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Full Length Research Paper

Effect of dietary protein, lipid and carbohydrate contents on the growth, feed efficiency and carcass composition of *Cyprinus carpio* communis fingerlings

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This study aimed to determine a feed formulation with best protein to energy ratio which would result in better growth, feed efficiency and carcass composition of *Cyprinus carpio* communis. Fingerlings having average weight 1.64 ± 0.13 g and length 5.26 ± 0.10 cm were fed on four different formulated feeds and a control feed (each in a triplicate set), 6% of their body weight, three times a day, during 90 days. Feeds were formulated using ground nut oil cake, mustard oil cake, rice bran, wheat bran, fish meal and soybean meal in order to suffice the balanced need of protein and energy of the Common carp. Growth, feed efficiency and carcass composition were measured. At the end of the study, the growth, feed efficiency and carcass composition of fingerlings was affected significantly ($P < 0.05$) with protein, lipid and carbohydrate contents in the feeds. Highest growth, best feed conversion ratio, best protein efficiency ratio, highest carcass dry matter, crude protein, crude lipid, ash and energy content, lowest moisture content and carbohydrate content were observed in fingerlings fed with Feed B which contained 40 ± 0.21% protein, 9.31 ± 0.25% lipid and 10.08 ± 0.10% carbohydrate. The fingerlings fed with Feed C which contained 25.98 ± 0.19% protein, 5.49 ± 0.18% lipid and 34.63 ± 0.19% carbohydrate showed least growth, poor feed conversion ratio, poor protein efficiency ratio, least carcass dry matter, crude protein, crude lipid, ash and energy content, highest moisture content and carbohydrate content. This work concluded that a diet containing 40% protein, 9.31% lipid and 10.08% carbohydrate is the best one for a more profitable and successful culture of the Common carp.

Key words: Protein to energy ratio, carp production, growth, feed efficiency, carcass composition.

INTRODUCTION

The dietary protein to energy ratio, in fish diets, is of great importance. Levels of dietary protein and energy, not only influence the growth and body composition, but also digestive enzymes activities and plasma metabolites in various fishes (Gangadhara et al., 1997; McGoogan and Gatlin III, 2000; Yamamoto et al., 2000). Providing adequate energy through dietary lipids can minimize the use of more costly protein as an energy source (Van der Meer et al., 1997; Jantrarotai et al., 1998; Company et al., 1999; McGoogan and Gatlin III, 2000). High-energy diets can also lead to excessive deposition of carcass lipids (Page and Andrews, 1973; Watanabe, 1982) and reduced growth rate (Daniels and Robinson, 1986). Excess carcass lipid accumulation and reduced growth rate due to increased dietary energy have also been shown for African catfish, *Clarias gariepinus* (Machiels and Henken, 1985), channel catfish (Mohsen and Lovell, 1990) and Indian major carp (Hassan et al., 1995; Hassan and Jafri, 1996). To reduce feeding costs in

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aquaculture, approaches to reducing dietary protein levels or improving protein utilization have been studied extensively. Most studies concentrate on increasing dietary energy levels, or lowering the protein to energy ratio (P/E ratio), to reduce the amount of protein in fish diets and have been confined mainly to studies of growth performance such as in channel catfish, rainbow trout, Nile tilapia, Indian major carp, snakehead, *Clarias* catfish and red drum (Takeuchi et al., 1979; Reis et al., 1989; El-Sayed and Teshima, 1992; Hassan and Jafri, 1996; Samantaray and Mohanty, 1997; Jantrarotai et al., 1998; Thoman et al., 1999).

The aim of the present study was to carry out orderly nutritional research with Common carp by using different dietary protein, lipid and carbohydrate contents for determination of a feed formulation with optimum protein to energy ratio (P/E ratio) which would result in better growth, feed efficiency and carcass composition so as to make production of Common carp economical.

MATERIALS AND METHODS

Composition of control and formulated feeds experimented

Four feeds (Feed A, B, C and D) were formulated using ground nut oil cake, mustard oil cake, rice bran, wheat bran, fish meal and soybean meal. The ingredients were selected so as to suffice the balanced need of protein and energy of the Common carp. Feeds were formulated using "Pearson-Square method" with different protein, carbohydrate and lipid contents. Control feed consisted of 50% mustard oil cake and 50% rice bran. Feed A consisted of ground nut oil cake (15%), mustard oil cake (15%), rice bran (10%), wheat bran (10%), fish meal (25%) and soybean meal (25%). The combination aimed at the supply of maximum protein component than energy. Feed B consisted of ground nut oil cake (18%), mustard oil cake (60%), rice bran (2%), wheat bran (8%), fish meal (4%) and soybean meal (8%). This combination, instead of having fish meal as a source of protein had mustard oil cake. Feed C consisted of ground nut oil cake (8%), mustard oil cake (12%), rice bran (40%), wheat bran (30%), fish meal (6%) and soybean meal (4%). This combination aimed at the use of carbohydrate rich diet for the growth. Feed D consisted of the mixture of equal quantity (16.66%) of all the ingredients. Vegetable oil (1.5 ml per 100 g of feed) and cod liver oil (1.5 ml per 100 g of feed) were incorporated in each formulated feed to ensure adequate supply of fatty acids of both n - 6 and n - 3 series, assumed to be essential for Common carp. Vitamin - mineral mixture (2 g per 100 g of feed) was added to each formulated feed for the maintenance of fish health. Sodium alginate (5 g per 100 g of feed) was used as binder and oxytetracycline (500 mg per 100 g of feed) as antibiotic for control and formulated feeds. Oxytetracycline was added to control and formulated feeds as precautionary measure against infection. Composition of control and formulated feeds (percent in dry weight basis) experimented is given in Table 2.

