Proceedings of the Pakistan Academy of Sciences:
B. Life and Environmental Sciences 55 (4): 29–38 (2018)

ISSN: 2518-4261 (print), ISSN 2518-427X (online)

Pakistan Academy of Sciences

Research Article

Growth Performance of *Labeo rohita and Gibelion catla* against Different Oilseed Meal Based Diets in Semi-intensive Culture

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Abstract: The present study was conducted to investigate efficacy of three different types of feeds formulated with low cost oil seed meal based proteins for growth of *Labeo rohita* and *Gibelion catla* cultured in semi-intensive system for 92 days. Formulated feeds incorporated soybean meal, guar meal and canola meal as major protein source with rice polish as control feed. Highest weight gain for *L. rohita* and *G. catla* was achieved with soybean meal based feed (121.8 g ± 4.02 g and 66.5 g ± 4.57 g) followed by canola meal based feed (107.5 g ± 17.1 g and 47.3 g ± 8.59 g), guar meal based feed (49.4 g ± 10.3 g and 19.6 g ± 8.55 g) and rice polish (31.8 g ± 1.40 g and 14.1 g ± 3.06 g), respectively. Growth performance of *L. rohita* was higher than *G. catla* in all treatments. During the experimental period, net production (kg/ tank) was 1.59 kg ± 0.07 kg, 6.02 kg ± 0.20 kg, 2.48 kg ± 0.52 kg and 5.37 kg ± 0.85 kg for *L. rohita* and 0.71 kg ± 0.15 kg, 3.32 kg ± 0.23 kg, 0.98 kg ± 0.43 kg and 2.37 kg ± 0.43 kg for *G. catla* achieved with rice polish, soybean meal, guarl meal and canola meal based feeds respectively. Results showed that soybean meal and canola meal based formulated diets can lead to higher fish growth and total fish production than other oilseed meals used in present investigation.

Keywords: Aquaculture, Formulated feed, Growth performance, Major carps, Condition factor.

1. INTRODUCTION

World population growth rate demands an increased food supply and sustainability of current food production systems [1]. Aquaculture is growing at the fastest rate among world's food production sectors [2] and can serve as a valuable resource to fight against the global issues of malnutrition and poverty. Fish and fish products are the source of highly digestible proteins in human diets comprising of all the essential amino acids [3]. Due to its high quality protein and other nutritional qualities, global fish per capita consumption has increased from 9.9 kg in 1963 to 19.7 kg in 2013 [4]. At present, the challenges faced by the sustainable growth of aquaculture are directly related to nutrition and feeding requirements of cultured fish [5, 6].

Fish oil and fish meal, the two major biological sources required to fulfill the feed based requirements of sector, are derived from world's declining marine capture fisheries resources [7]. In 2006, about 88.5% of total fish oil production in the world and 68.2% of world's total fish meal production was used for aquaculture feed inputs [8]. This reliance on finite natural fisheries resources not only lead to increased prices of pelagic fish used as fish meal but also result in increased market rates of cultured fish species as compared to their captured counterparts [9]. Therefore, the continuous development of aquaculture necessitates availability of economically compatible aqua feeds to ensure sector's viability for satisfying the protein demand of growing global population.

Efforts carried out to develop cost effective feeds for finfish are directed towards partial or complete replacement of fish meal with compatible raw materials of animal or plant origin. Oil seed meals; the byproducts leftover after oil extraction from oil bearing seeds are the most important plant based ingredients for use in aqua feeds due to their high protein (20-50%) content [10]. They are the focus of worldwide research in recent years for

Received: December 2017: Accepted; December 2018
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preparation of low cost diets for freshwater finfish and have resulted in promising results [11-13].

In Pakistan, freshwater aquaculture practices have been concentrated towards polyculture of major carps under semi intensive systems. Fish nutrition is considered an active area of research in the region for the development of economically compatible feeds that can aid the fish farmers with limited resources. None of the earlier investigations has compared oilseed meal based aquafeeds in culture of more than one species in semi intensive system. Present study was, therefore, carried out to evaluate growth of *Labeo rohita* (Rohu) and *Gibelion catla* (Catla) fed with plant based formulated feeds to supplement the research carried out on formulation of low cost feed for carp's culture.

2. MATERIALS AND METHODS

2.1 Study Site

The experiment was conducted for 92 days starting from 9 June, 2017 to 8 September, 2017 in outdoor cemented tanks at Fisheries Research and Training Institute (FR&TI), Lahore, Pakistan. The experiment was conducted in outdoor cemented cisterns each with dimensions of 8.9 m × 2.18 m × 1.16 m (length x width x depth). The bottom of tanks was covered with 0.015 m layer of soil and tanks were filled with water up to 0.85 m. Water volume in each tank was maintained at 53.36 m^3. Dissolved oxygen level in all the tanks was maintained through coarse bubble aeration. Any kind of organic/ inorganic fertilizers was not applied in treatment tanks.

