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GROWTH PERFORMANCE AND TISSUE FATTY ACID COMPOSITION OF *CYPRIUS CARPIO* (LINN.) REARED ON FEEDS CONTAINING ANIMAL FATS AS FISH OIL REPLACEMENT

SONU BAWEJA* AND BHUPINDER K. BABBAR
Department of Zoology, Punjab Agricultural University, Ludhiana - 141 004, INDIA
e-mail: sonubaweja3@gmail.com

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***Corresponding author**

ABSTRACT

A sixty day feeding experiment was conducted to study the effect of fish oil replacement in the diet of common carp fingerlings with two terrestrial animal fats *viz.* poultry fat (PF) and goat fat (GF) on survival, growth performance and fatty acid composition. Nine isonitrogenous and isoenergetic diets were formulated, containing 20% lipid sources. Fish oil (FO) was used in control diet, which was substituted by 25%, 50%, 75% and 100% with the alternative lipid sources in other eight diets. Survival rate recorded during the experimental period was 100% for all treatment groups. Net weight gain (1.22-1.41g), specific growth rate (0.19-0.22%) and proximate composition of fish fed different experimental diets were not significantly different ($p \leq 0.05$). However, tissue fatty acid compositions differ significantly among fish fed control diet and other treatment diets). The n-3/n-6 ratio of fish fed control diet (diet 1) was quite higher (1.31%) compared to that in fish fed the other diets. In conclusion, the results show that partial replacement (25 to 50%) of fish oil with animal fats is possible without any negative effect on growth performance, survival, proximate and fatty acid composition of fish with an additional benefit of reduction in the cost of fish feed.

INTRODUCTION

Fish oil (FO) has widely been used as the main lipid source in fish diets, as a source of n-3 polyunsaturated fatty acids (n-3 PUFA) mainly eicosapentanoic acid (20:5 n-3, EPA) and docosahexanoic acid (22:6 n-3, DHA) and fat-soluble vitamins (Bell *et al.*, 2001; Turchini *et al.*, 2005). n-3 PUFA content in aquaculture products is a major factor determining consumer preference because of their beneficial effects on human health (Bayir *et al.*, 2010). However, in the near future, the FO resources may not be enough to cover the increasing demand for oils in aquafeeds due to stagnating fisheries catches, which has resulted in higher FO prices (Turchini *et al.*, 2009; Glencross, 2009). The current trend is towards the replacement of FO by alternative lipid sources in aquaculture feeds for sustainable aquaculture production. Fish oil replacement with alternative dietary lipid sources seems to be possible if the essential fatty acid requirements are satisfied (Sargent *et al.*, 1999). Similar work in this direction has been done on many fish species fed upon poultry fat, soybean/corn lecithin, soybean oil, pork lard, beef tallow, goose fat, beef tallow, sheep tail fat alone or blended with other plant oils and/or animal fats (Martino *et al.*, 2002; Turchini *et al.*, 2003; Liu *et al.*, 2004; Noffs *et al.*, 2009; Bayir *et al.*, 2011, Bayraktar and Bayir, 2012).

Some freshwater fish can elongate and desaturate FAs with 18 carbons, specifically linolenic acid to PUFA with 20-22 carbons of the n-3 series. This ability to synthesize EPA and DHA from linolenic acid allows the formulation of diets containing less expensive plant oils/animal fats. The market value of cultured fish largely depends on their quality and feed composition is one of the factors that control quality (Morris, 2001; Shearer, 2001). Consequently, the links between fish as food and human health are strongly related to the fatty acid composition of the food (Steffens, 1997; Valdimarsson and James, 2001). The fatty acid profile of fish can be modified with diets containing alternative lipid sources (Valdimarsson and James, 2001). The hypothesis behind the work is that there is scanty information on the alternative lipid sources which can replace fish oil from aquafeeds and this information is completely lacking with respect to carps, which are one of the important fresh water food fishes cultured in Asia, India and Punjab. The objective of the present study was to investigate the effect of replacement of fish oil with animal fats in the diet of common carp, *Cyprinus carpio* (Linn.) on its survival, growth performance, proximate composition and muscle fatty acid profile.

MATERIALS AND METHODS

Formulation and Preparation of Experimental Diets

Nine isonitrogenous and isolipidic diets were formulated. Fish oil was used in control diet, which was substituted 25%, 50%, 75% and 100% with alternative lipid sources in other eight diets. The percent contribution of different ingredients to different experimental diets and their proximate composition is shown in Table 1.The fatty acid composition of different experimental diets is given in Table 2.

