www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 15: 29-38 (2015) DOI: 10.4194/1303-2712-v15_1_04

PROOF

Juvenile Shi Drum (*Umbrina cirrosa* L.) Responds Differently to Selected Commercial Fish Meals

Hüseyin Sevgili[1,*], Zafer Akpınar[4], Yılmaz Emre[1,2,3]

[1] Mediterranean Fisheries Research Production and Training Institute, Kepez Unit 07192, Antalya, Turkey.
[2] Mediterranean Fisheries Research Production and Training Institute, Beymelek Unit, Demre, Antalya, Turkey.
[3] Akdeniz University, Faculty of Sciences, Department of Biology, 07058-Campus, Antalya-Turkey.
[4] Central Fisheries Research Institute, Kasustu Beldesi, Yomra, 61250, Trabzon, Turkey.

* Corresponding Author: Tel.: +90.242 2510585 ; Fax: +90.242 510584 ;
E-mail: husevgili@yahoo.com

Received 12 May 2014
Accepted 25 February 2015

Abstract

This study aimed to evaluate the nutritional qualities of selected commercial fish meals (FM) in diets of juvenile shi drum, *Umbrina cirrosa* L..The five FMs diets based on two Peruvian anchovy meals (one is a flame dried FM: Peru-1 and the other steam-dried FM: Peru-2), a Danish low-temperature FM (Danish LT), a domestic anchovy LT meal (Domestic LT) and an Alaskan white FM (WFM) as major protein source were formulated to contain 56% protein. The diets were fed to triplicated groups of fish with initial average weight 25.06±0.11 g for 7 weeks. Fish on Peru-2 diet performed better than those on WFM in terms of final weight and specific growth rate. These fish were also significantly better regarding nutrient utilization efficiency than those fed WFM and Peru-1 diets, but similar to those on Danish LT and Domestic LT. WFM diet fed fish had significantly less amount of body lipid than those fed Danish LT diet and retained lower lipid than the other groups of fish. The results indicate that different commercial sources of FMs do not have an equal nutritional value for juvenile shi drum, an important finding that should be considered in future studies.

Keywords: Shi drum, *Umbrina cirrosa* L., fish meal, growth, nutrient utilization

Yavru Minekoplar (*Umbrina cirrosa*L.) Seçilen Bazı Ticari Balık Unlarına Farklı Şekilde Tepki Veriyor

Özet

Bu araştırma yavru minekoplarda (*Umbrina cirrosa* L.), seçilen bazı ticari balık unlarının (BU) besleme kalitelerini değerlendirmeyi amaçlamıştır. Başlıca protein kaynağı olarak, iki Peru hamsi unu (biri alev-kurutmalı BU:Peru-1, diğeri buhar-kurutmalı BU:Peru-2), düşük-sıcaklıkta işlem görmüş bir Danimarka BU (Danimarka LT), bir yerli hamsi BU (Yerli LT) ve Alaska beyaz BU (BBU) içeren beş adet deneme yemi (%56 proteinli) hazırlanmıştır. Yemler üç tekerrürlü olarak, başlangıç ağırlığı of 25.06±0.11 g olan balıklara 7 hafta boyunca verilmiştir. Peru-2 ile beslenen balıklar, BBU ile beslenenlerden daha yüksek deneme sonu ağırlığı ve spesifik büyüme oranı göstermiştir. Bu balıklar yemden yararlanma etkinliği bakımından da BBU ve Peru-1 alanlardan daha üstün olmuşlar, fakat Danimarka-LT ve Yerli-LT ile beslenenlere benzerlik göstermişlerdir. BBU ile beslenen balıkların vücut lipit düzeyleri Danimarka-LT ile beslenenlerden önemli derecede daha düşük olmuş ve vücutlarında diğer gruplardan daha az lipit tutmuşlardır. Bulgular, farklı ticari BU kaynaklarının yavru minekoplar için eşit bir besleme değerine sahip olmadıklarını göstermiş ve bunun türle ilgili gelecek çalışmalarda mutlaka dikkate alınmasını önermiştir.

Anahtar Kelimeler: Minekop, *Umbrina cirrosa*L., balık unu, büyüme, besin madde değerlendirme

Introduction

Shi drum (*Umbrina cirrosa*L.) is an economically important fish, and emerging alternative species in Mediterranean mariculture to the dominant species, European sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*) (Barbato and Corbari, 1995; Libertini *et al.*, 1998; Cárdenas, 2013). However, only limited information about nutrition of this carnivorous fish is available. The existing information is related to the potential use of vegetable protein and oil sources in its diets (Segato *et al.*, 2005a), dietary lipid to nitrogenous-free extract ratio (Segato *et al.*, 2005b), dietary protein (Akpınar *et al.*, 2012) and lipid requirements (Akpınar *et al.*, 2012) and optimal dietary protein/lipid ratio (Henry and Fountoulaki, 2014). These studies suggest that juvenile shi drum requires high protein (47- 50%) and relatively low lipid (<13%). Therefore, it appears that a careful selection of raw materials to meet dietary

