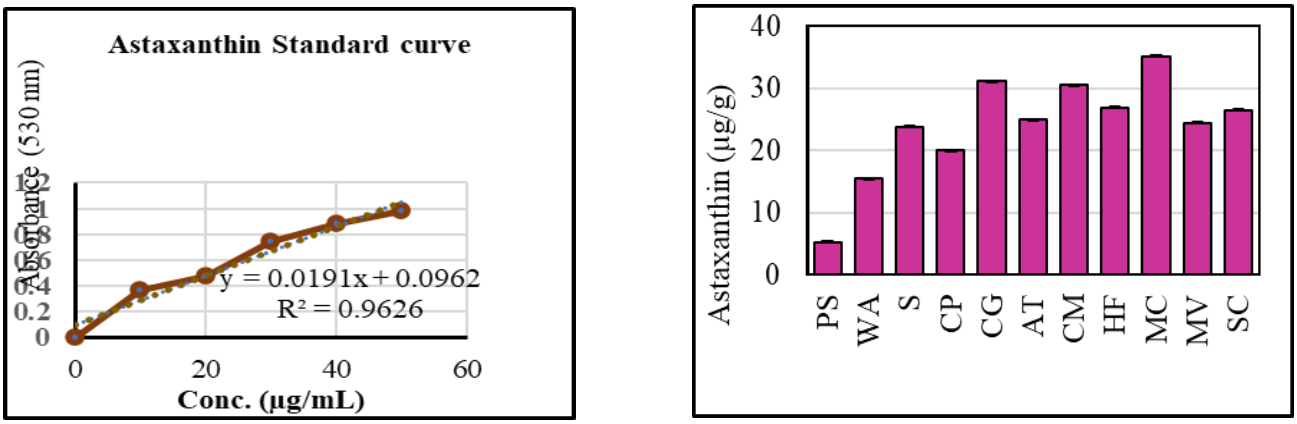

Figure 2. Standard curve of Astaxanthin (left panel) and Astaxanthin content (right panel) of various fish species considered for the study.

The analysis of astaxanthin content in the skin of selected freshwater fish species revealed substantial variation among species. The highest concentration was recorded in *Monopterus cuchia* (MC) at 35.15 µg/g, followed by *Channa gachua* (CG) and *Clarias magur* (CM), with values of 31.06 µg/g and 30.52 µg/g, respectively. Moderate astaxanthin levels were observed in *Heteropneustes fossilis* (HF) at 26.88 µg/g, *Channa striata* (CS) at 26.49 µg/g, *Anabas testudineus* (AT) at 24.92 µg/g, *Mystus vittatus* (MV) at 24.40 µg/g, and *Channa stewartii (S)*at 23.80 µg/g. *Channa punctata* (CP) exhibited slightly lower levels at 19.97 µg/g, whereas *Wallago attu* (WA) and *Puntius sophore* (PS) recorded the least astaxanthin content at 15.43 µg/g and 5.31 µg/g, respectively. The quantification of beta-carotene content in the skin of various freshwater fish species revealed distinct interspecific variations. The highest beta-carotene concentration was found in *Channa gachua* (CG) at 100.44 µg/g, followed closely by *Heteropneustes fossilis* (HF) with 96.51 µg/g and *Channa striata* (SC) with 82.74 µg/g. *Monopterus cuchia* (MC) and *Clarias magur* (CM) also exhibited relatively elevated levels of 78.56 µg/g and 74.63 µg/g, respectively. Moderate concentrations were observed in *Channa punctata* (CP) at 66.43 µg/g, *Mystus vittatus* (MV) at 65.83 µg/g, *Anabas testudineus* (AT) at 52.07 µg/g, and *Channa stewartii (S)*at 51.73 µg/g. Lower levels were recorded in *Wallago attu* (WA) with 36.22 µg/g, while *Puntius sophore* (PS) exhibited the least beta-carotene content at 27.33 µg/g.