Experimental Design

Common carp, *Cyprinus carpio communis* (Linn.) was procured from the Sahib Bachan Farm, Pandori, Ludhiana. The fish of 7.5-8.5 cm size and 9.5-10.5 g weight were randomly selected for the experiment which were acclimatized for 5-6 days to laboratory conditions in plastic tubs of 100 litre capacity. The experiment was run in triplicates for 60 days in plastic tubs of 34 litres capacity fitted with complete aeration and filteration system, with 12 fishes in each of it. Fishes were fed nine different experimental diets for 60 days. Fishes were fed twice daily @ 5% of fish biomass. Water quality estimation in terms of temperature, dissolved oxygen, pH, alkalinity, hardness, ammonia and salinity were done weekly during the experimental period.

Sample preparation

At the end of experiment each fish was scaled, finned, headed and gutted. The fish samples were then cleaned with tap water and the muscles were taken from whole fish body. Bones were removed and the boneless muscles thoroughly mixed together to form a composite or representative sample of edible portion of the fish. The whole procedure was done on ice that took about 10 minutes. The composite sample was packed in clean labelled ziplok polythene bags and stored at -25^{0}C for future use.

Survival and growth performance

Survival (%) was calculated by comparing the live carp recovered at the end of the experiment with the total carp stocked at the start of the experiment. Growth was estimated in terms of net weight gain (NWG), average daily weight gain (ADWG) and specific growth rate (SGR) by using following formulae:

NWG (g) = Final body weight (g) - Initial body weight (g)

$$\text{ADWG (g)} = \frac{\text{Average final body weight- Average initial body weight}}{\text{Period of culture (days)}}$$

$$\text{SGR (\%W/d)} = \frac{L_n \text{ final body weight} - L_n \text{ initial body weight}}{\text{Period of culture (days)}} \times 100$$

Chemical analysis

Proximate analysis was conducted using standard procedures (AOAC, 2000). Percentage moisture was estimated by drying 2g sample at 100±2ºC to constant weight, Crude proteins (CP) by Kjeldhal's method, total lipid content by solvent extraction method and ash by incineration in a muffle furnace. Carbohydrate content was calculated by difference method (FAO, 2004):

% Carbohydrate = 100 - (% moisture + % crude proteins + % total lipids + % ash)

Fatty acid analysis was carried out by Gas Chromatography (AOAC, 2000) using M/s Nucon Engineers AIMIL Gas Chromatograph (solid state) model Nucon series 5700/5765 equipped with flame ionization detector.

Statistical analysis

Results are expressed as mean ± standard error. The data for survival, growth performance, proximate composition and fatty acid composition were subjected to one-way analysis of variance (ANOVA) with the help of STATGRAPH and Microsoft Excels statistical packages. Differences were regarded as significant when $p \leq 0.05$.

RESULTS

Water quality monitoring showed no statistically significant differences ($p \leq 0.05$) among different diets and the observed values indicate that none of the experimental diets affected the quality of water (Table 3).

Growth performance and Survival

The average daily weight gain (ADWG) of fish were not significantly different among different dietary treatments. The NWG and SGR of fish ranging from 1.22-1.41g and 0.19-0.22%, respectively were not significantly different among different treatments (Table 4). At the end of experiment, survival was 100% in all the treatments (Table 4).

Proximate composition

The data on proximate composition of common carp fed different experimental diets are given in Table 5. No significant differences ($p \leq 0.05$) were detected among the different treatments in moisture, crude protein, total lipid, ash and carbohydrate content.

Fatty acid composition

Fatty acid composition of fish flesh is closely related to dietary fatty acids. The fish fed control diet (diet 1) contained highest levels of total n-3 PUFAs (20.58±0.16) and n-6 PUFAs (17.17±0.25), while among other treatments total n-3 PUFAs were highest ($p \leq 0.05$) in fish fed diet 2 (12.84±0.61) and total n-6 PUFAs were highest (Pd”0.05) in fish fed diet 3 (11.72±0.0) (Table 6). Among different dietary treatments, maximum ($p \leq 0.05$) MUFA was in fish fed diet 5 (45.53±0.37%) while SFA content was maximum ($p \leq 0.05$) in fish fed diet 9 (58.12±0.55%). Terrestrial animal fats increased 18:1n-9/n-3 ratios significantly, ranging from 1.72±0.13% to 29.57±5.45% as compare to fish fed diet 1 (0.41±0.01%). The palmitic acid was the predominant SFA in fish fed poultry fat diets (diets 2 to 5) and stearic was the predominant SFA in the fish fed goat fat diets (diets 6 to 9). The n-3/n-6 ratio of fish fed control diet (diet 1) was quite higher compared to that in fish fed the other diets (Table 6, $p \leq 0.05$).