2.2 Feed Formulation

Low cost, readily available raw materials were used to formulate three different types of feeds based on soybean meal, guar meal or canola meal (Table 1). Rice polish (by product of rice milling process) was used as control. Each type of feed was prepared by mixing the ingredients in required proportion followed by their grinding and homogenization in a feed mill. To determine the nutritional characteristics of prepared feeds, moisture content (105 °C, 2 hours), ash content (600 °C, 2 hours), crude protein (Kjeldahl digestion) and fat content (Soxhlet extraction) of feeds and their raw materials was determined in triplicate by Standard Methods as described in AOAC [14]. For first 23 days of experimental period, fry in each tank were fed with experimental diets in quantity equal to their total fish body weight stocked in each tank. Later, as fish grew in size and reached the fingerling stage, experimental diets were supplied at 5% of total fish body weight. In either case, feed in equal doses was supplied twice a day at fixed time intervals.

2.3 Fish Species and Stocking Density

Fry of two major carps, *L. rohita* and *G. catla* were procured from Fish Seed Hatchery, Mian Channu, Pakistan. Fish seed was transported to FR & TI, Lahore in plastic bags filled with appropriate amount of water and saturated with oxygen. Fish fry were acclimatized in separate cemented tanks for one week and fed with rice polish at weight equal to total body weight of fish stocked in each tank. At the end of acclimatization period, fry of each

Table 1. Composition of the experimental feeds

Feed Ingredients	Experimental Feeds			
	T1 (Control) (%)	T2 (%)	T3 (%)	T4 (%)
Rice polish	100	-	-	-
Soybean meal	-	70	-	-
Guar meal	-	-	70	
Canola meal	-	-		70
Wheat flour	-	15	15	15
Corn glutton meal	-	5.0	5.0	5.0
Rice bran	-	8.9	8.9	8.9
Vitamin & Mineral premix	-	1.0	1.0	1.0
Table salt	-	0.10	0.10	0.10
Total	100	100	100	100

major carp were randomly stocked in cemented tanks after recording of their average body weight and total length. Two major carps were stocked in stocking ratio of 1:1 and total stocking density of six fry in one cubic meter (6 fry/m^3).

2.4 Growth Parameters

Five specimen of each fish species were randomly captured from each tank after each 23 days for growth monitoring in terms of body weight and total length. Feed was continuously adjusted according to increase in fish biomass in each tank throughout the research period. At the end of experimental period, all fish specimens from each experimental tank were harvested for recording of fish survival, final wet body weight and total length. The collected data was used to calculate fish weight gain (WG), average daily weight gain (ADWG), length gain (LG), average daily length gain (ADLG), specific growth rate (SGR), survival rate (SR), condition factor (CF), gross & net production and feed conversion ratio (FCR) for each fish species by application of suitable formulae. Condition factor was calculated according to Froese [15] using the following formula:

Condition Factor: $(W/L^3) \times 100$

Where W: fish weight; L: Fish length

2.5 Water Quality Monitoring

The physico-chemical parameters i.e., water temperature, dissolved oxygen, pH and conductivity were monitored daily while total alkalinity, chloride content, total hardness and calcium hardness were analyzed on monthly basis. Water temperature was measured using glass thermometer while pH and conductivity were determined using pH meter (Jenway, 3505) and conductivity meter (Jenco, 3173), respectively. Total dissolved solids were calculated by multiplying water conductivity with a factor of 0.85. Dissolved oxygen was measured by Winkler method with azide modification [16]. Total alkalinity, total hardness, calcium hardness and chloride content were determined by volumetric titrations using standard methods as described in APHA [16]. A schematic presentation of methodology has been presented in Fig. 1.