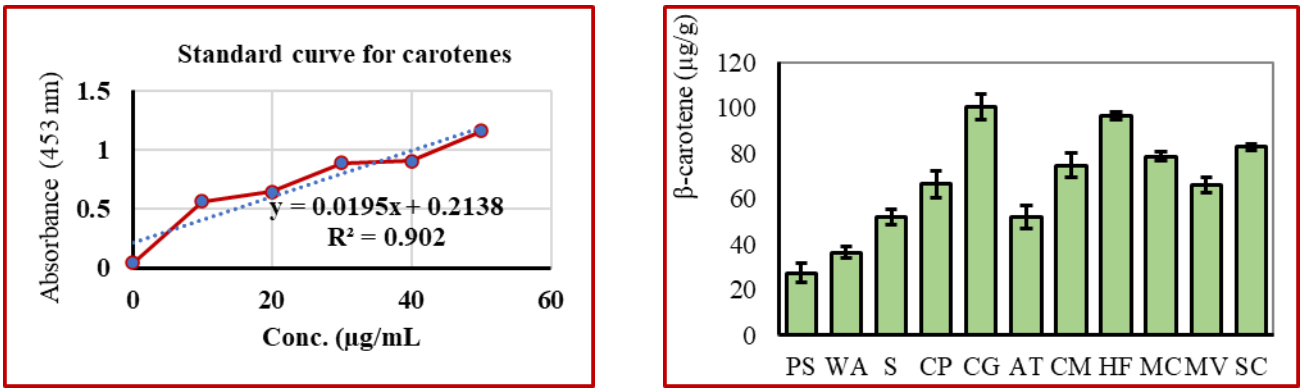

Figure 3. Standard curve of Carotene (left panel) and carotene content (right panel) of various fish species considered for the study.

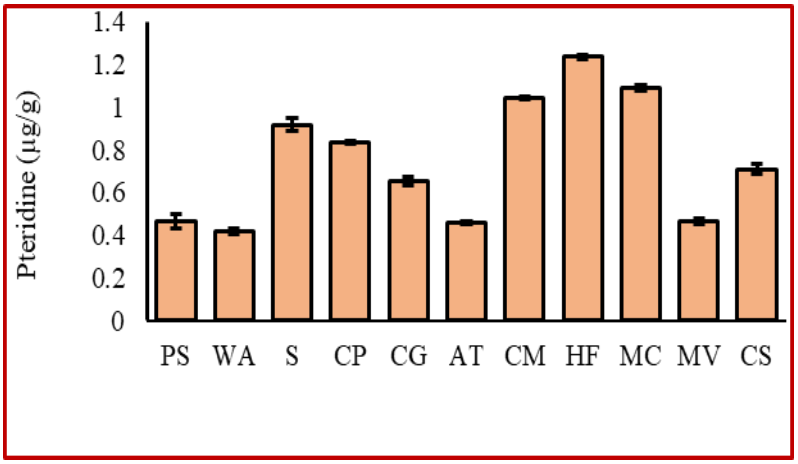

Figure 4. Pteridine content of various fish species considered for the study.

Table 1. Nutrient and pigment profiles of various fish species considered for the study.

Species	Carbohydrates (µg/gm)	Proteins (µg/gm)	Lipids (µg/gm)	Carotene (µg/gm)	Astaxanthin (µg/gm)	Pteridine (µg/gm)	Melanin (µg/gm)	Moistures (%)
PS	492.18±15.68	187.66±10.36	25.07±1.61	27.33±4.21	5.30±0.76	0.46±0.035	7.50±0.27	76.24±0.24
WA	427.32±2.82	127.66±7.00	21.59±1.63	36.22±3.32	15.43±1.36	0.41±0.012	6.82±0.24	79.83±0.54
S	304.61±16.17	275.16±10.51	48.11±1.96	51.72±5.84	23.80±0.63	0.91±0.030	117.05±3.41	74.37±0.53
CP	239.29±4.89	264.33±15.17	40.43±2.32	66.42±5.84	19.96±2.80	0.83±0.004	129.55±9.25	69.43±1.24
CG	287.43±2.39	318.91±6.13	49.85±1.18	100.44±5.63	31.06±0.31	0.65±0.018	55.59±2.89	72.13±0.89
AT	310.48±14.83	373.91±9.08	42.75±1.44	52.06±5.10	24.92±0.42	0.45±0.007	20.72±0.37	79.27±0.76
CM	307.32±4.35	412.25±11.20	80.65±1.72	74.63±5.30	30.52±0.22	1.04±0.005	87.89±3.40	74.10±0.94
HF	444.05±5.31	437.66±4.69	71.59±1.63	96.50±1.84	26.87±1.54	1.12±0.008	110.80±4.33	72.62±0.82
MC	357.51±9.78	378.50±16.12	73.40±1.70	78.56±1.84	35.15±1.53	1.09±0.012	93.35±1.96	78.85±0.91
MV	512.29±8.68	286.83±10.80	32.60±1.07	65.83±3.31	24.39±0.99	0.46±0.012	30.59±1.04	66.04±2.67
CS	352.06±8.21	276.00±8.50	54.13±2.34	82.73±1.36	26.49±1.88	0.70±0.022	93.61±2.27	75.75±1.65

