Pakistan J. Zool., vol. 46(1), pp. 253-260, 2014.

Effect of Plant-Fishmeal and Plant By-Product Based Feed on Growth, Body Composition and Organoleptic Flesh Qualities of *Labeo rohita*

Khalid Javed Iqbal,[1]* Muhammad Ashraf,[1] Farzana Abbas,[1] Arshad Javid[2], Muhammad Hafeez-ur-Rehman,[1] Sumaira Abbas[1], Fayyaz Rasool,[1] Noor Khan,[1] Saeed Akram Khan[1] and Muhammad Altaf[2]
[1]Department of Fisheries and Aquaculture, University of Veterinary and Animal Sciences, Lahore
[2]Department of Wildlife and Ecology, University of Veterinary and Animal Sciences, Lahore

Abstract.- Present study was aimed at evaluating the effect of plant-fishmeal feed and/or plant by-product based feed on growth, body composition and flesh quality of *Labeo rohita*. Fish fed on rice polish alone served as control (T_0). Fish feed ingredients were grouped together with two ingredients in each test diet i.e. guar meal and canola meal (T_1), soybean meal and cotton seed meal (T_2), guar meal and cotton seed meal (T_3), soybean meal and canola meal (T_4) and fishmeal and canola meal (T_5). Each treatment including control had two replicates. Earthen ponds (12) with uniform area of 0.03 ha each, were randomly stocked with 100 fish (average weight 200 g) in each. All the ponds were then randomly allotted to individual treatment including control and were fed at 4% of their wet biomass twice a day. Significantly higher growth performance, specific growth rate (SGR) and better food conversion ratio (FCR) in T_3 and T_1 than rest of the treatments suggested that guar meal and cotton seed meal, and guar meal and canola meal are better option to include in future feed formulations for maximum performance and minimum feed wastage. Fish samples showed higher protein values in T_4, fat in T_2, moisture contents in control, dry matter in T_1 and ash in T_5. Non-significant differences in flavor, juiciness, and oiliness indicated that the sensory attributes of fish flesh were not affected by feeding fish with blend of various ingredients. Our study revealed that the cotton seed meal which is considered toxic to fish and is restricted in fish feeds perform equally good and can be incorporated in future feed formulations for *Labeo rohita.*

Key Words: Indian major carps, selected feed ingredients, chemical evaluation, Sensory evaluation

INTRODUCTION

Indian major carps are amongst the dominating fish fauna of South Asia and are primary cultureable fish species both in public and private sectors (Khan *et al*., 2004; Hussain *et al*., 2011). *Labeo rohita* the most important member of current fish culture setup is well liked among producers and consumers and therefore has been adopted as major component of fish culture in sub-continent (Chaudhuri *et al.*, 1974). It is highly nutritious and good source of digestible (85-90%) protein with balanced amino acid profile (Rudolf, 1971; Choo and Williams, 2003; Astawan, 2004). Fish is a major source of protein, contributes 26.2% of the total animal meat in Asia and developing countries. Other than nutritional competencies it is an important source of livelihood for local community. Fish culture is on the rise not only in developing countries but in developed countries too (Delgado *et al.*, 2002; Louka *et al.*, 2004).

Selection of feed ingredients and their costs have pronounced effect on aquaculture industry (Craig and Helfrich, 2002). Similarly, presence of essential nutrients in appropriate concentrations and elimination/reduction of anti nutrients to the minimum acceptable level is of prime importance for better fish growth and feed conversion ratios (Mokolensang *et al.*, 2003). Feed formulation protocol demands amalgamation of different ingredients from wide variety of sources to achieve feed with desired qualities (Khan *et al.*, 2004). Several researchers (Shabbir *et al*., 2003; Ali and Salim, 2004; Jabeen *et al*., 2004; Gull *et al*., 2005; Inayat and Salim, 2005; Saeed *et al*., 2005) worked on effects of various ingredients, individually and in combinations on different fish species and found better results when feed ingredients were combined together to formulate fish feeds. Diets become cost effective and several negative growth inhibitory factors in feed ingredients neutralize each other due to their interactive effects (Shioya *et al*., 2011; Yang *et al*., 2011). However, the information is scarce for

* Corresponding author: khaliduvas@yahoo.com
0030-9923/2014/0001-0253 $ 8.00/0

formulation of artificial feeds for *Labeo rohita*.

