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Effect of Giving Purple Sweet Potato *(Ipomea batatas L.)* Extract in Feed to Increase the Color and Growth of Koi Fish (*Cyprinus carpio*)

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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

Purple sweet potato has the potential as a feed mixture ingredient to improve the color of ornamental fish, but it is not known how much the dose of purple sweet potato test extract in feed can increase the color of koi fish. Therefore, a study was carried out with the aim of knowing the effect of giving purple sweet potato extract in feed on color quality, total carotenoids, growth and survival of koi fish. This study used a completely randomized design consisting of five treatments and three replications, with the treatment of purple sweet potato extract in the feed. Giving purple sweet potato extract in commercial feed consisting of P0 (control) = without giving purple sweet potato extract, P1 = purple sweet potato extract 100 ml kg^{-1}, P2 = purple sweet potato extract 150 ml kg^{-1}, P3 = sweet potato extract purple 200 ml kg^{-1}, and P4 = purple sweet potato extract 250 ml

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kg^{-1}. The parameters measured in this study were color quality, growth and survival. The results showed that the feeding of purple sweet potato extract had a significant ($p<.05$) effect on the parameters of color quality, growth and survival, and not significant ($p>.05$) on the total carotenoids of koi fish. Thus, to improve the quality of color, growth and survival of koi fish, it is better to use feed with purple sweet potato extract of 250 mg kg^{-1} of feed.

Keywords: Purple sweet potato extract; color quality; growth; fish feed; koi fish.

1. INTRODUCTION

Ornamental fish is one of Indonesia's fishery commodities which could improve the country's economy in the non-oil and gas sector. Nationally, the volume of production of ornamental fish in Indonesia is always increasing from year to year. During the period 2017 - 2021, the average rate of increase in Indonesia's ornamental fish production is 1.04 billion heads/year [1]. In 2021, Indonesia's exports of the five types of ornamental fish will reach US$ 26.36 million, up 11.17% from 2020 which reached US$ 23.72 million with the five main export destination countries for Indonesia, namely Japan (14.83%), Hong Kong (13.03%), Vietnam (9.01%), United States (8.88%), and Singapore (5.92%) [2]. The dominant ornamental fish commodities are guppy, goldfish, corydoras, betta fish and koi fish.

If the price of consumption fish is determined by the body weight and taste of the meat, while ornamental fish have a variety of shapes and colors, and their patterns are very diverse [3]. One example of an ornamental fish that has a unique body and has a beautiful color is the koi fish [4]. Koi fish (*Cyprinus carpio* L.) is a high-economic ornamental fish which is still included in the Cyprinidae family [5]. Koi fish have colorful body colors with various types and patterns [6]. The quality of koi fish will determine its economic and aesthetic value; a beautiful color appearance is an indicator that becomes an attraction. The brighter the color of the fish, the more attractive it will be and the selling price will be higher.

The color in fish is caused by the presence of chromatophores which are found in the dermis on the scales, outside and under the scales [7]. Red or yellow is the color that dominates ornamental fish [8]. The color of ornamental fish is influenced by several factors, including genetic factors, glandular factors and feed [9]. Genetically, fish inherit certain colors from their parents. Likewise with glandular factors related to the hormonal system, usually male fish will display stronger colors than female fish. Feed contains nutrients and chemical substances that can affect the color pigment of fish. Thus, the addition of color enhancing sources in fish feed will result in an increase in color pigments in the fish's body, at least the fish are able to maintain the color pigments in their bodies during the rearing period. These additional ingredients are the main source in the red or yellow pigmentation process which dominates the color of many ornamental fish. The main component that forms the yellow color in koi fish is carotenoid pigments [4], which are natural pigments that can contribute to the red or yellow color of koi fish.

Some vegetables are known to contain β-carotene as an orange pigment such as carrots, pumpkin and sweet potatoes [10], where purple sweet potato (*Ipomoea batatas* L.) which shows this sweet potato contains anthocyanins and antioxidants that are greater than other types of other sweet potatoes [11]. This sweet potato has a deep purple tuber color so it can be used as an additional ingredient in mixed feeds that can brighten the body color of koi [12]. The potential of sweet potato as an ingredient in feed mixtures to improve the color of ornamental fish has been tested on several types of fish such as koi where 300 mg kg^{-1} of sweet potato extract added to the feed gave the best color brightness for 30 days of rearing [12]. Rainbow fish given sweet potato extract of 200 mg kg^{-1} showed the highest color which was getting better among all treatments for 40 days of rearing period [13]. Based on this description it is deemed necessary to carry out research with the aim of knowing the effect of giving purple sweet potato extract in feed on color quality, total carotenoids, growth and survival of koi fish.

