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# Effects of Natural Carotenoid Source Enriched Feed on the Growth, Flesh Carotenoid, Composition, and Palatability of a Silver Barb (*Barbonymus gonionotus*)

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

**Aim:** The study compared the effects of different natural carotenoid-enriched feeds with a commercial carp feed on the growth, flesh carotenoid, composition, and palatability of *Barbonymus gonionotus*.
**Study Design:** The study was conducted with four feeds treated as four treatments where, a commercial carp grower feed was used as control feed (CF) and three test feed were made by

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adding the powder of three carotenoid sources, viz., tomato (TMP), carrot (CRP), and beetroot (BRP) in the control feed at a rate of 2g/kg. Fifteen juveniles *of B. gonionotus* were stocked in each cage. The fish were fed with test feed twice a day at the rate of 5% (2.5% + 2.5%) of body weight and weighed fortnightly to adjust the ration size.

**Place and Duration of Study:** The trial was conducted in twelve cages set in a pond at the Department of Fisheries, University of Rajshahi, Bangladesh, for 90 days.

**Methodology:** At the end of the trial, the growth and feed utilization parameters, viz., weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR), and protein efficiency ratio (PER), flesh carotenoid and composition, and palatability indicators of the fish were evaluated according to standard formulae, spectrophotometry, AOAC, and organoleptic sensory technique, respectively.

**Results:** The higher WG (193.89±12.31 g) and SGR (1.41±0.08 %), better FCR (1.59±0.16) and PER (3.07±0.31), and higher carotenoids content (4.31±0.29 mg/g) were found in the fish fed with carrot-enriched feed, followed by the fish fed with tomato-enriched feed (WG: 174.86±11.50 g, SGR: 1.33±0.01 %, FCR: 1.74±0.04, PER: 2.78±0.06 and Carotenoids: 1.59±0.09 mg/g) and the beetroot-enriched feed (WG: 168.56±12.87 g, SGR: 1.30±0.08 %, FCR: 1.84±0.19, PER: 2.66±0.28 and carotenoids: 1.44±0.40 mg/g) when compared to the control fish. No significant difference in the flesh composition was found among the treatments. A significantly higher organoleptic sensory score (25.54±0.57) was recorded in the fish fed with carrot-enriched feed and lower in the control feed (19.52±0.77).

**Conclusion:** The study concludes that 2g/kg carrot powder supplementation in feed is better for enhancing the growth, carotenoid deposition, and palatability *of B. gonionotus*.

*Keywords: Carotenoid; feed; growth; flesh quality; palatability; silver barb.*

## 1. INTRODUCTION

Aquaculture is the dynamic, promising, and fast-growing economy sector all over the world, including Bangladesh. It plays an important role in the socio-economic and livelihood development of the rural population in Bangladesh (Shamsuzzaman *et al*., 2020). Nowadays, feed-based aquaculture with a high density of fish is increasing in the country. This high-density aquaculture practice subsequently leads to an unprecedented demand for feed (Khatun *et al*., 2017). To meet the increasing demand for feed, a lot of feed industries have expanded in the country (Ali, 2024). Disappointingly, most of the manufacturers fail to provide quality feed owing to a lack of quality feed ingredients, the use of contaminated ingredients, and other factors (Khatun *et al*., 2017).

Bangladesh has achieved self-sufficiency in fish production in recent times (DoF, 2020), the future of aquaculture research lies in sustainable production methods, value addition, and quality enhancement of the products. However, the ever-increasing demand for fish feed necessitates that every possible natural resource be considered as a potential feed ingredient. Hence, the available natural sources of carotenoid can be used as a feed ingredient that promotes growth and improves the colour, quality, and odour of fish flesh, which ultimately increases the market demand and value of the fish. Many vibrantly coloured vegetables, such as carrots (Bozalan and Karadeniz, 2011), tomatoes (Martí *et al*., 2016), and beetroot (Sentkowska and Pyrzyńska, 2023) are rich sources of carotenoids.