Artificial feed plays a significant role in fish production, sustainability of this industry and production of healthy product for consumers (Shioya *et al*., 2011; Yang *et al*., 2011). The sensory attributes viz. color, texture, smell and appearance may also be affected by changes in feed composition irrespective of the type of fish culture practiced (Khan *et al*., 2011). Population, fish species, spawning period, season, nutrition, post-harvest handling, and storage are some of the key factors that influence the quality of fish and its products (Kinsella, 1988; Nielsen *et al*., 2002). Data is sparse which explains the effect of feed on organoleptic quality of fish flesh. Studies on yellowtail fish (Viyakarn *et al.,* 1992) and rainbow trout (Smith *et al.,* 1988) indicated that soybean protein when used as partial substitute for fish meal did not show any significant differences in flesh quality. Nonetheless studies on some teleosts have shown that nutritional factors, such as dietary protein sources (Kaushik *et al.,* 1995), manuring, commercial diet (Moav *et al.,* 1977), fat sources (Guillou *et al.,* 1995), dietary fat content (Bjerkeng *et al.,* 1997), and vitamin E (Boggio *et al.,* 1985) can influence the physical and organoleptic flesh quality. Considering the breadth and depth of studies conducted so far on different fish species the present study was planned to evaluate the effect of combination of plant-fishmeal and/or plant based feed ingredients on growth, body composition and sensory attributes of juvenile *Labeo rohita*.

MATERIALS AND METHODS

Experimental site and study trials

This three month study was conducted in earthen ponds of the Department of Fisheries and Aquaculture, University of Veterinary and Animal Sciences, Ravi Campus Pattoki, using juvenile *Labeo rohita* as an experimental animal.

Experimental design

Studies were designed following Completely Randomized Design (CRD). There were 5 treatments and a control with two replicates in each group and whole trial was managed in 12 ponds. 100 fish (initial weight 200g) were randomly stocked in each pond (0.03 ha) and then all these ponds were arbitrarily distributed among 5 treatments and a control. Five experimental diets were prepared, each with two ingredients of known calories which are easily available in the market. The experimental diets were then subjected to proximate analysis. The proportionate ratio of the two was maintained at 1:1 i.e. guar meal and canola meal (T_1), soybean meal and cotton seed meal (T_2), guar meal and cotton seed meal (T_3), soybean meal and canola meal (T_4), fishmeal and canola meal (T_5) and a control diet (T_0) *i.e.* rice polish with two replicates in each. Fish were regularly fed at 4% of wet body weight twice a day.

Growth parameters

The weight and length of individual fish were recorded at the initiation of experiment and then fortnightly to ascertain the growth increments for subsequent feed adjustments. Average increase in weight (AWG), length (AIL) and specific growth rate (SGR) (Hopkins, 1992) was evaluated by following mathematical formulae;

AWG = Final average weight (g) - initial average weight (g)
AIL = Final average length (cm) - initial average length (cm)

$$\text{SGR (\%)} = \frac{\ln(\text{Final wet body weight}) - \ln(\text{Initial wet body weight})}{\text{Number of days}} \times 100$$

Water quality parameters

Dissolved oxygen (DO), pH, electrical conductivity, water temperature, salinity and total dissolved solids (TDS) were monitored daily at 09:00 A.M. and 02:00 P.M. Water temperature and DO were measured by DO meter (YSI 55 Incorporated, Yellow Springs, Ohio, 4387, USA), pH by pH meter (LT-Lutron pH-207 Taiwan) and electrical conductivity, salinity and TDS by salinity meter (Condi 330i WTW 82362 Weilheim Germany).

Proximate analysis

The technique Near Infrared Reflectance Spectroscopy (NIRS 5000 model, Foss Tecator, Sweden) was used for proximate analysis of feed ingredients and fish. The principle of NIRS is that bonds between organic molecules absorb a specific wavelength range of light in the near infrared region, and the near – infrared color of the sample provides information about its composition. Before submitting to analytical set-up, feed and fish were dried, finely ground in pestle and mortar and then placed in sampler cups. The cups were placed in NIRS machine for two minutes which displayed values for fat, moisture, protein and ash (Martinez *et al.,* 2003). Data sheet was collected and preserved for further processing and future usage.

Fish preparation for organoleptic evaluation

At the end of feeding trial, 10 fish were randomly picked up from the total catch of each treatment, degutted and well cleaned with fresh tap water for further processing. After preliminary dressing the flesh was uniformly filleted with fillet size of 3.8 x 6.6 cm having an average weight of 28.50g. One tablespoon iodized salt was sprinkled on each fillet and manually rubbed uniformly on its entire surface and then steamed in Orient microwave oven (Model OW-720ADL) at medium high temperature for 12 minutes. The cooked samples were placed them at safe place and allowed to equilibrate with room temperature before serving to panel of judges for sensory evaluation of these samples (Khan *et al.,* 2011).