The data represent the mean ± standard error from three biological replicates

Pteridine concentrations in the skin of the studied freshwater fish species were generally low but exhibited notable variation among species. The highest levels were detected in *Heteropneustes fossilis* (HF) at 1.24 µg/g, followed by *Monopterus cuchia* (MC) at 1.09 µg/g and *Clarias magur* (CM) at 1.04 µg/g. Intermediate concentrations were found in *Channa stewartii (S)*and *Channa punctata* (CP), with values of 0.92 µg/g and 0.84 µg/g, respectively. *Channa striata* (CS), *Channa gachua* (CG), and *Mystus vittatus* (MV) showed pteridine levels ranging from 0.66 to 0.71 µg/g. In contrast, the lowest pteridine contents were observed in *Wallago attu* (WA), *Puntius sophore* (PS), and *Anabas testudineus* (AT), with concentrations of 0.42 µg/g, 0.47 µg/g, and 0.46 µg/g, respectively.

The microscopic image of *Puntius sophore* skin reveals sparse and lightly clustered pigment cells, reflecting its low melanin content of 7.50 µg/g, one of the lowest among the studied species. This is consistent with its minimal levels of beta-carotene (27.33 µg/g), astaxanthin (5.31 µg/g), and pteridine (0.47 µg/g), indicating poor overall pigmentation. The image supports the biochemical data, suggesting that *Puntius sophore* exhibits a pale skin tone due to its limited pigment deposition. The microscopic image of *Wallago attu* skin shows a diffuse and faint distribution of pigment, with loosely arranged, fragmented melanophores and minimal pigment density. This aligns with its extremely low melanin content of 6.82 µg/g—the lowest among all species studied. Additionally, *W. attu* exhibited low levels of beta-carotene (36.22 µg/g), astaxanthin (15.43 µg/g), and pteridine (0.42 µg/g), confirming its poor pigmentation. The image and data suggest that *Wallago attu* has a pale appearance with limited chromatophore activity in the skin. The microscopic image of the fish skin of *Channa stewartii* shows a dense mosaic of pigment cells with a yellowish-green hue, indicating the presence of both melanophores and xanthophores. Channa striata displayed moderate melanin content (93.62 µg/g) and high beta-carotene (82.74 µg/g), along with considerable astaxanthin (26.49 µg/g), reflecting a rich carotenoid profile.

The skin of Channa punctata shows densely distributed dark pigment cells, likely melanophores, contributing to its deep colouration. This matches all studied species' highest recorded melanin content (129.56 µg/g). Moderate beta-carotene (66.43 µg/g) and lower astaxanthin (19.97 µg/g) levels suggest a balance between melanin and carotenoid pigments, aiding camouflage and visual signaling. The microscopic image of *Channa gachua* skin reveals a structured arrangement of pigment-bearing cells, with visible stratified layers suggesting the presence of chromatophores. The overall greenish-brown hue and fibrous texture indicate the distribution of melanophores and xanthophores. Quantitative analysis supports this visual observation, with *Channa gachua* exhibiting a moderately low melanin concentration (55.60 µg/g), but the highest beta-carotene content among all studied species (100.44 µg/g), highlighting its rich xanthophore presence. Additionally, levels of astaxanthin (31.06 µg/g) and pteridine (0.70 µg/g) suggest a balanced carotenoid profile contributing to its characteristic colouration.