Furthermore, the demand and consumer preference for fish and fish products are not only dependent on geographic location and socio-cultural norms (Pieniak *et al*., 2011) but also driven by the smell, taste, and colouration of that product (Uddin *et al*., 2019). Colouration and smell may have both psychological and physiological impacts on the mind and can dictate the buying behavior of consumers, which ultimately reflects in the market demand for fish (Kaushik, 2011). Chromatophores are primarily responsible for the colouration of fish, and they are broadly classified into four types, such as carotenoid, melanin, purin, and preidum (Hoar and Randall, 1992). Carotenoids produce a red-to-yellow colour in the tissue and skin of fish, and their presence can facilitate various physiological functions such as growth, survival rate, and disease resistance (Ezhil *et al*., 2008). Farmed fish have little access to carotenoid-rich food, and therefore, the necessary carotenoids must be added to the diet (Gupta *et al*., 2007). Several studies have evaluated different potential carotenoid sources like tomato, carrot, beetroot, red pepper, and spirulina (Swian *et al*., 2014; Lakshmi *et al*., 2015; Chow *et al*., 2017; Tiewsoh *et al*., 2019). Besides pigments, theses additives influence the flesh quality, survival, disease resistance, and growth of fish (Rema and Gouveia, 2005; Jha *et al*., 2012; Walaa *et al*., 2014).

For the utilization of natural carotenoid sources as feed additives, the addition of these sources in a commercial feed can be tested using a minor carp species, silver barb (*B. gonionotus*). Silver barb is one of the important cultural species in Bangladesh. It is a short-cycled, omnivorous species that can be farmed with relatively easy technology. The colour of this species is silvery-white. If natural carotenoid sources can be effectively used for the enhancement of the colour, growth, and flesh quality of this fish, that will boost its market demand and value. Although there are some research works on the effects of carotenoid sources on the growth and body compositions of various fish species all over the world (Teimouri *et al.,* 2013; Azab *et al.,* 2016; Maiti *et al*., 2017; Wagde *et al*., 2018; Jorjani *et al*., 2019), no research works have been carried out to explore the effects of natural carotenoid sources on the growth and flesh quality of minor carp species. Therefore, the present study was conducted to evaluate the effects of natural carotenoid-enriched feeds on the growth, flesh colour and composition, and palatability of a silver barb (*B. gonionotus*).

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site and Period

The study was conducted in 12 cages that were set in an earthen pond at the Department of Fisheries, University of Rajshahi, Rajshahi, Bangladesh, for a period of 3 months (July-September, 2022). The size and average depth of the pond were 10 decimal and 6 feet, and the source of water was ground water. Twelve iron-framed cages (each measuring 96 $ft^3$) were constructed and covered by a synthetic nylon knotless net of 5 mm mesh size with an opening at the top for feeding and sampling purposes and with a suspended feeding tray hanging from the top.

### 2.2 Experimental Design

In this trial, a commercial carp grower feed from the ACI group (Godrej) was used as control feed (CF) and three test feeds were made by adding the powder of three selected natural carotenoid sources, viz., tomato (TMP), carrot (CRP), and beetroot (BRP) in the commercial feed at a rate of 2 g/kg. The trial was conducted with these four feeds (CF, TMP, CRP, and BRP) treated as four treatments that were arranged in a complete randomized design (CRD) across the settled cages, with 3 replications for each. Fifteen juveniles *of B. gonionotus* (initial weight of each fish about 76 g) were stocked in each cage.