DISCUSSION

Nutrients essential to the freshwater fish are same as those required by most other animals. These include water, proteins, lipids (fat, oils, and fatty acid), carbohydrate (sugar, starch), vitamins and minerals (Devi and Mishra., 2013). In the present study, the results suggested that partial or complete replacement of FO with animal fats does not impair growth performance and survival of common carp fingerlings indicating that none of the experimental diets have adverse effect on the health of fish. Earlier studies also reported that growth parameters and survival are not affected in fish species fed upon poultry fat, soybean/corn lecithin, soybean oil, pork lard, beef tallow, goose fat, beef tallow, sheep tail fat alone or blended with other plant oils and/or animal fats (Martino *et al.*, 2002; Turchini *et al.*, 2003; Liu *et al.*, 2004; Noffs *et al.*, 2009; Bayir *et al.*,

Table 1: Formulation and proximate composition of experimental diets

Diets[a]	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
Ingredients (%)									
Fish oil	20	15	10	5	20	15	10	5	20
Poultry fat	-	5	10	15	-	5	10	15	-
Goat fat	-	-							
Soybean meal	20	20	20	20	20	20	20	20	20
Groundnut oil cake	20	20	20	20	20	20	20	20	20
Mustard oil cake	20	20	20	20	20	20	20	20	20
Wheat flour	5	5	5	5	5	5	5	5	5
Rice bran	5	5	5	5	5	5	5	5	5
Corn starch	5	5	5	5	5	5	5	5	5
Vitamin & mineral mixture	1	1	1	1	1	1	1	1	1
Molasses	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Iodized salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Proximate composition (%)									
Moisture	5.21 ± 0.08	5.22 ± 0.06	5.15 ± 0.11	5.13 ± 0.11	5.13 ± 0.06	5.21 ± 0.07	5.05 ± 0.05	5.13 ± 0.14	5.18 ± 0.08
Crude protein	26.83 ± 0.58	27.41 ± 1.05	26.24 ± 0.50	25.95 ± 0.77	25.95 ± 0.77	27.12 ± 0.05	25.95 ± 0.29	27.12 ± 1.33	27.12 ± 0.50
Total lipid	19.93 ± 0.13	19.39 ± 0.26	20.10 ± 0.15	20.36 ± 0.03	20.26 ± 0.08	19.88 ± 0.12	20.33 ± 0.08	20.16 ± 0.28	20.16 ± 0.08
Ash	8.43 ± 0.07	8.25 ± 0.16	8.36 ± 0.04	8.38 ± 0.16	8.63 ± 0.04	8.20 ± 0.16	8.46 ± 0.16	8.33 ± 0.06	8.55 ± 0.05
Carbohydrate	39.58 ± 0.80	39.17 ± 1.20	40.07 ± 0.26	40.22 ± 0.80	40.01 ± 0.67	39.59 ± 0.65	40.19 ± 0.25	39.24 ± 1.37	38.87 ± 0.41

[a] Diet abbreviations: Diet 1: 100% Fish oil; Diet 2: 75% fish oil + 25% poultry fat; Diet 3: 50% fish oil + 50% poultry fat: Diet 4: 25% fish oil + 75% poultry fat; Diet 5: 100% poultry fat; Diet 6: 75% fish oil + 25% goat fat; Diet 7: 50% fish oil + 50% goat fat: Diet 8: 25% fish oil + 75% goat fat; Diet 9: 100% goat fat