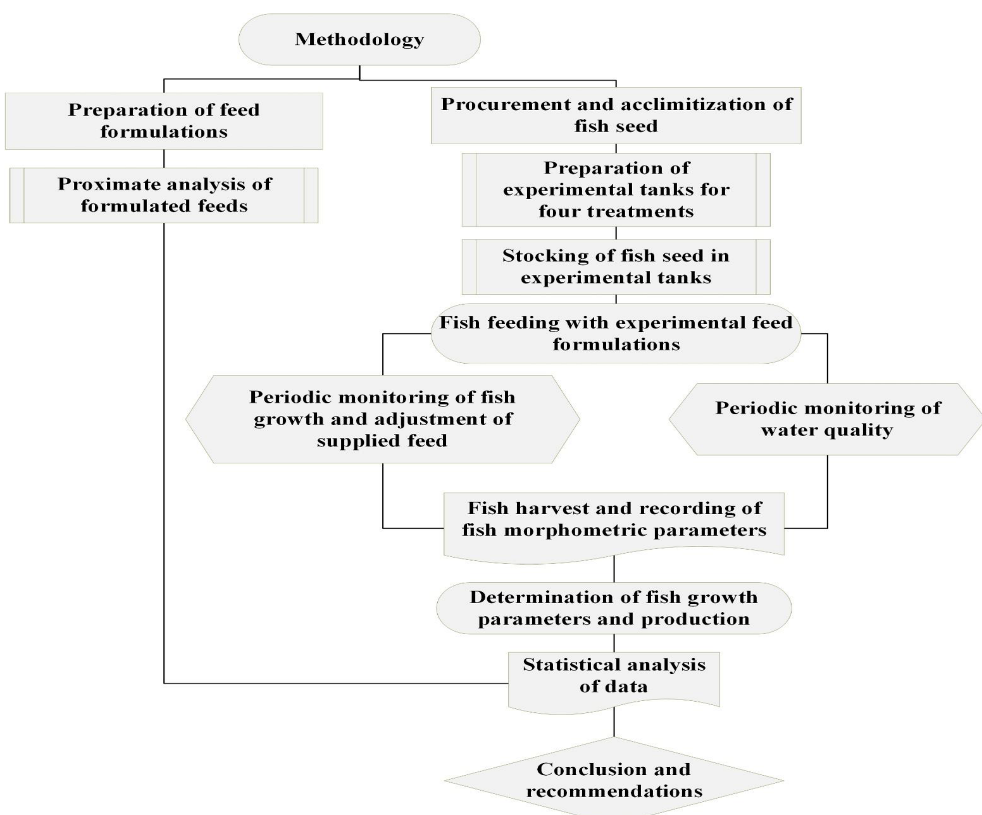

Fig 1. Schematic representation of methodology

2.6 Statistical Analysis

Statistical analysis of the data was carried out through SPSS (ver. 16.0) to find out statistically significant differences in growth performance of cultured fish species under various treatments through one way analysis of variance at $P<0.05$. Post hoc analysis was carried out to find differences between pair of means by Fisher's Least Significant Difference (LSD) test.

3. RESULTS

Proximate composition of experimental feeds and their ingredient has been presented in Table 2. Soybean meal based feed (T2) contained highest crude protein content (31.32% ± 0.32%) followed by guar meal based feed (T3) (26.20% ± 1.92%)) and canola meal based feed (T4) (24.54% ± 2.97%). Rice polish used as control diet in T1 was found to have lowest crude protein (12.19% ± 0.48%). However, its ash and crude fat content was higher as compared to formulated feeds used in rest of treatments.

Growth performance of Rohu and Catla has been presented in Table 3 along with gross and net production. Survival rate (SR) for both species was found to be 100% in all treatments. Analysis of variance indicated significant differences in growth of two fish species achieved in various feed treatments at $P< 0.05$. For Rohu, weight gain achieved in T2 and T4 was significantly higher than that of T3 and T1. However, for Catla, weigh gain in T2 was significantly higher than other three treatments. Weight gain decreased in the following order for four experimental feeds. Soybean meal based feed > Canola meal based feed > Guar meal based feed > Rice polish based feed.

For Rohu, highest WG was achieved in T2 (121.85 g ± 4.02 g) followed by T4 (107.48 g ± 17.07 g) and T3 (49.45 g ± 10.30 g). Control treatment (T1) showed least WG (31.77 g ± 1.40 g) for Rohu. Highest weight gain of Catla was found in T2 (66.47 g ± 4.57 g) followed by T4 (47.34 g ± 8.59 g), T3 (19.63 g ± 8.55 g) and T1 (14.14 g ± 3.06 g). In case of Rohu, SGR was highest in T4 followed by T2, T3 and T1 respectively. However, for Catla, SGR was highest in T2 followed by T4, T3 and T1 respectively. Differences between WG, ADWG and SGR of Rohu and Catla as achieved in T2 and T4 were not significant ($P<0.05$). Increase in weight of Rohu and Catla under all treatments over the entire experimental period has been shown in Fig. 2 and Fig. 3 respectively.

Net production (kg/tank) of both fish species was higher in T2 and T4 than that of T1 and T3. Lowest FCR (1.93 ± 0.06) was found in T4 for Rohu and in T2 (1.67 ± 0.15) for Catla. Control diet (T1) showed highest FCR for both fish species i.e. Rohu and Catla (2.73 ± 0.59 and 2.35 ± 0.41), respectively. Condition factor (CF) varied from

Table 2. Proximate composition (Mean ± Standard Deviation (SD)) of feed ingredients and experimental feeds

Feed Ingredient/ Formulated Feed	Proximate Composition			
	Moisture (%)	Ash (%)	Crude Protein (%)	Crude Fat (%)
Soybean meal	10.4 ± 1.94	6.59 ± 0.04	39.3 ± 1.67	1.12 ± 0.51
Guar meal	7.50 ± 0.24	4.61 ± 0.03	32.0 ± 2.43	4.80 ± 0.25
Canola meal	9.27 ± 0.56	6.78 ± 0.30	29.6 ± 0.48	4.29 ± 1.77
Wheat flour	9.39 ± 0.34	1.64 ± 0.06	11.4 ± 2.33	3.21 ± 0.41
Corn gluten meal	10.7 ± 0.23	8.35 ± 0.21	16.6 ± 0.49	1.93 ± 0.04
Rice bran	11.5 ± 0.17	0.53 ± 0.04	9.99 ± 0.18	0.33 ± 0.18
Feed in T1 (rice polish)	8.95 ± 0.30	9.26 ± 0.02	12.2 ± 0.48	15.2 ± 1.20
Formulated feed in T2 (based on soybean meal)	9.19 ± 0.19	5.72 ± 0.03	31.3 ± 0.28	1.02 ± 0.20
Formulated feed in T3 (based on guar meal)	7.94 ± 0.05	4.66 ± 0.03	26.2 ± 1.92	3.47 ± 0.68
Formulated feed in T4 (based on canola meal)	8.44 ± 0.45	6.23 ± 0.08	24.5 ± 2.97	1.94 ± 0.61

1.43 ± 0.05 to 1.27 ± 0.0 for Rohu and from 1.45 ± 0.06 to 1.33 ± 0.0 for Catla. In case of Rohu, highest CF was found in T4 followed by T2, T3 and T1 respectively. For Catla, highest CF was found in T2 followed by T4, T3 and T1. The physico-chemical parameters of water were found to be within suitable ranges as described by Boyd and Tucker [17] for cultured fish species and are presented in Table 4.

