The feeding value and protein quality in high-fibre and fibre-reduced sunflower cakes and Kenya's "omena" fishmeal for tilapia (*Oreochromis niloticus*)

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Abstract

This study was undertaken to assess the nutritive values of some locally available protein sources in Kenya, as replacements for anchovy fishmeal in tilapia diets. The test protein sources were omena fishmeal made from *Rastrineobola argentea*, anchovy fishmeal, as well as fibre-reduced and high-fibre sunflower cakes. The four protein sources were each tested at two protein concentrations. *Oreochromis niloticus* fingerlings with an initial weight of 16 g. were used for the study. Eight experimental diets, four based on fishmeal and four on sunflower cake were formulated. Each diet contained one of two levels of protein, viz., approximately 20% (low-protein) and 30% (high-protein). Further, each diet was fed to triplicate groups of fish for 78 days.

Diets based on the fibre-reduced cake had higher levels of all amino acids than the ones based on the high-fibre cake. Lysine and threonine concentrations were lower in diets based on the sunflower cakes than the ones based on the fishmeals. Fish fed diets with 20% protein gained less weight and had higher feed:gain ratios than those fed diets with 30% protein. Fish fed diets based on anchovy fishmeal had higher weight gains than those fed diets based on the high-fibre sunflower cake. Reducing the fibre content of sunflower cake improved growth rate and weight gain. Growth rates and weight gains of fish fed diets based on the two fish meals were not significantly different.

Key words: Amino acids, fibre, hulls, productive protein value, protein efficiency ratio

Introduction and objectives

Tilapia (*Oreochromis niloticus*) are herbivorous fish that possess morphological and physiological adaptations for utilization of diets high in fibre content. This aspect of its feeding habits has not been fully exploited in commercial aquaculture. Most formulated feeds for tilapia resemble those for omnivorous fish in that they contain significant levels of animal proteins (Hughes and Handwerker 1993). Much research has been done to evaluate new protein sources to partially or wholly replace fishmeal in diets for fish. Among the plant protein sources, soybean meal has been used widely because of its good amino acid profile. Used as the main protein source, soybean meal supports the growth of most fish species (Tacon et al 1984; Wilson and Poe 1985; Shiau et al 1987; Viola and Arieli 1983). Soybeans, however, are not suitable for growing in many countries; hence the need to evaluate other plant proteins sources.

Sunflower is cultivated extensively due to its adaptability to a wide range of climatic and soil conditions (Ravindran and Blair 1992). Its seeds are inexpensive to process, and the cake remaining after oil extraction is used as a protein supplement in animal diets (Daghir et al 1980). The crude protein content of the cake ranges from 25 to 45% (air-dry basis) depending on the extent of dehulling and the efficiency of the oil extraction process. The crude fibre level in the cake generally varies between 14% and 39% (air-dry basis) (Villamide and San Juan 1998). Protein concentration in sunflower cake is inversely proportional to the fibre content.

The potential use of sunflower cake in fish diets is limited by its high fibre content. Crude fibre not only has no known dietary value for fish, but it also dilutes digestible nutrient densities, thus increasing the release of polluting wastes into the environment. In view of the above, a fibre-reduced, high-fat sunflower cake was tested as a replacement for fishmeal in tilapia feeds. In addition to the sunflower cakes, Kenya's omena fishmeal was also evaluated as a source of protein.

The objectives of the study were to compare the nutritional values and protein qualities of diets based on high-fibre and low-fibre sunflower cakes, and omena and anchovy fishmeals when fed to tilapia (*Oreochromis niloticus)* at each of two levels of dietary protein.

Materials and methods

Experimental diets and design

The fibre-reduced sunflower cake was made from a hybrid sunflower seeds (Kenya Fedha) purchased from a commercial trader (Rift Valley Products, Nakuru, Kenya). The seeds were partly dehulled using a manually-operated Cecoco dehuller (Ibaraki, Osaka 567 Japan) which incorporated a dehuller and a sorting machine. All seeds were dried to less than 10% moisture before dehulling. The oil content of the partly dehulled seeds was reduced by a commercial screw press oil extractor (Gold Feeds, Nairobi, Kenya).
The high-fibre sunflower cake was processed from the same variety of sunflower as the low-fibre sunflower cake.

Omena fishmeal was purchased from Tamfeeds, (Nairobi, Kenya). It was made from the cyprinid fish, *Rastrineobola argentea.* The anchovy meal was a high quality Chilean LT. meal. The chemical compositions of the main ingredients used are shown in Table 1.