Table 2: Fatty acid composition of experimental diets

Diets[a]	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
Fatty acids									
10:0	3.89 ± 0.31^{a}	3.49 ± 0.20^{a}	2.32 ± 0.06^{b}	1.16 ± 0.11^{c}	0.21 ± 0.01^{d}	3.23 ± 0.12^{a}	2.16 ± 0.32^{b}	1.01 ± 0.02^{c}	0.32 ± 0.02^{d}
11:0	1.66 ± 0.04^{a}	1.04 ± 0.23^{ab}	0.76 ± 0.00^{b}	0.32 ± 0.00^{c}	0.08 ± 0.00^{d}	0.89 ± 0.02^{b}	0.41 ± 0.01^{c}	0.13 ± 0.00^{d}	0.00 ± 0.00
14:0	3.92 ± 0.38^{a}	2.45 ± 0.38^{b}	1.79 ± 0.10^{c}	0.85 ± 0.02^{d}	0.21 ± 0.02^{e}	2.56 ± 0.32^{b}	1.81 ± 0.16^{c}	0.89 ± 0.10^{d}	0.32 ± 0.02^{e}
16:0	17.5 ± 0.64^{e}	20.87 ± 0.59^{c}	23.24 ± 1.24^{b}	25.62 ± 0.87^{ab}	27.28 ± 0.72^{a}	19.32 ± 0.25^{d}	20.15 ± 0.56^{cd}	20.97 ± 0.56^{c}	21.63 ± 0.32^{c}
18:0	12.31 ± 0.40^{e}	10.34 ± 0.13^{f}	8.39 ± 0.08^{g}	6.42 ± 0.13^{h}	4.32 ± 0.21^{i}	17.58 ± 0.52^{d}	22.87 ± 1.21^{c}	27.14 ± 1.05^{b}	32.90 ± 1.12^{a}
ÓSFA[b]	39.28 ± 0.94^{e}	38.19 ± 0.35^{e}	36.50 ± 0.36^{f}	34.37 ± 0.25^{g}	32.10 ± 0.54^{h}	43.58 ± 0.45^{d}	47.40 ± 1.30^{c}	50.14 ± 1.11^{b}	55.17 ± 1.08^{a}
18:1 n-9	25.84 ± 0.28^{f}	30.33 ± 0.61^{de}	34.82 ± 0.25^{c}	38.31 ± 0.63^{b}	41.34 ± 1.21^{a}	28.88 ± 0.41^{e}	29.92 ± 0.62^{de}	30.96 ± 0.32^{d}	31.64 ± 0.45^{d}
ÓMUFA[c]	25.84 ± 0.28^{f}	30.33 ± 0.61^{de}	34.82 ± 0.25^{c}	38.31 ± 0.63^{b}	41.34 ± 1.21^{a}	28.88 ± 0.41^{a}	29.92 ± 0.62^{de}	30.96 ± 0.32^{d}	31.64 ± 0.45^{d}
18:3 n-3	12.40 ± 0.73^{a}	8.64 ± 0.60^{c}	6.90 ± 0.05^{d}	4.41 ± 0.04^{e}	1.28 ± 0.02^{f}	9.32 ± 0.05^{b}	6.77 ± 0.06^{d}	3.96 ± 0.02^{e}	1.25 ± 0.04^{f}
20:5 n-3	2.46 ± 0.30^{a}	1.76 ± 0.08^{b}	1.18 ± 0.02^{c}	0.54 ± 0.02^{d}	0.08 ± 0.00^{e}	1.74 ± 0.04^{b}	1.21 ± 0.02^{c}	0.51 ± 0.00^{d}	0.09 ± 0.01^{e}
22:6 n-3	3.04 ± 0.08^{a}	2.23 ± 0.09^{b}	1.45 ± 0.01^{c}	0.71 ± 0.02^{d}	0.11 ± 0.01^{e}	2.15 ± 0.02^{b}	1.49 ± 0.23^{c}	0.65 ± 0.04^{d}	0.13 ± 0.02^{e}
Ón-3PUFA[d]	17.90 ± 0.35^{a}	12.63 ± 0.12^{b}	9.53 ± 0.13^{c}	5.39 ± 0.22^{d}	1.47 ± 0.02^{e}	13.21 ± 0.06^{b}	9.67 ± 0.21^{c}	5.12 ± 0.08^{d}	1.47 ± 0.02^{e}
18:2 n-6	9.51 ± 0.09^{e}	12.73 ± 0.27^{d}	14.98 ± 0.12^{c}	19.21 ± 0.35^{b}	21.52 ± 0.26^{a}	7.91 ± 0.03^{f}	6.32 ± 0.24^{g}	4.72 ± 0.19^{h}	2.35 ± 0.06^{i}
20:4 n-6	5.75 ± 0.21^{a}	5.16 ± 0.13^{ab}	3.57 ± 0.02^{c}	1.51 ± 0.02^{d}	0.63 ± 0.03^{e}	5.04 ± 0.11^{b}	3.53 ± 0.03^{c}	1.57 ± 0.03^{d}	0.58 ± 0.00^{e}
Ón-6PUFA[e]	15.26 ± 0.25^{d}	17.89 ± 0.28^{c}	18.55 ± 0.11^{c}	20.72 ± 0.33^{b}	22.15 ± 0.25^{a}	12.95 ± 0.12^{e}	9.85 ± 0.26^{f}	6.39 ± 0.05^{g}	2.93 ± 0.05^{h}
ÓPUFA[f]	33.16 ± 1.45^{a}	30.52 ± 1.16^{b}	28.08 ± 0.58^{c}	26.11 ± 0.35^{d}	$22.99\pm.022^{e}$	26.16 ± 0.14^{d}	19.52 ± 0.25^{f}	11.51 ± 0.14^{g}	4.40 ± 0.06^{h}
ÓUFA[g]	59.00 ± 1.20^{b}	60.85 ± 1.55^{b}	62.90 ± 1.71^{ab}	64.42 ± 1.21^{a}	64.96 ± 1.36^{a}	55.04 ± 0.98^{c}	49.44 ± 0.84^{d}	42.47 ± 25^{e}	36.04 ± 0.12^{f}
n3/n6	1.17 ± 0.05^{a}	0.70 ± 0.01^{c}	0.51 ± 0.00^{d}	0.26 ± 0.00^{e}	0.06 ± 0.00^{f}	1.02 ± 0.02^{a}	0.98 ± 0.15^{a}	0.80 ± 0.02^{b}	0.50 ± 0.00^{d}
SFA/PUFA	1.18 ± 0.03^{de}	1.25 ± 0.03^{d}	1.30 ± 0.03^{d}	1.31 ± 0.04^{d}	1.40 ± 0.02^{d}	1.66 ± 0.12^{d}	2.43 ± 0.11^{c}	4.35 ± 0.00^{b}	12.53 ± 0.21^{a}
SFA/UFA	0.66 ± 0.04^{e}	0.62 ± 0.02^{e}	0.58 ± 0.02^{ef}	0.53 ± 0.01^{f}	0.49 ± 0.01^{g}	0.80 ± 0.02^{d}	0.95 ± 0.04^{c}	1.18 ± 0.01^{b}	1.53 ± 0.02^{a}
18:1n-9/n-3	1.44 ± 0.02^{g}	2.40 ± 0.00^{f}	3.65 ± 0.03^{e}	7.10 ± 0.08^{c}	28.12 ± 0.25^{a}	2.18 ± 0.10^{f}	3.09 ± 0.12^{e}	6.04 ± 0.02^{d}	21.52 ± 0.12^{b}

