Kafkas Univ Vet Fak Derg
17 (3): 363-369, 2011
DOI:10.9775/kvfd.2010.3418

RESEARCH ARTICLE

Effect of Replacement of Fishmeal with Sand Smelt *(Atherina boyeri)* Meal on Growth, Feed Utilization and Body Composition of Mirror Carp Fry *(Cyprinus carpio)* [1]

Erkan GÜMÜŞ *

[1] *This paper was produced from project (Grant number: 2007.01.0121.002) supported by The Scientific Research Projects Coordination Unit of Akdeniz University.*

* Department of Aquaculture, Faculty of Fisheries, Akdeniz University, TR-07058 Antalya - TURKEY

Makale Kodu (Article Code): KVFD-2010-3418

Summary

A 13-week feeding experiment was conducted to evaluate potential use of sand smelt meal (SSM) as a replacement of fishmeal in diets for mirror carp fry *Cyprinus carpio* (0.29±0.06 g fish^{-1}). Three groups were fed to apparent satiation twice daily each of five isonitrogenous (41%; dry matter) and isoenergetic (15.75 MJ DE kg^{-1}) diets formulated to include 0, 25, 50, 75, and 100% of fishmeal protein being substituted by SSM. The results indicate that growth performance and feed utilization efficiency for fish fed diets containing SSM up to 75% were similar (P>0.05) to the control diet, except for fish fed the 100% SSM diet. The dietary treatments affected significantly (P<0.05) the hepatosomatic and viscerosomatic indices of fish. There were no significant differences in body composition following inclusion level of SSM. Apparent digestibility coefficients (ADC) of dry matter, lipid and energy were not affected by dietary treatments. However, the ADC of protein for fish fed the %75 SSM diet was higher than the others. These results indicate that up to 75% of fishmeal protein can be replaced by SSM in diets for carp fry without adverse effects on growth, feed utilization and body composition.

Keywords: *Cyprinus carpio, Fish meal, Sand smelt meal, Growth, Digestibility*

Balık Unu Yerine Gümüş Balığı *(Atherina boyeri)* Unu Kullanımının Aynalı Sazan *(Cyprinus carpio)* Yavrusunun Büyümesi, Yem Kullanımı ve Vücut Kompozisyonu Üzerine Etkisi

Özet

Bu çalışma, balık unu yerine gümüş balığı ununun (GBU) aynalı sazan (*Cyprinus carpio*, başlangıç ağırlık: 0.29±0.06 g balık^{-1}) yavru yemlerinde kullanım potansiyelinin belirlenmesi amacıyla gerçekleştirilmiştir. Balık unu proteininin %0, 25, 50, 75 ve 100'ü oranında GBU proteini ilave edilerek protein (%41, kuru ağırlık) ve enerji (15.75 MJ SE kg^{-1}) oranları eşit beş farklı yemlerle akvaryumdaki balıklar üç tekrarlı olarak 13 hafta süreyle beslenmiştir. Elde edilen sonuçlara göre %75'e kadar GBU içeren yemlerle beslenen balıkların büyüme performansı ve yem kullanım etkinliği kontrol grubu ile benzer (P>0.05), ancak %100 GBU içeren yemle beslenen gruptan önemli oranda yüksek bulunmuştur (P<0.05). Yem uygulamaları balıkların hepatosomatik ve visserosomatik indekslerini önemli oranda etkilemiştir (P<0.05). GBU'nun artan oranları balıkların vücut kompozisyonlarında önemli farklılıklara neden olmamıştır. Kuru madde, yağ ve enerji sindirilebilirlik oranları yem uygulamalarıyla etkilenmemiş, ancak %75 GBU içeren yemle beslenen grupta protein sindirilebilirlik oranı diğer gruplara göre daha yüksek bulunmuştur. Sonuç olarak, sazan yavrusunun büyümesi, yem kullanımı ve vücut kompozisyonu üzerine olumsuz etkisi olmaksızın yemlerinde balık unu yerine %75'e varan oranda GBU kullanılabilir.

Anahtar sözcükler: *Cyprinus carpio, Balık unu, Gümüş balığı unu, Büyüme, Sindirilebilirlik*

İletişim (Correspondence)
+90 242 310 6636
egumus@akdeniz.edu.tr

INTRODUCTION

The demand for feed in fish aquaculture industry has expanded over recent years with the increases in total production within the industry. This production relies heavily on fish meal (FM) and oil supplies [1]. Restricted FM supplies, with high prices and limited availability, apparently can no longer meet the needs of the expanding fish feed industry. Thus, nowadays it is considered essential to reduce the FM used in aquaculture feed by replacing it with other protein sources of both plant and animal origin. Replacement for FM have an international research priority and have become the focus in current fish feed research [2]. Currently, many plant or animal by-product protein sources have been evaluated as replacements for FM [3-16].