protein requirement holds primary importance for the future development of shi drum aquaculture. Fish meal (FM) is traditionally thought to have a good amino acid profile that can generally cover essential amino acid requirements of many fish species (NRC, 2011). But, world FM availability is finite and seeking alternative protein sources to it in diets of aquaculture species is a major research area (Fournier *et al.*, 2004; Hasimoglu *et al.*, 2007; NRC, 2011; Hua and Bureau, 2012). To evaluate the nutritional value of the alternative protein sources, a control diet based on a FM as major protein source is employed. However, FMs vary in protein quality depending on species origin, raw material type (by product or whole fish) and freshness, production method and temperature (Hardy and Masumoto, 1990; Aderson and Lall, 1994; Anderson *et al.*, 1995; Hardy, 1996; Aksnes and Mundheim, 1997; Anderson *et al.*, 1997; Mundheim *et al.*, 2004; Forster *et al.*, 2005). Varying quality in FMs makes the results of studies on alternative protein sources difficult to compare each other (Hua and Bureau, 2012). Although several in vitro methods have been developed to estimate the starting material freshness (cadaverine, histamine, putrescine, tyramine, total volatile nitrogen and ammonia-nitrogen) and nutritional qualities of FMs, the biological testing should be the method of choice (Anderson *et al.*, 1993). So far, evaluation of various FMs have been made in a number of fish species including Atlantic salmon, *Salmosalar* (Pike *et al.*, 1990b), chinook salmon, *Oncorhynchus tshawytscha* (Hardy and Masumoto, 1990), wolfish, *Anarhichas lupus* (Moksness *et al.*, 1995), gilthead sea bream (Aksnes *et al.*, 1997), Atlantic halibut, *Hippoglossus hippoglossus* (Aksnes and Mundheim, 1997) and turbot, *Scophthalmus maximus* (Hasimoglu *et al.*, 2007; Sevgili *et al.*, 2014) and those produced at LT (less than 90^{o}C) have been credited compared with those processed at higher temperatures (McCallum and Higgs, 1989; Pike *et al.*, 1990a; Anderson *et al.*, 1993; Aksnes and Mundheim, 1997). However, different commercially available FM sources have not been assessed in shi drum feeding. An assessment of selected commercial FM sources would be important for establishment of nutritionally sound protein base in future studies dealing with alternative protein ingredients.

Therefore, the present investigation aimed to evaluate nutritional qualities of five commercial FM sources in diets of juvenile shi drum using growth and nutritional performance as well as environmental parameters.

Materials and Methods

Fish Meals and Experimental Diets

Five different commercial FMs were provided from various sources. A Danish LT FM (Danish LT, FF Skagen, Denmark; histamine content: 67.6 mg kg^{-1}) was obtained from Çağatay Yem Sanayi, İzmir, Turkey. A domestic anchovy meal (Domestic LT; histamine content: 8.9 mg kg^{-1}) was directly procured from the producer (Sibal A.Ş., Sinop, Turkey). A Peruvian flame-dried anchovy meal (Peru-1; histamine content: 87.7 mg kg^{-1}) was provided from Kılıç Deniz Ürünleri, Muğla, Turkey. A Peruvian steam-dried anchovy meal (Peru-2; 61.8 mg kg^{-1}) and an Alaskan WFM (WFM; histamine content: 0.5 mg kg^{-1}), origin not known but probably a by-product meal of Pollock, were obtained from a fish feed company (Scientific Feed Laboratory Co. Ltd., Japan). It is noteworthy that unlike drying method of the FMs, their other processing conditions such as precise cooking and drying temperatures, equipment type and capacities, fate of stick water etc. were not known. Proximate, amino acid and fatty acid compositions of FMs and other ingredients used in the experiment are shown in Table 1 and 2.

The FMs were used as main protein sources in the experimental diets. Wheat gluten meal was used at 5% in all diets as secondary protein source. Wheat flour and fish oil (salmon oil) were used as carbohydrate and lipid sources respectively. The diets were formulated to be isoproteic (56%) and isoenergetic (also iso-lipidic, 11%) and their formulations and proximate compositions are presented in Table 3. Amino acid and fatty acid profiles of the experimental diets are presented in Table 4 and 5 respectively. The ingredients were weighed at predetermined levels, mixed thoroughly, added about 5% water and pelleted into 2 mm diameter using a small-scale vertical pelletizer (Beysan Makine ve Torna, Rize, Turkey). The resulting pellets were put in plastic bags and stored at 4°C over the experiment. Fish were fed until apparent satiation twice a day at 09:00 and 18:00 for 49 days. Feed was carefully administered by dropping a few pellets until the feeding activity seized.

Fish and Rearing Conditions

The experiment was carried out at the Beymelek Unit of Mediterranean Fisheries Research Production and Training Institute, Antalya, Turkey. Shi drum broodstock were selected from a population captured from Aegean Sea coasts, Bodrum, Muğla, Turkey after an adaptation period of about 18 months. Fish used in the study were produced from this broodstock with natural spawning.

Experimental fish were selected from a base population and equally allocated to 15 rectangular tanks with about 100 L effective water holding capacity. The fish were acclimated to experimental conditions for about three weeks and fed a sinking type commercial sea bass diet including 49 % protein and 19 % lipid (Bioaqua, Çamlı Yem, İzmir, Turkey). At beginning of the experiment, stocking density was adjusted to 12 fish per tank. Initial average weight of fish was 25.06±0.11 g. Full strength sea water (38 g

Table 1. Proximate and amino acid composition of ingredients used in the experiment (Dry matter basis).

	Danish LT	Domestic LT	Peru-1	Peru-2	WFM	Wheat gluten	Wheat Flour
Dry matter	92.6	93.2	92.3	91.5	92.4	93.9	89.6
Crude Protein	74.9	76.8	71.4	74.9	74.0	82.8	17.7
Crude Lipid	10.3	8.7	10.8	11.5	9	1.1	4.9
Crude Ash	14.1	11.1	17.8	18.1	18.2	0.9	3.4
Gross Energy (MJ kg^{-1})	21.9	21.9	20.4	19.8	20.3	23.2	18.3
Histamin (mg kg^{-1})	67.6	8.9	87.7	61.8	0.5	-	-
Indispensable acid levels (% of protein)							
Arginine	5.19	5.77	5.08	5.11	5.50	5.48	2.97
Histidine	1.82	2.42	2.18	2.74	1.43	1.81	1.47
Isoleucine	3.60	3.56	3.21	3.56	3.04	2.42	2.57
Leucine	6.42	7.22	6.45	6.43	5.74	5.46	5.76
Lysine	6.86	7.87	6.80	6.82	6.04	2.80	1.12
Methionine + cystine	2.88	2.84	2.76	2.89	2.91	2.31	2.99
Phenylalanine + tyrosine	6.41	7.37	6.45	6.53	5.69	6.44	7.21
Threonine	3.51	4.48	3.65	3.60	3.29	2.79	2.10
Valine	4.21	4.19	3.73	4.14	3.57	2.72	2.97
Tryptophan	0.67	0.88	0.69	1.00	0.81	0.00	0.54
Dispensable amino acid levels (% of protein)							
Alanine	5.49	6.03	5.79	5.75	5.51	3.96	2.32
Aspartic acid	7.85	5.13	8.03	7.93	7.70	5.48	2.91
Glutamic acid	10.92	12.00	10.83	10.77	10.81	19.49	29.27
Glycine	5.15	5.10	5.18	5.73	7.65	4.08	2.93
Serine	3.28	4.08	3.36	3.29	3.86	4.00	4.07
Taurine	0.54	0.28	0.62	0.80	0.72	0.00	0.00