The microscopic image of *Anabas testudineus* skin reveals layered structures with faint pigmentation and a relatively uniform but low density of pigment cells. The melanophores appear thin and lightly stained, consistent with their low melanin content of 20.73 µg/g. Additionally, *A. testudineus* showed modest levels of beta-carotene (52.07 µg/g), astaxanthin (24.92 µg/g), and pteridine (0.46 µg/g), suggesting limited pigmentation overall. This image supports the biochemical data, indicating that *Anabas testudineus* possesses a moderately dull skin tone with restricted pigment distribution. The microscopic image of *Clarias magur* reveals a concentrated cluster of dark pigment cells, likely melanophores, indicating

significant melanin presence. This aligns with its measured melanin content of 87.89 µg/g. Additionally, the presence of beta-carotene (74.63 µg/g) and astaxanthin (30.52 µg/g) suggests a well-distributed mix of carotenoid pigments contributing to its adaptive skin colouration.

The microscopic image of *Heteropneustes fossilis* shows elongated, dark-stained pigment cells arranged along fibrous skin layers. The species displays high melanin content (110.81 µg/g), along with rich beta-carotene (96.51 µg/g), astaxanthin (26.88 µg/g), and the highest pteridine level (1.24 µg/g), indicating a dense and diverse chromatophore population supporting its adaptive pigmentation. The microscopic image of *Monopterus cuchia* shows a dense, fibrous arrangement of dark pigments extending in a radial pattern, indicating active melanophore and carotenoid presence. The species exhibits moderately high melanin (93.36 µg/g) and the highest astaxanthin level (35.15 µg/g), along with elevated beta-carotene (78.56 µg/g) and pteridine (1.09 µg/g), suggesting intense pigmentation suited for burrowing and low-light habitats. The microscopic view of *Mystus vittatus* reveals irregularly distributed pigment clusters, with dark patches interspersed across a lighter background, indicating a moderate presence of melanophores and xanthophores. The species exhibits low melanin content (30.60 µg/g), while showing moderate beta-carotene (65.83 µg/g) and astaxanthin (24.40 µg/g) levels, suggesting a carotenoid-driven pigmentation pattern that supports its ecological blending.

The microscopic observation of *Channa striata* skin reveals dense pigmentation with dark blotches interspersed across the tissue, suggesting an intense concentration of melanophores. This aligns with its moderately high melanin content (93.62 µg/g), along with elevated beta-carotene (82.74 µg/g) and astaxanthin (26.49 µg/g), highlighting a well-developed chromatophore system contributing to its adaptive colouration in murky aquatic environments. The microscopic image of *Anabas testudineus* skin reveals layered structures with faint pigmentation and a relatively uniform but low density of pigment cells. The melanophores appear thin and lightly stained, consistent with their low melanin content of 20.73 µg/g. Additionally, *A. testudineus* showed modest levels of beta-carotene (52.07 µg/g), astaxanthin (24.92 µg/g), and pteridine (0.46 µg/g), suggesting limited pigmentation overall. This image supports the biochemical data, indicating that *Anabas testudineus* possesses a moderately dull skin tone with restricted pigment. The protein composition of fish skin varied notably among the studied freshwater species. The highest protein content was recorded in *Heteropneustes fossilis* (HF) at 437.67 µg/g, followed closely by *Clarias magur* (CM) with 412.25 µg/g and *Macrognathus aral* (MA) at 378.50 µg/g. *Anabas testudineus* (AT) and *Channa gachua* (CG) also exhibited high protein levels of 373.92 µg/g and 318.92 µg/g, respectively. Moderate protein concentrations were observed in *Mystus vittatus* (MV), *Channa striata* (CS), and *Channa stewartii* (S), with values ranging from 275.17 µg/g to 286.83 µg/g. *Channa punctata* (CP) also showed a relatively high level at 264.33 µg/g. In contrast, lower protein contents were recorded in *Wallago attu* (WA) and *Puntius sophore* (PS), at 127.67 µg/g and 187.67 µg/g, respectively.