Large or small scale farmers in most developing countries have been forced by both the availability and cost of commercial pelleted fish feeds. Accordingly, since the expansion and profitability of aquaculture, investigating cheaper alternative protein sources has become a priority for farmers in such countries [6]. Hence, there is a need to encourage farmers to formulate their own pelleted feed using ingredients produced on farm; sand smelt meal (SSM) may represent one such ingredient.

Sand smelt *(Atherina boyeri* Risso, 1810) is accidentally introduced often to rivers, lakes, ponds, canals and reservoirs, but it becomes dominant in these habitats because of its biological features. Küçük [17] reported a three fold increase in sand smelt population in Lake Eğirdir in three years (2002-2005) and a significiant decrease in fish populations with substantial economic value (e.g. carp and pike perch) at the same period of time. According to the study, sand smelt has become the dominant species competing on food, dissolved oxygen, and space with other species inhabiting the lake. During the past several years, sand smelt industry in Turkey has grown dramatically: sand smelt production has almost tripled in the past seven years and in 2006 summed up to 6 677 tons, worthing an estimated US $ 2.671 million. Generally, sand smelt is priced US $ 400 per ton^{-1} in local markets as it is not preferred for human consumption. Sand smelt forms 15% of 44082 tons of annual fresh water production in Turkey [18] and this represents an important potential for domestic fish meal production. Although having no economic value, sand smelt is a rich source of animal protein (>70% of dry matter). Almost all caught sand smelt is used in fish farms as fresh feed. This practise often leads to health problems and it should be used after turning into meal as suggested by Gümüş [15], who used SSM as an alternative source for FM. However, there is a need to be extended experiments the nutritional quality of SSM as a protein source for replacement of FM in various fish diets. The aim of this investigation, therefore, was to assess the potential use of SSM as a partial or complete replacement for FM in diets on growth performance, feed utilization and body composition of mirror carp fry.

MATERIAL and METHODS

Experimental Conditions, Fish and Feeding

The experiment was carried out from 15th July to 15th October, 2008 at the Laboratory of Fisheries Faculty of Akdeniz University, Antalya, Turkey. Mirror carp *Cyprinus carpio* L. fry were obtained from a local fish hatchery (Mediterranean Fisheries Research Production and Training Institute, Antalya, Turkey). Prior to the experiment, all fry were acclimatized to laboratory conditions for 2 weeks in a 250-L glass aquarium. During this period, fry were fed with control diet (0.0% SSM) for twice daily. At the beginning of the experiment, each 15 glass aquaria (65-L) were randomly stocked with 25 fry with an average weight of 0.300±0.65 g fish^{-1}. The aquaria were filled with chlorine free tap water throughout the study. Two-thirds of the aquarium water was changed daily. Each aquarium was aerated with air produced by a central compressor. The test diets were fed to triplicate groups of fish. During the course of the experiment, each diet was fed manually to apparent satiation twice daily for 13 weeks. The feed intake was recorded daily.

Water temperature was also maintained constant with a 100 W automatic heater set at 24-26^{o}C. Water temperature and dissolved oxygen were recorded daily using a Model WTW Oxi 330i multi-oxygen meter (WTW Wissenschaftlich-Weilheim, Germany). A photoperiod of 12:12 h light/dark cycle using fluorescent lighting was maintained throughout the experiment.

Sand Smelt Meal and Diet Preparation

Sand smelt meal (SSM) was from the same source and prepared as in study on Nile tilapia fry [15]. The proximate composition and amino acid profiles of SSM and each of the principal dietary protein sources are given in *Table 1*.

Five diets were prepared to be isonitrogenous, isolipidic and isoenergetic in terms of crude protein (41%; on dry matter basis), lipid (10.5%; on dry matter basis) and digestible energy (15.75 MJ DE kg^{-1}) estimated using the DE values 20.9 MJ kg^{-1} protein, 37.7 MJ kg^{-1} lipid and 14.6 MJ kg^{-1} carbohydrate [19]. Formulation and ingredient composition of each experimental diet are presented in *Table 2*.

