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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.)

Severino Segato, Adolfo Corato, Luca Fasolato, Igino Andrighetto

Dipartimento di Scienze Animali. Università di Padova, Italy

Corresponding author: Dr. Severino Segato. Dipartimento di Scienze Animali. Università di Padova. Viale dell'Università 16, 35020 Legnaro (PD), Italy - Tel. +39 049 8272628 - Fax: +39 049 8272669 - Email: severino.segato@unipd.it

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ABSTRACT

A four-month growth trial was carried out in order to evaluate performance and quality traits of juvenile shi drum fed with two isonitrogenous and isoenergetic diets having different amounts of vegetable products (Vegetable diet vs. Control diet). Compared to the Control diet, the Vegetable diet was formulated by increasing the replacement of fish meal (14%) with soybean and cereal products, and fish oil (12%) with a mixture of vegetable oil. On June, 4 groups of 225 fish (2 replicates per dietary treatment) were sorted according to live weight and reared in fibreglass tanks over a four-month long experimental period. Fish were hand fed to apparent satiety. Offered feed, growth parameters and feed efficiency were recorded as productive performance. At the end of the trial (October) biometric, chemical and reological traits were examined to assess fish quality. The dietary treatments showed similar productive performance. The relatively high inclusion of vegetable sources led to a significant modification of body shape, mesenteric fat and viscera weight. Among quality traits, Vegetable diet-fed fish demonstrated a significantly lower whole body and fillet crude protein content. Yellowness value of the cooked fillet was significantly lower in the Control diet-fed fish, whereas fillet texture was similar. The results of this research showed that shi drum is a suitable candidate for Mediterranean marine aquaculture and its dietary formulation might include at least the amount of vegetable sources used in this trial.

Key Words: Vegetable products, Productive performance, Chemical composition, Reological traits, Shi drum.

RIASSUNTO

EFFETTO DELLA PARZIALE SOSTITUZIONE DI FARINA E OLIO DI PESCE CON DERIVATI VEGETALI SU PRESTAZIONI PRODUTTIVE E CARATTERISTICHE QUALITATIVE IN GIOVANILI DI OMBRINA (*UMBRINA CIRROSA* L.)

*L'introduzione di nuove specie ittiche eurialine nell'acquacoltura del bacino del Mediterraneo è una strategia emergente per la diversificazione dell'offerta del prodotto. In relazione alle recenti tecniche di alimentazione dei pesci marini che prevedono la riduzione dell'impiego di farina e olio di pesce, la presente sperimentazione ha testato l'effetto della parziale sostituzione di tali derivati con fonti alimentari vegetali su prestazioni zootecniche e caratteristiche qualitative di giovanili di ombrina (*Umbrina cirrosa* L.). Allo scopo si sono impiegate due diete estruse isoproteiche ed isoenergetiche denominate Vegetale e Controllo. La dieta Vegetale è stata formulata sostituendo la farina di pesce (14%) con farina di soia e cereali e l'olio di pesce (12%) con una miscela di oli vegetali. In giugno 2002, da una popolazione di 2000 soggetti, 4 gruppi di 225 ombrine (2 repliche per tesi alimentare) sono stati selezionati in base al peso vivo e alla lunghezza standard. I pesci sono stati allevati per 4 mesi in vasche di vetroresina e alimentati a sazietà. La dieta somministrata e l'accrescimento sono stati registrati al fine di determinare i parametri*

produttivi e l'efficienza alimentare. In ottobre, alla fine del periodo sperimentale, campioni di pesci (20 per vasca) sono stati sottoposti ad analisi biometriche, chimiche e reologiche al fine di valutare la qualità del prodotto. Le diete a confronto non hanno sortito alcuna significativa differenza in relazione alle performance di accrescimento ed efficienza alimentare. La maggior inclusione di derivati vegetali ha tuttavia influenzato alcuni aspetti morfologici quali la forma corporea, l'accumulo di grasso mesenterico e il peso dei visceri. I pesci alimentati con la dieta Vegetale si sono caratterizzati per un significativo minore contenuto di proteina grezza corporea e del filetto, risultato che tuttavia non ha influenzato il tasso di ritenzione proteica. Le caratteristiche qualitative del filetto crudo e cotto sono risultate simili tra le due tesi alimentari, ad eccezione dell'indice del giallo (b^*), significativamente superiore nel filetto cotto dei pesci della tesi Vegetale.