[a] See Table 1 for diet abbreviations; Values are means ± S.E; Values with different superscripts in a row differ significantly ($p\leq0.05$); [b]ÓSFA includes Capric acid (10:0), Undecyclic acid (11:0), Myristic acid (14:0), Palmitic acid (16:0) and Stearic acid (18:0); [c]ÓMUFA includes Oleic acid (18:1n-9); [d]Ón-3 PUFA includes Linolenic acid (18:3n-3), Eicosapentaenoic acid (20:5n-3) and Docosahexaenoic acid (22:6n-3); [e]Ón-6 PUFA includes Linoleic acid (18:2n-6) and Arachidonic acid (20:4n-6); [f]ÓPUFA includes Ón-3 PUFA and Ón-6 PUFA; [g]ÓUFA includes ÓPUFA and ÓMUFA.

2011, Bayraktar and Bayir., 2012). Earlier studies suggested that the sources of lipid used did not affect the weight gain and survival of the fish, but tissue fatty acid composition is largely reflected from the dietary fatty acid composition (Ozsahinoglu *et al.*, 2013).

Results revealed more MUFAs in fish fed poultry fat diets than fish fed goat fat diets, which have the highest SFA. Huang *et al.*, 2008 reported that animal fats such as lard or poultry fats are generally richer in SFA and in the case of poultry fat, have an appreciable amount of the MUFA (mainly 18:1 n-9). The SFA 16:0 and 18:0 can be biosynthesized de novo by all known organisms, including fish, by the conventional pathway (Sargent *et al.*, 2002). Oleic acid (18:1n-9) was the only MUFA in fish muscle fed different experimental diets. Higher 18:1n-9 indicates the fatty acid deficiency in some extent, and 18:1n-9/n-3 ratio can be a criterion to evaluate the fatty acid requirement (Takeuchi *et al.*, 1990; Sargent *et al.*, 2002). In the present study, 18:1n-9/ n-3 ratios were significantly different among different treatments. In the present study, replacement of fish oil with poultry and goat fats resulted in reduced levels of total n-3 and n-6 PUFAs. EPA and DHA levels were particularly reduced to negligible by the increase in the level of poultry and goat fat in the experimental diets. Same trend was also reflected in the fatty acid composition of both poultry fat and goat fat diets. Linoleic acid (18:2 n-6) and linolenic acid (18: 3 n-3) are substrates for the same enzymes i.e. Δ 6-desaturases suggesting the metabolic competition between 18:2 n-6 and 18: 3 n-3 (Caballero *et al.*, 2002; Bell and Dick., 2004). High content of 18:2 n-6 in experimental diets containing animal fats might have inhibited the conversion of 18: 3 n-3 into the longer chain 20:5 n-3 (EPA) and 22:6 n-3

Table 3: Summary of water quality parameters during the experimentation period

Diets[a]		Temperature (°C)	DO(mgl^{-1})	pH	Alkalinity (mgl^{-1})	Hardness(mgl^{-1})	Ammonia (mgl^{-1})	Salinity (ppt)
Diet 1	Mean	31.11	8.70	7.54	109	230	0.032	0.052
	Max	36.50	9.60	7.72	112	240	0.035	0.061
	Min	25.00	7.80	7.36	106	220	0.029	0.043
Diet 2	Mean	31.11	8.80	7.47	111	231	0.033	0.054
	Max	36.50	9.40	7.69	118	238	0.036	0.060
	Min	25.00	8.20	7.25	104	224	0.031	0.048
Diet 3	Mean	31.11	8.70	7.60	110	236	0.033	0.050
	Max	36.50	9.60	7.68	120	244	0.037	0.060
	Min	25.00	7.80	7.52	100	228	0.029	0.040
Diet 4	Mean	31.11	8.90	7.48	111	231	0.032	0.047
	Max	36.50	9.80	7.66	116	240	0.035	0.056
	Min	25.00	8.00	7.30	104	222	0.029	0.038
Diet 5	Mean	31.11	9.60	7.57	110	226	0.030	0.055
	Max	36.50	10.40	7.71	114	236	0.034	0.061
	Min	25.00	8.80	7.43	106	216	0.027	0.050
Diet 6	Mean	31.11	9.60	7.63	113	232	0.030	0.054
	Max	36.50	11.20	7.75	118	244	0.033	0.060
	Min	25.00	8.00	7.52	108	220	0.027	0.048
Diet 7	Mean	31.11	9.40	7.51	109	231	0.035	0.062
	Max	36.50	9.80	7.64	116	242	0.039	0.072
	Min	25.00	9.00	7.39	102	220	0.031	0.053
Diet 8	Mean	31.11	8.60	7.48	109	229	0.038	0.056
	Max	36.50	9.60	7.67	114	240	0.044	0.065
	Min	25.00	7.60	7.29	104	218	0.032	0.048
Diet 9	Mean	31.11	9.00	7.52	105	228	0.036	0.056
	Max	36.50	10.00	7.63	112	236	0.041	0.063
	Min	25.00	8.00	7.41	98	220	0.031	0.050