### 2.3 Collection of Carotenoid Sources and Feed Preparation

Natural carotenoid sources, viz., tomato, carrot, and beetroot were purchased from a local vegetable market called Shaheb Bazar, Rajshahi, Bangladesh. After purchasing, the carotenoid sources were washed, cut into thin slices, and dried under sunlight. After drying, the slices were ground by using grinder, converted into powder, and stored in a polythene bag for subsequent use. For feed preparation, a little water was added to the commercial feed to make it soft and malleable. Then fixed rates of carotenoid sources were added and thoroughly mixed to make dough. Then the dough was extruded with a pelleting machine to convert it into pellets (3-5 mm). Pellets were then dried under sunlight. After drying, the pellets were packed in lebelled polythene bags, sealed, and stored at refrigeration temperature until used. The proximate composition of the feeds was evaluated according to AOAC (2005). The proximate analysis of the feeds exhibited no significant difference among them, and the values were more or less isoproteinic and isolipidic in composition (Table 1).

**Table 1. Proximate composition of the feeds (% wet basis)**

| Component | CF | TMP | CRP | BRP |
|---|---|---|---|---|
| Moisture | $13.18 \pm 0.50^a$ | $13.51 \pm 0.41^a$ | $13.44 \pm 0.78^a$ | $13.36 \pm 0.35^a$ |
| Protein | $22.45 \pm 0.21^a$ | $22.59 \pm 0.31^a$ | $22.47 \pm 0.18^a$ | $22.51 \pm 0.25^a$ |
| Lipid | $6.22 \pm 0.47^a$ | $6.35 \pm 0.30^a$ | $6.18 \pm 0.42^a$ | $6.57 \pm 0.15^a$ |
| Ash | $9.70 \pm 0.35^a$ | $9.01 \pm 0.23^a$ | $9.22 \pm 0.18^a$ | $9.26 \pm 0.14^a$ |
| Carbohydrate | $43.11 \pm 0.60^a$ | $43.28 \pm 0.52^a$ | $43.24 \pm 0.41^a$ | $43.16 \pm 0.25^a$ |

**CF = Control feed; TMP = Tomato powder enriched feed; CRP = Carrot powder enriched feed; BRP = Beetroot powder enriched feed; Values in the same row with same superscripts are not significantly different (P=0.05)*

## 2.4 Collection of Experimental Fish and Rearing

One hundred and eighty juveniles of silver barb (more or less similar size and weight) were purchased from a local fish farmer, and were transported in the presence of an aeration system, and acclimatized in a circular cemented tank for a week. After the acclimatization period, fifteen fishes were randomly distributed among four treatments (CF, TMP, CRP, and BRP). During the whole feeding trial, the fish were fed twice a day at 9:30 a.m. and 4:30 p.m. at the rate of 5% (2.5% + 2.5%) of body weight, and the fish were weighed fortnightly for ration size adjustment.

## 2.5 Monitoring Water Quality Parameters

During the experimental period, water temperature, pH, DO, total alkalinity, and $NH_3$-N were measured fortnightly. Temperature was recorded by using a Celsius thermometer. The pH of the water was measured by digital pH meter. DO, $CO_2$, total alkalinity and $NH_4$-N were determined by using HACH Kit (Model: DR/2010). There was no significant difference in water quality parameters among the treatments, and were within the productive range.

## 2.6 Analysis of Growth and Feed Utilization

At the end of the feeding trial, the final weights of the fish were measured individually by electric balance. Growth performance and feed utilization were evaluated by means of weight gain (WG), percentage weight gain (PWG), specific growth rate (SGR), survival rate (SR), feed conversion ratio (FCR), and protein efficiency ratio (PER) according to the standard formulae.