Table 3. Growth performance (Mean ± SD) of Rohu and Catla under different feeding treatments

Parameters	Fish name	Treatments			
		T1	T2	T3	T4
Initial weight (g)	Rohu	0.57 ± 0.16	0.46 ± 0.03	0.47 ± 0.01	0.32 ± 0.02
	Catla	0.18 ± 0.04	0.11 ± 0.00	0.17 ± 0.08	0.10 ±0.00
Final weight (g)	Rohu	32.3 ± 1.60^{b}	122.3 ± 4.04^{a}	49.9 ± 10.3^{b}	107.8 ± 17.0^{a}
	Catla	14.3 ± 3.03^{c}	51.5 ± 4.57^{a}	19.8 ± 8.63^{c}	47.4 ± 8.58^{b}
Weight gain (g)	Rohu	31.8 ± 1.40^{b}	121.8 ± 4.02^{a}	49.4 ± 10.3^{b}	107.5 ± 17.07^{a}
	Catla	14.1 ± 3.06^{c}	66.5 ± 4.57^{a}	19.6 ± 8.55^{c}	47.34 ± 8.59^{b}
Average daily weight gain (g)	Rohu	0.35 ± 0.02^{b}	1.32 ± 0.04^{a}	0.54 ± 0.11^{b}	1.17 ± 0.18^{a}
	Catla	0.16 ± 0.03^{c}	0.74 ± 0.05^{a}	0.22 ± 0.09^{c}	0.53 ± 0.10^{b}
Specific growth rate (%)	Rohu	4.41 ± 0.25^{c}	6.07 ± 0.03^{a}	5.06 ± 0.19^{b}	6.30 ± 0.24^{a}
	Catla	4.89 ± 0.46^{b}	7.13 ± 0.07^{a}	5.30 ± 0.08^{b}	6.76 ± 0.25^{a}
Length gain (cm)	Rohu	10.5 ± 0.71^{b}	17.1 ± 021^{a}	13.2 ± 1.70^{b}	17.0 ± 1.20^{a}
	Catla	8.68 ± 0.32^{b}	15.0 ± 0.60^{a}	9.80 ± 0.99^{b}	13.7 ± 0.33^{a}
Average daily length gain (cm)	Rohu	0.12 ± 0.01^{b}	0.19 ± 0.00^{a}	0.15 ± 0.02^{b}	0.19 ± 0.01^{a}
	Catla	0.10 ± 0.00^{b}	0.17 ± 0.00^{a}	0.11 ± 0.01^{b}	0.15 ± 0.00^{a}
Condition factor	Rohu	1.27 ± 0.00^{b}	1.42 ± 0.07^{a}	1.34 ± 0.01^{a,b}	1.43 ± 0.05^{a}
	Catla	1.33 ± 0.00^{b}	1.45 ± 0.06^{a,b}	1.35 ± 0.04^{a,b}	1.39 ± 0.01^{a,b}
Survival rate (%)	Rohu	100.0	100.0	100.0	100.0
	Catla	100.0	100.0	100.0	100.0
Gross production (kg.tank^{-1})**	Rohu	1.62 ± 0.08^{b}	6.12 ± 0.20^{a}	2.50 ± 0 .52^{b}	5.39 ± 0.85^{a}
	Catla	0.72 ± 0.15^{b}	3.33 ± 0.23^{a}	0.99 ± 0.43^{b}	2.37 ± 0.43^{a}
Gross production** (kg.ha^{-1})	Rohu	808 ± 39^{b}	3058 ± 101^{a}	1248 ± 258^{b}	2695 ± 426^{a}
	Catla	358 ± 76^{b}	1664 ± 114^{a}	495 ± 216^{b}	1186 ± 215^{a}
Net production (kg.tank^{-1})**	Rohu	1.59 ± 0.07^{b}	6.09 ± 0.20^{a}	2.48 ± 0.52^{b}	5.37 ± 0.85^{a}
	Catla	0.71 ± 0.15^{c}	3.32 ± 0.23^{a}	0.98 ± 0.43^{c}	2.37 ± 0.43^{b}
Net production** (kg.ha^{-1})	Rohu	794 ± 35^{b}	3046 ± 100^{a}	1236 ± 258^{b}	2687 ± 426^{a}
	Catla	353 ± 76^{c}	1662 ± 114^{a}	491 ± 214^{c}	1184 ± 215^{b}
FCR	Rohu	2.73 ± 0.59^{a}	1.98 ± 0.14^{a}	1.94 ± 0.34^{a}	1.93 ± 0.06^{a}
	Catla	2.35 ± 0.41^{a}	1.67 ± 0.15^{b}	1.80 ± 0.18^{a,b}	1.89 ± 0.04^{a,b}

*: Means that do not share a letter in a same row are statistically significant (P<0.05).