[a] See Table 1 for diet abbreviations

Table 4: Survival and growth performance of common carp reared on different experimental diets

Diets[a]	Parameters			
	ADWG	NWG	SGR	Survival
Diet 1	0.021 ± 0.001	1.26 ± 0.07	0.19 ± 0.01	100 ± 0.00
Diet 2	0.022 ± 0.000	1.37 ± 0.08	0.20 ± 0.01	100 ± 0.00
Diet 3	0.021 ± 0.001	1.22 ± 0.08	0.21 ± 0.01	100 ± 0.00
Diet 4	0.021 ± 0.001	1.25 ± 0.06	0.22 ± 0.01	100 ± 0.00
Diet 5	0.021 ± 0.001	1.29 ± 0.04	0.19 ± 0.01	100 ± 0.00
Diet 6	0.021 ± 0.001	1.29 ± 0.10	0.21 ± 0.00	100 ± 0.00
Diet 7	0.022 ± 0.001	1.37 ± 0.09	0.19 ± 0.01	100 ± 0.00
Diet 8	0.023 ± 0.001	1.41 ± 0.08	0.19 ± 0.01	100 ± 0.00
Diet 9	0.020 ± 0.001	1.26 ± 0.09	0.20 ± 0.00	100 ± 0.00

[a] See Table 1 for diet abbreviations; ADWG: Average daily weight gain (g); NWG: Net weight gain (g); SGR: Specific growth rate (%W/d); Survival (%); Values are means ± S.E; Values with no superscript do not differ significantly at 5% level of significance.

Table 5: Proximate composition (%) of *Cyprinus carpio* (Linn.) fed different experimental diets.

Diets[a]	Muscle Proximate Composition				
	Moisture	Crude protein	Total lipid	Ash	Carbohydrate
Diet 1	74.35 ± 0.32	14.58 ± 0.30	3.94 ± 0.07	1.50 ± 0.03	5.63 ± 0.42
Diet 2	74.20 ± 0.76	14.87 ± 0.50	4.01 ± 0.01	1.53 ± 0.04	5.38 ± 0.30
Diet 3	74.40 ± 0.75	14.58 ± 0.29	3.94 ± 0.07	1.48 ± 0.06	5.59 ± 0.82
Diet 4	73.81 ± 0.30	15.16 ± 0.58	4.13 ± 0.02	1.45 ± 0.03	5.43 ± 0.68
Diet 5	74.93 ± 0.48	14.28 ± 0.58	4.12 ± 0.05	1.50 ± 0.05	5.16 ± 0.16
Diet 6	74.71 ± 0.62	14.29 ± 0.29	3.97 ± 0.04	1.53 ± 0.03	5.48 ± 0.57
Diet 7	74.65 ± 0.55	14.87 ± 0.50	4.06 ± 0.01	1.53 ± 0.01	4.48 ± 0.60
Diet 8	74.65 ± 0.55	14.95 ± 0.57	4.12 ± 0.02	1.53 ± 0.04	4.73 ± 0.67
Diet 9	74.90 ± 0.50	14.58 ± 0.58	4.11 ± 0.03	1.56 ± 0.01	4.83 ± 0.53

[a] See Table 1 for diet abbreviations; Values are means ± S.E; Values with no superscript do not differ significantly at 5% level of significance.

(DHA) essential fatty acids (Yildiz *et al.*, 2013). Total or 75% replacement of fish oil with poultry or goat fat (diets 4, 5, 8 and 9) completely inhibited the synthesis of EPA with significant adverse affect on DHA level. However 25 to 50% replacement of fish oil with poultry or goat fats (diets 2, 3, 6 and 7) had not affected the DHA level.