Sensory evaluation

Fillets were presented to 12 member semi-trained panel, randomly selected from students and faculty members of University of Veterinary and Animal Sciences, Lahore, Pakistan for organoleptic test. The descriptors for various sensory attributes were color and its intensity (whitish/creamish) (typical of steamed fish flesh), flavor, intensity of perceived taste of typical steamed fish flesh, juiciness(intensity of juiciness of steamed fish flesh while chewing), tenderness (intensity of softness perceived at the time of chewing), oiliness (intensity of oiliness that perceived taste of a typical steamed fish flesh) and finally overall acceptability (accumulative impression of steamed fish taken from above tested attributes). Prepared samples were presented in glass plates coded with three digit random numbers. Mineral water was provided for convenient rinsing of mouths after tasting and testing each sample to avoid unintentional mixing of the taste and confounding effects of different treatment groups. The panelists were asked to rank their acceptance for above sensory attributes according to hedonic scale: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely. Sensory tests for fish from each treatment were performed on the same day under white incandescent lights (Meilgaard *et al.,* 2007).

Statistical analysis

The data were subjected to ANOVA using SAS (statistical package; version 16.0) at $p \leq 0.05$. Duncan's Multiple Range Test (DMRT) was applied to compare means when the level of variation between dietary treatments was significant.

RESULTS AND DISCUSSION

Fish growth and its associated qualities depend upon quality and quantity of feed. Quality and cost effective feed is not only hard to formulate and develop but impossible if we do not have proper set of known and well tested feed ingredients. The main objective of these series of experiments was to select different ingredients from the bulk available in the market for the convenience of the farmer and manufacturer which can be used blindly for well being of fish and increase fish production at low cost. During present study significantly higher growth performance, SGR and better FCR were observed in T_3 and T_1 than rest of the treatments and control which suggested that fish fed on guar meal and cotton seed meal, and guar meal and canola meal performs better than the rest of the combinations (Table III). Our findings are in line with similar observations of others when fed *Labeo rohita* with other fish varieties on different feed ingredients (Ashraf *et al.,* 2008; Ahmad *et al.,* 2012; Abid and Ahmed, 2009a,b).

Proximate analysis of experimental diets revealed highest protein in T_5 than T_2, T_3, T_4, T_1 and T_0 in decreasing order (Table II) while better growth was observed when fish were fed with T_3 diet (Table III). Our findings contradict the work of

Abid and Ahmed (2009a) who observed significantly higher ($P<0.05$) weight gain (26.17g) with increasing crude protein levels in fish feed. Our studies indicate that protein is not the only factor in fish feed which promotes fish growth and ameliorates nutritional value of fish flesh. Li *et al*. (2000) observed significant differences among various protein rich artificial feeds when offered to channel catfish (*Ictalurus punctatus*). On the other hand, Hasan *et al.* (2005) could not observe any difference in growth and body composition of fish when reared on agro based diet and compared it with fishmeal based diet in common carp.

Table I.- Experimental diets were prepared using the formula.

Treatment	Feed ingredients	Percentage (%)
T_1	Guar Meal and Canola meal (GM+CM)	50:50
T_2	Soybean Meal and Cotton Seed Meal (SBM+CSM)	50:50
T_3	Guar meal and cotton seed meal (GM+CSM)	50:50
T_4	Soybean meal and canola meal (SBM+CM)	50:50
T_5	Fishmeal and canola meal (FM+CM)	50:50
T_0	Rice Polish (RP)	100

Table II.- Proximate analysis of feed combinations.

Analysis	T_1	T_2	T_3	T_4	T_5	T_0
Protein %	36.76	38.44	37.63	37.57	40.35	6.07
Moisture %	7.07	9.68	7.13	9.62	7.33	4.92
Fat %	1.77	1.42	1.60	1.35	4.87	3.15
Ash%	8.22	12.48	12.35	8.35	15.59	6.3
kcal/g	4.09	4.07	4.08	4.07	4.15	4.13

Proximate analysis of ground *Labeo rohita* from treated and control ponds revealed highest protein in T_4, originally fed on low protein diet, fat in T_2, moisture content in control, dry matter in T_1 and ash in T_5 ponds (Table IV) which confirms findings of Khan *et al.* (2012) who observed non-significant differences in major carp body composition fed on artificial feed with different crude protein levels. It further revealed that protein deposition in fish does not reflect the protein composition of diet rather it may be interaction among nutrients, their anti-nutritional level, acceptability/palatability of each ingredient and its behavior in digestive system (Moraes and Bidinotto, 2000; Lim and Dominy, 1991).