Diets were made based upon the results of the chemical composition of the ingredients. The control diet contained Peruvian fish (Anchovy; *Engraulidae spp.*) meal (44.99%) and soybean meal (16.85 %) as the main sources of dietary protein. In four out of five diets prepared the fish meal protein was gradually replaced by 25, 50, 75, or 100% of SSM protein. Diets for the digestibility assay included 0.5% chromic oxide as inert marker. Prior to preparation of experimental diets, all ingredients were ground in a hammer mill and screened through a 0.5 mm mesh sieve. All dry ingredients of each diet were thoroughly mixed with a food mixer until they were homogenous. The fish oil and water were then added to the mixed ingredients and thoroughly mixed. The resulting mixture was made into pellets using a meat grinder and a 2 mm die. The pellets were dried in an oven at 70°C for 24 h. The pellets were than crumbled in suitable size (0.8-1 mm diameter) for the fry and sealed in plastic bags and kept at -20°C until use.

Feces Collection and Calculation

Fry within each aquarium were fed twice daily with the experimental diets containing 0.5% chromic oxide as a marker. Fish were allowed to feed on the chromic oxide diets for one week before any fecal samples were taken. Feces were then collected, using the siphoning method, until the end of the experimental study. After each feeding, in the morning and in the evening, uneaten feeds were removed from the aquarium by siphon after 1 h feeding. After 3 h each feeding, feces from each aquarium were siphoned through a fine mesh netting (80 µm), and separately collected in separate jars and then stored at -20°C until analysis. Fecal samples were dried in an oven at 70°C for 24 h, ground by a blinder, and prepared for chemical analysis. Apparent digestibility coefficients (ADC) of diet composition were calculated according to the following formula: ADC of the dry matter (%) = 100-[100 (%Cr_2O_3 in feed/%Cr_2O_3 in feces)]; ADC of nutrients (%) = 100-100 [(%Cr_2O_3 in feed/%Cr_2O_3 in feces) x (%nutrient in feces/%nutrient in feed)] [20].

Sample Collection

Initially, 40 fry of similar body weight to the experimental fish were sampled for analysis and kept frozen. At the end of the 13 weeks growth study, all fish in each aquarium were collected, anaesthetized with clove oil (20%, v:v) and batch weighed. After weighing, 15 fish were randomly removed from each experimental group, killed and then immediately frozen at -20°C until analysis of carcass composition. Also, 10 fish from each treatment were randomly selected for the determination of the viscero-somatic index (VSI) and hepatosomatic index (HSI).

Chemical Analysis

Proximate composition of feed ingredients, experimental diets, feces and fish body was analyzed for dry matter after desiccation in an oven (105°C for 24 h). Crude protein (by acid digestion using the Kjeldahl method, N x 6.25); crude fat (ether extraction using the Soxhlet method); ash (incineration at 550°C for 24 h); crude cellulose (alkali and acid digestion); and nitrogen free extract (by subtracting the other components from 100) contents were measured according to the methods of AOAC [21]. Chromic oxide (Cr_2O_3) in the diets and feces samples was measured using a spectrophotometer procedure involving perchloric acid digestion [22]. The amino acids were analysed following acid hydrolysis using phenomenex EZ fast GC-FID hydrolyzed amino acid analysis kit (Varian GC, CP-3800 GC).

Statistical Analysis

Data analysis was performed by one-way analysis of variance (ANOVA) using SPSS 15.0 (SPSS INC. Chicago, IL, USA). Differences among the means were compared using Duncan's *post hoc* test at a 5% probability level [23].

RESULTS

The water temperature ranged from 24 to 26°C, dissolved oxygen from 4.5 to 5.2 mgL^{-1}, pH from 7.8 to 8.4. Water quality parameters remained within the acceptable ranges for carp fry growth during the experimental period [24].

The amino acid profile as well as the nutrient composition of the main protein sources and the experimental diets is presented in *Table 1-3*. In each experimental diet, data on the essential amino acid composition were adequate to meet the amino acid requirements of carp. Compared with FM-based diet, the essential amino acid content of diets

Table 1. *Proximate composition (% of dry matter) and amino acid profiles of the main protein sources used in the experimental diets*

Tablo 1. *Deneme yemlerinde kullanılan temel protein kaynaklarının ham değerleri (% kuru ağırlık) ve amino asit profilleri*

Parameters [1]	Fish Meal	Sand Smelt Meal	Soybean Meal
Dry matter	89.42	91.11	86.84
Crude protein	74.60	78.13	53.16
Crude lipid	7.47	10.07	1.24
Ash	17.23	10.78	7.89
Crude fibre	0.44	0.43	4.49
NFE [2]	0.22	0.54	33.18
Amino acid (% of dry diet)			
Alanine	3.55	4.65	2.48
Glycine	4.28	4.43	2.57
Valine	3.10	3.78	2.41
Leucine	5.17	5.34	2.88
Isoleucine	3.06	3.17	1.93
Threonine	2.83	3.12	1.93
Serine	2.66	2.50	1.63
Proline	3.16	3.10	1.55
Aspartic acid	6.64	13.51	8.58
Methionine	1.17	1.12	0.72
Glutamic acid	8.42	9.63	5.51
Phenylalanine	2.53	2.58	1.41
Lysine	7.94	4.87	3.91
Histidine	2.60	1.75	1.24
Thyrosine	3.67	1.87	1.37