Table 6: Fatty acid composition of *Cyprinus carpio* (Linn.) fed different experimental diets

Diets[a]	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
Fatty acids									
10:0	4.36 ± 0.40^{a}	3.51 ± 0.74^{b}	2.33 ± 0.26^{c}	3.70 ± 0.05^{b}	3.52 ± 0.27^{b}	2.42 ± 0.09^{c}	3.30 ± 0.11^{b}	3.53 ± 0.26^{b}	2.87 ± 0.16^{c}
11:0	2.01 ± 0.02^{a}	0.61 ± 0.13^{de}	0.73 ± 0.12^{d}	1.62 ± 0.12^{b}	2.11 ± 0.07^{a}	0.70 ± 0.02^{d}	1.15 ± 0.02^{c}	1.30 ± 0.25^{bc}	1.32 ± 0.09^{bc}
14:0	0.31 ± 0.09^{c}	-	0.20 ± 0.01^{c}	0.23 ± 0.01^{c}	-	1.05 ± 0.04^{b}	2.48 ± 0.12^{a}	2.47 ± 0.04^{a}	2.73 ± 0.20^{a}
16:0	9.65 ± 0.30^{e}	14.34 ± 0.60^{c}	19.80 ± 0.01^{b}	23.84 ± 0.90^{a}	25.80 ± 0.32^{a}	12.65 ± 0.25^{d}	14.11 ± 0.60^{c}	18.15 ± 0.01^{b}	19.50 ± 0.52^{b}
18:0	16.01 ± 0.05^{d}	11.41 ± 0.47^{e}	5.062 ± 0.00^{f}	6.26 ± 0.05^{f}	6.12 ± 0.09^{f}	20.31 ± 0.25^{c}	27.13 ± 0.10^{b}	29.04 ± 0.57^{a}	30.11 ± 0.58^{a}
ÓSFA[b]	32.03 ± 0.66^{d}	30.22 ± 1.05^{d}	28.78 ± 0.22^{e}	35.59 ± 0.97^{d}	37.55 ± 0.54^{c}	37.52 ± 0.67^{c}	49.56 ± 0.77^{b}	55.21 ± 0.57^{a}	58.12 ± 0.55^{a}
18:1 n-9	9.13 ± 0.04^{g}	21.93 ± 0.72^{d}	36.05 ± 0.01^{b}	37.18 ± 2.13^{b}	45.53 ± 0.37^{a}	19.50 ± 0.32^{f}	24.58 ± 0.53^{e}	27.04 ± 0.13^{c}	28.86 ± 0.42^{c}
ÓMUFA[c]	9.13 ± 0.04^{g}	21.93 ± 0.72^{d}	36.05 ± 0.01^{b}	37.18 ± 2.13^{b}	45.53 ± 0.37^{a}	19.50 ± 0.32^{f}	24.58 ± 0.53^{e}	27.04 ± 0.13^{c}	28.86 ± 0.42^{c}
18:3 n-3	18.52 ± 0.22^{a}	10.69 ± 1.04^{b}	6.77 ± 0.00^{d}	5.88 ± 0.07^{e}	1.52 ± 0.37^{g}	8.79 ± 0.28^{c}	5.96 ± 0.04^{e}	5.08 ± 0.02^{e}	1.30 ± 0.31^{f}
20:5 n-3	1.96 ± 0.06^{a}	0.56 ± 0.14^{b}	0.24 ± 0.02^{d}	-	-	0.31 ± 0.01^{c}	0.08 ± 0.01^{d}	-	-
22:6 n-3	2.10 ± 0.02^{a}	1.58 ± 0.06^{b}	0.87 ± 0.03^{c}	0.48 ± 0.03^{d}	0.13 ± 0.01^{e}	1.54 ± 0.02^{b}	0.80 ± 0.09^{c}	0.44 ± 0.01^{d}	0.10 ± 0.00^{e}
Ón-3PUFA[d]	20.58 ± 0.16^{a}	12.84 ± 0.61^{b}	7.83 ± 0.05^{d}	6.36 ± 0.06^{e}	1.52 ± 0.37^{h}	10.64 ± 0.27^{c}	6.83 ± 0.11^{de}	5.52 ± 0.02^{f}	1.40 ± 0.31^{g}
18:2 n-6	8.17 ± 0.30^{a}	3.77 ± 0.52^{d}	8.60 ± 0.00^{a}	6.78 ± 0.35^{b}	5.55 ± 0.25^{c}	5.45 ± 0.23^{c}	7.03 ± 0.03^{b}	5.84 ± 0.31^{c}	5.71 ± 0.08^{c}
20:4 n-6	9.05 ± 0.06^{a}	3.16 ± 0.48^{c}	3.12 ± 0.00^{c}	1.72 ± 0.24^{d}	1.50 ± 0.00^{e}	4.62 ± 0.30^{b}	2.04 ± 0.02^{d}	1.52 ± 0.18^{e}	1.12 ± 0.02^{f}
Ón-6PUFA[e]	17.17 ± 0.25^{a}	11.27 ± 0.39^{b}	11.72 ± 0.0^{b}	8.50 ± 0.60^{e}	7.06 ± 0.25^{de}	10.08 ± 0.07^{c}	9.08 ± 0.04^{cd}	7.37 ± 0.14^{de}	6.83 ± 0.07^{e}
ÓPUFA[f]	39.75 ± 0.17^{a}	24.11 ± 0.50^{b}	19.61 ± 0.06^{c}	14.87 ± 0.54^{d}	8.71 ± 0.40^{f}	20.76 ± 0.18^{c}	15.91 ± 0.08^{d}	12.89 ± 0.15^{e}	7.24 ± 0.37^{ef}
ÓUFA[g]	48.88 ± 0.12^{a}	46.05 ± 0.61^{c}	55.66 ± 0.08^{a}	52.05 ± 2.60^{b}	54.26 ± 0.28^{a}	40.26 ± 0.48^{d}	40.46 ± 0.56^{d}	39.94 ± 0.27^{e}	36.07 ± 0.08^{d}
n3/n6	1.31 ± 0.26^{a}	1.14 ± 0.08^{b}	0.66 ± 0.00^{e}	0.75 ± 0.05^{d}	0.23 ± 0.05^{f}	1.05 ± 0.03^{c}	0.75 ± 0.01^{d}	0.74 ± 0.01^{d}	0.20 ± 0.04^{e}
SFA/PUFA	0.80 ± 0.02^{f}	1.25 ± 0.06^{e}	1.47 ± 0.01^{e}	2.39 ± 0.14^{d}	4.31 ± 0.24^{b}	1.80 ± 0.02^{de}	3.11 ± 0.03^{c}	4.28 ± 0.04^{b}	8.02 ± 0.02^{a}
SFA/UFA	0.65 ± 0.01^{d}	0.65 ± 0.01^{d}	0.51 ± 0.00^{e}	0.69 ± 0.05^{d}	0.70 ± 0.01^{d}	0.92 ± 0.01^{c}	1.22 ± 0.02^{b}	1.38 ± 0.01^{a}	1.61 ± 0.01^{a}
18:1 n-9/n-3	0.41 ± 0.01^{f}	1.72 ± 0.13^{e}	4.60 ± 0.03^{c}	5.83 ± 0.36^{b}	29.57 ± 5.45^{a}	2.49 ± 0.68^{d}	4.00 ± 0.06^{c}	4.90 ± 0.03^{c}	20.61 ± 0.52^{b}

