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A Comparison of Growth and Colouration of *Carassius auratus* (Linnaeus, 1758) under Different Culture Systems

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Abstract

The present experiment was conducted for 60 days to compare growth and colouration of *Carassius auratus* (Linnaeus, 1758) among three culture systems such as aquaria (AQ), cement tanks (CT) and cages (CG) suspended in pond. Fry of gold fish with mean length 4.1 ± 0.19 cm and mean weight 2.26 ± 0.24g were stocked with 0.2 nos/l and fed with marigold (*Tagetes erecta*) enriched diet at 5% of body weight. Highest (P<0.05) growth was showed in cages (8.14±0.29 cm and 7.96±0.70 g.) followed by cement tanks (7.13±0.17 cm and .46 ±0.22 g) and aquaria (6.51±0.13 cm and 5.65±0.14g). Survival was highest in aquaria (68%) followed by cages (60%) and cement tank (59%). Fish skin colour parameters reacted differently according to culture systems. After 60 days of rearing, lightness (L*) and whiteness (W*) values decreased in all three systems and highest (P<0.05) was found in aquaria (L*, 49.0. ±1.18; W* 23.5±1.43) followed by cement tanks (L*, 45.2. ±1.01; W* 17.9±0.59) and cages (L*, 41.54. ±1.31; W* 11.50±1.04). Redness (a*), Yellowness (b*) and saturation (C*) values increased in all three systems and highest (P<0.05) were in cages (a* 36.3±2.9; b* 55.48±1.33; c* 66.46±1.01) followed by cement tanks (a* 31.3±1.11; b* 52.40±1.22; c* 61.05±0.87) and Aquaria (a* 22.6±1.08; b* 45.70±1.8; c* 57.8±0.48). Muscle carotenoid content were highest (P<0.05) in caged fish (24.80±1.44 µg/g) followed by cement tanks (19.26±0.63µg/g) and aquaria (12.26±1.13µg/g). At the end of experiment, there were significant differences between aquaria, cement tanks and cages in final mean length, mean weight, percent weight gain, SGR, FCR, FER, PER, colouration and muscle carotenoid content of gold fish.

Keywords: *Aquaria, Cement tanks, Cages, Gold fish, Redness, whiteness, saturation*

Introduction

At the dawn of 21st century, fish keeping is reflected in ubiquitous aquaria that feature as an integral part of modern interior decoration (Oliver, 2001). Ornamental fish is regarded as the star product of pet market in the world today. It is a multi-million-dollar industry that supports thousands of the rural people in developing countries. Ornamental fish production is slowly gaining momentum in India and efforts are being made to increase the country's share in the global market. To develop India into a leading exporter, it is necessary to produce high quality fishes in bulk quantity, which is major requirement in the international trade. It is well known that, in addition to body shape and fin shape, attractive size and skin pigmentation are the most important quality criteria that determine the commercial value of gold fish (Paripatananont *et.al* 1999, Gouveia *et.al* 2003). Gold fish is one of the most popular ornamental fish and have a high market value in ornamental fish trade. (Lee & Newman, 1977). Therefore culture of gold fish (*Carassius auratus*) envisages not only production but also improvement of their colour and aesthetic beauty. Fish are not able to perform de novo synthesis of carotenoids (Goodwin, 1984) and depends on dietary carotenoid content for colouration. Hence, a direct relationship between dietary carotenoid and skin pigmentation exists in them (Halten *et.al.* 1997). Besides dietary carotenoid pigments, availability of natural fish food organism, water quality developmental status of animal also influences the skin pigmentation.

Survival and growth of organisms in aquatic environment are determined to a large extent by the physical, chemical and biological properties of the water (Rogan and Cross, 1996; Diana *et.al.* 1997). Generally, ornamental fish ponds and tanks of India are subjected to a wide range of management practices, from application

of organic manure (Jha *et.al*. 2004) to supplementary feeding with imported pelleted feed (Sinha and Das, 2004) and introduction of exogenous zooplankton (Jha & Bharat 2005a), for increasing yield. Good colour qualities in fish can be achieved by feeding them a high quality diet and maintain optimum water quality. Any culture system and management protocol would have a different effect on the interaction of water quality, phytoplankton & Zooplankton. This could lead to difference in survival, growth and colouration of gold fish produced in different aquaculture systems. In the present experiment, we attempted to compare growth and colouration of gold fish *Carassius auratus* reared in glass aquaria, cemented tanks and net cages suspended in pond.