[1] Values are mean of triplicate analysis, except for amino acids, which were analyzed two times, [2] Nitrogen-free extract. Arginine and Cystine were not analysed

Table 2. *Formulation and proximate composition of the experimental diets*
Tablo 2. *Deneme yemlerinin formülasyonu ve ham değerleri*

Ingredients (%)	**% SSM Replacing FM in Diets**				
	0 (Control)	**25**	**50**	**75**	**100**
Fish meal [1]	44.99	33.74	22.49	11.25	0
Sand smelt meal [2]	0	10.54	21.07	31.6	42.13
Soybean meal [3]	16.85	16.85	16.85	16.85	16.85
Corn starch [4]	23.05	23.05	23.05	23.05	23.05
Soybean oil [5]	3.0	3.0	3.0	3.0	3.0
Fish oil [6]	1.9	1.7	1.47	1.25	1.05
Vitamin premix [7]	2.0	2.0	2.0	2.0	2.0
Mineral premix [8]	3.0	3.0	3.0	3.0	3.0
L-methionine [10]	0.2	0.2	0.2	0.2	0.2
Iodized salt	0.1	0.1	0.1	0.1	0.1
$CaHPO_4 2H_2O$	2.0	2.45	2.85	3.38	3.8
CMC	1.0	1.0	1.0	1.0	1.0
Cellulose	1.41	1.87	2.42	2.82	3.32
Chromic oxide	0.5	0.5	0.5	0.5	0.5
Total	100	100	100	100	100
Proximate composition (% of dry matter) [11]					
Moisture	8.45±0.08	7.76±0.27	8.46±0.76	7.79±0.12	7.25±1.06
Crude protein	41.56±0.07	40.98±0.43	41.45±0.14	41.00±0.34	41.15±0.19
Ether extract	10.63±0.39	10.74±0.34	11.02±0.67	11.17±0.44	10.69±0.34
Ash	13.40±0.06	13.57±0.47	12.80±0.17	11.73±0.00	11.92±0.18
Crude fibre	3.53±0.03	3.91±0.37	4.78±0.37	4.87±0.08	5.50±0.06
NFE [12]	30.88±0.29	30.80±1.04	29.95±1.08	31.23±0.07	30.74±1.02
DE (MJ/kg feed) [13]	15.74±12.2	15.77±11.2	15.73±6.52	15.98±8.59	15.87±23.9

[1,3-10] obtained from Kilic feed manufacture factory Co. Ltd.[2]Sand smelt was obtained from Lake Eğirdir, Isparta, Turkey and Sand smelt meal was prepared at the laboratory of fisheries faculty of Akdeniz University,[7,8] Gümüş [15], [11] Values are mean (±SD) of triplicate analysis, [12] Nitrogen-free extract, [13] Digestible energy

Table 3. *Composition of the amino acids in the experimental diets and essential amino acid requirements of carp (% of dry diet)*
Tablo 3. *Deneme yemlerinin amino asit değerleri ve sazanın esansiyel amino asit gereksinimi(% kuru ağırlık)*

Parameters [1]	**Required** [2]	**% SSM Replacing FM in Diets**				
		0 (Control)	**25**	**50**	**75**	**100**
Alanine		2.55	2.74	2.65	2.49	2.41
Glycine		2.77	2.99	2.91	2.72	2.62
Valine	1.16	2.31	2.35	2.45	2.40	2.32
Leucine	1.64	3.38	3.46	3.60	3.36	3.29
Isoleucine	0.92	2.18	2.01	2.28	2.17	2.07
Threonine	1.32	2.11	2.18	2.24	2.22	2.19
Serine		2.12	1.90	1.81	1.74	1.60
Proline		2.27	2.36	2.33	2.16	2.02
Aspartic acid		4.48	4.59	5.43	5.51	5.60
Methionine	0.64	0.87	0.84	0.82	0.76	0.68
Glutamic acid		4.13	4.99	5.07	5.39	5.74
Phenylalanine	1.16	1.61	1.78	1.68	1.60	1.46
Lysine	2.12	3.34	2.99	2.86	2.83	2.73
Histidine	0.56	1.02	0.88	0.79	1.73	0.65
Thyrosine		1.51	1.38	1.31	1.24	1.05

[1] Values for amino acids were analyzed two times, [2] Data of essential amino acid (EAAs) requirement (g100 g^{-1} feed) for carp taken from Ogino [28]. Arginine and Cystine were not analysed

was not negatively affected by SSM under experimental conditions. The crude lipid and crude protein content of SSM are similar to those of FM, whereas the level of SSM ash (9.76%) is lower than that of FM (13.71%) *(Table 1)*.