2. MATERIALS AND METHODS

2.1 Research Design

This study used a completely randomized design consisting of five treatments and three replications, with the treatment of purple sweet potato extract in the feed. Giving purple sweet potato extract in commercial feed consisting of

P0 (control) = without giving purple sweet potato extract, P1 = purple sweet potato extract 100 ml kg^{-1}, P2 = purple sweet potato extract 150 ml kg^{-1}, P3 = sweet potato extract purple 200 ml kg^{-1}, and P4 = purple sweet potato extract 250 ml kg^{-1}. The research procedure was divided into stages, namely making sweet potato extract, adding sweet potato extract to artificial feed, rearing test fish and observing parameters.

2.2 Preparation of Purple Sweet Potato Extract

Four grams of purple sweet potato peeled thoroughly and then washed under running water and blended until smooth then dried. The dried purple sweet potato was then extracted with 1L of ethanol solvent and then deposited for 24 hours then squeezed out the precipitate until only the water extract was taken, then evaporated at 75^{o}C and in water baths with the final result purple sweet potato extract [11].

2.3 Addition of Sweet Potato Extract

The feed used in this study was brand X commercial feed. The addition of purple sweet potato extract was carried out by mixing evenly into the feed with the dose according to the treatment modified by previous research [12,13], namely 0 – 250 mg kg^{-1} feed. Then 2 ml of egg yolk was added to the mixture of feed and sweet potato extract and stirred evenly. The feed mixture is then air-dried for 10 minutes until the purple sweet potato extract absorbs the maximum into the feed.

2.4 Research Implementation

The test fish used in this research were koi fish seeds (*Cyprinus carpio* L.) obtained from PT. Deheus Global Hatchery, Bunkate Village, Jonggat District, Central Lombok Regency, Indonesia. Weighing was done at the beginning of the study in order to obtain uniform seed, seed weight 1.5 - 2g. Seeds are selected in order to obtain healthy seeds. The need for seeds during the study amounted to 150 fish, each aquarium containing 1 fish $2.5L^{-1}$. The rearing medium used in the study was 15 fruit tubs (50x35x40) cm^3 in size, before being used the tubs were washed until they were clean so that they were sterile. The volume of water used in each aquarium was 25L and each was aerated. During maintenance which lasted 30 days, 90% media water was replaced every day. Disposal of faeces is carried out 2 per day, in the morning and evening before the fish are fed. Feed is given at satiation little by little until the fish can be assumed to be full. Feeding was carried out three times a day, namely morning, afternoon, and evening, while sampling for measuring color quality, karotenoid and growth was carried out every 10 days.

2.5 Parameter Observation

Parameters observed were color quality, carotenoid content, growth and survival. Color quality measurement used a colorimeter (Minolta Chroma CR-400, Osaka Japan), based on the CIE L a b color system (CIE LAB) with parameters lightness (L), redness (a), yellowness (b) [14], with the Hunter color notation system characterized by three values, namely L, a, and b [15]. The L, a, b values have scale intervals that indicate the color level of the material being tested. The L notation denotes the brightness (light) parameter, the a notation (redness) shows from green to red and the b (yellowness) notation shows from blue to yellow [16]. Hue (H) and Chroma (C) are calculated based on the formula H= arc tan (b/a) and C= $(a^2 + b^2)^{1/2}$. H is the type of color in object measurements (such as yellow, red, or green), and C is the color density, the higher the chroma value, the darker the color of an object [17]. The total content of carotenoids in fish tissue was measured using a spectrophotometer, with the procedure as much as 0.1 g of koi fish scales was put into a test tube, then 10 ml of acetone was added, 3 ml of diethyl ether and 2 ml of distilled water, after which it was homogenized until completely dissolved. Then the solution was analyzed using a spectrophotometer at a wavelength of 480, 645 and 663 nm. Carotenoid content was calculated using the Henry and Gime (1993) formula [18].