Table 2. Fatty acid profile of fish meal sources

Fatty acid (% of total fatty acids)	Danish LT	Domestic LT	Peru-1	Peru-2	WFM	Salmon oil
14:0	7.7	7.6	6.3	5.2	3.4	4.5
16:0	23.7	32.2	21.6	22.5	19.1	13.2
18:0	4.5	5.8	4.6	3.1	3.8	2.3
20:0	0.1	1.4	0.1	0.2	0.1	0.2
16:1n-7	7.9	8.0	6.4	5.9	5.7	5.8
18:1n-(9+7)	12.2	24.3	10.8	21.7	24.5	33.2
20:1n-(11+9)	0.6	0.6	0.6	2.3	5.9	5.1
22:1n-(11+13+9)	0.8	0.7	0.5	2.7	4.2	4.2
18:2n-6	0.8	1.4	0.8	2.5	0.7	8.5
20:2n-6	0.1	0.2	0.1	0.3	0.0	0.5
20:3n-6	0.1	0.0	0.1	0.0	0.0	0.1
20:4n-6 (ARA)	1.0	0.4	1.4	0.7	0.7	0.4
22:4n-6	0.1	0.0	0.1	0.1	0.1	0.1
22:5n-6	0.3	0.2	0.3	0.2	0.1	0.1
18:3n-3	0.4	0.3	0.3	1.4	0.3	2.3
18:4n-3	1.4	0.4	1.3	1.5	1.2	0.9
20:4n-3	0.1	0.1	0.4	0.1	0.4	0.9
20:5n-3 (EPA)	15.6	3.2	17.0	8.3	13.1	5.8
22:5n-3 (DPA)	2.1	0.3	2.2	0.9	1.1	2.2
22:6n-3 (DHA)	12.2	6.3	17.2	15.2	10.6	6.2
22:4n-9	0.5	0.1	0.5	0.2	0.4	0.3
Others	7.9	6.3	7.1	4.9	4.6	3.3
Total saturates	36.0	47.1	32.7	31.0	26.4	20.2
Total monoenes	21.5	33.7	18.3	32.7	40.2	48.2
Total n-3 PUFA	31.7	10.7	38.5	27.4	26.7	18.3
Total n-6 PUFA	2.4	2.2	2.8	3.8	1.6	9.7
Total PUFA	34.1	12.8	41.3	31.2	28.3	28.0
DHA/EPA	0.8	2.0	1.0	1.8	0.8	1.1
n-3 LC-PUFA	29.9	9.9	36.8	24.5	25.2	15.1

ARA, *Arachidonic* acid; EPA**,** *Eicosapentaenoic acid; DPA*, Docosapentaenoic acid; DHA, Docosahexaenoic acid; PUFA, polyunsaturated fatty acids; n-3 LC-HUFA, n-3 long chai npolyunsaturated fatty acids.

L^{-1}) filtered through 50 μm screen and UV treated was supplied to each tank at a rate of about 1.2 L min^{-1}. Water parameters such as temperature, dissolved oxygen and pH were daily monitored with OxyGuard Handy Gamma DO meter (DK-3460, Birkerod, Denmark; Deviation 9) and Testo pH meter (Testo, Victoria, Australia), respectively. Water temperature, dissolved oxygen, and pH values of the tanks were

Table 3. Ingredient and proximate compositions of experimental diets

Ingredients (g kg^{-1})	Danish LT	Domestic LT	Peru-1	Peru-2	WFM
Danish FM	637				
Local FM		615			
Peru-1 FM			673		
Peru-2 FM				640	
White FM					643
Wheat Flour	248	260	246	268	264
Salmonoil	28	39	22	21	35
Wheat Gluten	50	50	50	50	50
Vitamin[1]	5	5	5	5	5
Mineral[2]	1	1	1	1	1
Choline cloride[3]	2	2	2	2	2
Alpha Cellulose[4]	28	28	2	13	0
Nutrient composition (g kg^{-1} dry matter)					
Dry matter	914	909	918	910	921
Crude protein	575	574	561	563	563
Crude ash	104	82	134	127	128
Crude fat	116	112	109	105	114
Phosphorus	18	18	24	22	25
Gross energy (MJ kg^{-1})	22,5	23,1	21,3	21,3	21,4

[1] Same as Akpınar *et al.* (2012).

Table 4. Amino acid compositions (g kg^{-1} protein) of diets used in experiment

	Danish LT	Domestic LT	Peru-1	Peru-2	WFM
Indispensable amino acids					
Arginine	49	54	50	50	53
Histidine	18	24	20	26	15
Isoleucine	34	33	30	34	30
Leucine	62	68	61	64	57
Lysine	60	68	59	61	54
Methionine + cysteine	28	27	27	29	29
Phenylalanine + tyrosine	63	71	63	66	59
Threonine	33	41	34	35	32
Valine	39	39	35	40	35
Tryptophan	6	8	6	9	7
Dispensable amino acids					
Alanine	50	55	52	54	52
Aspartic acid	72	49	72	74	72
Glutamic acid	127	136	126	130	129
Glycine	48	47	48	55	70
Serine	33	40	34	34	39
Taurine	5	2	5	7	6

21.25±0.03°C, 8.38±0.01. mg L^{-1} and 7.68±0.04 respectively. An artificial photoperiod fitting natural day length between 14.11.2008 and 02.01.2009 was provided throughout the study. Fish were collectively weighed at weeks 2, 4 and 7. At the commencement of the study, 15 fish was separated for determination of initial body composition whereas three fish from each experimental tank were sacrificed for determination of condition factor and final body composition at the end of the experiment. The whole body samples were kept at -20 ºC pending analysis.