The growth performance and feed utilization data for carp fry fed with the five diets are shown in *Table 4*. There were significant ($P<0.05$) differences in final body weight (FBW), body weight gain (BWG) and specific growth rate (SGR) among the treatments. The present study showed that the mean FBW, BWG and SGR for fish fed diets containing SSM up to 75% were not significantly lower ($P>0.05$) compared to fish fed the control diet, while fish fed the 100% SSM diet had the lowest FBW, BWG and SGR. High survival (97.33-100%) was observed in all dietary treatment and no significant differences with relevance to dietary SSM replacement ($P>0.05$, *Table 4*) could be observed.

There was significant effects of diet on the feed

Table 4. *The growth performance of mirror carp fry fed with experimental diets for three months*

Tablo 4. *Deneme yemleri ile beslenen aynalı sazan yavrularının üç aylık büyüme performansı*

Parameters	% SSM Replacing FM in Diets				
	0 (Control)	25	50	75	100
IBW (g)	0.296±0.00	0.290±0.00	0.301±0.00	0.296±0.00	0.298±0.00
FBW (g)	6.177±0.156^{a}	6.156±0.031^{a}	6.142±0.000^{a}	6.135±0.365^{a}	5.562±0.222^{b}
BWG (g) [1]	5.881±0.150^{a}	5.866±0.023^{a}	5.840±0.006^{a}	5.838±0.361^{a}	5.264±0.217^{b}
SGR (%day^{-1}) [2]	3.375±0.005^{a}	3.394±0.026^{a}	3.350±0.028^{a}	3.364±0.052^{a}	3.250±0.023^{b}
FI (g fish^{-1}) [3]	8.259±0.117	8.284±0.014	8.297±0.028	8.250±0.207	8.326±0.082
FCR [4]	1.404±0.015^{a}	1.412±0.008^{a}	1.420±0.003^{a}	1.414±0.052^{a}	1.582±0.049^{b}
PER [5]	1.837±0.02^{a}	1.827±0.04^{a}	1.811±0.00^{a}	1.820±0.01^{a}	1.666±0.05^{b}
CF [6]	1.465±0.09	1.364±0.04	1.394±0.01	1.434±0.07	1.437±0.04
HSI (%) [7]	2.148±0.17^{ab}	2.363±0.52^{a}	1.886±0.07^{ab}	1.736±0.24^{ab}	1.444±0.09^{b}
VSI(%) [8]	10.62±0.69^{a}	9.32±0.46^{ab}	9.174±0.24^{ab}	8.421±0.97^{bc}	7.061±0.70^{c}
Survival (%) [9]	100.0±0.00	100.0±0.00	98.66±2.30	98.66±2.30	97.33±4.61

Each value is the mean (±SD) of three replicates. ^{a,b,c} Values in the same row with different superscripts are significantly different from each other (P<0.05), IBW, initial body weight; FBW, final body weight; [1] BWG, body weight gain = FBW(g)-IBW (g); [2] SGR, specific growth rate = (Ln FBW(g)-Ln IBW(g)/time days x 100); [3] FI, feed intake = dry feed intake (g)/number of fish over 90 days; [4] FCR, feed conversion ratio = FI (g)/BWG(g); [5] PER, protein efficiency ratio = BWG (g)/protein intake (g); [6] CF, condition factor = FBW (g)/(total body length, cm)^3 x 100; [7] HSI, hepatosomatic index = Wet liver wt. (g) /FBW (g) x100; [8] VSI, viscerosomatic index= Visceral wt. (g))/ FBW (g) x 100; [9] Survival = Final fish number/initial fish number x 100

Table 5. *Final whole body composition (% of dry matter) of mirror carp fry fed with experimental diet*

Tablo 5. *Deneme yemleri ile beslenen aynalı sazan yavrularının vücut kompozisyonu (% kuru ağırlık)*

Parameters	% SSM Replacing FM in Diets				
	0 (Control)	25	50	75	100
Dry matter	24.76±0.79	23.07±0.48	23.56±0.25	24.49±1.39	22.86±0.38
Protein	70.44±1.78	72.02±1.10	71.04±0.05	70.28±1.97	73.41±0.27
Lipid	18.32±2.60	14.85±0.88	15.45±0.66	16.94±2.59	13.72±0.95
Ash	12.22±0.82	13.30±0.15	13.49±0.72	12.77±0.62	12.99±0.17