The growth performance and survival of koi fish were observed every 10 days, in the morning by measuring the weight and length of 10 test fish. Weight gain (WG) and length gain (LG), specific growth rate (SGR) and survival rate (SR) according to [19,20] with the following formula:

WG (g) = average final weight – average initial weight

LG (cm) = average final length – average initial length

SGR (% day^{-1}) = 100 (*ln* final weight – *ln* initial weight) ÷ total duration of the experiment

SR (%) = (final number of koi ÷ initial number of koi) x 100

Water quality affects the growth and survival of fish and also indirectly affects the color of ornamental fish. Water quality parameters were measured which included temperature, degree of acidity (pH), and DO (Dissolved Oxygen) using tools in the form of a thermometer, pH meter, and DO test kit. Measurements were taken every day, namely 2 times a day in the morning and evening.

2.6 Data Analysis

The research data are presented in the form of mean ± standard deviation, then analyzed one way ANOVA statistics using SPSS 16 software. The results showed a significant effect, then further analysis was carried out using Duncan's test at a 95% confidence level.

3. RESULTS AND DISCUSSION

3.1 Color Quality and Total Carotenoids

The results showed that the purple walk test extract in the feed had a significant effect ($p<.05$) on the color quality parameters (L, a, b, C, H) and not significant ($p>.05$) on the total carotenoids of koi fish (Table 1). Treatment of purple sweet potato extract 100 mg kg^{-1} (P1) gave significant results ($p<.05$) and higher lightness (L) values compared to other treatments. This shows that the color of koi fish in treatment P1 is brighter (light) than other treatments, and proves that purple sweet potato extract in feed can increase the L value by giving purple sweet potato extract 100 mg kg^{-1}. The smaller the L value indicates the darker the color of an object according to the base color [14]. Purple sweet potato extract treatment of 250 mg kg^{-1} (P4) gave insignificant results ($p<.05$) on redness (a) compared to the control treatment, giving purple sweet potato extract 150 mg kg^{-1}, and 200 mg/kg, and significant ($p<.05$) with 100 mg kg^{-1} of purple sweet potato extract. Giving purple sweet potato extract 250 mg kg^{-1} (P1) gave significant results ($p <.05$) and higher yellowness (b) compared to other treatments. This shows that the administration of purple sweet potato extract can increase the red and yellow colors, but the increase in yellow color (b value) is more dominant. The increase in the color of koi fish is influenced by the level of absorption of the type of color pigment and the dose given in the feed [6]. The concentration of carotenoid pigments in purple sweet potatoes plays a very important role in increasing the color of koi fish [12], where beta-carotene levels in purple sweet potatoes range from 0.165 - 0.290 mg 100 g^{-1} [21].

Giving purple sweet potato extract 250 mg kg^{-1} (P4) gave significant results ($p<.05$) and higher in chroma (C) and hue (H) values compared to other treatments. A high chroma value indicates an increasing number of pigment cells (chromatophores) in the flesh or skin tissue, both red and yellow pigments [17]. Various beautiful colors in koi are basically produced by pigment cells with names according to the types of pigment they contain, namely: melanofore which stores black pigment, erythrophore stores red pigment, xantofore stores yellow pigment, and iridofore which does not contain pigment but contains guanine crystals that are able to reflect or emit light into its constituent color components [7]. The hue value is a reflection of the structure and color of carotenoids, which shows a color change from red, yellow, blue, and purple to red again in the color system [22]. The results showed that the hue value of the sweet potato extract treatment was significant ($p<.05$) compared to the control treatment, which was in the range of 63 - 69 degrees. Values of 0–90 degrees indicate a color movement from red to orange to yellow.

The increase in chrome and hue values is not entirely due to the content and structure of carotenoids in the feed, but is influenced by the content of other substances that affect the absorption of carotenoids and fat [22]. Carotenoid absorption in fish tissue is determined by the movement of pigment granules resulting in color changes caused by temperature, light and others which are controlled by the nervous system and hormones [5,7]. Thus, the addition of carotenoids to feed has a maximum limit that will not give better color changes and can even reduce color values [13]. The results of total carotenoid analysis and their relationship to chroma values are presented in Fig. 1.