Dry ingredients were mixed for about 30 min in a Hobart mixer (Belle, Mini 150; England) to ensure that the mixture was well homogenized and then blended with oil for about 15 min. Water was added at 20 to 30% v/w to give a pelletable mixture. A pelleting machine (Hobart, model, A 200) was used to pellet the feeds. An appropriate die was used to form pellets of desired sizes (1.0 to 3.0 mm). Pellets were oven dried and fed to the fishes, 6% of the body weight, three times a day at 10 A.M., 2.0 P.M. and 5.0 P.M. every day.

Cyprinus carpio communis fingerlings having average weight 1.64 ± 0.13 g and length 5.26 ± 0.10 cm were used for the experiment. Prior to the initiation of the feeding trail, fingerlings were acclimatized for one week. During this period, traditional mixture of mustard oil cake and rice bran (1:1) was fed to the fingerlings. Each formulated feed and control feed was fed to triplicate group of fingerlings for 90 days. Fifty fingerlings were reared in each fiber glass tank. Water was supplied to each tank at the rate of 1 L min^{-1}. About thirty percent of water was replaced weekly with freshwater to adjust water quality. Water analysis (temperature, pH and dissolved oxygen) of the experimental tanks was done regularly using oxygen meter temperature probe (YSI 57 Clandon, Ohio, USA), pH meter (CG 840, Schott) and oxygen meter (YSI 57 Clandon, Ohio, USA) to monitor any unusual changes. The tanks were aerated throughout the experiments with aquarium air pumps (RS-180, Zhongshan Risheng Co. Ltd., China). Biochemical analysis (dry matter, moisture, crude protein, crude lipid, carbohydrate and ash of feed ingredients, feeds and carcass) was determined by using standard procedures (AOAC, 1995). The energy content of feed ingredients, feed and carcass were calculated calorimetrically.

All data were subjected to analysis of variance (ANOVA) using Minitab statistical software for Windows (release 12, 1998). Comparisons among treatment means were carried out by one way analysis of variance followed by Tukey's test (0.05). Standard deviation (±SD) was calculated to identify the range of means. Percentage data were transformed by arc - sine transformation (Zar, 1984) prior to ANOVA and reversed afterwards. The following parameters were recorded to assess the growth and feed efficiency of fingerlings fed on control and formulated feeds.

Net weight gain (NWG)

Net Weight Gain (g) = Mean final fish weight (g) - Mean initial fish weight (g)

Average daily growth (ADG)

ADG (g) = Net Weight Gain (g) / number of days

Specific growth rate (SGR % / day)

SGR is the average percentage weight change per day between any two weightings provided that the growth curve is exponential in form.

$$SGR (\% / Day) = [(LnW_2 - LnW_1) / (T_2 - T_1)] \times 100$$

Where W_1 is the initial fish weight (g) at time T_1 (day) and W_2 is the final fish weight (g) at time T_2 (day).

Feed conversion ratio (FCR)

FCR is defined as the feed consumed in dry weight per unit live weight gain.

FCR= Feed consumed (g dry weight) / Live weight gain (g)

Protein efficiency ratio (PER)

PER is defined as fish live weight gain per gram of protein fed.
PER = Live weight gain (g) / protein consumed (g)

Table 1. Biochemical composition of fish feed ingredients.

S. No.	Ingredient	Dry matter	Moisture	Crude protein	Crude lipid	Carbohydrate	Ash	Energy (Kcal/g)
1	Ground nut oil cake	$95.09^{c} \pm 0.21$	$4.91^{a} \pm 0.18$	$42.21^{b} \pm 0.17$	$9.05^{c} \pm 0.28$	$8.62^{b} \pm 0.13$	$4.62^{a} \pm 0.21$	$4.74^{b} \pm 0.13$
2	Mustard oil cake	$95.37^{c} \pm 0.17$	$4.63^{a} \pm 0.13$	$39.56^{b} \pm 0.18$	$9.73^{c} \pm 0.19$	$7.32^{b} \pm 0.12$	$4.12^{a} \pm 0.17$	$4.92^{b} \pm 0.21$
3	Rice bran	$91.55^{a} \pm 0.28$	$8.45^{c} \pm 0.21$	$13.45^{a} \pm 0.13$	$3.37^{a} \pm 0.17$	$19.61^{c} \pm 0.17$	$12.50^{c} \pm 0.16$	$1.86^{a} \pm 0.22$
4	Wheat bran	$91.84^{a} \pm 0.23$	$8.16^{c} \pm 0.26$	$16.10^{a} \pm 0.12$	$4.58^{a} \pm 0.13$	$16.26^{c} \pm 0.19$	$11.92^{c} \pm 0.21$	$1.99^{a} \pm 0.26$
5	Fish meal	$93.82^{b} \pm 0.19$	$6.18^{b} \pm 0.16$	$53.60^{c} \pm 0.21$	$7.78^{b} \pm 0.26$	$4.33^{a} \pm 0.14$	$10.60^{b} \pm 0.20$	$3.92^{c} \pm 0.23$
6	Soybean meal	$93.63^{b} \pm 0.12$	$6.37^{b} \pm 0.15$	$50.12^{c} \pm 0.17$	$7.56^{b} \pm 0.24$	$4.72^{a} \pm 0.10$	$10.05^{b} \pm 0.18$	$3.63^{c} \pm 0.13$

(% in dry weight basis), Values are means ± SD. Means in the same column having different superscripts are significantly different (P < 0.05) and means in the same column with same superscript are not significantly different (P > 0.05).