Each value is the mean (±SD) of triplicate analysis. The same superscript letters in the same row are not significantly different from each other (P>0.05)

Table 6. *Effects of experimental diets on apparent digestibility coefficients (ADC, %) of nutrients*

Tablo 6. *Deneme yemlerinin besin madde sindirilebilirlik katsayıları üzerine etkileri (%)*

Parameters	% SSM Replacing FM in Diets				
	0 (Control)	25	50	75	100
Dry matter	71.00±0.87	70.46±0.70	71.34±0.80	72.77±2.52	70.87±0.58
Protein	81.32±0.37^{c}	81.66±0.71^{bc}	84.18±1.66^{ab}	85.29±0.43^{a}	83.59±1.10^{abc}
Lipid	79.79±4.15	82.10±5.54	86.47±5.40	84.22±3.83	79.00±5.25
Energy	83.10±1.23	83.18±1.23	84.90±2.08	85.22±0.60	83.09±0.03

Each value is the mean (±SD) of three replicates, $^{a.b.c}$ Values in the same row with different superscripts are significantly different from each other (P<0.05) conversion ratio (FCR) and the protein efficiency ratio (PER) (P<0.05), whereas feed intake (FI) was not influenced by dietary treatments. PER value increased significantly, while FCR decreased significantly with increasing the SSM level up to 75% in diets. In contrast, PER were significantly reduced while FCR significantly increased as the proportion of SSM was increased to 100% in the diet *(Table 4)*.

The condition factor (CF) did not change between treatments throughout the experiment, whereas HSI and VSI values of carp fry fed experimental diets differed significantly (P<0.05) among the treatments. The highest HSI and VSI values were obtained in fish fed with control diet and 25% SSM diet, respectively.

Final whole body composition values for fish fed with experimental diets are given in *Table 5*. At the end of the experiment, no significant differences were found in the whole body dry matter (22.86-24.76%), protein (70.28-73.41%; dry matter), lipid (13.72-18.32%; dry matter) and ash (12.22-13.49%; dry matter) contents of fish fed with the different experimental diets (P>0.05).

The apparent digestibility coefficients (ADC) of the experimental diets are given in *Table 6*. The ADC for dry matter, lipid and energy was not affected by different levels of SSM in the experimental diets (P>0.05), while there was a significant (P<0.05) difference in the ADC of protein. The highest ADC of protein was observed in fish fed with 75% SSM diet. The range of the ADC for dietary protein and energy were 81.32-85.29% and 79.00-86.47%, respectively.

DISCUSSION

The results of the present study clearly indicate that the growth performance or feed utilization of mirror carp fry was affected by different experimental diets (P<0.05). Growth performance of carp fry fed with up to 75% SSM diets was similar to that fed with 0.0% SSM diet in which fish meal was the sole protein source. These results are agreement with those of Gümüş [15], who also found no significant differences (P>0.05%) between growth performances of Nile tilapia fry *(Oreochromis niloticus)* fed with up to 75% SSM and fish meal based diets. However, Abdelghany [5] and Ahmad [25] found that the highest growth was obtained at 50% and 75% replacement of fishmeal protein with gambusia fish (*Gambusia affinis)* meal protein in diets for red tilapia *(O. niloticus* x *O. mossambicus)* and Nile tilapia fry *(Oreochromis niloticus)*, respectively. These differences may have resulted from the differences in behaviour, nutrient requirements especially for essential amino acids, the culture conditions of the fish and/or proximate composition of replacement ingredients.

It can be said that the growth performance was reduced with the SSM content higher than 75% as the lowest growth was obtained in fish fed with 100% SSM diet *(Table 4)*. Along with sand smelt meal, several other ingredients of animal origin such as feather meal, poultry by-product meal, meat meal, turkey meal, gambusia meal or tuna liver meal have been used as alternative protein sources of FM or other protein sources in diets of various fish species and with varying degrees of success [5,8-10,14,15,25]. But, as seen in the present study, growth performance tends to be reduced when high proportion or all of fish meal is replaced with various ingredients. Gümüş [15] stated that the growth reduction in fish fed with the diet containing 100% SSM may be attributed to reduced palatability or attractiveness of the diet causing a reduced feed intake. Also, it might be ascribed to deficiencies caused by low availability of certain EAAs in SSM or AA imbalances [5,15,26].