In conclusione, i risultati della prova indicano che l'ombrina tollera un livello relativamente alto di sostituzione di fonti proteiche e lipidiche di origine ittica con prodotti vegetali. Lo studio conferma le interessanti performance zootecniche dell'ombrina e l'adattabilità della specie ai sistemi convenzionali d'allevamento intensivo nel mare Adriatico.

Parole chiave: Derivati vegetali, Prestazioni produttive, Composizione chimica, Caratteristiche reologiche, Ombrina.

Introduction

The increase in European aquaculture is creating an ever-growing need for fish meal and oil as dietary sources. The phenomenon of overfishing and the competitive use of fish sources from both terrestrial and fish farming have led to the substitution of fish meal-based diets with plant sources (Kaushik *et al.*, 2003). In carnivorous marine finfish, the partial replacement of dietary fish meal and oil with plant products does not seem to affect growth and feed efficiency (Alexis and Nengas, 2001), whereas the effects on whole body and muscle proximate composition is more closely related to species and feeding regimen (Kissil *et al.*, 2000; Aragão *et al.*, 2003). The inclusion of soybean and cereal products did not affect texture (Vivayakarn *et al.*, 1992; de Francesco *et al.*, 2004) but could modify skin and muscle colour (Robaina *et al.*, 1995; Parisi *et al.*, 2004).

Shi drum (*Umbrina cirrosa* L., Sciaenidae) is a potential new species for Mediterranean marine aquaculture with regard to its fast growth and high feeding efficiency (Segato *et al.*, 2005). Limited data are available with respect to the nutritional requirements of shi drum and red drum (*Sciaenops ocellatus*) in the on-growing phase, although preliminary studies have shown a relatively high capacity for utilizing carbohydrates (Craig *et al.*, 1999).

The aim of this study was to evaluate the effects of the partial substitution of fish meal and oil with vegetable products on the productive performance and quality traits of juvenile shi drum.

Material and methods

Culture system and fish

The trial took place in 2002 at Bonello (Rovigo, Italy) during a 125-day period (June 3 - October 7). On the 3rd of June, from a population of 2000 subjects, 4 groups of 225 fish (2 replicates per thesis) were sorted according to live weight (60.1 ± 6.7 g) and standard length (14.3 ± 0.3 cm). The fish were reared in 4 hemispheric fibreglass tanks (about 4.5 m³) inside a glasshouse with natural air circulation. Each tank was supplied with brackish water flow (on average: pH = 8.0 and salinity = 25 ppt; flow rate = 1.1 l·s⁻¹) in a continuously oxygenated open circuit. Mortality was daily registered and dead fish were immediately removed.

Diet and feeding

Two complete isoenergetic and isonitrogenous extruded diets were formulated by using market available ingredients: fish meal and oil, wheat and maize products, soybean meal, vitamin and mineral premix (Table 1). The so-called 'Vegetable' diet, with respect to the 'Control' diet, was obtained by partially replacing fish meal (14%) with soybean meal and cereal products (wheat and maize) and fish oil (12%) with a mixture of vegetable oil. The Vegetable diet was not supplemented with amino acids (AA) and essential fatty acids.

The proximate composition of the diets was (AOAC, 2000): moisture, crude protein (CP), crude fat (CF; Soxhlet, diethyl ether) and ash, while crude fibre was analysed using the ANKON methodology and NFE was calculated as complement. According to Miglavs and

Table 1. Diet formulation and proximate composition.