Table 2. Composition of control and formulated feeds experimented.

Ingredient	Control	Feed A	Feed B	Feed C	Feed D
Ground nut oil cake	Nil	15	18	8	16.66
Mustard oil cake	50	15	60	12	16.66
Rice bran	50	10	2	40	16.66
Wheat bran	Nil	10	8	30	16.66
Fish meal	Nil	25	4	6	16.66
Soybean meal	Nil	25	8	4	16.66
Sodium alginate (g)	5	5	5	5	5
Vitamin[1] mineral mixture (g)	Nil	2	2	2	2
Vegetable oil (ml)	Nil	1.5	1.5	1.5	1.5
Cod liver oil[2] (ml)	Nil	1.5	1.5	1.5	1.5
Oxytetracycline (mg)	500	500	500	500	500

(% in dry weight basis), [1]Supplevite – M (Sarabhai Chemicals India),[2]Cod liver oil (Sea cod, M/S Universal Medicare Ltd. Mumbai).

RESULTS

Biochemical composition of fish feed ingredients

Biochemical composition of fish feed ingredients (% in dry weight basis) used for the present research work is given in Table 1. The dry matter content of fish feed ingredients is the highest (95.37 ± 0.17%) in mustard oil cake and the least (91.55 ± 0.28%) in rice bran. The moisture content of fish feed ingredients is the highest (8.45 ± 0.21%) in rice bran and the least (4.63 ± 0.13%) in mustard oil cake. The crude protein of fish feed ingredients is the highest (53.60 ± 0.21%) in fish meal and the least (13.45 ± 0.13%) in rice bran. The crude lipid of fish feed ingredients is the highest (9.73 ± 0.19%) in mustard oil cake and the least (3.37 ± 0.17%) in rice bran. The carbohydrate content of fish feed ingredients is the highest (19.61 ± 0.17%) in rice bran and the least (4.33 ± 0.14%) in fish meal. The ash content of fish feed ingredients is the highest (12.50 ± 0.16%) in rice bran and the least (4.12 ± 0.17%) in

Table 3. Biochemical composition of control and formulated feeds experimented.

Biochemical composition	Control	Feed A	Feed B	Feed C	Feed D
Dry matter	92.89^{a}± 0.17	93.77^{b}± 0.21	94.01^{b} ± 0.19	92.73^{a} ± 0.28	93.44^{b}± 0.16
Moisture	7.11^{b}± 0.21	6.23^{a}± 0.16	5.99^{a}± 0.17	7.27^{b}± 0.23	6.56^{a}± 0.19
Crude protein	26.50^{a}± 0.31	42.00^{c}± 0.26	40.00^{b}± 0.21	25.98^{a}± 0.19	34.75^{ab}± 0.17
Crude lipid	5.80^{a}± 0.26	8.94^{b}± 0.19	9.31^{b}± 0.25	5.49^{a}± 0.18	8.22^{b}± 0.16
Carbohydrate	32.95^{b}± 0.18	12.92^{a}± 0.16	10.08^{a}± 0.10	34.63^{b}± 0.19	15.07^{a}± 0.22
Ash	8.68^{a}± 0.21	9.39^{b}± 0.19	9.45^{b} ± 0.16	8.59^{a}± 0.26	9.15^{b} ± 0.15
Energy (Kcal/g)	3.66^{a}± 0.15	4.44^{b}± 0.11	4.65^{b} ± 0.13	3.48^{a}± 0.16	4.26^{b}± 0.19
P/E(mg protein/Kj)	17.33^{a}± 0.22	22.64^{c}± 0.36	20.54^{b} ± 0.21	17.18^{a}± 0.19	19.53^{ab}± 0.15

(% in dry weight basis), Values are means ± SD. Means in the same row having different superscripts are significantly different (P < 0.05) and means in the same row with same superscript are not significantly different (P > 0.05).

Table 4. Water quality parameters recorded during the experiment along with their tolerable limits.

Parameter	Range of parameters recorded	Tolerable limits
Temperature (℃)	25.0 - 30.0	3.0 - 35.0
pH	7.5 - 8.5	6.5 - 8.0
Dissolved oxygen (mg/l)	6.5 - 7.0	6.0 - 15.0

mustard oil cake. The energy content of fish feed ingredients is the highest (4.92 ± 0.21 Kcal/g) in mustard oil cake and the least (1.86 ± 0.22 Kcal/g) in rice bran. Out of six ingredients, ground nut oil cake and mustard oil cake were used as the source of lipid to provide energy of 4.74 ± 0.13 Kcal/g and 4.92 ± 0.21 Kcal/g, respectively. Fish meal and soybean meal were used as protein source, providing 53.60 ± 0.21% and 50.12 ± 0.17% crude protein, respectively. Rice bran and wheat bran were used as the source of carbohydrate to provide instant energy of 1.86 ± 0.22 Kcal/g and 1.99 ± 0.26 Kcal/g, respectively. There is no significant difference (P > 0.05) in the biochemical composition of ground nut oil cake and mustard oil cake; rice bran and wheat bran; fish meal and soybean meal.