$$\text{MWG} = \text{Mean Final Weight (MFW)} - \text{Mean Initial Weight (MIW)}$$

$$\text{SGR} = \frac{\ln(\text{MFW}) - \ln(\text{MIW})}{\text{Culture Duration (Days)}} \times 100$$

$$\text{SR} = \frac{\text{No.of Fish Harvested}}{\text{No.of Fish Stocked}} \times 100$$

$$\text{FCR} = \frac{\text{Feed Fed}}{\text{Live Weight Gain}}$$

$$\text{PER} = \frac{\text{Live Weight Gain}}{\text{Protein Fed}}$$

## 2.7 Carotene Content Analysis

The fresh flesh samples of the fish were weighted and ground by mortar and pestle using 90% methanol. After grinding, the sample mixtures were subsequently centrifuged at 12,000 rpm for 12 minutes, and the supernatant was transferred into another centrifuge tube. Finally, the optical density of the supernatant was recorded at 662 nm, 653 nm, and 470 nm by using a spectrophotometer (Analytic Gena). The total concentration of carotenoids was measured using the following equation (Lichtenthaler and Wellburn, 1983).

$$Ca = 15.65\,A666 - 7.340\,A653$$

$$Cb = 27.05\,A653 - 11.21\,A666$$

$$\text{Total carotene (mg/g)} = \frac{1000A470 - 2.86Ca - 129.2Cb}{245}$$

Where, $A_{666}$ = OD at 666 nm, $A_{653}$= OD at 653 nm and $A_{470}$= OD at 470 nm

## 2.8 Proximate Analysis of Fish Flesh

The proximate analysis by means of crude protein, lipid, carbohydrate, fiber, moisture, and ash content in the flesh of fish was determined using the standard method (AOAC, 2005).

## 2.9 Palatability Test

At first, fish collected from the four treatments were scaled, gutted, and cut into fish loins. After washing, 500 g of fish flesh from each treatment was cooked following conventional procedures and spices. The fish loins from each treatment were marked and cooked together to avoid cooking bias. After cooking, the fish were served to an expert panel of 12 members for organoleptic (sensory) evaluation. After consuming the cooked flesh, the expert panelists gave their scores blindly on the flesh's odour, taste, and texture following the specific structured scaling system (Table 2) described by Huss (1995).

## 2.10 Statistical Analysis

After determining the normality of the data set through Levine's test, a one-way analysis of variance (ANOVA) was conducted to test for the level of significance using SPSS 21 (the statistical package for social science). The significant difference among the mean values was determined by Duncan's multiple range test at level 5% (*P = 0.05*).

**Table 2. Organoleptic scoring scale for palatability evaluation**

| Organoleptic Attributes | | | Score |
|---|---|---|---|
| Odor | Taste | Texture | |
| Species-specific | Meaty flavor | Firm/elastic | 10 |
| Fresh fish | Sweet | Firm/springy | 8 |
| Slightly fishy/ sour | Slightly fishy | Less firm | 6 |
| Sour and stale | Slight sour/off flavor | Softer | 4 |
| Strong ammonia | Slightly rotten | Very soft | 2 |
| Rotten smell | Spoiled | Slippery | 0 |

## 3. RESULTS AND DISCUSSION

### 3.1 Growth Performance and Feed Utilization

The experimental fish fed with natural carotenoid-enriched feeds (TMP, CRP, and BRP) exhibited significantly better growth performance compared to the control fish (Table 3). The highest weight gain, percent weight gain, and SGR were recorded in the fish treated with CRP, followed by TMP and BRP. However, the growth performance of the fish treated with TMP and BRP didn't differ significantly from each other. Additionally, carotenoid supplementation didn't affect the survival rate of the fish across the treatments. The FCR and PER values in the fish of TMP, CRP, and BRP were found to be significantly better compared to the control fish, while the fish treated with CRP demonstrated the highest values in all these parameters (Table 3). Similar to the growth parameters, no significant difference was observed in the FCR values between TMP and BRP-treated fish. The PER values of TMP, CRP, and BRP-treated fish didn't show any significant difference among them as well.