Based on Fig. 1, it can be seen that there is no relationship between the addition of purple sweet potato extract and the chroma value and total carotenoids in koi fish skin. These results contradict previous reports which stated that the higher the total carotenoid, the higher the chroma value produced, but the relationship between the two is not linear [14]. However, the results of the study as a whole showed that giving purple sweet potato extract was able to improve the

color quality of koi fish. Giving purple sweet potato extract 100 mg kg^{-1} of feed effectively increased brightness with a lightness (L) value of 81.05 ± 2.08 %, while giving purple sweet potato extract 250 mg kg^{-1} of feed was effective in increasing red and yellow colors but more dominantly yellow with a yellowness value (b) of 30.89 ± 3.63, and a hue value of 69.42 ± 2.23.

3.2 Growth and Survival Rate

The results showed that the addition of purple sweet potato extract to the feed had a significant effect ($p<.05$) on the growth parameters (WG, LG, SGR) and survival rate (SR) of koi fish (Table 2). Giving purple sweet potato extract 250 mg kg^{-1} (P4) gave significant results ($p<.05$) and higher weight gain (WG) compared to other treatments. Giving purple sweet potato extract 100 mg kg^{-1} (P1) gave significant results ($p<.05$) and higher growth in length gain (LG) compared to giving purple sweet potato extract 200 mg kg^{-1} (P3) and 250 mg kg^{-1} (P4) and not significant ($p>.05$) compared to the control treatment (P0) and the treatments of purple sweet potato extract 150 mg kg^{-1} (P2). Giving purple sweet potato extract 250 mg kg^{-1} (P4) gave significant results ($p<.05$) and higher specific growth rate (SGR) compared to other treatments.

The results of the average weight and length measurements every ten days during the study are presented in Fig. 2. From the 10th day to the 30th day the treatment of purple sweet potato extract 250 mg kg^{-1} (P4) showed higher weight growth compared to the treatment P0, P1, P2 and P4 (Fig. 2a), while the growth in length until the 30th day seemed to coincide with each other (Fig. 2b), although between treatments had a significant effect ($p<.05$) on length growth (Table 2). The control treatment or without purple sweet potato extract was not significant ($p>.05$) compared to the purple sweet potato extract treatment. Giving purple sweet potato extract 250 mg kg^{-1} of feed was most effective in increasing weight gain (WG) of 2.38 ± 0.05 g, and specific growth rate (SGR) of 141.08 ± 0.72 % day^{-1}. Previous research reported that the daily growth rate has a positive correlation with individual weight gain, where the higher the daily specific growth rate the higher the resulting individual weight gain [23]. This is because the individual weight gain is the end product of the daily growth rate of a test organism. This is different from the treatment without treatment with purple sweet potato extract which resulted in a low daily growth rate and individual weight gain. The results of this research are in line with previous research which stated that koi fish treated with purple sweet potato extract had higher SGR than those without purple sweet potato extract [13].

According to Maiti et al. [24] carotenoid content in feed, apart from functioning as pigment cells, carotenoids have a role in metabolic processes in the body which can increase nutrient utilization and growth and have added value for fish health. Purple sweet potato contains high anthocyanins, reaching 61.85 mg $100g^{-1}$ [25]. Apart from being a natural coloring agent, anthocyanins also act as antioxidants that are beneficial to fish health, where purple sweet potato extract has strong antioxidant activity [11]. Thus, apart from being effective in increasing the performance of koi fish growth, giving purple sweet potato extract in the feed had a significant effect ($p<.05$) on survival rate. Survival in the treatment without giving sweet potato extract was lower than giving sweet potato extract 100 mg kg^{-1} of feed. The ability of koi fish to live in this study was also supported by water quality conditions; in this case the parameters of temperature, dissolved oxygen and pH were still within the normal range (Table 3).

Table 1. Effect of giving purple sweet potato extract to feed on color quality (L, a, b, C. H) and total carotenoids of koi fish

Parameters	Giving purple sweet potato extract in feed				
	P0 (control)	P1 (100 ml kg^{-1})	P2 (150 ml kg^{-1})	P3 (200 ml kg^{-1})	P4 (250 ml kg^{-1})
L (%)	62.88±2.72^{a*}	81.05±2.08^{d}	66.65±4.01^{ab}	72.35±1.64^{c}	69.07±3.89^{bc}
a	12.63±0.46^{c}	6.93±0.57^{a}	10.50±1.07^{b}	11.78±0.25^{bc}	11.54±1.48^{bc}
b	24.04±2.27^{bc}	18.02±0.36^{a}	20.35±2.42^{ab}	26.95±1.72^{cd}	30.89±3.63^{d}
C (%)	27.16±1.81^{b}	19.31±0.14^{a}	22.90±2.16^{a}	29.42±1.26^{bc}	33.00±2.92^{c}
H (^{o})	62.21±1.14^{a}	67.64±1.57^{b}	62.68±0.34^{a}	66.34±1.28^{b}	69.42±2.23^{b}
TK (mg g^{-1})	5.07±2.00 ^{a}	5.96±2.04 ^{a}	6.29±1.35 ^{a}	6.10±1.34 ^{a}	6.67±2.57 ^{a}