All variables related to feed utilization efficiencies such as SGR, FCR and PER in all experimental diets were influenced by dietary treatments. SGR, FCR and PER of mirror carp fry were improved slightly when fed with diets containing up to 75% SSM without significant difference among them (P>0.05), while significant decreases were obtained with the increase in SSM replacement rate from 75% to 100% (P<0.05; *Table 4*). However, Yang [9] found that FI and PER estimated for gibel carp fed diets containing different PBM levels were higher than those in fish fed the control diet. Ahmad [25] reported that fish fed with diets having up to 75% gambusia fish meal replacements of fish meal protein had the best FI, SGR, FCR and PER to fish fed with the fish meal-based diet. Abdelghany [5] also found that fish fed diets in which gambusia fish meal protein replaced up to 100% of fishmeal protein had similar FCR and PER compared with fishmeal control diet. Gümüş [15] offered that up to 75% replacement of sand smelt meal protein can be used successfully as a total replacement for FM protein in practical diets of Nile tilapia fry without adverse effects on feed utilization.

In some studies, mean CF, HSI and VSI values have been reported to be significantly affected by the dietary nutritional factors [8,27]. In the present study, there were no differences in CF, but HSI and VSI values were influenced by the level of FM protein replaced by SSM and the mean HSI and VSI values measured for 100% SSM diet were significantly lower as compared to other diets. However, Hu [11] and Gümüş [15] found that CF, HSI and VSI values were not influenced by the replacement levels of rendered animal protein ingredients and SSM for FM, respectively. The difference in the HSI and VSI values in the present study could be attributed to reduced palatability or attractiveness of the feeds.

There were no differences in the whole body dry matter, protein, lipid and ash content of fish fed the experimental diets. Similar results have been presented by Muzinic [10] in sunshine bass, Abdelghany [5] in red tilapia, Yang [9] in gibel carp, Ahmad [25] and Gümüş [15] in Nile tilapia.

The ADC of protein increased with increase in dietary SSM, while there were no significant differences in the ADC of dry matter, lipid and energy. However, the ADC of lipid and energy slightly decreased only at 100% SSM diet. The protein digestibility values obtained from dietary SSM replacements up to 75% indicate that inclusion of SSM in experimental diets was responded by significantly high feed utilization. The highest protein digestibility was observed in fish fed with 75% SSM diet. The ADC of protein was similar to the findings of Wee and Shu [3], Abdelghany [5], Ahmad [25] and Gümüş [15].

Growth performance and nutrient utilization of carp fry fed at varying inclusion levels of SSM indicated that SSM could be a substitute for FM up to 75% replacement rates in practical diets without compromising growth. Further research is needed to investigate the nutritional value of SSM as an alternative for FM in formulated large carp diets.

Acknowledgments

Author would like to thanks Y. KAYA, A. B. BALCI and B. AYDIN for their helps throughout the period of the study.

REFERENCES

1. Glencross BD, Booth M, Allan GL: A feed is only as good as its ingredients-a review of ingredient evaluation strategies for aquaculture feeds. *Aquacult Nutr,* 13, 17-34, 2007.

2. Hardy RW, Tacon AGJ: Fish meal: Historical uses, production trends and future outlook for supplies. **In,** Stickney RR, MacVey JP (Eds): Responsible Marine Aquaculture. pp. 311-325. CABI Publishing, New York, 391 pp, 2002.

3. Wee KL, Shu SW: The nutritive value of boiled full-fat soybean in pelleted feed for Nile tilapia. *Aquaculture,* 81, 303-314, 1989.

4. Webster CD, Thompson KR, Morgan AM, Grisby EJ, Gannam AL: Used of hempseed meal poultry by-product meal and canola meal in practical diets without fish meal for Sunshine Bass. (*Morone chrysops* X *M. saxatilis*) fed practical diets. *Aquaculture,* 188, 299-309, 2000.

5. Abdelghany AE: Partial and complate replacement of fish meal with gambusia meal in diets for red tilapia *(Oreochramis niloticus X O.mosambicus)*. *Aquacult Nutr,* 9, 145-154, 2003.

6. Adebayo OT, Fagbenro OA, Jegerde T: Evaluation of *Cassia fistula* meal as a replacement for soybean meal in practical diets *Oreochromis niloticus* fingerlings. *Aquacult Nutr,* 10, 99-104, 2004.

7. Zhou QC, Mai KS, Tan BP, Liu YJ: Partial replacement of fishmeal by soybean meal in diets for juvenile cobia *(Rachycentron canadum)*. *Aquacult Nutr,* 11, 175-182, 2005.

8. Zhang S, Xie S, Zhu X, Lei W, Yang Y, Zhao M: Meat and bone meal replacement in diets for juvenile gibel carp *(Carassius gibelio)*: Effects on growth performance, phosphorus and nitrogen loading. *Aquacult Nutr,* 12, 353-362, 2006.