Table 1. Chemical compositions of the ingredients (air-dry basis)

Ingredients	**Dry matter, %**	**Crude protein, %**	**Lipid, %**	**Crude fibre, %**	**[1]ADF, %**	**[2]NDF, %**	**Gross energy, Kcal/kg**
Anchovy fishmeal	90	64.9	9.63	-	-	-	4.47
Omena fishmeal	92	55.0	13.50	-	-	-	4.61

Whole wheat	89	11.5	1.20	1.3	-	-	3.99
Fibre-reduced sunflower cake	92	39.0	22.2	10.4	12.65	21.8	4.70
High-fibre sunflower cake	91	28.0	8.92	26.7	20.50	42.0	4.51
Cornstarch	-	-	-	-	-	-	-

[1]ADF = acid detergent fibre. [2]NDF = neutral detergent fibre

Eight diets whose compositions are shown in Table 2 were formulated. LT anchovy fishmeal, omena fishmeal, high-fibre and fibre-reduced sunflower cakes were used as sources of protein.

Table 2. Compositions of the diets used in Experiment 2

Protein level	**20% Protein**				**30 % Protein**			
Diets	**[1]O-20**	**[2]A-20**	**[3]FRSC-20**	**[4]HFSC-20**	**O-30**	**A-30**	**FRSC-30**	**HFSC-30**
LT-Anchovy fish meal	-	30.0	13.2	13.5	-	44.0	20.9	20.9
Omena fish meal	33.7	-	-	-	52.0	-	-	-
Fibre-reduced SFC	-	-	26.1	-	-	-	38.5	-
High-fibre SFC	-	-	-	35.7	-	-	-	53.6
Corn starch	34.9	34.2	36.9	27.6	12.7	16.9	22.9	-
Whole wheat flour	12.6	13.0	12.6	12.6	12.0	13.0	12.2	12.6
Cellulose	12.6	15.7	4.0	-	18.3	20.1	-	-
Corn oil	2.2	3.7	1.6	5.0	2.5	3.6	0.4	7.8
Ascorbic acid	1.0	1.0	0.9	0.9	1.0	1.0	0.9	0.9
Vitamin/mineral premix	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9
Dicalcium phosphate	1.5	1.0	3.2	3.2	-	-	2.8	2.8
Iodized salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Choline chloride (50%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Proximate and mineral composition (DM basis)[5]								
DM, %	90	91.44	91.19	91.17	92.04	92.56	91.56	91.62
DE, Kcal/kg (calculated)	2961	2965	2814	2751	3077	3050	2915	2797
Protein, %	20.05	22.50	23.60	21.90	29.10	33.0	33.80	33.0
Crude fat, %	9.60	8.30	12.61	10.40	12.40	10.40	14.70	15.80
ADF, %	13.20	17.30	7.00	7.70	17.60	25.10	5.60	12.00
NDF, %	22.20	31.80	12.30	17.40	26.10	37.80	12.30	23.70
Ash, %	7.00	6.80	6.90	-	8.50	8.40	7.80	8.00
Ca, %	1.90	1.90	1.60	1.60	1.90	2.00	1.70	1.70
Phosphorus, %	1.60	1.60	1.50	1.40	1.70	1.80	1.50	1.50

The vitamin/mineral premix provided the following per kilogram of the diet: vitamin A, 6000 IU; vitamin D_3, 600 IU: vitamin E, 100 mg; vitamin K_3, 3 mg; vitamin B_1, 10 mg; vitamin B_2, 20 mg; niacin, 150 mg; D-pantothenic acid, 50 mg; vitamin B_6, 10 mg; vitamin B_{12}, 0.03 mg; folic acid, 4 mg; biotin 0.8 mg; choline, 600 mg; vitamin C, 600 mg; inositol, 300 mg; manganese, 192 mg; iron 51.2 mg; copper, 6.4 mg; zinc, 57.6mg; selenium, 0.15 mg; Traces of cobalt and iodine
[1]0- omena fishmeal; [2]A; Anchovy fishmea;l [3]FRSC fibre-reduced sunflower cake;
[4]HFSC high-fibre sunflower cake. (20 and 30 refer to protein levels 20% and 30 % respectively).
[5]All values were determined by analysis except for DE, which was estimated from published data.