		Vegetable diet	Control diet
Ingredients (g 1000g ⁻¹ wet weight):			
Fish meal		410	475
Fish oil		145	165
Vegetable oil		20	-
Soybean meal		200	160
Cereal products		205	180
Vitamin-mineral mix		20	20
Proximate composition:			
Crude protein	g 100g ⁻¹ wet weight	45.2	44.6
Ether extract	" "	19.2	18.9
N-free extract	" "	18.3	17.7
Crude fibre	" "	0.3	0.3
Ash	" "	9.4	8.9
Gross energy	MJ kg ⁻¹	21.2	20.8
CP/EE ratio	g protein MJ ⁻¹	21.3	21.4

CP/EE, Crude Protein to Ether Extract ratio

Jobling (1989), gross energy was calculated using energetic coefficients (kJ·g⁻¹): CP = 23.6; CF = 38.9 and NFE = 16.7.

Fish were fed by hand until the visual satiation, four times a day and seven days a week, taking care that no food was left uneaten. At first the feeding rate was 2-2.2% of biomass (live weight, LW), but during the later months of the experimental period, it was progressively reduced to 1.0% of LW, due to the decreasing water temperature. Offered feed was recorded daily for each tank.

In vivo measures and performance indexes

The effect of the inclusion of increased vegetable sources on performance was evaluated by determining weight gain and calculating specific growth rate (SGR), daily intake rate (DIR), and food conversion ratio (FCR). Moreover, feed utilization was estimated by offered feed, gross energy retention (GER), crude protein retention (CPR), and protein efficiency ratio (PER).

Biometric measurements, somatic indexes and proximate composition of fish

At the beginning (June 3) and at the end of the experimental period (October 7), samples of fish were submitted to biometric, chemical and rheological analysis. Data from total body weight, standard and trunk length, as well as viscera, liver, mesenteric fat weights were recorded and used to calculate condition factor and dressing (DI), hepatosomatic (HSI), viscerosomatic (VSI) and mesenteric fat (MFI) indexes. After grinding and freeze-drying, whole body and dorsal white muscle, proximate compositions were determined (AOAC, 2000). The twenty-four-hour *post mortem* muscle pH and instrumental colour were measured on raw dorsal fillet at five positions from head to the tail. After exposition for 1h to air at 2°C, dorsal fillet colour was determined by a chromameter (Minolta CR-100) set on average daylight illumination (source C) and data were reported using the Hunter-L*a*b* system. Samples of gutted trunk were steam cooked in polyurethane bags in

Table 2. Effects of dietary treatment on juvenile shi drum performance.

		Dietary Treatment		P	SEM
		Vegetable	Control		
Initial weight	g	60.0	60.0	ns	0.8
Final weight	"	364.2	375.6	ns	7.1
Weight gain	"	304.2	315.6	ns	7.1
SGR	% d ⁻¹	1.44	1.48	ns	0.02
Offered feed	g	428.6	428.5	ns	6.4
FCR		1.41	1.36	ns	0.04
DIR	% d ⁻¹	1.62	1.57	ns	0.04
GER	%	32.0	33.1	ns	1.1
CPR	"	28.4	30.2	ns	0.9
PER		1.59	1.63	ns	0.05
Mortality	"	6.2	6.2	ns	1.4

SGR, specific growth rate: $100 \times (\ln \text{ final weight} - \ln \text{ initial weight})/\text{days}$

FCR, food conversion ratio: $\text{feed given}/\text{live weight gain}$

DIR, daily intake rate: $\{\text{feed given}/[(\text{initial weight} + \text{final weight})/2]/\text{days}\} \times 100$

GER, gross energy retention: $(\text{fish energy gain}/\text{energy given}) \times 100$

CPR, crude protein retention: $(\text{fish protein gain}/\text{protein given}) \times 100$

PER, protein efficiency ratio: $\text{weight gain}/\text{protein given}$

a thermostatic bath (25 minutes at 75°C) to assess cooking losses and cooked dorsal fillet colour. After the heating procedure, instrumental tenderness (maximum shear force) was also performed by a Warner-Bratzler texture analyser (Instron 1000) on the cylindrical cores (1.25 cm of diameter) of dorsal fillets.