Material and Methods

Experimental work was undertaken in four glass aquaria (0.45 mx 0.3m x 0.3 m; 40 l capacity), four cemented tanks (1.5m x 1.25m x 1m ; 1875 l capacity) and four net cages (1m x 1m x 1m ; 1000 l capacity) placed in cemented pond at the Central Institute of Fisheries Education (CIFE), Mumbai, India. Gold fish fry were collected from local ornamental fish market (Kurla, Mumbai) and transferred to ornamental fish rearing unit of CIFE, where they wee acclimated in an aerated FRP tank for 15 days prior to the study. Fish (mean length 4.1±0.19 cm and mean weight 2.26 ±0.24 g) were randomly assigned to each culture units with 0.2 nos/l stocking density, as optimized in an earlier experiment and were reared for 60 days. Feed was prepared using marigold (*Tagetes erecta*) petal meal as carotenoid source. The Cyanotech (2002) method was adopted to estimate the total carotenoids in marigold petal meal. Proximate composition of feed was analysed according to methods described by AOAC (1990). During the experiment, goldfish were fed twice a day (at 10 am and 5 pm) with 5% of their body weight. Uneaten feed and faecal matter were siphoned once in two days. Dead fish were removed daily, they were not replaced during the course of study.

Water samples were collected weekly at 9 A.M. and routine water quality parameters (Temperature, dissolved oxygen, pH, total alkalinity, total hardness, ammonia, nitrite, nitrate, salinity) were estimated according to methods as described by APHA (2005). Samples of plankton were collected with plankton net made of standard bolting silk cloth (No. 21 with 77 mesh/ cm^2). Collected plankton samples were concentrated to 20 ml and preserved in 4% formalin. Enumerations of plankton were performed under a stereoscopic microscope using Sedgwick Rafter Counting Cell. Primary productivity (Gross and Net) of each culture systems were measured by Light and Dark bottle method. Fortnight sampling was done for growth (length and weight) and skin colour of gold fish. The Olson (1979) method was adopted to estimate the total amount of carotenoid present in fish muscle tissue, at the beginning and end of the experiment.

Fish skin colour was measured using Lab Scan XE Colorimeter having a wavelength range from 400 – 700 nm and equipped with EasyMatch @QC software to collect, display, analyze and store colour data (Made in USA), with measurements standardized with respect to the white calibration plate. The value of L* represents lightness (0 for black and 100 for white), the a* value represents the red/ green dimension with positive value for red, negative ones for green and 0 is neutral and the value of b* represents the yellow/ blue dimension with positive values for yellow and negative ones for blue and 0 is neutral. A standard white tile with reflectance value of L* = 95.91, a*= +0.09 and b* = +0.2,02 was used as the reference. The sample is illuminated by a xenon flash lamp and reflected light is collected by a 15 – station fibre optic ring. For maximum stability, the instrument is automatically standardized to an internal reference tile whenever measurements are made. Colorimetric values of skin colour were performed on both lateral sides of each fish body. Whiteness (W*) and saturation (C*) values were obtained after calculation, using L* a* b* values (Han *et.al*. 2005).

Statistical Analysis

The Statistical Analysis was carried out using PC-SAS programme for windows, release v6.12 (SAS Institute, Cary, NC, UK). Comparison among all the culture systems was done by one way ANOVA. Duncan's multiple range test (Duncan, 1955) was used to detect the significance of differences of mean between groups. The

level of significance employed was 0.05. The results were expressed as mean ± standards error (Mean ± S.E.) for the respective effect.

Results

Water quality

The physico -chemical parameters of water monitored during the experimental period of 60 days. Water temperature was observed to be in the range of 20 to 28° C. Dissolved oxygen was in the range of 3.2 to 6.5 mg l^{-1} throughout the experiment, while pH was in the range of 7 to 8.5. Free carbon dioxide was 0 – 3 mg l^{-1}, total hardness was in the range of 200 to 320 mg l^{-1}. Total alkalinity was 50 to 130 mg l^{-1}, while ammonia concentration was in the range of 0.1 to 0.35 mg l^{-1} Nitrite and Nitrate were in the range of to and to respectively.

Primary productivity

Gross primary productivity (GPP) and Net Primary productivity (NPP) was recorded at fortnightly intervals. Highest GPP (1560 to 2371.2 mg C/ m^3/day) was observed in cages at every sampling followed by cement tanks. Aquaria showed negative NPP .