**: During 92 days experimental period

Table 4. Water quality parameters (Mean ± SD) recorded during experimental period

Parameter	Treatments			
	T1	T2	T3	T4
Temperature (°C)	30.7 ± 0.03	30.8 ± 0.00	30.84 ± 0.01	30.7 ± 0.09
Dissolved oxygen (mg.L^{-1})	5.60 ± 0.37	5.40 ± 0.00	5.80 ± 0.11	5.60 ± 0.36
pH	8.50 ± 0.00	8.52 ± 0.03	8.57 ± 0.01	8.53 ± 0.01
Conductivity (µS.cm^{-1})	579.3 ± 4.92	589.0 ± 5.76	575.2 ± 1.66	593.9 ± 4.31
Total dissolved solids	10.7 ± 0.23	8.35 ± 0.21	16.6 ± 0.49	1.93 ± 0.04
(mg.L^{-1})	492.4± 4.18	500.6± 4.90	488.8 ± 1.41	504.8 ± 3.66
Total alkalinity (mg.L^{-1})	367.6 ± 3.52	366.4 ± 7.03	364.2± 1.40	356.5 ± 9.38
Chloride (mg.L^{-1})	14.1 ± 0.16	16.3 ± 0.55	14.9 ± 0.80	15.6 ± 0.00
Total hardness (mg.L^{-1})	171.8± 10.6	153.3 ± 4.84	161.9 ± 1.10	162.0 ± 6.05
Calcium hardness (mg.L^{-1})	56.6 ± 1.83	58.6 ± 7.28	61.4 ± 0.18	75.9 ± 0.82

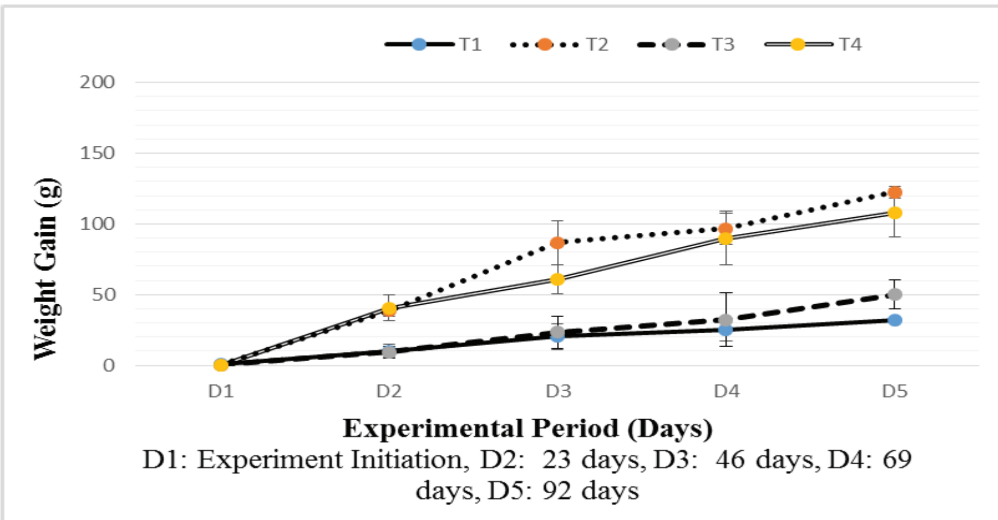

Fig. 2. Weight gain (g) of Rohu during experimental period (Error bars show SD)

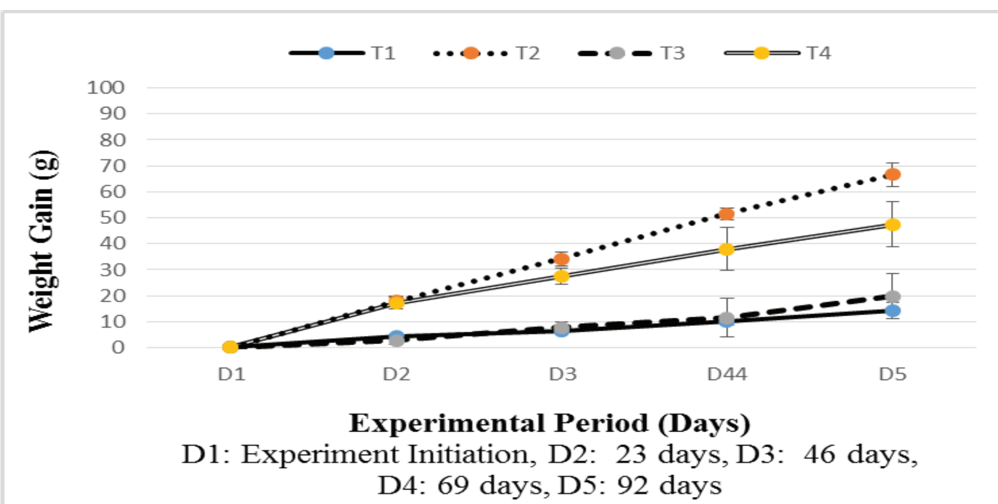

Fig. 3. Weight gain (g) of Catla during experimental period (Error bars show SD)