According to the findings of the present study, the addition of natural carotenoid sources in the feed appeared to have positive effects on the growth performance and feed utilization of the fish. Based on the data, better growth performance (weight gain and SGR) and feed utilization (FCR) were recorded in the fish fed with carrot powder-treated feed (CRP), followed by tomato and beetroot powder-treated feed, whereas the fish treated with control feed showed lower growth performance and feed utilization. This result agrees with Maiti *et al.* (2017), where significantly better weight gain was reported in *Cyprinus carpio* by supplementing carrot-treated feed, followed by tomato and beetroot-treated feed. Lakshmi et al. (2015) also reported an improved growth rate of Albino Tiger barb by using carrot-enriched feed compared to the dietary provision of beetroot. Supporting evidence of the current study has also been found in the reports of Swian *et al*. (2014), who studied the positive effects of natural carotenoids on the growth of Koi carp. The findings of the present study also coincide with the reports of Tiewsoh *et al.* (2019) and Hafeez-ur-Rehman *et al*. (2015), where the higher weight gain and specific growth rate of goldfish (*Carassius auratus*) were found in carrot powder-treated fish compared to the control fish (fed feed without CRP).

**Table 3. Growth performance and Feed Utilization of the Fish**

| Parameter | CF | TMP | CRP | BRP |
|---|---|---|---|---|
| IW (g) | 76.44 ± 6.51$^{a}$ | 76.31 ± 6.43$^{a}$ | 76.13 ± 4.80$^{a}$ | 76.06 ± 5.01$^{a}$ |
| FW (g) | 200.81 ± 10.20$^{c}$ | 251.19 ± 11.99$^{b}$ | 269.63 ± 12.45$^{a}$ | 244.06 ± 13.03$^{b}$ |
| WG (g) | 124.35 ± 9.20$^{c}$ | 174.86 ± 11.50$^{b}$ | 193.89 ± 12.31$^{a}$ | 168.56 ± 12.87$^{b}$ |
| % WG | 162.83 ± 1.28$^{c}$ | 232.18 ± 1.04$^{b}$ | 255.90 ± 1.16$^{a}$ | 222.53 ± 1.19$^{b}$ |
| SGR | 1.07 ± 0.07$^{c}$ | 1.33 ± 0.01$^{b}$ | 1.41 ± 0.08$^{a}$ | 1.30 ± 0.08$^{b}$ |
| FCR | 2.50 ± 0.28$^{c}$ | 1.74 ± 0.04$^{b}$ | 1.59 ± 0.16$^{a}$ | 1.84 ± 0.19$^{b}$ |
| PER | 1.97 ± 0.22$^{b}$ | 2.78 ± 0.06$^{a}$ | 3.07 ± 0.31$^{a}$ | 2.66 ± 0.28$^{a}$ |

** CF = Control feed; TMP = Tomato powder enriched feed; CRP = Carrot powder enriched feed; BRP = Beetroot powder enriched feed*

** IW = Initial weight, FW = Final weight, GW = Weight gain, SGR = Specific growth rate, SGR = Specific growth rate, PER = Protein efficiency ratio.*

** Values in the same row with different superscripts are significantly different (P=0.05).*

Among the carotenoid-based feeds, carrot powder-incorporated feeds produced better FCR in the fish than tomato and beetroot powder-treated feeds. More or less similar results were also reported in *Pelteobagrus fulvidraco* (Fei *et al*., 2019). Earlier researchers (Amar *et al*., 2001; Watanabe and Vasallo-Agius, 2003) reported that carotenoids play a role in the intermediary metabolism of fish by improving the utilization of nutrients, resulting in improved growth. However, besides the effectiveness of carotenoids in growth performance, they also have a positive effect on the survival rate of fish. A previous study (Torrissen, 1995) reported that carotenoid sources like astaxanthin are essential for the growth and survival of fish and crawfish. However, in this experiment, the result showed that no mortality was found among the treatments. This might be due to the stocking of relatively large and healthy fish.