Plankton analysis

The abundance of plankton differed greatly among the three culture systems. In general, the plankton community was represented largely by Cladocerans (*Daphnia carinata*, *Moinamicrura*), copepods (*Cyclops*) and rotifers (*Brachionus spp. Keratellaspp*) and phytoplankton (*Chorella sp.*, *Microcystis sp.*, *Pediastrum sp.*,). Average plankton abundance was highest in cage followed by tanks, but it was absent in aquaria throughout the experiment.

Chemical analysis of feed

Eight parameters (crude protein, crude fat, total carbohydrate, crude fibre, crude ash, moisture, nitrogen free extract and gross energy) were estimated to find out the composition of the feed given to the experimental fishes. Table 1.

Table 1: Chemical analysis of feed used during the experiment

Crude Protein(%)	Crude Fat(%)	Total Carbohydrate (%)	Crude fibre (%)	Crude ash (%)	Moisture (%)	NFE (%)	Energy (Kcal/kg)
32.375	6.2	54.26	10.75	7.16	6	43.515	4.16
31.5	6.2	53.34	9.85	8.96	7	43.49	4.17
33.25	5.2	51.7	10.2	9.85	7	41.5	4.15
32.37±0.50*	5.86±0.33*	53.10±0.74*	10.26±0.26*	8.65±0.79*	6.6±0.33*	42.83±0.66*	4.16±0.00*

N.B. * indicates (Mean ±S.E.)

Growth parameters

Mean length was 6.51 ± 0.13 cm in aquaria, 7.13±0.17 cm in cement tanks and 8.14±0.29 cm in cages (Table 5, Fig. 1) & Mean weight was 5.65 ± 0.14g in aquaria 6.46 ± 0.22 g, in cement tanks and 7.96 ± 0.70 g in cage. Highest average daily growth (ADG) was recorded in cages (0.094± 0.002 g) followed by cement tank (0.074 ±0.002 g). Lowest ADG was observed in aquaria (0.056 ±0.003 g). Highest percent weight gain (PWG) was recorded in cages (278.17 ±2.54) followed by cement tanks (203.93±0.35) and aquaria (159.12±0.07). Highest specific growth rate (SGR) was recorded in cage (21.60 ±0.37), followed by cement tanks (18.34 ± 0.18 and aquaria (15.55 ± 0.22). Feed Conversion Ratio (FCR) of *Carassius auratus* in different culture systems ranged from 3.1 ±0.05 (aquaria) to 2.33 ± 0.02 (cages). Moreover FCR of cement tanks (2.73± 0.06 is acceptable as per the commercial culture aspects. The feed efficiency ratio (FER) values of *Carassius auratus* in different culture system lies between 0.30 ± 0.00(aquaria)to 0.41 ± 0.00 (cages). However FER of fishes of cement tanks was

0.35± 0.02. FER of Cage (0.17 ±0.01) culture system was found highest followed by Cement tanks (0.13 ±0.00) and aquaria (0.17±0.01). All the growth parameters are given in Table 2.

Table 2: Growth parameters

Culture system	ADG	PWG	SGR	FCR	FER	PER
AQ	0.056±0.003^a	159.12±0.07^a	15.55±0.22^a	3.1±0.05^a	0.30±0.00^a	0.10±0.00^a
CT	0.074±0.002^b	203.93±0.35^b	18.34±0.18^b	2.73±0.00^b	0.35±0.02^b	0.13±0.02^b
CG	0.094±0.002^c	278.17±2.54^c	21.60±0.37^c	2.33±0.02^c	0.41±0.00^c	0.17±0.01^c

Means with different superscripts in the same column are significantly different (P <0.05).

Survival rate

During the course of experiment, survival rate of *Carassius auratus* was observed and at the end of 60 days survival percentage was calculated. Highest survival was achieved in aquaria (68%) followed by cages (60%) and cement tanks (59%).

Colour analysis

Lightness (L*)

The value of skin colour of *Carassius auratus* was obtained from the instrument directly and the result are shown in the Table 3.The better L* was found in cages (41.54±1.3) followed by cement tanks (45.21±1.01) and aquaria (49.0±1.18). There was significant difference of L* value among culture systems.

Redness (a*)

The Redness value of experimental fish obtained from the instrument for three production system is shown in the Table 3. The highest a* value was found in cages (36.29±1.07) and lowest in aquaria (22.6±1.08).. There was significant difference of a* value among the three culture systems.

Yellowness (b*)

The Yellowness value of skin colour of experimental fish species was obtained from the instrument directly and is given in the Table 3. Fishes of cages showed maximum yellowness (55.48±1.33) in contrast to minimum seen from aquaria (45.7±1.8). There was significant difference of b* value among culture systems.