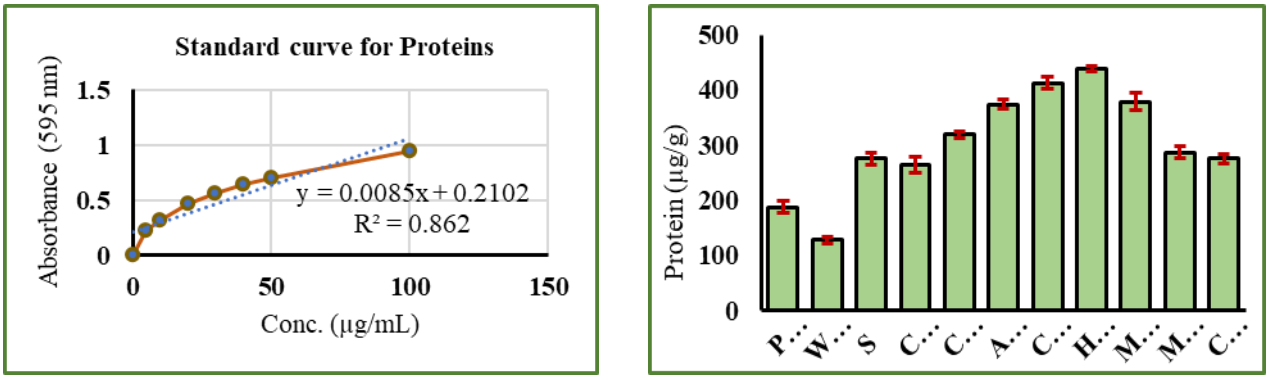

Figure 5. Standard curve of BSA (left panel) and total Protein content (right panel) of various fish species considered for the study.

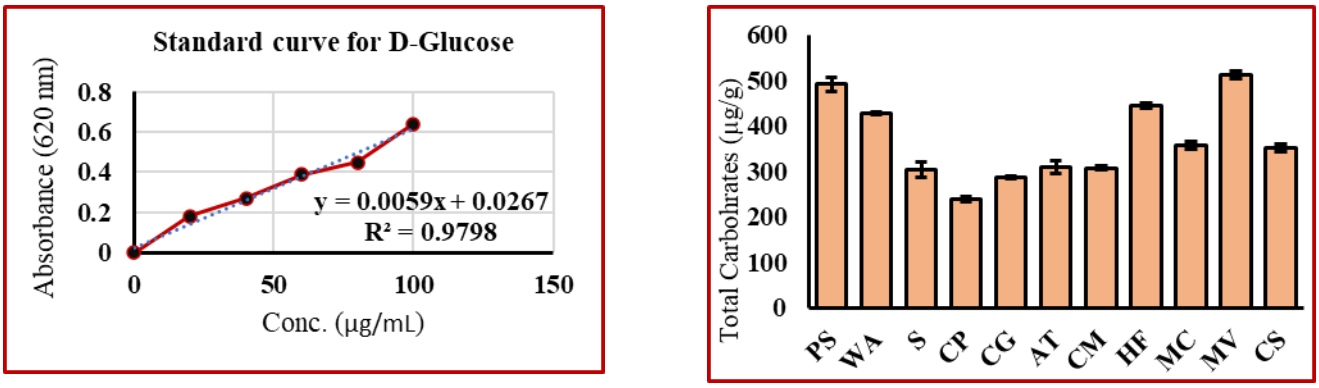

Figure 6. Standard curve of Soybean oil (left panel) and total lipid content (right panel) of various fish species considered for the study.

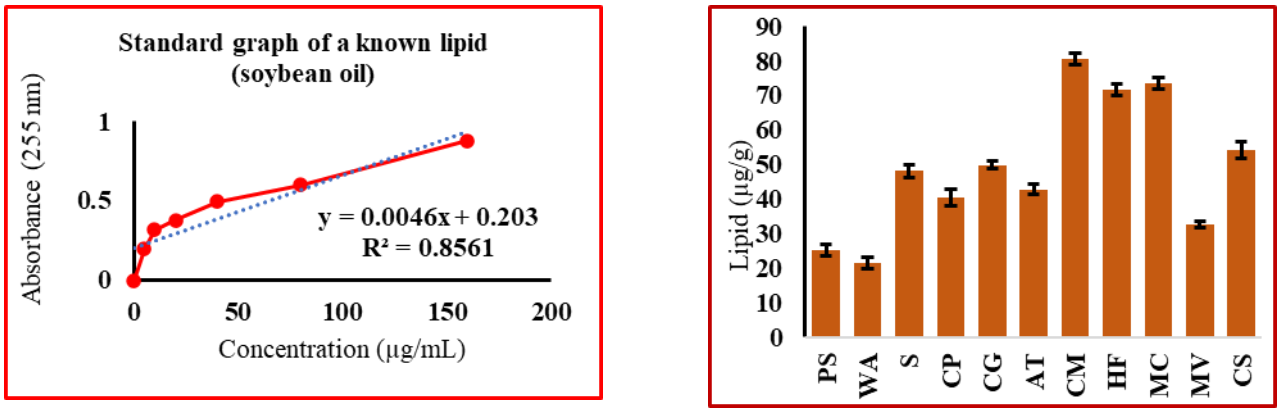

Figure 7. Standard curve of D-Glucose (left panel) and total carbohydrate content (right panel) of various fish species considered for the study.