Calculations

Metabolic body weight (kg MBW) = (Geometric mean of initial weight (IW) and final weight (FW))$^{0.8}$

Daily feed intake (DFI) (g kg MBWday^{-1}) = (dry matter intake / MBW$^{0.8}$) / day

Specific Growth Rate (SGR) = [(*ln*FW)-*ln* IW) /day] × 100

Feed conversion ratio (FCR) = dry matter intake / weight gain

Protein efficiency ratio (PER) = weight gain / protein fed

Condition factor (CF) = (average weight / standard length^3) × 100

Daily nutrient intake (g kg MBW day^{-1}) = [(N, lipid, energy intake / MBW$^{0.8}$) / days

Daily nutrient gain (g kg MBW day^{-1}) = [(final body weight ×final body nutrient) – (initial body weight × initial body nutrient)] / MBW$^{0.8}$ / days

Nutrient retention (%) = 100 × (daily nutrient

Table 5. Fatty acid composition (% of total fatty acids)of diets used in experiment 1

Fatty Acids	Danish LT	Domestic LT	Peru-1	Peru-2	WFM
14:0	5.5	5.2	5.1	4.5	3.1
16:0	18.4	22.0	19.0	20.5	15.7
18:0	3.2	3.7	3.7	2.7	2.7
20:0	0.2	0.8	0.2	0.2	0.1
16:1n-7	5.9	5.9	5.4	5.3	4.7
18:1n-(9+7)	16.8	25.2	15.7	23.9	24.6
20:1n-(11+9)	1.8	2.3	1.6	2.8	4.7
22:1n-(11+13+9)	1.5	1.8	1.2	2.8	3.5
18:2n-6	8.8	10.4	8.8	10.8	9.7
20:2n-6	0.2	0.3	0.2	0.3	0.2
20:3n-6	0.1	0.1	0.1	0.1	0.1
20:4n-6 (ARA)	0.7	0.3	1.0	0.6	0.5
22:4n-6	0.1	0.1	0.1	0.1	0.1
22:5n-6	0.2	0.1	0.3	0.2	0.1
18:3n-3	1.5	1.7	1.4	2.3	1.6
18:4n-3	1.0	0.5	1.1	1.2	0.9
20:4n-3	0.3	0.4	0.5	0.3	0.5
20:5n-3 (EPA)	10.3	3.5	12.5	7.0	8.5
22:5n-3 (DPA)	1.7	0.9	1.9	1.0	1.2
22:6n-3 (DHA)	8.4	5.2	12.7	11.8	7.3
22:4n-9	0.4	0.1	0.4	0.2	0.3
Others	5.2	4.0	5.3	3.9	3.2
Total saturates	27.2	31.7	27.9	27.9	21.7
Total monoenes	26.0	35.1	24.0	34.8	37.5
Total n-3 PUFA	23.1	12.2	30.1	23.6	20.0
Total n-6 PUFA	10.0	11.2	10.4	12.0	10.6
Total PUFA	33.1	23.5	40.6	35.6	30.6
DHA/EPA	0.7	1.3	0.9	1.5	0.7
n-3 LC-PUFA	20.6	10.0	27.7	20.1	17.5

ARA,Arachidonic acid; EPA,Eicosapentaenoic acid; DPA, Docosapentaenoic acid; DHA, Docosahexaenoic acid; PUFA, polyunsaturated fatty acids; n-3 LC-HUFA, n-3 long chain polyunsaturated fatty acids.

gain / daily nutrient intake).

N loss (g kg WG^{-1}) = (N intake – N deposited) / weight gain (WG).

Chemical Analysis

Fish samples were homogenized using a kitchen meat chopper (Tefal Le Hachoir 1500, Ecully Cedex, France). Proximate analysis, except crude lipid, of ingredients, experimental diets and fish were performed according to the methods of (AOAC, 1990): dry matter at 104 °C till constant weight, ash content by incineration in a muffle furnace at 600 °C for 2 h; crude protein (N×6.25) by the Kjeldhal method after acid digestion. Lipid was determined with ether extraction using an automatic extraction system (ANKOMXT15 Extractor, ANKOM Technology, Macedon, USA). Phosphorus analysis of the experimental diets was conducted according to Tanner *et al.* (1999). Amino acid compositions of ingredients, experimental diets were determined using an automatic amino acid analyzer (JLC-500/v; Jeol, Tokyo, Japan) following digestion of samples with 4N methanesulfonic acid for 24 hours at 110 ^{O}C. Fatty acid profiles of FMs and experimental diets were determined according to (Alimuddin *et al.*, 2005) following extraction of total lipid using the chloroform–methanol (2:1) (Folch *et al.*, 1957). Gross energy levels of ingredients, diets and fish samples were estimated using the conversion factors of 39.5, 23.7 and 17.2 for lipid, protein and carbohydrate levels, respectively. Histamin levels of FMs were determined with an HPLC method after dansyl derivatiation by Japan Food Research Laboratories, Tokyo, Japan.

Statistical Analysis

The experimental design was a completely random scheme, five levels of treatment (FM diets) and three replicates (tanks per treatment). Normality and homogeneity were checked by Shapiro-Wilk W Test and Bartlett's test, respectively. All percentage values were arcsine transformed before analysis of variance. One-way analysis of variance (ANOVA) followed by Tukey HSD post hoc test was used to detect the significant differences between the treatments. A significance level of $P<0.05$ was used. A Statistical package JMP v.8.0 for Windows was used for all statistical analyses.