Table 3. Fortnight colour analysis of *Carassius auratus* in aquaria, Cement tank and cages for 60 days (Mean ±S.E.)

Sampling	L* (Lightness)			a* (Redness)			b*(Yellowness)			W* (Whiteness) = 100-√((100-L*)² + a*²+ a*²)			C* (Saturation = √(a*²+ a*²)		
	AQ	CT	CG	AQ	CT	CG	AQ	CT	CG	AQ	CT	CG	AQ	CT	CG
1	55.1±0.79	55.1±0.79	55.1±0.79	18.2±0.68	18.2±0.68	18.2±0.68	37.6±0.83	37.6±0.83	37.6±0.83	41.4±0.76	41.4±0.76	41.4±0.76	41.3±0.76	41.3±0.76	41.3±0.76
15	54.0±1.00^a	54.0±1.89^b	52.5±1.56^c	20.8±1.23^a	22.8±1.08^b	25.10±1.00^c	43.0±1.58^a	43.9±2.33^b	45.79±1.51^c	35.7±1.00^a	32.1±0.95^b	29.50±0.59^c	47.7±1.00^a	49.6±2.54^b	59.0±2.34^c
30	52.3±0.61^a	51.3±0.87^b	50.1±0.82^c	22.7±0.6^a	26.9±8.86^b	28.18±0.77^c	45.0±0.86^a	47.8±0.8^b	48.88±1.03^c	30.5±0.12^a	26.6±0.77^b	24.68±0.60^c	50.4±2.22^a	54.8±0.86^b	56.41±0.56^c
45	49.3±1.11^a	47.7±0.64^b	46.69±0.54^c	25.2±0.74^a	28.4±0.96^b	31.94±0.9^c	46.1±1.14^a	49.7±0.8^b	52.69±0.84^c	26.9±0.58^a	22.4±0.12^b	18.52±0.58^c	52.6±1.11^a	57.24±0.56^b	61.61±0.41^c
60	49.0±1.18^a	45.2±1.01^b	41.54±1.31^c	22.6±1.08^a	31.3±1.11^b	36.29±1.07^c	45.7±1.8^a	52.4±1.22^b	55.48±1.33^c	23.5±1.43^a	17.9±0.59^b	11.50±1.09^c	57.8±0.48^a	61.05±0.87^b	66.46±1.01^c

Whiteness (W*)

Whiteness value of *Carassius auratus* obtained after calculation are shown in the Table 3.W* value found in aquaria (23.54±1.43) was higher than cement tanks(17.96±0.59) and cages (11.59±1.09) and significant difference was found among culture systems.

Saturation (C*)

The saturation value of skin colour of experimental fishes was obtained by using formula are given in the Table 3. The Saturation value of redness and yellowness constituted the leqast in aquaria (57.80±0.08), medium in cement tanks(61.05±0.87) and highest in cage culture system (66.46±1.01.

Carotenoid content of Marigold and fish muscle

Carotenoid content of Marigold was 3.34 ± 0.45. Initial carotenoid content of gold fish muscle was 2.13 ± 0.35 µg/g. After 60 days of rearing it was 12.26±1.13 µg/g in aquaria reared fish, 19.26±0.63 µg/g in cement tanks reared fish and 24.80±1.44 µg/g in caged fish. The carotenoid values obtained are given in Table No. 4

Table 4: Carotenoid content (µg/g) of marigold petal and fish muscle

Culture systems	Marigold (%)	Fish muscle (µg/g)	
		Initial (0 days)	Final (60 days)
AQ	3.34±0.45	2.13±0.35	12.26±1.13[a]
CT		2.13±0.35	19.26±0.63[b]
CG		2.13±0.35	24.80±1.44[c]

Means with different superscripts in the same column are significantly different ($p<0.05$)

Discussion

Nothing influences health and well being of fish as much as water quality. The explanation for this is sample, fish metabolism and biological functions are directly linked to the physical, chemical and biological properties of water. Ornamental fish are highly adaptable to culture conditions and are capable of living under a wider range of environmental condition (Chapman, 2000). Throughout the present experiment, water quality parameters of all culture systems were within the optimum level of gold fish production (Jhingram, 1991), which indicated that water quality did not produce any stress to the fish during the experiment.