## 3.2 Carotenoid Content

The concentrations of carotenoid deposition in the flesh of fish treated with TMP, CRP, and BRP were significantly higher than the control fish, CF (Table 4). The carotenoid content in the fish flesh of CRP was the highest, followed by TMP and BRP. Natural carotenoid inclusion in feed showed a positive effect on carotene deposition in the fish flesh. The present study result exhibited that the flesh of fish treated with natural carotenoid-enriched feed had higher carotene content than the control fish. A similar result was obtained by Maiti *et al.* (2017), where the inclusion of natural carotenoids in feed increased the carotene deposition in the meat of *Cyprinus carpio*. In another study, Tiewsoh *et al.* (2019) registered that the gradual higher inclusion of carrots in feed increases the carotenoid deposition in the goldfish. The results of the present study are also associated with the findings of Swian *et al.* (2014) and Ezhil *et al.* (2008), who found higher carotenoid deposition in the flesh of *Xiphophorus helleri* and *C. carpio* treated with natural carotenoid-enriched feed.

## 3.3 Proximate Composition of Fish Flesh

Changes in carcass compositions (% wet basis) of the fish fed with carotenoid-enriched feeds are shown in Table 5. Proximate analysis showed no significant differences in carcass protein, lipid, carbohydrate, fiber moisture, and ash content in the flesh of *B. gonionotus* among the treatments. However, relatively higher carcass protein and ash content were recorded in the fish of BRP, whereas relatively higher lipid, fiber, and moisture content was found in the fish of CRP compared to the control fish (CF).

The results of the present study indicate that the inclusion of natural carotenoid sources in the diet does not impart any positive or negative effects on the carcass of *B. gonionotus*. More or less similar results were registered by Jorjani *et al.* (2019), who observed no effects of *Hibiscus rosasiensis* (as a natural carotenoid source) on the body composition of blue gourami (*Trichogaster trichopterus*). However, Jha *et al.* (2012) found an increase in carotenoid sources in the diet significantly affected the proximate composition of *Barilius bendelisis* when spirulina was the source, while marigold did not have any significant impact on the carcass of the fish. In another study, Kelestemur and Çoban (2016) found that the crude protein value of fish's meat was higher in a beta-carotene-supplemented diet in rainbow trout, which is a disparity with the present study. The report of Walaa *et al.* (2014) revealed a significant positive effect of carotenoid supplements from crayfish meal and squilla meal on crude protein and ether extracts of red tilapia, which is also an inequality of the present findings. The results of the present study and the findings of preceding research are in concurrence with Boonyaratpalin *et al.* (2001), who reported that different sources of carotenoids might have different impacts on the proximate composition of fish and prawns.

## 3.4 Palatability Test

After the consumption of cooked fish, a number of panelist's consumers made their comments on odour, taste and texture of fish through the specific scoring scale on a score sheet and the mean scores are shown in Table 6. From the assessment of the expert panel, we observed that the cooked flesh of the fish treated with different carotenoid sources had significantly improved odour, taste, and texture compared to the fish treated with control feed. Based on the comments of the panelists regarding palatability, it can be stated that the fish treated with CRP-enriched-feed scored the highest in terms of organoleptic score, followed by the flesh of fish treated with TMP, BRP, and CF. According to the total organoleptic score of three sensory qualities (odour, taste, and texture), the flesh of the fish treated with CRP-enriched feed was the most palatable (Table 6). This might be due to the higher carotenoid deposition in the flesh of carrot-treated fish (Table 4), though no scientific documents are available relating to the relationship between palatability and carotenoid deposition in fish flesh. The higher organoleptic

**Table 4. Carotene content (mg/g) in the flesh of the fish**

| Treatments | CF | TMP | CRP | BRP |
|---|---|---|---|---|
| Carotenoid | 0.29 ± 0.17[c] | 1.59 ± 0.09[b] | 4.31 ± 0.29[a] | 1.44 ± 0.40[b] |

** CF = Control feed; TMP = Tomato powder enriched feed; CRP = Carrot powder enriched feed; BRP = Beetroot powder enriched feed*