Note: Different superscript letters in the same column show a significant difference (P<0.05), L=lightness, a=redness, b=yellowness, C=density color (chroma), H = color type (Hue), TK = total carotenoid

Table 2. Effect of giving purple sweet potato extract to feed on growth parameters (WG, LG, SGR) and survival rate (SR) of koi fish

Parameters	Giving purple sweet potato extract in feed				
	P0 (kontrol)	P1 (100 ml kg^{-1})	P2 (150 ml kg^{-1})	P3 (200 ml kg^{-1})	P4 (250 ml kg^{-1})
WG (g)	1.89 ± 0.04^{a}	1.95 ± 0.08^{a}	2.05 ± 0.04^{b}	2.07 ± 0.02^{b}	2.38 ± 0.05^{c}
LG (cm)	1.45 ± 0.02^{ab}	1.56 ± 0.07^{b}	1.49 ± 0.06^{ab}	1.43 ± 0.04^{a}	1.41 ± 0.06^{a}
SGR (% day^{-1})	128.61 ± 0.05^{a}	133.31 ± 0.90^{b}	135.62 ± 0.50^{c}	135.81 ± 0.76^{c}	141.08 ± 0.72^{d}
SR (%)	91.1 ± 3.85^{a}	100 ± 0.00^{b}	95.5 ± 3.85^{ab}	100 ± 0.00^{b}	93.3 ± 0.00^{b}

Note: different superscript letters in the same column show significant differences (p<.05), WG = weight gain, LG = length gain, SGR = specific growth rate, SR = survival rate

Table 3. Data of water quality on the rearing of koi carp

Parameters	Giving purple sweet potato extract in feed					Eligibility range [26]
	P0 (kontrol)	P1 (100 ml kg^{-1})	P2 (150 ml kg^{-1})	P3 (200 ml kg^{-1})	P4 (250 ml kg^{-1})	
Temperature (°C)	25 – 28.3	26 – 27.9	25 – 27.9	25 - 28.9	27 - 28.9	25-31
DO (ppm)	5.8 – 6.9	5.4 – 6.9	5.3 – 6.9	5.2 – 6.9	5.2 – 6.9	>5
pH	7 – 8.1	7.1 – 7.7	7 – 7.8	7 – 7.5	7 – 7.5	6.5-8.5