Results

At the end of the study, FW and SGR values of fish fed WFM diet were significantly lower than the

others except for those fed Peru-1 (Table 6). Over the first four weeks of the study, mean weights of fish fed Peru-1 and WFM diets, the former in particular, were lower than the other groups. During the last three weeks WFM fed fish remained lower as opposed to those fed Peru-1 which performed better and were statistically comparable to other treatments. There were no significant differences in the amounts of FI among the treatments. However, when FI was computed as DFI per MBW, a significant difference between fish on WFM and Peru-2 diet appeared. The FCR and PER of fish on WFM diet was significantly worse than those on the other diets. These variables of fish on Peru-1 diet were also significantly worse than those on Peru-2 diet but similar to those on Danish LT and Domestic LT diets. CFs of fish were not significantly affected by the treatments. Final whole body compositions of shi drum were similar among the treatments, except lipid which was significantly lower in fish on WFM than those on Danish LT (Table 7).

N, lipid and energy balances obtained from the treatments are presented in Table 8. The N intake and gain values were not significantly altered regardless of FMs used. However N retention values differed among the treatments, with a significantly higher value in fish fed Peru-2 than those fed Peru-1 and WFM. An exactly inverse pattern of this was

Table 6. Growth and feed utilization of shi drum fed various commercial FMs for 49 days

	Danish LT	Domestic LT	Peru-1	Peru-2	WFM	Pooled SEM
IW (g fish^{-1})	25.08	25.22	24.72	25.06	25.19	0.25
W (g fish^{-1}) (week 2)	40.75^{a}	39.73^{a}	35.00^{b}	41.19^{a}	37.78^{ab}	0.94
W (g fish^{-1}) (week 4)	51.64^{a}	50.97^{ab}	44.51^{c}	51.97^{a}	46.06^{bc}	1.07
FW (g fish^{-1})	65.03^{a}	65.12^{a}	62.21^{ab}	66.61^{a}	57.58^{b}	1.43
FI (gfish^{-1})	45.76	45.05	47.37	43.83	46.87	1.48
DFI (g kg MBW$^{0.8}$ day^{-1})	12.17^{ab}	11.95^{ab}	12.89^{ab}	11.55^{b}	13.06^{a}	0.33
SGR (% day^{-1})	1.94^{a}	1.94^{a}	1.88^{ab}	1.99^{a}	1.68^{b}	0.06
FCR	1.15^{bc}	1.13^{bc}	1.26^{b}	1.06^{c}	1.45^{a}	0.03
PER	1.52^{ab}	1.54^{ab}	1.41^{b}	1.69^{a}	1.23^{c}	0.04
CF	2.18	2.18	2.13	2.06	2.01	0.06

Mean values (n=3) and pooled standard error of mean (SEM) are presented for each variable. Means in the same row with different superscript are significantly different (P<0.05). IW, initial weight; W, weight; FW, final weight, FI, feed intake (dry matter basis); DFI, daily feed intake (dry matter basis), FCR, feed conversion ratio; SGR, specific growth rate; DFI, daily feed intake; MBW, metabolic body weight; PER, protein efficiency rate;CF, condition factor.

Table 7. Whole body composition (g kg wet weight^{-1}) of shi drum fed various commercial FMs for 49 days

	Initial	Danish LT	Domestic LT	Peru-1	Peru-2	WFM	Pooled SEM
Dry matter	190	276	275	277	271	268	2.4
Lipid	25	49^{a}	47^{ab}	46^{ab}	43^{ab}	40^{b}	2.0
Protein	130	178	183	182	180	181	2.2
Ash	41	41	41	41	40	43	1.0

Mean values (n=3) and pooled standard error of mean (SEM) are presented for each variable. Means in the same row with different superscript are significantly different (P<0.05).

Table 8. N, lipid and energy balances in shi drum fed various commercial FMs for 49 days

	Danish LT	Domestic LT	Peru-1	Peru-2	WFM	Pooled SEM
N						
Intake (g kg MBW$^{0.8}$ day^{-1})	1.12	1.10	1.16	1.04	1.18	0.03
Gain (g kg MBW$^{0.8}$ day^{-1})	0.36	0.37	0.35	0.37	0.32	0.01
Retention (%)	31.71^{abc}	33.34^{ab}	30.50^{bc}	35.51^{a}	27.11^{c}	1.03
Loss (g kg WG^{-1})	72.10^{bc}	69.23^{bc}	78.83^{b}	61.42^{c}	95.49^{a}	3.09
Lipid						
Intake (g kg MBW$^{0.8}$ day^{-1})	1.41^{a}	1.33^{ab}	1.40^{a}	1.22^{b}	1.49^{a}	0.04
Gain (g kg MBW$^{0.8}$ day^{-1})	0.69^{a}	0.64^{a}	0.61^{a}	0.59^{ab}	0.46^{b}	0.03
Retention (%)	48.70^{a}	47.91^{a}	43.58^{a}	48.35^{a}	30.59^{b}	2.63
Energy						
Intake (kcal kg MBW$^{0.8}$ day^{-1})	273.79^{ab}	275.78^{ab}	274.54^{ab}	245.55^{b}	280.06^{a}	7.24
Gain (kcal kg MBW$^{0.8}$ day^{-1})	79.68^{a}	79.43^{a}	76.35^{a}	77.85^{a}	65.18^{b}	1.95
Retention (%)	29.14^{a}	28.80^{a}	27.86^{a}	31.73^{a}	23.28^{b}	0.84

Mean values (n=3) and pooled standard error of mean (SEM) are presented for each variable. Means in the same row with different superscript are significantly different (P<0.05). MBW, metabolic body weight; WG, weight gain.

observed in N losses to the to the environment, being highest in fish on WFM diet, followed by those on Peru-1, Danish LT, Domestic-LT and Peru-2 diets.

Peru-2 diet fed fish ingested significantly less lipid than those on WFM, Danish LT and Peru-1 diets, but similar to Domestic-LT. Interestingly, lipid gains by WFM diet fed fish were lower than those on the other FMs except Peru-2. Lipid retention values of fish fed WFM diet was also poor and the significantly lower than the others. The trend in energy intake values was the same as DFI. Energy gain and retentions were significantly dropped only in WFM diet fed fish.