** Values in the same row with different superscripts are significantly different (P=0.05).*

**Table 5. Proximate compositions (%) of the fish flesh**

| Component | CF | TMP | CRP | BRP |
|---|---|---|---|---|
| Protein | 14.50 ± 1.16[a] | 14.82 ± 0.23[a] | 14.44 ± 0.04[a] | 15.15 ± 0.07[a] |
| Lipid | 2.18 ± 0.03[a] | 2.06 ± 0.11[a] | 2.48 ± 0.33[a] | 2.20 ± 0.007[a] |
| Ash | 1.70 ± 0.02[a] | 1.82 ± 0.07[a] | 1.70 ± 0.31[a] | 1.86 ± 0.27[a] |
| Carbohydrate | 9.22 ± 0.83[a] | 10.68 ± 1.09[a] | 9.32 ± 1.86[a] | 10.37 ± 0.39[a] |
| Fiber | 1.05 ± 0.19[a] | 1.03 ± 0.11[a] | 1.25 ± 0.007[a] | 1.11 ± 0.18[a] |
| Moisture | 70.64 ± 0.62[a] | 71.47 ± 0.0[a] | 70.06 ± 1.87[a] | 69.60 ± 0.72[a] |

**CF = Control feed; TMP = Tomato powder enriched feed; CRP = Carrot powder enriched feed; BRP = Beetroot powder enriched feed*

**Values in the same row with different superscripts are significantly different (P=0.05).*

**Table 6. Organoleptic test scores for palatability test of the cooked fish flesh**

| Attributes | CF | TMP | CRP | BRP |
|---|---|---|---|---|
| Odour | 6.51±0.45[c] | 7.5±0.45[b] | 8.52±0.52[a] | 7.7±0.63[b] |
| Taste | 6.5±0.65[c] | 7.66±0.47[b] | 8.61±0.78[a] | 7.8±0.63[b] |
| Texture | 6.59±1.23[c] | 7.4±1.65[b] | 8.41±0.43[a] | 6.1±1.63[c] |
| Total Score | 19.52±0.77[c] | 22.56±0.85[b] | 25.54±0.57[a] | 21.6±0.96[b] |
| Rank | 4th | 2nd | 1st | 3rd |

**CF = Control feed; TMP = Tomato powder enriched feed; CRP = Carrot powder enriched feed; BRP = Beetroot powder enriched feed*

**Values in the same row with different superscripts are significantly different (P =0.05).*

sensory score was found from the flesh of the fish fed with CRP-enriched feed might also be due to the result of those fish having higher lipid content in their carcasses (Table 5). Food texture and flavour are known to be influenced by lipids, which can be found in foods as free oil or fat scattered throughout a solid matrix or as emulsions. By generating volatile oxidation products and transferring the flavour of short-chain free fatty acids, lipids enhance the flavour of food (Shahidi and Weenen, 2005). Nevertheless, studies on the impact of natural carotenoid sources on the palatability of fish are scarce, and thus additional research is required to draw definitive conclusions.

## 4. CONCLUSION

In comparison to the chosen commercial feed, this study finds that feed made with locally available ingredients and growth-promoting natural carotenoid sources improves *B. gonionotus* growth, flesh carotenoid content, and palatability. The best outcome was achieved when 2 g/kg of carrots were added to the feed. To establish an appropriate dosage and ascertain the long-term impact of utilizing natural carotenoid sources in large-scale farms, more research should be done.

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## ETHICAL APPROVAL

The Rajshahi University Research Ethics Committee has exempted the need for ethics approval for this investigation in accordance with the National Wildlife Protection and Conservation Act, 2012 as the fish species used in this study are commercially produced and not a wild or endangered species. However, all procedures performed in this investigation were in accordance with the ethical guidelines provided by The International Council for Laboratory Animal Science (ICLAS) for researchers.

### COMPETING INTERESTS

The authors state that they have no known conflicting financial or non-financial interests or personal ties that may be seen as having influenced the work described in this manuscript.

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