4. DISCUSSION

Optimum fish growth and health which is the primary objective of aquaculture activities depends upon appropriate nutrition of cultured animals. Exogenous feeds providing minerals, vitamins and essential nutrients are the crucial source of nutrition in intensive and semi intensive fish culture. Raw materials used in fish feed formulations should be digestible, palatable and of high nutritive quality. Historically, fish meal has been used as major protein source in aqua feeds due to its nutritional characteristics and digestibility [18]. However, on the basis of current rate of fish meal consumption in aquafeeds and expected development of aquaculture in future, it has been estimated that sector's demand for fishmeal will outrun the annual production of latter [19]. Use of fishmeal based aquafeeds not only raise concerns about viable development of aquaculture but also result in an increase in challenging issues that the sector has to cope with in future. Use of trash fish in feed that can lead to viral and bacterial infection of cultured fish [20] adulteration of fish feeds with melamine to artificially increase its protein content [21], use of contaminated fish meal in feed preparation and subsequent bioaccumulation of toxic materials in cultured animals [22] are to name a few. This scenario has incentivized the replacement of fish meal with other readily available, cost effective alternatives of high nutritional quality. The only solution to this dilemma is replacement of fish meal with low cost and readily available animal and plant based raw materials without any compromise on growth and production of cultured animals. Fortunately, low trophic level finfish are more acquiescent in terms of protein source in their feed and not necessarily require fish meal and fish oil based diets like carnivorous species and shellfish [23].

In present study, efficacy of four different types of formulated feeds based on cost effective ingredients from plant sources were evaluated in terms of growth performance of two major carps. A comparison of crude protein content of plant feed stuff as determined in the present study with the values cited in literature has been described in Table 5. Plant based ingredients are deficient in certain amino acids whose adequate supply in feed is imperative for fish [24]. Soybean meal, for example, contain limited concentration of sulphur bearing indispensable amino acid; methionine [25]. This obstacle can, however, be overcome by either supplementation of plant based feedstuff with limiting amino acids [26] or alternatively formulation of the feed with plant feedstuffs of different origin that can supplement amino acids deficiency of each other [27, 28]. In the present study, second strategy was adopted and corn gluten meal, wheat flour and rice bran were used to reduce amino acid deficiency caused by limiting amino acids of basic oilseed meals used. Nutritional composition of formulated feeds was balanced by addition of vitamins and mineral premix and table salt. Highest fish growth in terms of weight gain and average daily weight gain of Rohu and Catla was achieved with Soybean meal based formulated feed. The results are in agreement with those of Khan *et al*. [26] who reported higher weight gain with

Table 5. Comparison of crude protein content of feed ingredients with literature

Feed ingredient	Crude protein content (%) (Literature based value)	Crude protein content (%) (Present study)
Rice polish	4.70-14.9[30]	12.2
Soybean meal	49.2[31]	39.3
Guar meal	33.0 - 45.0[32]	32.0
Canola meal	36.5[31]	29.6
Wheat flour	7.13 -14.4[33]	11.4
Corn gluten meal	60.0[34]	24.7*
Rice bran	12.5[35]	9.99

*Commercial corn gluten meal (30%) that claims to be 30% protein content and is prepared by mixing of corn gluten meal with corn gluten feed to produce low protein content variet soybean meal based diets than those of groundnut and canola meal based diets and concluded that soybean meal supplemented with methionine and minerals can effectively replace fish meal in Rohu feed. Rehman *et al*. [29] have also reported that fish meal can be partially replaced with soybean meal and sunflower meal in diets of Rohu without any negative effect on fish growth.

Results of present study are contradictory with those Iqbal *et al.* [36] who reported highest weigh gain of Rohu with guar meal than canola meal, soybean meal, cottonseed meal and fish meal. Lowest weight gain of both cultured fish species with rice polish are in agreement with those of Abid and Ahmed [37] and Ahmed *et al.* [38] who have also reported least weight gain of Rohu with rice polish when compared with other plant materials based diets. Higher FCR values found in present study are in line with those of Khan *et al.* [26] who have reported FCR of 2.2 ± 0.06 for Rohu fed with plants based diet based on soybean meal. Growth performance of Rohu was higher than Catla in terms of WG, ADWG, LG, ADLG and production in present investigation. SGR of Catla was, however, found to be higher than Rohu under all treatments. Condition factor has been considered as an indicator of fish health as higher condition factor relates to healthier fish [39]. Higher condition factor of Rohu and Catla fed with soybean meal based feed and canola meal based feed indicated improved fish health in these treatments.

According to present study, use of feeds formulated with soybean meal and canola meal as source of oilseed meal has resulted in higher fish production and weight gain. Net production of Rohu ($kg.ha^{-1}$) achieved with soybean meal based diet was about 59% and 74% higher than that of guar meal and rice polish based diets respectively. In the case of Catla, net fish production ($kg.ha^{-1}$) with soybean meal based feed was 70% and 79% higher than that found with guar meal and rice polish based diets respectively. For canola meal based feed, net Rohu production was found to be 54% & 70% and net Catla production was 58% and 70% higher than that of guar meal and rice polish based diets respectively. A comparison of estimated costs of formulated feeds and commercial feeds available in market for carps has been presented in Table 6. Estimated cost of soybean meal based feed is higher than that of rest of the experimental diets due to relatively high rate of soybean meal. However, the rates of soybean meal based feed and canola meal based feed are about 26% lower than that of commercially available feed of comparable protein content (CP; 30% and 23% respectively). Higher growth of fish fed with formulated diet containing soybean meal can be attributed to its amino acid composition that is considered as one of the best among plant based raw materials to meet the fish demand for indispensable amino acids [10]. Soybean meal is often referred as “gold standard” in aquafeeds due to its high nutritional value and abundant availability in international market feed raw materials [40].