Biochemical composition of control and formulated feeds experimented

Biochemical composition of control and formulated feeds experimented (% in dry weight basis) is given in Table 3. The highest dry matter content (94.01 ± 0.19%) was recorded in Feed B and the least (92.73 ± 0.28%) in Feed C. The highest moisture content (7.27 ± 0.23%) was recorded in Feed C and the least (5.99 ± 0.17%) in Feed B. The highest crude protein (42 ± 0.26%) was recorded in Feed A and the least (25.98 ± 0.19%) in Feed C. The highest crude lipid (9.31 ± 0.25%) was recorded in Feed B and the least (5.49 ± 0.18%) in Feed C. The highest carbohydrate content (34.63 ± 0.19%) was recorded in Feed C and the least (10.08 ± 0.10%) in Feed B. The highest ash content (9.45 ± 0.16%) was recorded in Feed B and the least (8.59 ± 0.26%) in Feed C. The highest energy content (4.65 ± 0.13 Kcal/g) was recorded in Feed B and the least (3.48 ± 0.16 Kcal/g) in Feed C. The highest P/E ratio (22.64 ± 0.36 mg protein/Kj) was recorded in Feed A and the least (17.18 mg protein/Kj ± 0.19) in Feed C.

Water quality parameters

Water quality parameters recorded during the experiments along with their tolerable limits are given in Table 4. During the whole experiment period, the water quality parameters were within tolerable limits. Water temperature ranged from 25.0 to 30.0℃ (tolerable limits 3 to 35℃). pH ranged from 7.5 to 8.5 (tolerable limits 6.5 to 8.0). Dissolved oxygen ranged from 6.5 to 7.0 mg/L (tolerable limits 6 to 15 mg/L).

Growth and feed efficiency

The growth and feed efficiency of fingerlings fed on control and formulated feeds for 90 days is given in Table 5.

Final weight

After 90 days, the highest average final weight (14.38 ± 0.28 g) was recorded in the fingerlings fed on Feed B and

Table 5. Growth and feed efficiency of fingerlings fed on control and formulated feeds for 90 days.

Parameter / Feed	Control	Feed A	Feed B	Feed C	Feed D	± SEM
Average initial weight (g)	1.73 ± 0.06	1.53 ± 0.04	1.60 ± 0.03	1.48 ± 0.02	1.87 ± 0.05	0.03
Average final weight (g)	6.09 ± 0.16[a]	11.07 ± 0.22[b]	14.38 ± 0.28[c]	5.31 ± 0.19[a]	9.44 ± 0.17[ab]	0.20
Net weight gain (NWG) in (g)	4.36 ± 0.17[a]	9.54 ± 0.21[b]	12.78 ± 0.14[c]	3.83 ± 0.16[a]	7.57 ± 0.20[ab]	0.18
Average daily growth (ADG) in (g)	0.048 ± 0.002[a]	0.105 ± 0.008[b]	0.141 ± 0.006[c]	0.042 ± 0.001[a]	0.084 ± 0.003[ab]	0.004
Specific growth rate (SGR) (%/day)	1.70 ± 0.03[a]	2.44 ± 0.08[b]	2.74 ± 0.02[c]	1.59 ± 0.06[a]	2.20 ± 0.05[ab]	0.05
Feed conversion ratio (FCR)	1.46 ± 0.02[c]	1.11 ± 0.02[b]	0.94 ± 0.03[a]	1.58 ± 0.05[c]	1.27 ± 0.03[bc]	0.03
Protein efficiency ratio (PER)	2.09 ± 0.03[a]	2.48 ± 0.04[b]	2.66 ± 0.01[c]	2.06 ± 0.02[a]	2.26 ± 0.02[ab]	0.02

Values are means ± SD of three replications (d.f. 5, 17). Means in the same row having different superscripts are significantly different (P < 0.05) and means in the same row with same superscript are not significantly different (P > 0.05).

the least (5.31 ± 0.19 g) in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the average final weight of the fingerlings fed on control feed and Feed C. The average final weight of the fingerlings fed on Feed A was significantly lower (P < 0.05) as compared to the average final weight of the fingerlings fed on Feed B.

Net weight gain (NWG)

After 90 days, the highest NWG (12.78 ± 0.14 g) was recorded in the fingerlings fed on Feed B and the least (3.83 ± 0.16 g) in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the NWG of the fingerlings fed on control feed and Feed C. The NWG of the fingerlings fed on Feed A was significantly lower (P < 0.05) as compared to the NWG of the fingerlings fed on Feed B.

Average daily growth (ADG)

After 90 days, the highest ADG (0.141 ± 0.006 g) was recorded in the fingerlings fed on Feed B and the least (0.042 ± 0.001 g) in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the ADG of the fingerlings fed on control feed and Feed C. The ADG of the fingerlings fed on Feed A was significantly lower (P < 0.05) as compared to the ADG of the fingerlings fed on Feed B.

Specific growth rate (SGR, %/day)

After 90 days, the highest SGR (2.74 ± 0.02%/day) was recorded in the fingerlings fed on Feed B and the least (1.59 ± 0.06%/day) in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the SGR of the fingerlings fed on control feed and Feed C. The SGR of the fingerlings fed on Feed A was significantly lower (P < 0.05) as compared to the SGR of the fingerlings fed on Feed B.

Feed conversion ratio (FCR)

After 90 days, the highest FCR (1.58 ± 0.05) was recorded in the fingerlings fed on Feed C and the least (0.94 ± 0.03) in the fingerlings fed on Feed B. There was no significant difference (P > 0.05) in the FCR of the fingerlings fed on control feed and Feed C. The FCR of the fingerlings fed on Feed A was significantly higher (P < 0.05) as compared to the FCR of the fingerlings fed on Feed B.