Discussion

The same diets in a sister study with turbot performed a comparable growth rate and feed utilization (Sevgili *et al.*, 2014). However, the FM sources in the present experiment significantly affected growth and feed utilization of juvenile shi drum within a period of 7 weeks. Fish on WFM diet performed worse than the others except Peru-1. In consistent with observations of Aksnes and Mundheim (1997), an adaptive growth response in fish fed Peru-1 diet over the study period was the case. Several factors such as starting species, type of raw material, processing methods and conditions, and raw material freshness play a role in the quality of FMs (Hardy and Masumoto, 1990; Pike *et al.*, 1990b; Hardy, 1996). The poor performance of WFM group cannot be explained by a freshness problem because its histamine content was the lowest among the FMs. Furthermore, the histamine levels of all FMs used were much lower than the levels that caused histological and morphological abnormalities in digestive systems of fish (Watanabe *et al.*, 1987; Fairgrieve *et al.*, 1994). Also, it is known that high levels of biogenic amines in FM may not necessarily result in poor growth in fish (Fairgrieve *et al.*, 1994).

There was a remarkable variation in fatty acid compositions of FMs and experimental diets. Fatty acid profile of Domestic LT differed from the others, particularly being higher in 16:0, 18:1n (9+7) and lower in n-3 LC-PUFA (EPA, DHA), which was also the case in the corresponding diets. Accordingly, LC-PUFA levels of the diets varied between 10% in Domestic LT and 27.7% in Peru-1. However, since the growth and other response levels by Domestic LT diet were always numerically better than WFM, Peru-1 and Danish LT diets, we can argue that the variations in n-3 LC PUFA levels did not have an apparent effect on the growth and other responses. Indeed, n-3 LC-PUFA content of Domestic LT diet can be estimated to be around 1.1% and this level seems to cover essential fatty acid requirements of shi drum if it is considered as equal to the requirements (0.5-1.0%, (NRC, 2011) of red drum (*Sciaenops ocellatus*), a closely related species.

Since we did not measure nutrient digestibility coefficients of the diets, it is difficult for us to comment on impacts of the FM sources on the observed responses. However, LT FMs are generally known to provide a better growth performance and FCR than regular FMs in Atlantic salmon, *Salmo salar* (Pike *et al.*, 1990b; Anderson *et al.*, 1993), chinook salmon, (Hardy and Masumoto, 1990), wolfish, *Anarhichas lupus* (Moksness *et al.*, 1995), gilthead sea bream, (Aksnes *et al.*, 1997) and Atlantic halibut (Aksnes and Mundheim, 1997). In consistent with these observations to a certain degree, a better growth, FCR and PER by Peru-2, Danish LT, Domestic LT than Peru-1 were observed in the current study. However, some other factor/s should also have played a role in altered responses at the end of the experiment. Indeed, a closer look at protein utilization data reveals that protein qualities of the FMs could have been one of the major decisive factors. PER and N retentions by experimental fish suggest that WFM and Peru-1 had poor protein quality whereas Peru-2 had the best for shi drum. Although individual digestibility coefficients of amino acids are not available here, we may speculate that amino acid profile of Peru-2 diet can be a good reference to compare those of other FMs. An attempted to calculate relative amino acid profiles of other diets in comparison to Peru-2 diet by simply dividing each amino acid level of a diet by each of Peru-2 diet (Figure 1) revealed that WFM was deficient in several essential amino acids including histidine, branched chain amino acids (leucine, isoleucine and valine), lysine, phenylalanine+tyrosine and tryptophan. One striking result from the present study is that two Peruvian FMs performed quite differently. This could be partly resulted from that Peru-1 diet was lower in histidine, isoleucine, valine and tryptophan than Peru-2 diet. Another possible explanation could be that Peru-2 was produced under more gently processing conditions than Peru-1 which was flame dried. Harsh production conditions such as excessively high temperature are already known to reduce nutrient availability of FMs for fish (Aksnes and Mundheim, 1997).

In the present experiment, DFI of fish on WFM diet was significantly higher than those on Peru-2 diet. This does not imply diet Peru-2 diet has a palatability problem; rather, it suggests that WFM could have lower quality for juvenile shi drum considering that low nutritional quality of FMs if not a result of raw material spoilage is generally compensated by a higher level of consumption by fish (Aksnes and Mundheim, 1997; Mundheim *et al.*, 2004). In the study of turbot, DFI of the WFM diet was lower than Peru-1 diet, which was not the case in the present study (Sevgili *et al.*, 2014), emphasizing the importance of species specific differences in response to the same FM sources. Aksnes and Mundheim (1997) reported that lower quality FM due to high temperature processing led to a reduction in protein retention and increase in lipid deposition in

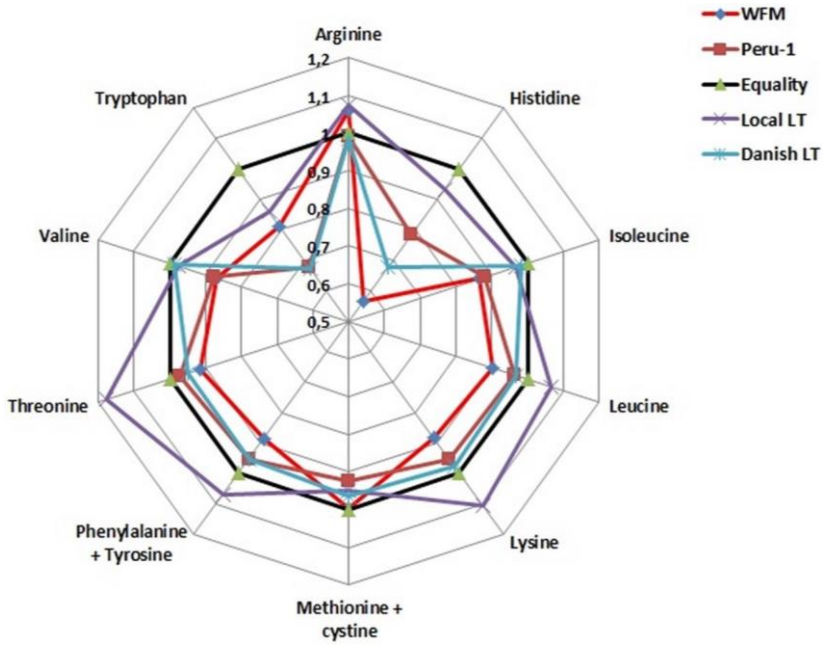

Figure 1. Relative amino acid profiles of WFM, Peru-1, Danish LT and Domestic LT compared with Peru-2 that was accepted as 1. A value of 1 indicates equality between Peru-2 and other FMs.