5. CONCLUSION

Present study has led to the conclusion that soybean meal complemented with corn gluten meal, rice bran and wheat flour can be used in formulation of cost effective diets for *L. rohita* and *G. catla*. In future, there is the need to evaluate effects of long term use of plant based aquafeeds on fish physiology, nutritional quality and consumer health.

Table 6. Comparison of cost of formulated feeds with available commercial feed

Feed	CP (%)	Estimated Cost		Net production ($kg.ha^{-1}$)	
		(PKR*/kg)	(PKR*/50kg)	*L. rohita*	*G. catla*
Feed in T1 (rice polish)	12.2	23.0	1150.0	1.59	0.71
Formulated feed in T2 (based on soybean meal)	31.3	63.0	3135.0	6.09	3.32
Formulated feed in T3 (based on guar meal)	26.2	44.0	2190.0	2.48	0.98
Formulated feed in T4 (based on canola meal)	24.5	47.0	2365.0	5.37	2.37
Commercial feed (available in market)	30.0	85.0	4250.0	---	
Commercial feed (available in market)	23.0	64.0	3187.0	---	

*PKR: Pakistani Rupees

6. ACKNOWLEDGMENT

The authors are thankful to the Chemistry Section, Fish Quality Control Laboratory, Lahore, Pakistan for providing the facility of proximate analysis of feed.

7. REFERENCES

1. Godfray, H.C.J., J.R. Beddington, I.R. Crute, L. Haddad, D. Lawrence, J.F. Muir, J. Pretty, S. Robinson, S.M. Thomas, & C. Toulmin. Food security: The challenge of feeding 9 billion people. *Science* 327(5967): 812-818 (2010).
2. FAO. *FAO yearbook 2010: Fishery and aquaculture statistics.* Food and agriculture organisation of the United Nations, Rome (2012). Retrieved from http://www.fao.org/docrep/015/ba0058t/ba0058t.pdf.
3. Ruxton, C. The benefits of fish consumption. *Nutrition Bulletin* 36(1): 6-19 (2011).
4. FAO. *The state of world fisheries and aquaculture 2016:Contributing to food security and nutrition for all.* Food and agriculture organisation of the United Nations, Rome (2016). Retrieved from http://www.fao.org/3/a-i5555e.pdf.
5. Hixson, S.M. Fish nutrition and current issues in aquaculture: The balance in providing safe and nutritious seafood, in an environmentally sustainable manner. *Journal of Aquaculture Research & Development* 5(3): 1-10 (2014).
6. The World Bank. *Fish to 2030 prospects for fisheries and aquaculture.* Agriculture and environmental services discussion paper 03. The World Bank, Washington, DC. USA (2013).
7. De Silva, S.S., D.S. Francis, & A.G. Tacon. Fish oils in aquaculture: In retrospect. In: *Fish oil replacement and alternative lipid sources in aquaculture feeds.* Turchini, G.M., W.-K. Ng, & D.R. Tocher (Ed.), CRC Press, Boca Raton, Florida, USA. p. 1-20 (2011).
8. Tacon, A.G. & M. Metian. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. *Aquaculture* 285(1): 146-158 (2008).
9. Villasante, S., D. Rodríguez-González, M. Antelo, S. Rivero-Rodríguez, & J. Lebrancón-Nieto. Why are prices in wild catch and aquaculture industries so different? *Ambio* 42(8): 937-950 (2013).
10. Hertrampf, J.W., F. Piedad-Pascual, & O. Sik Lee. *Handbook on ingredients for aquaculture feeds.* Springer Science + Business Media, Dordrecht, Netherlands (2003).
11. Mahboob, S. Replacing fish meal with a blend of alternative plant proteins and its effect on the growth performance of *Catla catla* and *Hypophthalmichthys molitrix*. *Pakistan Journal of Zoology* 46(3): 747-752 (2014).
12. Obirikorang, K.A., S. Amisah, S.C. Fialor, & P.V. Skov. Effects of dietary inclusions of oilseed meals on physical characteristics and feed intake of diets for the nile tilapia, *Oreochromis niloticus*. *Aquaculture Reports* 1: 43-49 (2015).
13. Djissou, A.S., D.C. Adjahouinou, S. Koshio, & E.D. Fiogbe. Complete replacement of fish meal by other animal protein sources on growth performance of *Clarias gariepinus* fingerlings. *International Aquatic Research* 8(4): 333-341 (2016).
14. AOAC. *Official methods of analysis of AOAC International*. 18th Ed., AOAC International, Gaithersburg, Maryland (2005).
15. Froese, R. Cube law, condition factor and weight–length relationships: history, metal analysis and recommendations. *Journal of Applied Ichthyology* 22 (4): 241-253(2006).
16. APHA. *Standard methods for the examination of water and wastewater*. 22nd Ed., American Public Health Association, Washington, DC. USA (2012).
17. Boyd, C.E. & C.S. Tucker. *Pond aquaculture water quality management*. Springer Science+Business Media, LLC, New York, NY. USA (2012).
18. Tucker, C.S., J.A. Hargreaves, & C.E. Boyd. Aquaculture and the environment in the united states. In: *Environmental best management practices for aquaculture*. Tucker, C.S. & J.A. Hargreaves (Ed.), John Wiley & Sons, Hoboken, New Jersey, USA. p. 3-54 (2009).
19. Hardy, R.W. Utilization of plant proteins in fish diets: Effects of global demand and supplies of fishmeal. *Aquaculture Research* 41(5): 770-776 (2010).
20. Kim, J.H., D.K. Gomez, C.H. Choresca, & S.C. Park. Detection of major bacterial and viral pathogens in trash fish used to feed cultured flounder in korea. *Aquaculture* 272(1): 105-110 (2007).
21. Karunasagar, I. Melamine in fish feed and implications for safety of aquaculture products. *FAO Aquaculture Newsletter* 42: 29-31 (2009).
22. Rana, K.J., S. Siriwardena, & M.R. Hasan, Impact of rising feed ingredient prices on aquafeeds and aquaculture production. FAO fisheries and aquaculture technical paper 541. Food and Agriculture Organization of the United Nations,