Protein efficiency ratio (PER)

After 90 days, the highest PER (2.66 ± 0.01) was recorded in the fingerlings fed on Feed B and the least PER (2.06 ± 0.02) was recorded in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the PER of the fingerlings fed on control feed and Feed C. The PER of the fingerlings fed on Feed A was significantly lower (P < 0.05) as compared to the PER of the fingerlings fed on Feed B.

Carcass composition

Carcass composition (% mean wet weight basis) of the fingerlings fed on control and formulated feeds after 30 and 90 days of experiment is given in Table 6.

Dry matter

The initial carcass dry matter content of the fingerlings was recorded 24.18 ± 0.19%. After 30 days, there was no significant difference (P > 0.05) in the carcass dry matter content of the fingerlings fed on control feed, Feed A,

Table 6. Carcass composition (% mean wet weight basis) of fingerlings fed on control and formulated feeds after 30 and 90 days of experiment.

Observations after 30 days of experiment							
Parameter (%)	**Initial**	**Control**	**Feed A**	**Feed B**	**Feed C**	**Feed D**	**± SEM**
Dry matter	24.18± 0.19	25.22^{a}± 0.16	25.64^{a} ± 0.12	25.79^{a} ± 0.10	25.14^{a} ± 0.24	25.57^{a}± 0.16	0.17
Moisture	75.82± 0.31	74.78^{a} ± 0.23	74.36^{a} ± 0.21	74.21^{a} ± 0.19	74.86^{a} ± 0.27	74.43^{a}± 0.22	0.22
Crude protein	18.43± 0.24	19.16^{a} ± 0.17	19.76^{a} ± 0.14	19.83^{a}± 0.16	19.06^{a} ± 0.21	19.52^{a}± 0.19	0.19
Crude lipid	2.19± 0.12	2.83^{a} ± 0.22	3.16^{a}±0.26	3.21^{a} ± 0.16	2.76^{a} ± 0.24	3.06^{a}± 0.18	0.23
Carbohydrate	1.43± 0.10	1.71^{a}± 0.21	1.49^{a} ± 0.16	1.46^{a} ± 0.10	1.76^{a} ± 0.19	1.54^{a}± 0.18	0.15
Ash	2.58± 0.16	2.86^{a} ± 0.15	3.12^{a} ± 0.21	3.18^{a} ± 0.20	2.79^{a} ± 0.19	3.04^{a}± 0.16	0.18
Energy (Kcal/g)	7.67± 0.26	8.15^{a} ± 0.21	8.67^{a} ± 0.18	8.76^{a} ± 0.17	8.06^{a}± 0.20	8.53^{a}± 0.19	0.22

Observations after 90 days of experiment						
Parameter (%)	**Control**	**Feed A**	**Feed B**	**Feed C**	**Feed D**	**± SEM**
Dry matter	28.27^{a} ± 0.17	29.26^{b}± 0.16	29.35^{b} ± 0.14	28.18^{a}± 0.19	29.18^{b}± 0.22	0.18
Moisture	71.73^{b}± 0.12	70.74^{a}± 0.10	70.65^{a} ± 0.11	71.82^{b}± 0.13	70.82^{a}± 0.14	0.11
Crude protein	21.63^{a} ± 0.34	24.23^{b}± 0.16	25.03^{c} ± 0.12	21.54^{a}± 0.29	23.92^{ab}± 0.16	0.20
Crude lipid	3.61^{a} ± 0.20	4.23^{b} ± 0.16	4.30^{b} ± 0.22	3.53^{a}± 0.19	4.12^{b}± 0.17	0.18
Carbohydrate	2.79^{a} ± 0.11	2.47^{a}± 0.12	2.42^{a} ± 0.10	2.88^{a}± 0.13	2.56^{a}± 0.14	0.12
Ash	5.19^{a} ± 0.16	5.53^{a} ± 0.19	5.59^{a}± 0.18	5.12^{a}± 0.22	5.38^{a}± 0.15	0.18
Energy (Kcal/g)	10.36^{a} ± 0.26	12.38^{b} ± 0.22	12.47^{b}± 0.19	10.24^{a}± 0.20	12.13^{b}± 0.21	0.23

Values are means ± SD of five replications (d.f. 5, 35). Means in the same row in the same block having different superscripts are significantly different (P <0.05) and means in the same row in the same block with same superscript are not significantly different (P>0.05).

Feed B, Feed C and Feed D. After 90 days, the carcass dry matter content was recorded the highest (29.35±0.14%) in the fingerlings fed on Feed B and the least (28.18 ± 0.19%) in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the carcass dry matter content of the fingerlings fed on control feed and Feed C; Feed A, Feed B and Feed D.

Moisture

The initial carcass moisture content of the fingerlings was recorded 75.82 ± 0.31%. After 30 days, there was no significant difference (P > 0.05) in the carcass moisture content of the fingerlings fed on control feed, Feed A, Feed B, Feed C and Feed D. After 90 days, the carcass moisture content was recorded the highest (71.82 ± 0.13%) in the fingerlings fed on Feed C and the least (70.65 ± 0.11%) in the fingerlings fed on Feed B. There was no significant difference (P > 0.05) in the carcass moisture content of the fingerlings fed on control feed and Feed C; Feed A, Feed B and Feed D.

Crude protein

The initial carcass crude protein of the fingerlings was recorded 18.43 ± 0.24%. After 30 days, there was no significant difference (P > 0.05) in the carcass crude protein of the fingerlings fed on control feed, Feed A, Feed B, Feed C and Feed D. After 90 days, the carcass crude protein was recorded the highest (25.03 ± 0.12%) in the fingerlings fed on Feed B and the least (21.54 ± 0.29%) in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the carcass crude protein of the fingerlings fed on control feed and Feed C. The carcass crude protein of the fingerlings fed on Feed A was significantly lower (P < 0.05) as compared to the carcass crude protein of the fingerlings fed on Feed B.