Significantly higher SGR $P<0.05$ was observed in fish fed T_3 diet followed by T_1, T_0, T_2, T_3 and T_4 (Table III) in decreasing order. Our results are contradictory to the findings of Abid and Ahmed (2009a) who observed non-significant differences in SGR between treatments in which fish were fed with increasing crude protein levels of feed. FCR is the best parameter to assess the acceptability of feed and its ultimate performance in fish (Inayat and Salim, 2005). In present study better FCR was observed in treatment T_3 (2.602±0.35) when compared to T_0 (4.700±0.23) (Table III). Our results confirm the previous findings of Abid and Salim (200) and Ashraf *et al.* (2008) in mrigal (*Cirrhinus mrigala)* and rohu (*Labeo rohita)* (Abid and Ahmed, 2009a,b) who found similar outcomes by using feed ingredients in combination. Li *et al.* (2000) also reported significantly higher FCR when they compared plant based feed with animal based feed. On the other hand, Hasan *et al.* (2005) reported non-significant differences on plant origin feed when compared with animal origin feed in common carp. The results of present study are in line with the work of Latif *et al.* (2008) who combined feed ingredients to prepare experimental diets and obtained similar results.

In present study physico-chemical water parameters such as temperature, dissolved oxygen, pH, salinity, TDS and electrical conductivity remained within the desired range (Table V) and well corroborated with previous findings (Ali *et al*., 2000; Abid and Ahmed, 2009a,b).

Sensory evaluation showed that color, flavor, juiciness, tenderness, oiliness and overall acceptability of fried fish flesh showed non-significant differences irrespective of diet composition among various dietary treatments (Table VI). Some earlier researchers have reported similar sensory attributes when fish was fed on varying protein levels (Rora *et al*., 2005; Koshio *et al*., 1994). Findings of Khan *et al.* (2011), further

Table III.- Comparison of growth increments and attached growth indicators in *Labeo rohita.*

Treatment	Weight gain %	Weight gain (g)	Length increase (cm)	FCR	SGR %
T_1	58.29	246.16±6.17[a]	21.96±0.95[a]	3.03±0.04[bc]	0.42±0.05[ab]
T_2	43.11	162.66±20.00[b]	13.54±0.72[b]	4.69±0.91[ab]	0.27±0.05[b]
T_3	65.99	294.00±30.00[a]	24.27±0.83[a]	2.60±0.35[c]	0.52±0.08[a]
T_4	42.08	159.09±4.90[b]	14.34±0.65[b]	4.91±0.55[a]	0.26±0.03[b]
T_5	43.24	161.00±6.33[b]	13.10±0.91[b]	4.65±0.19[ab]	0.27 ±0.02[b]
T_0	43.71	164.66±4.66[b]	14.57±1.29[b]	4.70±0.23[ab]	0.27±0.02[b]

Table IV.- Proximate composition of *Labeo rohita (*on dry weight basis) fed on different dietary combinations.

Sr. No.	CP %	Fat %	Dry matter %	Ash %
T_1	70.00±1.75[ab]	4.46±0.15[c]	29.76±6.33[a]	16.33±3.21[a]
T_2	63.00±0.87[c]	6.73±0.25[a]	25.92±1.22[ab]	15.00±1.00[a]
T_3	65.62±3.50[bc]	6.23±0.20[b]	24.18±1.53[ab]	15.00±3.00[a]
T_4	74.81±2.18[a]	5.80±0.30[b]	24.11±2.49[ab]	16.00±2.00[a]
T_5	69.12±6.12[abc]	4.93±0.20[c]	23.46±1.01[b]	22.33±5.50[a]
T_0	65.18±3.06[bc]	4.53±0.35[c]	22.43±1.36[b]	18.33±6.50[a]

Table V.- Ranges of various physicochemical parameters observed during the course of trial.