In the diets based on anchovy and omena fishmeals, the fishmeals provided most of the dietary protein, while in the diets based on sunflower cakes, only 50% of the dietary protein was provided by the cake, while the remaining 50% was provided by anchovy fishmeal, as shown in Table 2. Each diet contained one of two levels of protein, approximately 20% or 30%. At each protein level, the diets were formulated to contain similar levels of digestible energy by varying the level of corn oil.

Each diet was randomly assigned to triplicate groups of 25 fish, and all groups were fed their prescribed diets by hand to satiation three times daily.

Fish sampling

Male *Oreochromis niloticus* fingerlings weighing 16g were purchased from Baobab Fish Farm (Bamburi Nature Trail, Mombasa) and transferred to the University of Nairobi for this experiment. They were acclimated to laboratory conditions for a period of two weeks.
They were later weighed in groups of 25 fish selected at random and allocated to the experimental circular tanks. Twenty four tanks with a diameter of one metre and filled with water to a depth of 0.50 metres were used for this experiment. The water level was adjusted as the fish biomass increased to maintain the stocking density below 0.1 kilograms of fish per litre of water.

A Sweetwater TM Regenerative blower was used for aeration. Each tank was fitted with an AS8-1 (3 inches) diffuser. Water temperatures and dissolved oxygen concentration in the tanks was maintained at 26ºC $\pm$ 2ºC and above 5.5 mg/liter, respectively. Water was completely exchanged in each tank every 48 hours. The fish were kept under a natural photoperiod (Nairobi, Kenya, 1º 16' S, 36º 48' E). The duration of the experiment was 78 days.

The fish were starved for 24 hours before weighing, and each fish was weighed individually. Sampling of the fish for determination of whole body compositions was done at the end of the experiment and in this regard, five fish representative of each group (tank) were selected for this purpose.

They were killed with an overdose of MS222, and frozen at -20°C in plastic bags until analyzed. During analysis, all five fish from each tank were chopped into small pieces and thoroughly minced in a blender.

Data collection and analytical procedures

Fish growth and performance were assessed by calculating the following parameters: initial and final absolute weights, weight gain and specific growth rates (SGR, % $day^{-1)}$ which were calculated as follows: 100 [(ln final wt (g) – ln initial wt (g))/number of experimental days], feed consumption (g/fish), and feed conversion ratio (feed consumption, g/wet weight gain, g). The protein quality parameters that were assessed included: protein efficiency ratio (PER: wet weight gain, g/protein consumption, g), and productive protein value (PPV: 100*(gain in body protein/protein intake)).

Chemical analyses

AOAC (1984) procedures were used to determine the various proximate fractions of raw materials and diets. All analyses were carried out in duplicate. Calcium was determined by atomic absorption spectroscopy (Perkin-Elmer, model 2380), while phosphorus was determined colorimetrically using a Beckman Model Du-8B spectrophotometer at 450 nm wavelength. Samples for the analyses of calcium and phosphorous were digested by wet ashing. Amino acid analyses of the feed samples were conducted at the University of Alberta in Canada according to standard procedures (AOAC 1998). Individual amino acids were quantified using a HPLC.

Statistical analyses

The data were analyzed using PROC GLM of the SAS Statistical Package (1985). The means were compared using Tukey's test with level of significance set at $P < 0.05$. All parameters were analyzed as a 4 x 2 factorial design (4 protein sources at 2 levels of protein intake).

Results and discussion

Chemical composition of the diets

The chemical compositions of the diets used in this experiment are presented in Table 1, while the compositions of the ingredients used are shown in Table 2. The low protein diets were formulated to contain less DE concentration than the high-protein diets in order to minimize differences in energy:protein ratios between the diets at the two protein levels. The stipulated DE requirement for tilapia (*Oreochromis niloticus*) is 3000 kcal/kg DM (NRC 1993). The calculated DE concentrations in most of the low protein diets were just slightly below this level.

In the diets where fishmeal was partially replaced by the sunflower cakes, phosphorus was balanced by the addition of dicalcium phosphate.

The amino acid profiles of the diets are shown in Table 3.