Crude lipid

The initial carcass crude lipid of the fingerlings was recorded 2.19 ± 0.12%. After 30 days, there was no significant difference (P > 0.05) in the carcass crude lipid of the fingerlings fed on control feed, Feed A, Feed B, Feed C and Feed D. After 90 days, the carcass crude lipid was recorded the highest (4.30 ± 0.22%) in the fingerlings fed on Feed B and the least (3.53 ± 0.19%) in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the carcass crude lipid of the fingerlings fed on control feed and Feed C; Feed A, Feed B and Feed D.

Carbohydrate

The initial carcass carbohydrate content of the fingerlings was recorded 1.43 ± 0.10%. After 30 days, there was no significant difference (P > 0.05) in the carcass carbohydrate content of the fingerlings fed on control feed, Feed A, Feed B, Feed C and Feed D. After 90 days, the carcass carbohydrate content was recorded the highest (2.88% ± 0.13) in the fingerlings fed on Feed C and the least (2.42 ± 0.10%) in the fingerlings fed on Feed B. There was no significant difference (P > 0.05) in the carcass carbohydrate content of the fingerlings fed on control feed, Feed A, Feed B, Feed C and Feed D.

Ash

The initial carcass ash content of the fingerlings was recorded 2.58 ± 0.16%. After 30 days, there was no significant difference (P > 0.05) in the carcass ash content of the fingerlings fed on control feed, Feed A, Feed B, Feed C and Feed D. After 90 days, the carcass ash content was recorded the highest (5.59 ± 0.18%) in the fingerlings fed on Feed B and the least (5.12 ± 0.22%) in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the carcass ash content of the fingerlings fed on the control feed, Feed A, Feed B, Feed C and Feed D.

Energy

The initial carcass energy content of the fingerlings was recorded 7.67 ± 0.26 Kcal/g. After 30 days, there was no significant difference (P > 0.05) in the carcass energy content of the fingerlings fed on control feed, Feed A, Feed B, Feed C and Feed D. After 90 days, the carcass energy content was recorded the highest (12.47 ± 0.19 Kcal/g) in the fingerlings fed on Feed B and the least carcass energy content (10.24 ± 0.20 Kcal/g) was recorded in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the carcass energy content of the fingerlings fed on control feed and Feed C; Feed A, Feed B and Feed D.

DISCUSSION

Growth and feed efficiency

After 90 days, the maximum growth was recorded in the fingerlings fed on Feed B in terms of average final weight (14.38 ± 0.28 g), NWG (12.78 ± 0.14 g), ADG (0.141 ± 0.006 g and SGR (2.74 ± 0.02%/day). The highest growth indices achieved in Feed B having 40% dietary protein level during the present research period, is in accordance with the work of Ronald and Paul (1997) who used the highest dietary crude protein of 37% in perch which attained 155.3% weight gain. Diyaware et al. (2009) reported the better growth rate in hybrid catfish, *Heterobranchus bidorsalis × Clarias anguillaris* fry at 40% dietary crude protein level which also lend support to our finding. Generally, increasing protein levels in fish diets can lead to improved fish production though it may be expensive (Babalola and Adebayo, 2006). Agbebi et al. (2009) replaced fish meal (crude protein = 53.5%) with blood meal (crude protein = 80%) in pelleted feed given to *Clarias gariepinus* and reported that increase in crude protein resulted in efficient average final weight, daily weight gain, specific growth rate, protein efficiency ratio, survival and total fish production. Our result showing better growth indices at 40% dietary protein level also gets support from the work of Sotolu (2010) who reported 40% dietary protein level resulted in efficient mean weight gain, specific growth rate, feed conversion ratio and protein efficiency ratio in *C. gariepinus*. Adewolu and Adoti (2010) reported that fish fed continuously on high protein diets (35%) resulted in significantly (P < 0.05) the higher growth rate and feed utilization in *C. gariepinus*.

The minimum growth was recorded in the fingerlings fed on Feed C in terms of average final weight (5.31 ± 0.19 g), NWG (3.83 ± 0.16 g), ADG (0.042 ± 0.001 g) and SGR (1.59 ± 0.06%/day). The poor growth performance in Feed C having 25.98% dietary protein level conforms with the work of Ronald and Paul (1997), Babalola and Adebayo, (2006), Agbebi et al. (2009), Diyaware et al. (2009), Adewolu and Adoti (2010) and Sotolu (2010), who reported that fish fed continuously on low crude protein (25 to 30%) resulted in significantly (P < 0.05) lower growth rate and feed utilization in different fish species.