Rome (2009). Retrieved from www.fao.org/docrep/012/i1143e/i1143e.pdf.

23. Tacon, A.G. & M. Metian. Feed matters: Satisfying the feed demand of aquaculture. *Reviews in Fisheries Science & Aquaculture* 23(1): 1-10 (2015).
24. Kaushik, S., J. Cravedi, J. Lalles, J. Sumpter, B. Fauconneau, & M. Laroche. Partial or total replacement of fish meal by soybean protein on growth, protein utilization, potential estrogenic or antigenic effects, cholesterolemia and flesh quality in rainbow trout, *Oncorhynchus mykiss*. *Aquaculture* 133(3): 257-274 (1995).
25. Jobling, M. On-growing to market size, In: *Culture of cold-water marine fish*. Moksness, E., E. Kjorsvik, & Y. Olsen (Ed.), Blackwell Publishing Ltd., New York, NY. USA.p. 363-432 (2004).
26. Khan, M.A., A.K. Jafri, N.K. Chadha, & N. Usmani. Growth and body composition of rohu (*Labeo rohita*) fed diets containing oilseed meals: Partial or total replacement of fish meal with soybean meal. *Aquaculture Nutrition* 9(6): 391-396 (2003).
27. Burdock, G.A. *Encyclopedia of food and color additives. A- E. Volume 1*. CRC Press, Boca Raton (1997).
28. Boyle, M.A. *Personal nutrition*. 9th Ed., Cengage Learning, Boston, Massachusetts, USA (2015).
29. Rehman, T., F. Asad, N.A. Qureshi, & S. Iqbal. Effect of plant feed ingredients (soybean and sunflower meal) on the growth and body composition of *Labeo rohita. American Journal of Life Sciences* 1(3): 125-129 (2014).
30. Hossain, M., S. Sultana, S. Shahriar, & M. Khatun. Nutritive value of rice polish. *Online Journal of Animal Feed Research* 2: 235-239 (2012).
31. Khajali, F. & B. Slominski. Factors that affect the nutritive value of canola meal for poultry. *Poultry Science* 91(10): 2564-2575 (2012).
32. Hussain, M., A. Rehman, & M. Khalid. Feeding value of guar meal and the application of enzymes in improving nutritive value for broilers. *World's Poultry Science Journal* 68(2): 253-268 (2012).
33. Heshe, G.G., G.D. Haki, A.Z. Woldegiorgis, & H.F. Gemede. Effect of conventional milling on the nutritional value and antioxidant capacity of wheat types common in ethiopia and a recovery attempt with bran supplementation in bread. *Food Science & Nutrition* 4(4): 534-543 (2016).
34. Johnson, L.A. Corn: The major cereal of the americas. In: *Handbook of cereal science and technology*. Kulp, K. & J.G. Ponte (Ed.), Marcel Dekker. New York, NY. USA. p. 31-80 (2003).
35. Fabian, C. & Y. H. Ju. A review on rice bran protein: Its properties and extraction methods. *Critical Reviews in Food Science and Nutrition* 51(9): 816-827 (2011).
36. Iqbal, K., M. Ashraf, A. Javid, N. Qureshi, N. Khan, H. Azmat, M. Altaf, H. Majeed, M. Haider, & Irfan. Effect of different feed ingredients on growth, sensory attributes and body composition of *Labeo rohita. The Journal of Animal and Plant Sciences* 25: 514-518 (2015).
37. Abid, M. & M. Ahmed. Growth response of *Labeo rohita* fingerlings fed with different feeding regimes under intensive rearing. *The Jounral of Animal and Plant Sciences* 19: 45-49 (2009).
38. Ahmed, M., K. Shafiq, & M. Kiani. Growth performance of major carp, *Labeo rohita* fingerlings on commercial feeds. *The Jounral of Animal and Plant Sciences* 22(1): 93-96 (2012).
39. Girdler, A., I. Wellby, & R.L. Welcomme. *Freshwater fisheries management: A manual for still-water coarse fisheries*. Blackwell Publishing Ltd., Chichester, England (2010).
40. Jobling, M. Fish culture: Feeds and feeding, In: *Finfish aquaculture diversification*. FrançOis, N.L., M. Jobling, C. Carter, & P. Blier (Ed.), CABI, Wallingford, England. p. 61-83 (2010).