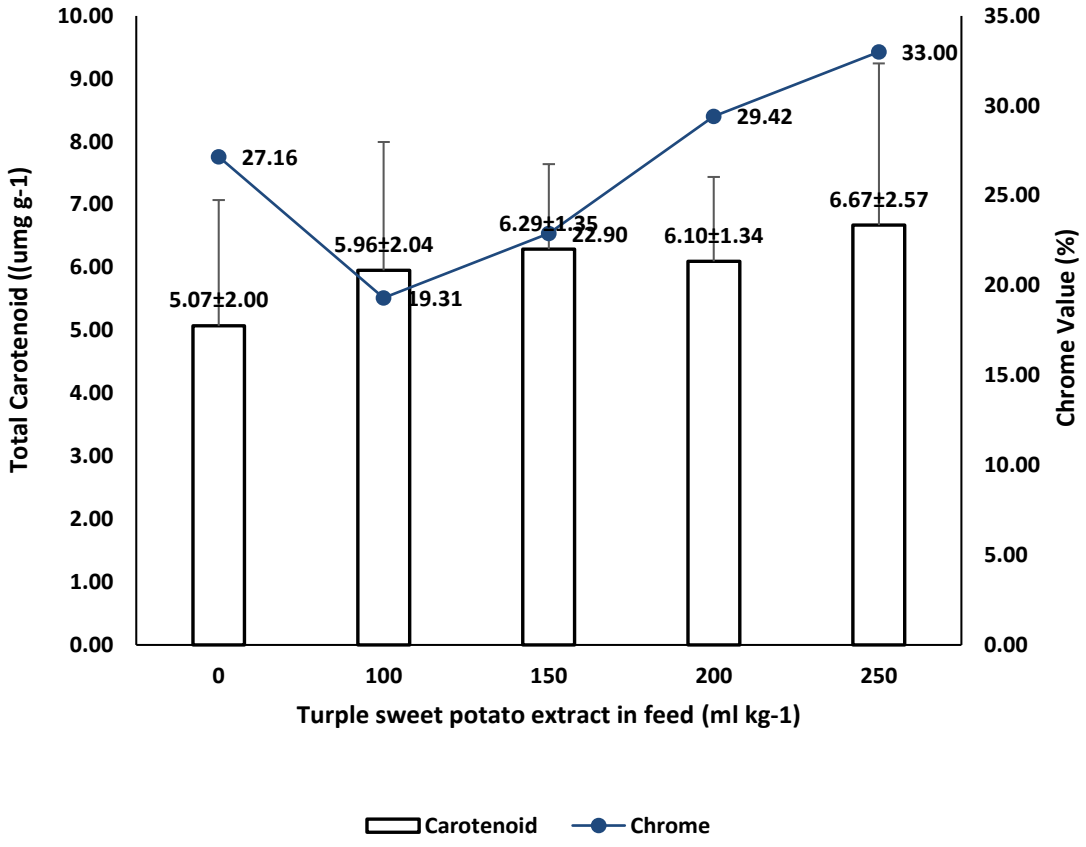

Fig. 1. Results of analysis of total carotenoids and their relationship to chroma values

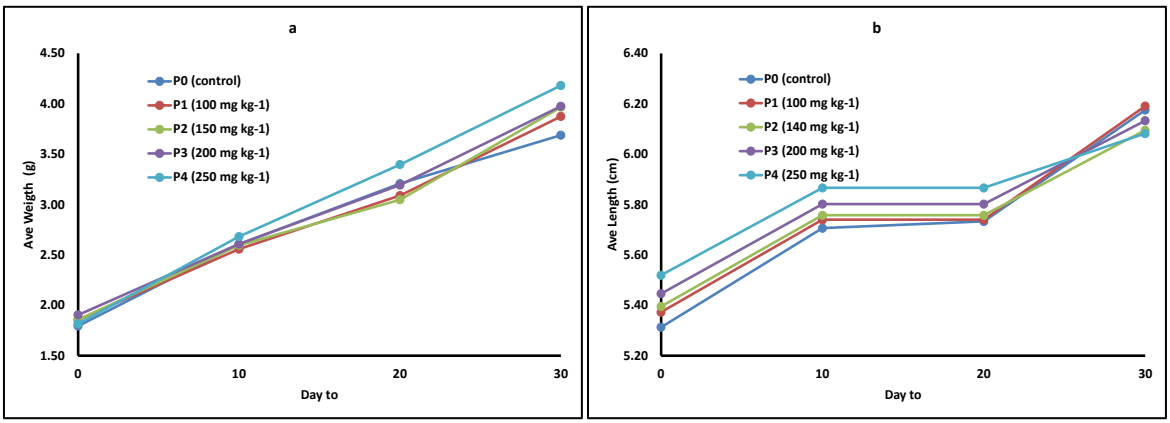

Fig. 2. Average weight (a) and average length (b) of koi fish with different sweet potato extracts

4. CONCLUSION

The addition of purple sweet potato extract in the feed has a significant effect on the color quality parameters and not significantly on the total carotenoids of koi fish. Giving purple sweet potato extract 100 mg kg^{-1} of feed had the highest effect on lightness (L) compared to other treatments. Giving purple sweet potato extract 250 mg kg^{-1} of feed had the highest effect on the quality of red (redness, a), yellow (yellowness, b), density (chroma, C) and type of color (hue, H).

The addition of purple sweet potato extract in the feed has a significant effect on the growth parameters and survival of koi fish. Giving purple sweet potato extract 250 mg kg^{-1} of feed had the highest effect on weight gain (WG), length gain (LG), specific growth rate (SGR) and survival rate of koi fish. Thus, to improve the quality of color, growth and survival of koi fish, it is better to use feed with purple sweet potato extract of 250 mg kg^{-1} of feed.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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