Treatment	DO	pH	Temperature	EC	TDS	Salinity
Morning						
T_1	5.86±0.06	8.33±0.04	34.55±0.42	2.64±0.03	1001.56±11.76	0.87±0.02
T_2	5.89±0.08	8.34±0.05	34.67±0.47	2.60±0.04	974.69±33.04	0.91±0.03
T_3	5.85±0.09	8.30±0.04	34.64±0.37	2.61±0.03	972.83±9.11	0.96±0.01
T_4	5.82±0.07	8.30±0.03	34.91±1.54	2.65±0.06	980.72±8.32	0.84±0.05
T_5	5.95±0.7	8.37±0.18	33.73±0.92	2.59±1.08	947.17±31.09	0.81±0.01
T_0	5.79±0.06	8.37±0.03	34.67±0.34	2.58±0.03	992.09±12.31	0.94±0.02
Evening						
T_1	5.36±0.06	8.13±0.04	35.58±0.42	2.74±0.03	1006.90±11.76	0.89±0.02
T_2	5.39±0.08	8.14±0.05	35.70±0.47	2.70±0.04	980.03±9.54	0.92±0.05
T_3	5.35±0.09	8.10±0.04	35.67±0.39	2.71±0.03	978.17±9.11	0.96±0.01
T_4	5.32±0.07	8.10±0.03	35.94±0.44	2.75±0.03	986.05±8.32	0.98±0.01
T_5	5.45±0.07	8.17±0.05	35.26±0.56	2.70±0.05	980.52±9.32	0.82±0.04
T_0	5.29±0.06	8.17±0.03	35.70±0.34	2.68±0.03	997.43±12.31	0.94±0.02

Mean±SE

support our findings who did not find any difference in meat quality of fish either reared on natural or artificial feed in fish raised in poly culture system. In another study, Khan *et al.* (2012a) had similar findings when fingerlings of Indian major carps were grown up on plant based artificial feeds under monoculture system. But contrary to our study they also reported that in monoculture system, the sensory attributes like juiciness and tenderness scores of *Labeo rohita* differed significantly in treatments versus control. Javed *et al.* (1995) also found significant differences among the taste scores of three fish species *C. catla, C. mrigala* and *L. rohita*. Findings of Jayaram *et al.* (1980) and Tahir (2008), further support our observations who reported non-significant differences in taste and overall quality of all the three Indian major carps when cultured in manured ponds and/or fed on

Table VI.- Organoleptic/sensory score of fish flesh against various parameters tested.

Feed ingredients	Color	Flavor	Tenderness	Juiciness	Oiliness	Overall acceptability
T_1	6.50±0.23[a]	6.50±0.35[a]	6.94±0.31[a]	6.58±0.31[a]	6.58±0.46[a]	6.66±0.28[a]
T_2	6.25±0.25[a]	6.41±0.43[a]	6.58±0.35[a]	6.25±0.44[a]	5.91±0.46[a]	6.33±0.22[a]
T_3	6.89±0.22[a]	6.91±0.33[a]	6.75±0.32[a]	6.66±0.39[a]	6.66±0.35[a]	6.97±0.24[a]
T_4	6.50±0.26[a]	6.75±0.35[a]	6.41±0.39[a]	6.41±0.35[a]	6.25±0.44[a]	6.33±0.35[a]
T_5	6.25±0.37[a]	6.83±0.29[a]	6.58±0.39[a]	6.91±0.33[a]	5.91±0.54[a]	6.83±0.34[a]
T_0	6.75±0.37[a]	6.66±0.35[a]	6.50±0.35[a]	6.08±0.37[a]	6.00±0.32[a]	6.58±0.33[a]

Note: - The results show organoleptic evaluation test marks out of ten,
Figures with same superscript letters in columns are not significantly different from each other at $p>0.05$

artificial feed. Similarly, findings of Khan *et al.* (2011) are quite in line with our results who observed no difference in taste, texture and aroma when fish diet was supplemented with either poultry fat or fish oil. Hassan (1996) while working on Indian major carps in similar context under natural food and artificial feeding environment could not identify any difference in sensory and organoleptic qualities of fish flesh from two different and independent sources. From previous as well as current studies it can be deduced that type of fish, culture environment and type of feed offered have significant bearing on flesh quality. These differences narrow down with changes and modifications in habitats, feeding manipulations, species proximity, sensitivity of the experimental studies and training of the panelists who can validate subtle differences. Nevertheless majority of such type of studies previous as well as current incline towards non-significance. Therefore, like previous authors we also end up with the inference that different feed sources do not have much impact on sensory qualities of fish flesh. Nonetheless until and unless discrete differences among various ingredient including macro as well as micronutrients are not critically visualized it will remain unresolved puzzle.

It can be concluded from the present study that protein is not the only nutrient which enhances growth of herbivorous fish but feed quality, its acceptability to the fish and water quality of rearing unit also play a pivotal role in this direction. All these factors mentioned above in this contact will be focused in our future research. Guar meal and cotton seed meal, and guar meal and canola meal resulted better as compared to the other feed ingredients and can be used for future *Labeo rohita* feed formulations.

ACKNOWLEDGEMENTS

Financial support provided by the Higher Education Commission (HEC), Pakistan for the compilation of present work is highly acknowledged.