Table 3. Amino acid compositions of the test diets (expressed as g/100g DM and as a % of the dietary protein)[a]

Protein level	**20 % protein**				**30 % protein**				**Tilapia reqts**	
Diets	**[1]O-20**	**[2]A-20**	**[3]FRSC-20**	**[4]HFSC-20**	**O-30**	**A-30**	**FRSC-30**	**HFSC-30**	**% diet**	**% protein**
Amino acids										
Arginine	0.94	1.0	1.13	0.98	1.43	1.44	1.52	1.67	1.26	4.20

	(4.70)	(4.49)	(4.79)	(4.47)	(4.91)	(4.36)	(4.50)	(5.06)		
Histidine	0.37 (1.84)	0.49 (2.18)	0.49 (2.08)	0.42 (1.92)	0.55 (1.89)	0.59 (1.80)	0.66 (1.95)	0.59 (1.79)	0.52	1.72
Isoleucine	0.73 (3.63)	0.83 (3.70)	0.77 (3.26)	0.67 (3.06)	1.10 (3.78)	1.09 (3.30)	1.07 (3.17)	0.92 (2.79)	0.93	3.11
Leucine	1.24 (6.17)	1.41 (6.27)	1.24 (5.25)	1.11 (5.07)	1.90 (6.53)	1.92 (5.82)	1.75 (5.18)	1.51 (4.58)	1.02	3.39
Lysine	1.33 (6.62)	1.49(6.62)	1.06 (4.49)	0.94 (4.29)	2.05 (7.04)	2.06 (6.24)	1.59 (4.70)	1.32 (4.00)	1.54	5.12
Methionine	0.43 (2.14)	0.56 (2.49)	0.47 (1.99)	0.37 (1.69)	0.76 (2.61)	0.80 (2.42)	0.70 (2.26)	0.55 (1.82)	0.80	2.68
[a]Cystine	0.27 (1.35)	0.28 (1.24)	0.36 (1.67)	0.27 (1.35)	0.36 (1.24)	0.34 (1.12)	0.45 (1.45)	0.37 (1.22)	-	-
[b]Phenylalanine	0.72 (3.58)	0.76 (3.40)	0.76 (3.22)	0.67 (3.06)	1.09 (3.75)	1.04 (3.14)	1.12 (3.31)	0.94 (2.85)	1.13	3.75
Threonine	0.76 (3.46)	0.85 (3.78)	0.73 (3.09)	0.65 (2.97)	1.13 (3.88)	1.1. (3.34)	1.04 (3.08)	0.90 (2.73)	1.12	3.75
Valine	0.84 (4.18)	1.00 (4.44)	0.92 (3.90)	0.82 (3.74)	1.28 (4.40)	1.37 (3.99)	1.29 (3.82)	1.11 (3.36)	0.84	2.80
Aspartic acid	1.74	1.95	1.72	1.61	2.53	2.63	2.41	2.17	-	-
Glutamic acid	2.86	3.29	3.31	3.06	4.08	4.32	4.34	4.24	-	-
Serine	0.77	0.83	0.79	0.68	1.10	1.07	1.06	0.94	-	-
Glycine	1.09	1.19	1.04	0.91	1.74	1.57	1.53	1.31	-	-
Alanine	0.97	1.14	0.92	0.84	1.56	1.53	1.30	1.16	-	-

Figures in parentheses refer to dietary amino acids expressed as percentage of protein..
[1]O – Omena; [2]A – Anchovy; [3]FRSC – Fibre-reduced sunflower cake; [4]HFSC – High –fibre sunflower cake 20 and 30 refer to protein level.
[a]Cystine level should be at least 0.15% of the diet (DM basis) or 0.54% of dietary protein
[b]Tyrosine level in the diets should be 0.5% of diet (DM basis) or 1.79% of protein

When the amino acids were expressed as a percentage of the dietary protein, diets based on the two fishmeals had a profile that was almost similar. The diets based on the two sunflower cakes had lower levels of lysine and threonine than the diets made from the fishmeals.

When the dietary amino acids were expressed as a percentage of the diet, the diets with a crude protein content of 20% did not meet tilapia requirements for most of the essential amino acids except leucine and valine. It must be cautioned at this point that strict comparisons between the requirements as stipulated in NRC (1993) may not be appropriate because the NRC figures quoted are for juvenile tilapia weighing less than 1 gram. The fish used in this study had an initial weight of about 16 g. In fish, as in all animals, protein and consequently amino acid requirements (as percentage of the diet) decrease as the animal grows.