9. Yang Y, Xie S, Cui Y, Zhu X, Lei W, Yang Y: Partial and total replacement of fish meal with poultry by-product meal in diets for gibel carp, *Carassius auratus gibelio* Bloch. *Aquac Res,* 37, 40-48, 2006.

10. Muzinic LA, Thompson LS, Metts S, Dasgupta S, Webster CD: Use of turkey meal as partial and replacement of fish meal in practical diets for sunshine bass *(Morone chryops* X *M. saxatilis)* grown in tanks. *Aquacult Nutr,* 12, 71-81, 2006.

11. Hu M, Wang Y, Wang Q, Zhao M, Xiong B, Qian X, Zhao Y, Luo Z: Replacement of fish meal by rendered animal protein ingredients with lysine and methionine supplementation to practical diets for gibel carp, *Carassius auratus gibelio*. *Aquaculture,* 275, 260-265, 2008.

12. Azaza MS, Kammoun W, Abdelmouleh A, Kraiem MM: Growth performance, feed utilization, and body composition of Nile tilapia (*Oreochromis niloticus* L.) fed with differently heated soybean-meal-based diets. *Aquacult Int,* 17, 507-521, 2009. DOI 10.1007/s10499-008-9220-8.

13. Ergun S, Yigit M, Turker A, Harmantepe B: Incorporation of soybean meal and hazelnut meal in diets for Black sea turbot (*Scophthalmus maeoticus*). *Isr J Aquac-Bamidgeh,* 60 (1): 27-36, 2008.

14. Gümüş E, Kaya Y, Balcı BA, Acar BB: Partial replacement of fishmeal with tuna liver meal in diets for common carp fry, *Cyprinus carpio* L., 1758. *Pak Vet J,* 29, 154-160, 2009.

15. Gümüş E, Kaya Y, Balcı BA, Aydın B, Gülle İ, Gökoğlu M: Replacement of fishmeal with sand smelt *(Atherina boyeri)* meal in practical diets for Nile tilapia fry *(Oreochromis niloticus)*. *Isr J Aquac-Bamidgeh,* 62 (3): 172-180, 2010.

16. Gümüş E, Erdogan F: Effects of Partial Substitution of Fish Meal with Tuna Liver Meal on the Fatty Acid Profile of Nile Tilapia Fry, *Oreochromis niloticus. Kafkas Univ Vet Fak Derg,* 16 (Suppl-B), S283-S290, 2010.

17. Küçük F, Gülle İ, Güçlü SS, Gümüş E, Demir O: Effect on fishing and lake ecosystem of sand smelt *(Atherine boyeri* Risso, 1810) as an invasive species. *I. National Fishing and Reservoir Management Symp.* 7-9 February, Antalya, Turkey, pp. 119-128, (In Turkish), 2006.

18. TFS (Turkstat Fisheries Statistics): Fishery statistics. Agricultural and Rural Affairs Ministry. Ankara, Turkey, 2007.

19. NRC (National Research Council): Nutrient Requirements of Fish. National Academy Press, Washington, D.C., USA, 1993.

20. Maynard LA, Loosli JK: Animal Nutrition, 6th Edition, McGraw-Hill, New York, 613 pp, 1969.

21. AOAC: Offical Methods of Analysis 16th ed. Association of Offical Analitical Chemists, Inc., Arlington,VA, USA, 1995.

22. Furukawa A, Tsukahara H: On the acid digestion method for determination of chromic oxide as an indicator substance in the study of digestibility in fish. *Bull J Soc Sci Fish*, 32, 502-506, 1966.

23. Steel RGD, Torrie JH, Dickey DA: Principles and Procedures of Statistics. A biometrical approach. 3rd ed. McGraw Hill Book Company Inc, New York, USA, 1996.

24. Horvath L, Tamas G, Seagrave C: Carp and Pond Culture. 2th ed, p. 170. Fishing News Books, A division of Blackwell Science Ltd., Oxford, UK, 2002.

25. Ahmad MH: Evaluation of gambusia, *Gambusia affinis*, fish meal in practical diets for fry Nile tilapia, *Oreochromis niloticus*. *J World Aquac Soc*, 39, 243-250, 2008.

26. Peres H, Oliva-Teles A: Effect of the dietary essential amino acid pattern on growth, feed utilization and nitrohen metabolism of European sea bass *(Dicentrarchus labrax)*. *Aquaculture,* 267, 119-128, 2007.

27. Kim JD, Lall SP: Effects of dietary protein level on growth and utilization of protein and energy by juvenile haddock *(Melanogrammus aeglefinus)*. *Aquaculture*, 195, 311-319, 2001.

28. Ogino C: Requirements of carp and rainbow trout for essential amino acids. *Bull J Soc Sci Fish*, 46, 171-174, 1980.