REFERENCES

ABID, M. AND AHMED, M. S., 2009b. Efficacy of feeding frequency on growth and survival of *Labeo rohita* (Ham.) fingerlings under intensive rearing. *J. Anim. Pl. Sci.*, **19**: 111-113.

ABID, M. AND AHMED, M.S., 2009a. Growth response of *Labeo rohita* fingerlings fed with different feeding regimes under intensive rearing. *J. Anim. Pl. Sci.*, **19**:45-49.

ABID, M. AND SALIM, M., 2004. Efficacy of varying dietary protein levels on growth, feed conversion and body composition of *Cirrhinus mrigala* fingerlings. *Pak. J. Life Soc. Sci*. **2**: 91-94.

AHMED S. M., SHAFIQ, K. AND KIANI, M. S., 2012. Growth performance of major carp, *Labeo rohita* fingerlings on commercial feeds. *J. Anim. Pl Sci*., **22**: 91-94

ALI, M., SALAM, A., AZEEM, A., SHAFIQ, M. AND KHAN, B. A., 2000. Studies on the effect of seasonal variations on physical and chemical characteristics of mixed water from River Ravi and Chenab at union site in Pakistan. *J. Res. (Sci.)*, **11**: 11-17.

ALI, T. AND SALIM, M., 2004. Growth Response and Feed Conversion Ratio of *Labeo rohita* Fingerlings for Rice Polishing, Sunflower Meal and Fish Meal intern. *J. Agric. Biol*., **6**:914-917.

ASHRAF, M., AYUB, M. AND RAUF, A., 2008. Effect of different feed ingredients and low temperature on diet acceptability, growth and survival of Mrigal, *Cirrhinus mrigala* fingerlings. *Pakistan J. Zool.*, **40**: 83-90.

ASTAWAN, M., 2004. *Ikan yang sedap dan bergizi*. Penerbit Tiga Serangkai. Solo.

BJERKENG, B., REFSTIE, S., FJALESTAD, K. T., STOREBAKKEN, T., ROEDBOTTEN, M. AND ROEM, A. J., 1997. Quality parameters of the flesh of Atlantic salmon (*Salmo salar*) as affected by dietary fat content and full-fat soybean meal as a partial substitute for fish meal in the diet. *Aquaculture,* **157**: 297-309.

BOGGIO, S. M., HARDY, R.W., BABBITT, J. K. AND BRANNON, E. L., 1985. The influence of dietary lipid source and alpha-tocopheryl acetate level on product quality of rainbow trout (*Salmo gairdneri*). *Aquaculture*, **51**: 13-24.

CHAUDHURI, H., CHAKRABORTY, R. D., RAO, N. G. S., JANAKIRAM, K., CHATTERJEE, D. K. AND JENA, S., 1974. Record production with intensive culture of Indian and exotic carps. *Curr. Sci.*, **43**:303-304.

CHOO, P.S. AND WILLIAMS, M.J., 2003. Fisheries production in Asia: Its role in food security and nutrition. *Wild Fish Cen. Q.*, **26**:11-16.

CRAIG, S. AND HELFRICH, L. A., 2002. *Understanding fish nutrition, feeds and feeding*. Department of Fisheries and Wild Life Sciences, Virginia Tech., pp. 420-456.

DELGADO, C. L., ROSEGRANT, M.W., WADA, N., MEIJER, S. AND AHMED, M., 2002. Fish as food: *Projections to 2020 under different scenarios.* Washington, D.C.: Markets and Structural Studies Division, International Food Policy Research Institute, 2002. Online at: http:www.ifpri.org/divs/mtid/dp/papers/mssdp52.pdf.

FAO, 2006. Food and Agriculture Organization of the United Nations. *The State of World Fisheries and Aquaculture* (SOFIA). Rome. 153 pp. Available at http://www.fao.org/sof/sofia/

GUILLOU, A., SOUCY, P., KHALIL, M. AND ADAMBOUNOU, L., 1995. Effects of dietary vegetable and marine lipid on growth, muscle fatty acid composition and organoleptic quality of flesh of brook charr (*Salvelinus fontinalis*). *Aquaculture*, **136**:351-362.

GULL, Y., SALIM, M., SHAHZAD, K. AND NOREEN, U., 2005. Study on the growth performance and feed conversion ratio of *Labeo rohita* fed on soybean meal, blood meal and corn gluten 60%. *Indus J. biol. Sci.*, **2**: 556-562.

HASAN, M. R., MACINTOSH, D. J. AND JAUNCEY, K., 2005. Evaluation of some plant ingredients as dietary protein sources for common carp (*Cyprinus carpio L.*) fry. *Aquaculture,* **151**:55-70.