At a protein level of 30%, diets based on omena fishmeal, anchovy fishmeal, and fibre-reduced sunflower cake met all the essential amino acid requirements for tilapia (NRC 1993). The lysine levels were lower in the sunflower cake diets than in the diets based on fishmeals at both protein levels. Lysine has been identified as one of the limiting amino acids in sunflower cake

(McGinnis et al 1948; Klain et al 1956). Methionine and cystine levels in the fibre-reduced sunflower cake were almost similar to the levels in the fishmeal diets. Jackson et al (1982) observed that sunflower cake had high levels of methionine and cystine compared to other plant proteins.

Fish performance, PER and PPV

The effects of the dietary protein level and protein source on absolute weights, weight gains, growth rates, and feed and protein utilizations after 78 days of feeding on the various diets are shown in Tables 4 and 5, respectively.

Table 4. Effect of protein level on fish performance

Protein level	Low Protein	High Protein	SEM
Fish performance			
Final weight, g/fish[1]	51.40[b]	57.10[a]	0.96
Weight gain, g/fish[2]	35.00[b]	40.40[a]	0.90
Specific growth rate, % per day[2]	1.47[b]	1.58[a]	0.03
Feed intake, g/fish[2]	76.70[a]	75.30[a]	0.47
FCR: feed:gain[2]	2.20[a]	1.87[b]	0.04
PER[2]	2.16[a]	1.69[b]	0.02
PPV[2]	39.44[a]	32.21[b]	0.36

Means with a different superscript for each factor in a row are significantly different (P <0.05)
[1] Means (n = 300) (Individual fish weights were used, 4 diets x 75 fish/diet); [2] Means (n = 12)
PER = protein efficiency ratio; PPV = productive protein value

Table 5. Effect of source of protein on fish performance

	Omena fishmeal	Anchovy fishmeal	Fibre-reduced sunflower cake	High fibre sunflower cake	SEM
Fish performance					
Final weight, g/fish[1]	52.40[b]	57.70[a]	54.90[ab]	52.00[b]	1.34
Weight gain, g/fish[2]	35.92[ab]	40.86[a]	38.73[ab]	35.39[b]	1.27
Specific growth rate, % per day[2]	1.48	1.59	1.57	1.47	0.04
Feed consumption, g/fish[2]	77.10	75.90	76.10	74.90	0.66
FCR: Feed:gain[2]	2.17	1.87	1.98	2.12	0.07
PER[2]	2.01	1.98	1.86	1.84	0.06
PPV[2]	38.90[a]	37.00[ab]	35.14[ab]	32.30[b]	1.27

Means that do not have a superscript or share a common superscript letter for each factor within a row, are not significantly different (P > 0.05)
[1]Means (n = 150) (Individual fish weights used, 2 diets x 75 fish/diet); [2]Means (n= 6)
PER = protein efficiency ratio; PPV = productive protein value

The effects of both protein level and protein source on the various parameters are shown in Table 6.

Table 6. Performance of *Oreochromis niloticus* fed diets containing high-fibre and fibre-reduced sunflower cakes and LT Anchovy and Omena fishmeals for 78 days

Protein level	**20 % protein**				**30% protein**				**SEM**	**Main effects**		**Interaction**
Diets	**OM-20**	**AM-20**	**FRSC 20**	**HFSC 20**	**OM-30**	**AM-30**	**FRSC 30**	**HFSC 30**		**Protein source**	**Protein level**	**Protein Source x level**
Fish performance												
Final weights, g/fish[1]	47.80	54.60	52.30	50.80	56.90	60.70	57.40	53.30	1.90	P < 0.05	P < 0.05	NS
Weight gain, g/fish[2]	31.90	37.70	36.20	34.40	40.00	44.00	41.30	36.40	1.80	P < 0.05	P < 0.05	NS
Specific growth, % per day[2]	1.40	1.52	1.52	1.45	1.55	1.66	1.62	1.48	0.17	NS	P < 0.05	NS
Feed consumption, g/fish[2]	77.0	76.50	77.10	76.00	77.10	75.30	75.10	73.70	0.99	NS	NS	NS
FCR: feed:gain[2]	2.41	2.03	2.13	2.21	1.93	1.71	1.82	2.02	0.09	P < 0.05	P < 0.05	NS
PER[2]	2.15	2.28	2.05	2.15	1.87	1.69	1.67	1.53	0.08	NS	P < 0.05	NS
PPV[2]	40.60	41.10	39.00	37.10	37.20	32.80	31.30	27.50	1.77	P < 0.05	P < 0.05	NS
Mortality	0.00	6.70	0.00	0.00	2.67	1.33	1.33	1.33	-	-	-	-

Diets OM -Omena fishmeal; AM - Anchovy fishmeal; FRSC Fibre-reduced sunflower cake; HFSC High fibre sunflower cake

20 and 30 represent the dietary protein level.