The better growth performance in the fingerlings fed on Feed B is due to the optimum dietary P/E ratio of 20.54 ± 0.21 mg protein/Kj. At optimum dietary P/E ratio, the dietary proteins are spared by the energy and hence are utilized for growth. In the present study, the dietary lipids spared the proteins in the fingerlings fed on Feed B. Providing adequate energy through dietary lipids can minimize the use of more costly protein as an energy source (Company et al., 1999; McGoogan and Gatlin III, 2000; Lee et al., 2002; Zen et al., 2009). The P/E ratio of Feed B is comparable to the P/E ratio reported by Habib et al. (1994) for the optimum growth of *Puntius gonionotus*, Lee et al. (2002) for the optimum growth of

Sebastes schlegeli and Zen et al. (2009) for optimum growth of *Ctenopharyngodon idella*. The poorest growth performance in fingerlings fed on Feed C is due to the least dietary P/E ratio (17.18 ± 0.19 mg protein/Kj). At least dietary P/E ratio, the dietary proteins are catabolized to meet the energy demands of fish, hence resulting in poor growth. Hassan et al. (1995), Jantrarotai et al. (1998), Yamamoto et al. (2000), Stone (2003) and Krogdahl et al. (2005) reported that at low dietary energy levels, dietary proteins are used for energy. The growth performance of the fingerlings fed on Feed A having the highest dietary P/E ratio of 22.64 ± 0.36 mg protein/Kj was significantly lower ($P < 0.05$) as compared to the growth performance of the fingerlings fed on Feed B having optimum dietary P/E ratio. This is due to less energy content of Feed A than Feed B, as a result of which dietary proteins are catabolized to provide energy in the fingerlings fed on Feed A, resulting in less growth in the fingerlings fed on Feed A as compared to the fingerlings fed on Feed B. Hassan et al. (1995), Hassan and Jafri (1996), Hossain et al. (2001), Stone (2003) and Krogdahl et al. (2005) reported reduced growth performance with decrease in energy content of the feed in several fish species.

Since Feed B, having optimum P/E ratio resulted in better growth of the fingerlings, it could be said that dietary protein level 40%, lipid level 9.31% and carbohydrate level 10.08% is suitable for the growth of *C. carpio communis* fingerlings. Khan and Jafri (1992), Saha and Ray (1998), Nandeesha et al. (2002) and Hamre et al. (2003) reported better growth performance at higher dietary protein levels. The decrease in growth performance in fishes fed protein levels above the requirement have been observed in various fish species (Siddiqui et al., 1988; El-Sayed and Teshima, 1992). The better growth of fish fed high energy diets has been reported in channel catfish (Page and Andrews, 1973), carp (Watanabe et al., 1987) and Japanese flounder (Yigit, 2001). According to Bogut and Opacak (1996), the optimum growth was attained in *Oncorhynchus kistuch*, *Oncorhynchus keta*, *Oncorhynchus nerka* and *Oncorhynchus mykiss* at 9.5% dietary lipid level. The earlier reports on *Ictalurus punctatus* (Dupree, 1979), *Salmo gairdnerii* (Watanabe et al., 1979) and *Sciaenops ocellatus* (Williams and Robinson, 1988; Ellis and Reigh, 1991) indicated 6 to 11% dietary lipid level as optimum for fish growth. Austreng et al. (1977), Shimeno et al. (1985) and Swamy et al. (1990) reported poor growth at higher dietary carbohydrate levels. The same trend was observed in the present study because poor growth was recorded in fingerlings fed on Feed C having dietary carbohydrate level 34.63%.

The least FCR (0.94 ± 0.03) was recorded in the fingerlings fed on Feed B and the highest FCR (1.58 ± 0.05) was recorded in the fingerlings fed on Feed C. There was no significant difference ($P > 0.05$) in the FCR of the fingerlings fed on control feed and Feed C. Fingerlings fed on Feed B consumed the least feed per unit weight gain due to the optimum dietary P/E ratio of 20.54 ± 0.21 mg protein/Kj, hence possessed the least FCR. The FCR of Feed B is comparable to the FCR value (0.89) reported by Wang et al. (2005) in juvenile cobia, (0.85) reported by Uyan et al. (2007) in rainbow trout and (0.81) reported by Diyaware et al. (2009) in hybrid catfish. Fingerlings fed on Feed C consumed high amount of feed per unit weight gain due to the least dietary P/E ratio of 17.18 ± 0.19 mg protein/Kj hence possessed the highest FCR. The FCR of fingerlings fed on Feed A having the highest dietary P/E ratio of 22.64 ± 0.36 mg protein/Kj was significantly higher ($P < 0.05$) as compared to the FCR of the fingerlings fed on Feed B. Fingerlings fed on Feed A consumed more feed than Feed B per unit weight gain due to the less energy content of Feed A than Feed B hence FCR of the fingerlings fed on Feed A was higher as compared to the FCR of fingerlings fed on Feed B. Page and Andrews (1973), Dupree et al. (1979), Daniels and Robinson (1986), Shiau and Huang (1990), De Silva et al. (1991), Hassan et al. (1995), Jantrarotai et al. (1998) and Yamamoto et al. (2000) reported decrease in FCR with increase in dietary energy upto certain level, in various fish species.

The PER was recorded the highest (2.66 ± 0.01) in the fingerlings fed on Feed B and the least (2.06 ± 0.02) in the fingerlings fed on Feed C. There was no significant difference ($P > 0.05$) in the PER of the fingerlings fed on control feed and Feed C. The PER of the fingerlings fed on Feed A was significantly lower ($P < 0.05$) as compared to the PER of the fingerlings fed on Feed B. The highest PER in Feed B having 40% dietary protein level gets support from the work of Babalola and Adebayo (2006) who reported the highest PER 3.98 in catfish fed with higher crude protein (50%). Similar values of higher PER attained at higher dietary protein levels has been reported by Ronald and Paul (1997), Diyaware et al. (2009), Adewolu and Adoti (2010) and Sotolu (2010) in several fish species. The PER exhibited positive correlation with the dietary protein level upto 40% and above 40% dietary protein level, the PER decreased significantly ($P < 0.05$). The PER also exhibited positive correlation with the lipid level of feed. Machiels and Henken (1985) and Jantrarotai et al. (1998) reported increase in PER with the increase in dietary protein and lipid level in catfish, these observations support present finding related to the increase in PER with the increase in dietary protein and lipid levels.