HASSAN, M., 1996. *Influence of pond fertilization with broiler droppings on the growth performance and meat quality of major carps*. Ph.D. thesis, Department of Zoology & Fisheries, Univ. Agric, Faisalabad, Pakistan, pp: 195.

HOPKINS, K. D., 1992. Reporting fish growth. A review of the basics. *J. World Aquacult. Soc.*, **23**:173-179.

HUSSAIN, S. M., RANA, S. A., AFZAL, M. AND SHAHID, M., 2011. Efficacy of phytase supplementation on mineral digestibility in *Labeo rohita* fingerlings fed on corn gluten meal (30%) based diets. *Pak. J. agric. Sci*., **48**:237-241.

INAYAT, L. AND SALIM, M., 2005. Feed conversion ratio of major carp, *Cirrhinus mrigala* fingerlings fed on soybean meal, maize and maize gluten. *Pak. Vet. J.*, **25**: 13-16.

JABEEN, S., SALIM, M. AND AKHTAR, P., 2004. Feed conversion ratio of major carp *Cirrhinus mrigala* fingerlings fed on cotton seed meal, fish meal and barley. *Pak. Vet. J.*, **24**: 42-45.

JAVED, M., SHERI, A. N., HAYAT, S. AND HASSAN, M., 1995. Organoleptic evaluation of fish reared under organic and inorganic fertilizers and feed supplementation of ponds. *Pak. J. Agric. Sci*., **32**: 1- 4.

JAYARAM, M.G., SCHETTY, H.P.C. AND UDUPA, K.S., 1980. Organoleptic evaluation of flesh of carps fed on different kinds of feed. *Maysore J. agric. Sci*., **14**: 421-424.

KAUSHIK, S. J., CRAVEDI, J. P., LALLES, J. P., SUMPTER, J., FAUCONNEAU, B. AND LAROCHE, M., 1995. 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**:257-334.

KHAN, N., QURESHI, N. A., NASIR, M., RASOOL, F. AND IQBAL, K. J., 2011. Effect of artificial diet and culture systems on sensory quality of fried fish flesh of Indian Major carps. *Pakistan J. Zool*., **43**:1177-1182.

KHAN, M. A., AHMED, I. AND ABIDI, S. F., 2004. Effect of ration size on growth, conversion efficiency and body composition of fingerling mrigal, *Cirrhinus mrigala* (Hamilton). *Aquacult. Nutr*., **10**: 47-53.

KHAN, M. A., JAFRI, A.K. AND CHADHA, N. K., 2004. Growth and body composition of rohu, *Labeo rohita* (Hamilton), fed compound diet: Winter feeding and rearing to marketable size. *J. appl. Ichthyol.,* **20**: 265-270.

KHAN, N., ASHRAF, M., QURESHI, N. A., SARKER, P. K., VANDENBERG, G. W. AND RASOOL, F., 2012. Effect of similar feeding regime on growth and body composition of Indian major carps (*Catla catla, Cirrhinus mrigala* and *Labeo rohita*) under mono and polyculture. *Afr. J. Biotechnol.*, **11**: 10280-10290.

KHAN, N., QURESHI, N. A., NASIR, M., VANDENBERG, G. W., MUGHAL, M. S., MAQBOOL, A., JABBAR, M. A. AND ZIKRIA, N., 2012a. Effect of artificial feed on sensory attributes of flesh of indian major carps (*Labeo rohita*, *Catla catla* and *Cirrhinus mrigala*) fed in monoculture and polyculture systems. *Pak. Vet. J.*, **32**: 349-353.

KINSELLA, J. E., 1988. Fish and seafoods: nutritional implications and quality issues. *Food Technnol*., **42**: 146-150, 160.

KOSHIO, S., ACKMAN, R. G. AND LALL, S. P., 1994. Effects of oxidized herring and canola oils in diets on growth, survival, and flavour of Atlantic salmon, *Salmo salar*. *J. Agric. Food Chem.,* **42**:1164-1169.

LATIF, K. A., ALAM, M.T., SAYEED, M. A., HUSSAIN, M. A., SULTANA, S. AND HOSSAIN, M. A., 2008. Comparative study on the effects of low cost oil seed cakes and fish meal as dietary protein sources for *Labeo rohita* (Hamilton) fingerling. *Univ. J. Zool. Rajshahi Univ.*, **27**:25-30.

LI, M. H., BOSWORTH, B. G. AND ROBINSON, E. H., 2000. Effect of dietary protein concentration on growth and processing yield of channel catfish (*Ictalurus punctatus*). *J. World Aquacult. Soc*., **31**: 592-598.