S – Source of protein. L-Level of protein in the diet

[1]Means (n = 75); [2]Means (n= 3)

PER = protein efficiency ratio; PPV = productive protein value

At the start of the study, the mean weights of fish in all the groups were not significantly different (P > 0.05). After 78 days, the fish fed the diets with high protein contents had higher weight gains and growth rates (P < 0.05) than those fed the diets with low protein contents

(Table 6). The interaction between protein level and protein source was not significant for any of the parameters (Table 6). The growth rates of the fish increased in direct relation to the dietary protein level. Feed intake was not significantly affected by dietary protein level, but feed utilization was better for fish fed the high protein diets than the low protein diets. Protein utilization (PER and PPV) decreased at the higher level of protein intake.

A wide range of estimates have been reported for the optimal dietary protein content of tilapia feeds. Winfree and Stickney (1981) reported that 56% dietary crude protein level promoted maximum weight gain of tilapia (*Oreochromis aureus*) weighing 2.5g, while in those weighing 7.5 g., 34% dietary crude protein was adequate. Shiau and Huang (1989) reported 24% crude protein as the optimum for tilapia (*Oreochromis niloticus* x *Oreochromis aureus*) weighing 2.9 g.

Luquet (1991) reviewed several studies and recommended a protein content of 30 – 35% as the optimum for tilapia. This recommendation was based on studies that utilized good protein sources such as fishmeal and casein. The stated requirements for protein show a wide variation, reflecting the different environmental conditions in which the experiments were done, and the different fish and feed factors involved. There is evidence that the optimal protein requirement for tilapia is inversely related to fish size. In studies by Twibell and Brown (1998) using (*Oreochromis niloticus* x *Oreochromis aureus*) fingerlings with an initial weight of 21 g., there was no improvement in growth at dietary protein levels higher than 28%. The initial weight of the fish used in this study was 16 g., which was close to the starting weight of the fish employed in the latter study.

Conclusions

- The source of protein (omena fishmeal, anchovy fishmeal, fibre-reduced and high-fibre sunflower cakes) had a significant effect on the final fish weights, weight gains, and PPV values (Table 5), but not on growth rates, feed intakes, feed utilization and PER values. Fish fed diets based on anchovy fishmeal, omena fishmeal and the fibre-reduced sunflower cake had higher weights at the end of the experimental period than those fed diets based on the high-fibre sunflower cake.

- Fish fed diets based on the high-fibre cake tended to have lower feed intake, and a higher feed:gain ratio compared to those fed on the other three diets. Tilapia, like other fish, consume organoleptically acceptable diets in an attempt to satisfy energy demands. The DE concentration in all the diets was almost similar, which may explain the similarity in feed intake. Diets based on the high-fibre cake had a slightly lower DE concentration compared to the other diets. Despite this, the fish fed on these diets did not increase their feed intakes to compensate for the lower dietary DE content. Residual hulls in the high-fibre sunflower cake diets (HF-SC20 and HF-SC30) may have hindered this compensatory increase in feed intake.

- Protein source did not significantly affect PER, although fish fed diets based on the two fishmeals tended to have a higher value. PER is a measure of protein quality that is presented as a ratio of gain/protein intake and is affected by the level of protein in the diet, the digestibility of the protein, and the levels of essential amino acids, particularly the first limiting amino acid. Within each protein level, dietary protein content was not appreciably different between diets, while the digestibility of protein in fishmeal and sunflower cakes was similar (Maina et al 2002). Consequently, the observed trends for PER for fish ingesting the diets containing the various protein sources likely resulted from differences in amino acid levels (particularly lysine) between the diets based on fishmeals and those based on sunflower cakes.

- The trend observed for PPV in relation to diet treatment was similar to PER. Fish fed on the high-fibre sunflower cake diets had significantly ($P < 0.05$) lower values than those fish fed on the diets based on the omena fishmeal. PPV, like PER, is sensitive to dietary protein level. Diets based on omena fishmeal had slightly lower protein levels compared to the other diets and this may have contributed to the observed differences. The differences would also have resulted from differences in the dietary levels of essential amino acids, particularly lysine, which was low in the diets based on the high-fibre sunflower cake.

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