The lipid content in the skin of the selected freshwater fish species showed substantial interspecific variation. The highest lipid concentration was observed in *Clarias magur* (CM) at 80.65 µg/g, followed by *Monopterus cuchia* (MC) and *Heteropneustes fossilis* (HF), with values of 73.41 µg/g and 71.59 µg/g, respectively. *Channa striata* (CS) and *Channa gachua* (CG) also exhibited relatively high lipid levels at 54.13 µg/g and 49.86 µg/g. Moderate concentrations were noted in *Channa stewartii* (S), *Anabas testudineus* (AT), and *Channa punctata* (CP), with values ranging from 40.43 µg/g to 48.12 µg/g. In contrast, lower lipid levels were found in *Mystus vittatus* (MV), *Puntius sophore* (PS), and *Wallago attu* (WA), with 32.61 µg/g, 25.07 µg/g, and 21.59 µg/g, respectively. The carbohydrate composition of fish skin displayed notable variation across the studied freshwater species. The highest carbohydrate content was recorded in *Mystus vittatus* (MV) at 512.29 µg/g, followed by *Puntius sophore* (PS) and *Heteropneustes fossilis* (HF), with values of 492.18 µg/g and 444.05 µg/g, respectively. *Wallago attu* (WA) also showed a relatively high carbohydrate concentration of 427.32 µg/g. Moderate levels were observed in *Monopterus cuchia* (MC) and *Channa striata* (CS), at 357.72 µg/g and 352.07 µg/g, respectively. *Anabas testudineus* (AT), *Clarias magur* (CM), and *Channa gachua* (CG) displayed values ranging from 287.44 µg/g to 310.49 µg/g. Lower carbohydrate content was noted in *Channa stewartii (S)*at 304.61 µg/g and *Channa punctata* (CP), which recorded the lowest value at 239.30 µg/g.

Moisture content in the skin of the analyzed freshwater fish species exhibited relatively narrow variation, yet species-specific differences were evident. The highest moisture content was observed in *Wallago attu* (WA) at 79.83 g, followed closely by *Anabas testudineus* (AT) at 79.27 g and *Monopterus cuchia* (MC) at 78.85 g. *Puntius sophore* (PS) and *Channa striata* (CS) also showed comparatively high moisture levels at 76.24 g and 75.75 g, respectively. Intermediate values were recorded in *Channa stewartii* (S), *Clarias magur* (CM), *Channa gachua* (CG), and *Heteropneustes fossilis* (HF), ranging between 72.14 g and 74.38 g. Lower moisture content was found in *Channa punctata* (CP) at 69.44 g and *Mystus vittatus* (MV), which exhibited the lowest level at 66.04 g.

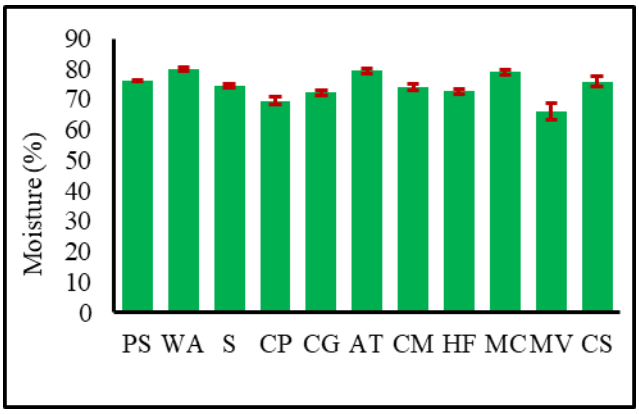

Figure 8. Standard curve of moisture content of various fish species considered for the study.