[a] See Table 1 for diet abbreviations; Values are means $\pm$ S.E; Values with different superscripts in a row differ significantly ($p \leq 0.05$); [b]ÓSFA includes Capric acid (10:0), Undecyclic acid (11:0), Myristic acid (14:0), Palmitic acid (16:0) and Stearic acid (18:0); [c]ÓMUFA includes Oleic acid (18:1n-9); [d]Ón-3 PUFA includes Linolenic acid (18:3n-3), Eicosapentaenoic acid (20:5n-3) and Docosahexaenoic acid (22:6n-3); [e]Ón-6 PUFA includes Linoleic acid (18:2n-6) and Arachidonic acid (20:4n-6); [f]ÓPUFA includes Ón-3 PUFA and Ón-6 PUFA; [g]ÓUFA includes ÓPUFA and ÓMUFA.

Earlier studies suggested that although plant oils and terrestrial animal fats can be used up to a certain level to replace fish oil (Bell *et al.*, 2001; Turchini *et al.*, 2003), adequate amounts of fish oil must be incorporated in the diets to cover the EFA requirements, as fish oils are the only dietary source of n-3 HUFA (Sargent *et al.*, 2002). All fish fed different experimental diets except diet 5 had the n-3/n-6 ratios better than the recommended ratios of 1/2 to 1/3 (Simopoulos *et al.*, 1999). The ratios of PUFA/SFA in the muscle of fish fed diets 1, 2, 3, 4, 5 and 6) diets were higher than minimum recommended levels of 0.45 (Justi *et al.*, 2003) and PUFA/MUFA ratio in the muscle of fish fed on diets 1, 2, 3, 6 and 7 were also higher than minimum recommended levels of 0.50 (Ogwok *et al.*, 2008).

In conclusion, the results of this study suggest that total substitution of fish oil with animal fats impair nutritional value of the fatty acid composition of common carp fingerlings by inhibiting the synthesis of EPA and decreasing DHA level, total n-3 PUFA levels and n-3/n-6 ratio. However, animal fats in this study did not impair growth performance, survival rate and muscle proximate composition of common carp fingerlings after 60 day feeding trial. But partial replacement of fish oil with animal fats (25 to 50%) retained the n-3/n-6, PUFA/SFA and PUFA/MUFA within recommended range. 25 to 50% replacement of fish oil with animal fats also reduced the cost of fish diet. So partial replacement (25 to 50%) of fish oil with animal fats is possible without any negative effect on growth performance, survival, proximate and fatty acid composition of fish with an additional benefit of reduction in the cost of fish feed.

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