In the present study, pond-based cage culture system showed higher length increment and weight gain of *Carassius auratus* compared to cement tank and glass aquaria confirming that different culture systems affect the growth and survival of fish. In the beginning of the experiment, all the culture systems had more or less similar mean length and weight. After 15 days of rearing, all the three systems recorded length increment and weight gain, this continued till end of the experiment. The higher growth rate has been observed in cages, possibly due to natural feed and supplementary feed. Studies with other fish species have yielded similar results; for example, significantly lower growth rate of channel catfish, *Ictalurus punctatus* were obtained in concrete pools compared to earthen ponds (Shell, 1996). Even in cases of walleye, *Stizostedionvitreum*, younger fry (upto 6.5 cm) are usually cultured in ponds as the growth rate is better compared to tanks (Summerfelt *et.al.* 1996). Other studies also revealed that live food alone or live food mixed with artificial food improves fish production (production (Dabrowski*et.al* 1983; Lubzens*et.al*, 1984; Abi-Ayad and Kestemont, 1994). Mitra & Mahapatra (1056) and Jhingran& Pullin (1985) have attested the importance of zooplankton in carp nursery ponds of India.

Growth observed in aquaria and cemented tanks may be due to growth stimulatory effect of Marigold. The addition of carotenoid rich micro algae *Haematococcus pluvialis* has been found to enhance the growth of rainbow trout, *Onchorhynchus mykiss* (Sommer et.al. 1992). A higher growth rate was achieved in red swordtail by feeding with 8% Spirulina in the diet (James et.al. 2006). Further, there are also reports (Torrissen, 1984) that link carotenoids to growth enhancement in Atlantic salmon fry (*Salmo salar*), or to improvement of survival rate in kuruma prawn, *P. japonicas* (Chien & Jeng, 1992).

The present study resulted nearly similar rates of survival of *Carassius auratus*in cemented tanks (59%0

and cages (60%) as compared to aquaria (68%). In this case, mortality in tanks and cages were probably associated to handling during harvesting. High survival in aquaria may be due to good maintenance in controlled condition.

Lightness (L*) and Whiteness (W*) values of gold fish (*C. auratus*) were decreasing in fishes of each culture systems after every sampling. At the end of rearing period, these values were significantly ($p<0.05$) decreased and the lowest value was observed in fish reared in cages. As the time progressed, redness (a*), yellowness (b*) and saturation (C*) values of fishes were significantly increased in all the culture systems. The highest value was found in cages followed by cement tanks and aquaria. This is supported by findings of Yanar *et.al.* (2010) for gold fish and electric yellow cichlid. They found that a higher red (a*) and yellow (b*) colouration and a lower lightness (L*) were obtained on skin of gold fish reared in fibre glass aquarium compared to those in glass one. During rearing period, the fish may obtain additional red and yellow pigment from consuming natural foods present in the pond water and cement tanks. The aquaria water was devoid of natural food, this may be the reason for low skin pigmentation aquaria reared fish. The pigmentation obtained in aquaria may be due to carotenoids of feed only. Feeding diets containing natural carotenoid sources such as paprika, marigold, Spirulina, shrimp shell meal, micro-algae and china rose was reported to improve skin pigmentation of several fish species including Koi carp, gold fish, red porgy (Gouveia *et.al.* 2003; Hancz *et.al.* 2003; Kalinowski *et.al.* 2007; Sinha and Asimi, 2007).

Analysis of carotenoid content in Marigold (*Tagetes erecta*) petal meal showed 3.34 ± 0.45 % in dry weight. Ramamoorty *et.al.* (2010) reported that the carotenoid pigment in marigold was 2.30% in his experiment. These differences might be due to the origin of the marigold flower since differences in pigment composition have been observed even among closely related species cultivated in conditions absolutely identical.

Muscle carotenoid content of gold fish was increased in three culture systems after 60 days of rearing. Highest carotenoid was found in cages followed by cement tanks (less live food density) and aquaria (devoid of live food). The result in cages may be due to live food present in pond water (where cage was installed and carotenoid content of marigold. The result in aquaria and cement tanks may be dur to marigold only. Ezhil *et.al.* (2008) studied the total carotenoids in red swordtail colour enhancer at cheaper price. Sommer et. al. (1992) observed that the pigment deposition in muscle of rainbow trout, *Oncorhynchus mykiss* increased with increase in concentration of green algae, *Haematococcus pluvialis* in the feed. The total carotenoid content in the muscle of red sword tail, Xiphophorus helleri increased when fed with 8% Spirulina in their diet (James *et.al.* 2006).

Conclusion

From the experimental results, cage culture system appeared to be better alternative to cement tank and glass aquarium due to their higher assimilatory capacity and greater abundance of plankton in natural environment. Further research in this aspect might bring still better improvement in survival rate, growth and colouration.

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