Atlantic halibut. Apparently this was not the case in the present study since the highest lipid deposition occurred in Danish LT fed fish. Our results from WFM diet are not consistent with those of Forster *et al.* (2004; 2005) and Hasimoglu *et al.*(2007), who reported that WFM promoted a good growth rate in fish and shrimp. This contradiction could be resulted from variations in nutritional compositions of WFM that could occur between production batches, because it is largely produced from processing wastes of pollock and cod, and proportions and nutrient compositions of these by products can be inherently variable depending on season and production methods (Hardy and Masumoto, 1990; Rabbitt, 1990; Bechtel and Johnson, 2004; Forster *et al.*, 2005). Briefly, it should be underlined that even though WFM and Peru-1 appears to have lower protein quality, nutritional quality of an FM may show some variations from season to season or even batch to batch.

The findings of the present experiment clearly show that not all FMs sources have a similar nutritional value for juvenile shi drum. Low quality of FMs could not only cause depressions in growth and nutrient retentions but also an increase in N losses to the environment. Amino acid profile of Peru-2 diet could be taken as example in future shi drum diet formulations considering its growth and feed utilization as well as protein quality data until more information on amino acid nutrition of this species becomes available.

Acknowledgments

General Directorate of Agricultural Research, Ministry of Agriculture and Rural Affairs, Turkey supported this research under grant no TAGEM/HAYSÜD/2006/09/03/02. Japan International Cooperation Agency is greatly acknowledged for their supports in procurement of some feed stuffs. We would like to thank Prof. Shuichi Satoh, Assoc. Prof. Yutaka Haga and fish nutrition staff of Tokyo University of Marine Science and Technology, Tokyo, Japan for their great support for amino acid and fatty acid analysis. The authors would like to thank also Emine Gümrü Şahin for her dedicated contributions throughout the experiment.

References

Aderson, J.S. and Lall, S.P. 1994. Nutritive value of fish meal for salmonids. In: MAcKinlay, D.D.(Ed.), High performance fish. Proceedings in International Fish Physiology Sysposium, Fish Physology Association, Vancouver, Canada: 389-393.

Akpınar, Z., Sevgili, H., Demir, A., Özgen, T., Emre, Y. and Eroldoğan, O.T. 2012. Effects of dietary lipid levels on growth, nutrient utilization, and nitrogen and carbon balances in shi drum (*Umbrina cirrosa* L.). Aquaculture International, 20: 131-143. doi: 10.1007/s10499-011-9447-7

Akpınar, Z., Sevgili, H., Özgen, T., Demir, A. and Emre, Y. 2012. Dietary protein requirement of juvenile shi drum, *Umbrina cirrosa* (L.). Aquaculture Research, 43: 421-429. doi: 10.1111/j.1365-2109.2011.02845.x

Aksnes, A., Izquierdo, M.S., Robaina, L., Vergara, J.M. and Montero, D. 1997. Influence of fish meal quality and feed pellet on growth, feed efficiency and muscle composition in gilthead seabream (*Sparus aurata*). Aquaculture, 153: 251-261. doi: http://dx.doi.org/10.1016/S0044-8486(97)00046-X

Aksnes, A. and Mundheim, H. 1997. The impact of raw

material freshness and processing temperature for fish meal on growth, feed efficiency and chemical composition of Atlantic halibut (*Hippoglossus hippoglossus*). Aquaculture, 149: 87-106. doi: http://dx.doi.org/10.1016/S0044-8486(96)01438-X

Alimuddin, Yoshizaki, G., Kiron, V., Satoh, S. and Takeuchi, T. 2005. Enhancement of EPA and DHA biosynthesis by over-expression of masu salmon Δ6-desaturase-like gene in zebrafish. Transgenic Research, 14: 159-165. doi: 10.1007/s11248-004-7435-7

Anderson, J.S., Higgs, D.A., Beames, R.M. and Rowshandeli, M. 1997. Fish meal quality assessment for Atlantic salmon (*Salmo salar* L.) reared in sea water. Aquaculture Nutrition, 3: 25-38. doi: 10.1046/j.1365-2095.1997.00067.x

Anderson, J.S., Lall, S.P., Anderson, D.M. and McNiven, M.A. 1993. Evaluation of protein quality in fish meals by chemical and biological assays. Aquaculture, 115: 305-325. doi: http://dx.doi.org/10.1016/0044-8486(93)90145-O

Anderson, J.S., Lall, S.P., Anderson, D.M. and McNiven, M.A. 1995. Availability of amino acids from various fish meals fed to Atlantic salmon (*Salmo solar*). Aquaculture, 138: 291-301. doi: http://dx.doi.org/10.1016/0044-8486(95)01131-5

AOAC. 1990. Official Methods of Analysis. Association of Official Analytical Chemists, Arlington, VA.

Barbato, F. and Corbari, L. 1995. New species in Italy. Cahiers Options Mediterraneennes, 14: 123–128.

Bechtel, P.J. and Johnson, R.B. 2004. Nutritional properties of pollock, cod and salmon processing by-products. Journal of Aquatic Food Product Technology, 13: 125-142. doi: 10.1300/J030v13n02_11

Cárdenas, S. 2013. Biología y acuicultura de corvinas en el mundo. Revista AquaTIC: 1-13.