Carcass composition

The carcass dry matter content, moisture content, crude protein, crude lipid, carbohydrate content, ash content and energy content of the fingerlings fed on control and formulated feeds did not vary significantly ($P > 0.05$) after

30 days of the experiment. After 90 days of experiment, the carcass dry matter content was recorded the highest (29.35 ± 0.14%) in the fingerlings fed on Feed B. The least carcass dry matter content (28.18 ± 0.19%) was recorded in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the carcass dry matter content of the fingerlings fed on control feed and Feed C; Feed A, Feed B and Feed D. Pedro et al. (2001) reported 30% carcass dry matter content in trench fed diets with 35% dietary protein level and Amoah et al. (2008) reported 31% carcass dry matter content in largemouth bass fed diets with 38% dietary protein level. Both the findings lend support to the present observation of highest carcass dry matter content in Feed B having 40% dietary protein level.

The carcass moisture content was recorded the highest (71.82 ± 0.13%) in the fingerlings fed on Feed C. The least carcass moisture content (70.65 ± 0.11%) was recorded in the fingerlings fed on Feed B. There was no significant difference (P > 0.05) in the carcass moisture content of the fingerlings fed on control feed and Feed C; Feed A , Feed B and Feed D. The carcass moisture content exhibited inverse relationship with the carcass lipid and also with the dietary lipid level. The same observations have been reported in European white fish (Vielma et al., 2003) and largemouth bass (Tidwell et al., 2005).

The carcass crude protein was recorded the highest (25.03 ± 0.12%) in the fingerlings fed on Feed B. The least carcass crude protein (21.54 ± 0.29%) was recorded in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the carcass crude protein of the fingerlings fed on control feed and Feed C. The carcass crude protein of the fingerlings fed on Feed A was significantly lower (P < 0.05) as compared to the carcass crude protein of the fingerlings fed on Feed B. The carcass protein content increased significantly (P < 0.05) with the increase in dietary protein level upto 40% and above 40% of dietary protein level, the carcass protein content decreased significantly (P < 0.05). The increase in carcass protein content with the increase in dietary protein level upto 40% is due to the increase in protein utilization and digestibility with the increase in dietary protein level upto 40%. The decrease in the carcass protein above 40% dietary protein level is due to the decrease in protein utilization and digestibility above 40% dietary protein level. Pedro et al. (2001) and Tidwell et al. (2005) reported the increase in carcass protein content with the increase in dietary protein level.

The carcass crude lipid was recorded the highest (4.30 ± 0.22%) in the fingerlings fed on Feed B. The least carcass crude lipid (3.53 ± 0.19%) was recorded in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the carcass crude lipid of the fingerlings fed on control feed and Feed C; Feed A , Feed B, and Feed D. The carcass lipid content exhibited positive relationship with the dietary lipid level which is in agreement with the results reported by Yamamoto et al. (2000) in rainbow trout and Gumus and Ikiz (2009) in rainbow trout. The carcass lipid content and the carcass energy content exhibited direct relationship. It is a finding comparable with the observations of Gumus and Ikiz (2009) in rainbow trout. The carcass lipid content decreased significantly (P < 0.05) with the increase in dietary carbohydrate level. The decrease in lipid digestibility and lipid utilization with the increase in dietary carbohydrate level resulted in the decrease in carcass lipid with the increase in dietary carbohydrate level. Morais et al. (2001) reported the decrease in carcass lipid with the increase in dietary carbohydrate level.

The carcass carbohydrate content was recorded the highest (2.88 ± 0.13%) in the fingerlings fed on Feed C. The least carcass carbohydrate content (2.42 ± 0.10%) was recorded in the fingerlings fed on Feed B. There was no significant difference (P > 0.05) in the carcass carbohydrate content of the fingerlings fed on control feed , Feed A , Feed B, Feed C and Feed D. The carcass carbohydrate content did not show significant difference (P > 0.05) with the increase in dietary carbohydrate level from 10.08 to 34.63%. This is in conformation to the results reported in European white fish (Vielma et al., 2003) and largemouth bass (Amoah et al., 2008)

The carcass ash content was recorded the highest (5.59 ± 0.18%) in the fingerlings fed on Feed B. The least carcass ash content (5.12 ± 0.22%) was recorded in the fingerlings fed on Feed C. The carcass ash content did not vary significantly (P > 0.05) among the fingerlings fed on control and formulated feeds. The same trend has been reported in grass carp by Du et al. (2008) and Atlantic halibut by Hamre et al. (2003).

The carcass energy content was recorded the highest (12.47 ± 0.19 Kcal/g) in the fingerlings fed on Feed B. The least carcass energy content (10.24 ± 0.20 Kcal/g) was recorded in the fingerlings fed on Feed C. There was no significant difference (P > 0.05) in the carcass energy content of the fingerlings fed on control feed and Feed C; Feed A , Feed B, and Feed D. Yamamoto et al. (2000) reported 12 Kcal/g carcass energy content in rainbow trout fed diets with 37% crude protein. Pedro et al. (2001) reported 13 Kcal/g carcass energy content in tench fed diets with 40% crude protein. Both the findings lend support to present observation of the highest carcass energy content in Feed B having 40% dietary protein level.

Based on growth, feed efficiency and carcass composition this work concludes that a diet containing 40% protein, 9.31% lipid, 10.08% carbohydrate and having P/E ratio 20.54 mg protein/Kj is the best one for a more profitable and successful culture of the Common carp.

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