LIM, C. AND DOMINY, W., 1991. *Utilization of plant proteins by warm water fish.* Proc. the Aquaculture Feed Processing and Nutrition Workshop, September, 19-25, 1991 Thailand and Indonesia, American Soybean-Association, pp. 163-172.

LOUKA, N., JUHEL, F., FAZILLEAU, V. AND LOONIS, P., 2004. A novel colorimetry analysis used to compare different drying fish processes. *Fd. Cont*., **15**: 327-334.

MARTINEZ, S., NAVALON, J. L., ORTIZ, A., MONTALVO, G., FERRERO, J.L. AND GONZALEZ, A., 2003. The use of NIRS to predict chemical composition of ungrounded poultry feeds. 14th Eur. Symp. Poult.Nutr., Aug. 2003 (Lillehammer, Norway), pp. 91-92.

MEILGAARD, M. C., CIVILLE, G.V. AND CARR, B. T., 2007. *Sensory evaluation techniques*, 4th Edition, CRC Press, Boca Raton, FL USA.

MOAV, R., WOHLFARTH, G., SCHROEDER, G. L., HULATA, G. AND BARASH, H., 1977. Intensive polyculture of fish in freshwater ponds. 1. Substitution of expensive feeds by liquid cow manure. *Aquaculture,* **10**: 25-43.

MOKOLENSANG, J. F., YAMASAKI, S. AND ONOUE, Y., 2003. Utilization of Shochu distillery by-products for culturing the common carp (*Cyprinus carpio L.*) On *Line J. biol. Sci.,* **3**:502-507.

MORAES, G. AND BIDINOTTO, P.M., 2000. Induced changes in the amylohydrolytic profile of the gut of *Piaractus mesopotamicus* (Holmberg, 1885) fed different levels of soluble carbohydrate: its correlation with metabolic aspects. *Rev. Ictiol*., **8**: 47-51.

NIELSEN, J., HYDLIG, G. AND LARSEN, E., 2002. Eating quality of fish- A review. *J. Aquat. Fd. Prod. Technol*., **11**: 125-141.

RORA, A.M.B., RUYTER, B., SKORVE, J., BERGE, R.K. AND SLINNING, K. E., 2005. Influence of high content of dietary soybean oil on quality of large fresh, smoked and frozen Atlantic salmon (*Salmo salar*). *Aquac. Int*., **13**: 217-231.

RUDOLF, K., 1971. *Fish inspection and quality*. Fishing News Books Ltd., London, UK.

SAEED, M., SALIM, M. AND NOREEN, U., 2005. Study on the growth performance and feed conversion ratio of *labeo rohita* fed on soybean meal, blood meal and corn gluten 60%. *Pak. Vet. J*., **25**:121-126.

SHABIR, S., SALIM, M. AND RASHID, M., 2003. Study on the feed conversion ratio in major carp *Cirrhinus mrigala* fingerlings fed on sunflower meal, wheat bran and maize gluten 30%. *Pak. Vet. J*., **23**: 1-3.

SHIOYA, I., INOUE, K., ABE, A., TAKESHITA, A. AND YAMAGUCHI, T., 2011. Beneficial effects on meat quality of yellowtail Seriolaquinqueradiata induced by diets containing red pepper. *Fish Sci*., **77**: 883-889.

SMITH, R. R., KINCAID, H. L., REGENSTEIN, J. M. AND RUMSEY, G. L., 1988. Growth, carcass composition, and taste of rainbow trout of different strains fed diets containing primarily plant or animal protein. *Aquaculture*, **70**: 309-321.

TAHIR, M. Z. I., 2008. *Studies on partial replacement of fish meal with oil seed meals in the diet of major carps in semi-intensive culture system.* Ph.D. thesis. Department of Zoology, University of Agriculture, Faisalabad, Pakistan, pp. 174-178.

VIYAKARN, V., WATANABE, T., AOKI, H., TSUDA, H., SAKAMOTO, H., OKAMOTO, N., ISO, N., SATOH, S. AND TAKEUCHI, T., 1992. Use of soybean meal as a substitute for fish meal in a newly developed soft-dry pellet for yellowtail. *Nippon Suisan Gakk*., **58**: 1991-2000.

YANG, S.D., TUNG, T. Y., CHOU, R. L., LAN, H. L., CHEN, G. R., PAI, J. N., LIU, F. G. AND CHEN, T. I., 2011. Comparison of the effects of two floating pellets on the growth and meat quality of Japanese Eel (*Anguilla japonica*). *J. Taiwan Fish Res*., **19**: 17-28.

(Received 11 June 2013, revised 19 December 2013)