Fairgrieve, W.T., Myers, M.S., Hardy, R.W. and Dong, F.M. 1994. Gastric abnormalities in rainbow trout (*Oncorhynchus mykiss*) fed amine-supplemented diets or chicken gizzard-erosion-positive fish meal. Aquaculture, 127: 219-232. doi: http://dx.doi.org/10.1016/0044-8486(94)90428-6

Folch, J., Lees, M. and Sloane-Stanley, G. 1957. A simple method for the isolation and purification of total lipids from animal tissues. Journal of Biological Chemistry, 226: 497-509.

Forster, I., Babbitt, J. and Smiley, S. 2004. Nutritional quality of fish meals made from by-products of the Alaska fishing industry in diets for Pacific white shrimp (*Litopenaeus vannamei*). Journal of Aquatic Food Product Technology, 13: 115-123. doi: 10.1300/J030v13n02_10

Forster, I., Babbitt, J.K. and Smiley, S. 2005. Comparison of the nutritional quality of fish meals made from by-products of the Alaska fishing industry in diets for Pacific threadfin (*Polydactylus sexfilis*). Journal of the World Aquaculture Society, 36: 530-537. doi: 10.1111/j.1749-7345.2005.tb00401.x

Fournier, V., Huelvan, C. and Desbruyeres, E. 2004. Incorporation of a mixture of plant feedstuffs as substitute for fish meal in diets of juvenile turbot (*Psetta maxima*). Aquaculture, 236: 451-465. doi: http://dx.doi.org/10.1016/j.aquaculture.2004.01.035

Hardy, R.W. 1996. Alternate protein sources for salmon and trout diets. Animal Feed Science and Technology, 59: 71-80. doi: http://dx.doi.org/10.1016/0377-8401(95)00888-8

Hardy, R.W. and Masumoto, T. 1990. Specifications for marine by-products for aquaculture. In: Keller, S. (Ed.), International By-Products Conference, Alaska Se Grant Program, Report No:90-07, Fairbanks, AK: 109-120.

Hasimoglu, A., Erteken, A., Kino, S. and Nakagawa, H. 2007. Evaluation of anchovy meal and soybean meal as dietary protein sources for the black sea turbot, *Psetta maxima*. Israeli Journal of Aquaculture-Bamidgeh, 59: 73-80. doi:

Henry, M. and Fountoulaki, E. 2014. Optimal dietary protein/lipid ratio for improved immune status of a newly cultivated Mediterranean fish species, the shi drum *Umbrina cirrosa*, L. Fish & Shellfish Immunology, 37: 215-219. doi: http://dx.doi.org/10.1016/j.fsi.2014.02.005

Hua, K. and Bureau, D.P. 2012. Exploring the possibility of quantifying the effects of plant protein ingredients in fish feeds using meta-analysis and nutritional model simulation-based approaches. Aquaculture, 356–357: 284-301. doi: http://dx.doi.org/10.1016/j.aquaculture.2012.05.003

Libertini, A., Francescon, A., Bozzato, G. and Barbaro, A. 1998. The shi drum, *Umbrina cirrosa* (L.), an unexploited resource for Mediterranean aquaculture: recent advances in captive reproduction and applied cytogenetics. In: Enne, G. and Greppi, G.F. (Eds.), New species for mediterranean aquaculture biofutur, Elsevier, Paris, France: 237-244.

McCallum, I.M. and Higgs, D.A. 1989. An assessment of processing effects on the nutritive value of marine protein sources for juvenile chinook salmon (*Oncorhynchus tshawytscha*). Aquaculture, 77: 181-200. doi: http://dx.doi.org/10.1016/0044-8486(89)90201-9

Moksness, E., Rosenlund, G. and Lie, Ø. 1995. Effect of fish meal quality on growth of juvenile wolffish, *Anarhichas lupus* L. Aquaculture Research, 26: 109-115. doi: 10.1111/j.1365-2109.1995.tb00890.x

Mundheim, H., Aksnes, A. and Hope, B. 2004. Growth, feed efficiency and digestibility in salmon (*Salmo salar* L.) fed different dietary proportions of vegetable protein sources in combination with two fish meal qualities. Aquaculture, 237: 315-331. doi: http://dx.doi.org/10.1016/j.aquaculture.2004.03.011

NRC. 2011. Nutrient requirement of fish and shrimp. National Academic Press, Washington, DC, 376 pp.

Pike, I.H., Andorsdottir, G. and Mundheim, H. 1990a. The role of fish meal in diets for salmonids. International Association of Fish Meal Manufacturers, Technical Bulletin, No.24, Hertfordshire, UK, 39 pp.

Rabbitt, J.K. 1990. Intrinsic quality and species of North Pacific fish. In: Keller, S. (Ed.),International By-Products Conference, Alaska Se Grant Program, Report No:90-07, Fairbanks, AK: 39-43.

Segato, S., Corato, A., Fasolato, L. and Andrighetto, I. 2005a. Effect of the partial replacement of fish meal and oil by vegetable products on performance and quality traits of juvenile shi drum (*Umbrina cirrosa* L.). Italian Journal of Animal Science, 4: 159-166.

Segato, S., Lopparelli, R., Borgoni, N., Zanella, L., Corato, A. and Andrighetto, I. 2005b. Effect of dietary crude fat to NFE ratio on growth, feed efficiency and quality traits in juvenile shi drum (*Umbrina cirrosa*). Cah. Options Méditérr, 63: 27–34.

Sevgili, H., Kurtoğlu, A., Oikawa, M., Fedekar, D., Emre, Y. and Takeno, N. 2014. Evaluation of nutritional

values of selected commercial fish meal sources in turbot (*Psetta maxima*) diets. Aquaculture Research: (in press). doi: 10.1111/are.12389

Tanner, D., Leonard, E.N. and Brazner, J.C. 1999. Microwave digestion method for phosphorus determination of fish tissue. Limnology and Oceanography 44: 708–709.

Watanabe, T., Takeuchi, T., Satoh, S., Toyama, K. and Okuzumi, M. 1987. Effect of dietary histidine or histamine on growth and development of stomach erosion in rainbow trout (*Salmo gairdnerii*). Bulletin of the Japanese Society of Scientific Fisheries, 53: 1207-1214.