These findings stated that snakeheads (*Channa spp.)* and catfishes (*H. fossilis*) showed melanin more efficiently than cyprinids (*Puntius sophore)* and large catfish (*W. attu*). Recent studies by Singh and Naga (2017) stated similar patterns of high melanin concentration in *Channa striata*, attaching it to adaptive foods for camouflage and environmental stress resistance. Sinha and Asimi (2007), who observed that *Channa gachua* fed carotenoid-rich diets exhibited boosted carotene deposition. Devi and Mahanta (2019) demonstrated that catfish species also show significant carotenoid accumulation, likely due to their feeding behaviors that contain insect larvae and detritus containing carotenoid precursors. The high astaxanthin levels in *M. cuchia* and *Clarias magur (*30.52 ± 3.85 µg/g) suggest that benthic feeders accumulate the astaxanthin pigment more effectively than surface-dwelling species. Similar results were reported by Devi and Mahanta (2019), that Indian catfish species have high astaxanthin content, which boosts both antioxidant defense and skin coloration. Torrissen (1989) highlighted that astaxanthin is one of the most effective carotenoids influencing pigmentation and is often higher in species with benthic feeding behavior. Ziegler (2003) similarly noted that pteridines, though minor compared to melanin and carotenoids, play a significant role in reflective coloration and UV protection in fishes. These results are consistent with the findings of recent studies (Chatzifotis *et al*., 2005; Devi & Mahanta, 2019), which highlight that pigment accumulation in fish is influenced by ecological niche, feeding habits, and dietary availability of carotenoids.

CONCLUSION

The indigenous fishes of Assam possess significant biochemical richness and pigment diversity, warranting greater attention in research, public health policy, and sustainable fisheries development. Their promotion in local diets and their potential inclusion in functional food and aquaculture programs can contribute to nutritional well-being, economic upliftment, and biodiversity conservation. This study is a scientific foundation for further explorations into the value-added utilisation and ecological monitoring of these important aquatic resources.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

REFERENCES

Chatzifotis, S., Pavlidis, M., Jimeno, C. D., & Divanach, P. (2005). The effect of dietary carotenoids on skin colouration of red porgy (*Pagrus pagrus*). *Aquaculture Research, 36*(15), 1517–1525. https://doi.org/10.1111/j.1365-2109.2005.01371.x

Devi, R., & Mahanta, P. C. (2019). Pigmentation and carotenoid content in selected Indian catfishes: Implications for aquaculture. *Journal of Applied Ichthyology, 35*(6), 1285–1292. https://doi.org/10.1111/jai.13962.

Fujii, R. (2000). The regulation of motile activity in fish chromatophores. *Pigment Cell Research, 13*(5), 300–319. https://doi.org/10.1034/j.1600-0749.2000.130502.x.

Gupta, S., Gupta, P. C., & Singh, H. (2007). Role of dietary carotenoids in fish nutrition. *Indian Journal of Fisheries, 54*(1), 1–9.

Olson, V. A., & Owens, I. P. F. (1998). Costly sexual signals: Are carotenoids rare, risky or required? *Trends in Ecology & Evolution, 13*(12), 510–514. https://doi.org/10.1016/S0169-5347(98)01484-0.

Singh, R., & Naga, R. (2017). Melanin deposition in *Channa striata*: Ecological and adaptive significance. *Journal of Fish Biology, 90*(3), 1042–1050. https://doi.org/10.1111/jfb.13223.

Sinha, A., & Asimi, O. A. (2007). Effect of dietary carotenoids on pigmentation and growth of freshwater fish species. *Indian Journal of Fisheries, 54*(4), 425–430.

Sugimoto, M. (2002). Morphological color changes in fish: Regulation of pigment cell density and morphology. *Microscopy Research and Technique, 58*(6), 496–503. https://doi.org/10.1002/jemt.10168.

Torrissen, O. J. (1989). Pigmentation of salmonids: A comparison of astaxanthin and canthaxanthin as pigment sources for rainbow trout. *Aquaculture, 79*(3–4), 363–374. https://doi.org/10.1016/0044-8486(89)90474-0.

Ziegler, I. (2003). The pteridines as pigments and vitamins. *Pigment Cell Research, 16*(6), 661–662. https://doi.org/10.1034/j.1600-0749.2003.00088.x.