Statistical analysis

The trial was designed according to a monofactorial design with two levels of dietary factors (two replicates for level). ANOVA was supported by PROC GLM of SAS (1999).

Results and discussion

Mortality was not affected by dietary treatment. Considering a four-month feeding period, the increased replacement of fish meal and oil with vegetable sources (soybean meal and cereal products) did not result in any significant differ-

ence in growth performance and feeding efficiency (Table 2). Apart from dietary treatment, the juvenile shi drum performance recorded presenting this study could be compared with a previous study on this species (Segato *et al.*, 2005) and resulted similar to those of other marine finfish (Lanari *et al.*, 1999; Rueda and Martinez, 2001). During one on-growing summer there was a 310 g weight gain, which corresponded to a SGR of 1.46 %·d⁻¹ and a FCR lower than 1.4.

Offered feed and feeding behaviour were also similar between the two experimental diets. The increase in dietary vegetable sources did not affect feed efficiency such as GER and CPR. Productive results suggested that shi drum is able to tolerate and assimilate a relatively high inclusion of plant products. The substitution of fish meal with alternative protein sources (soybean and maize) up to 30% does not seem to decrease productive performance in marine fish (Oliva Teles, 2000; Alexis and Nengas, 2001). However, an addition of indis-

pensable amino acids (IAA) should be considered in the formulation of high dietary vegetable protein supplements, depending on the level of fish meal replacement, nutritional availability of vegetable sources and fish size (Robaina *et al.*, 1995; Tibaldi and Tulli, 1999; Kissil *et al.*, 2000; Alexis and Nengas, 2001). Several studies with dietary inclusion of plant products in the feeding of marine fish demonstrated a reduction in growth performance due to the deficiency of amino acids (particularly for lysine and sulphur AA) associated with a reduction in CPR, especially for new species such as red drum (McGoogan and Reigh, 1996), turbot (Day and Plascencia Gonzalez, 2000) and tin foil barb (Elangovan and Shim, 2000), or other common carnivorous finfish, i.e. gilthead sea bream (Pereira and Oliva-Teles, 2003).

Biometric and body traits were affected by dietary treatment (Table 3). Standard length was higher for vegetable-diet fed fish resulting in a greater condition factor (2.31 *vs.* 2.16 $10^2 \text{g}\cdot\text{cm}^{-3}$; $P < 0.05$). Mesenteric fat also resulted significantly higher in vegetable thesis (4.1 *vs.* 2.7 g; $P < 0.05$),

even if total celomatic fat and its relative index were not affected (Table 4). The relatively high inclusion of vegetable proteins and oil led to a significant increase in VSI, probably due to a higher gut development. The inclusion of plant products seems to enhance gut enzyme excretion (Alexis and Nengas, 2001), and this could be associated with an increase in the intestinal length and absorptive surface area. HSI and CFI did not significantly change between diets. Whole body and fillet proximate composition were similar between diets (Table 5); however, in fish fed the Vegetable-diet a significantly lower crude protein content in the whole body (18.0 *vs.* 18.6%; $P < 0.01$) and white muscle (19.8 *vs.* 20.3%; $P < 0.05$) was observed. In marine fish the effects on whole body proximate composition resulting from increased replacement of dietary fish meal and oil by plant products are debated (Kissil *et al.* 2000; Aragão *et al.*, 2003). Carcass quality seems to be influenced by feeding regimen (satiety *vs.* restricted) and the imbalance of dietary nutrients. In the present trial, although significant whole body crude protein differences were observed between the two

Table 3. Effects of dietary treatment on juvenile shi drum biometric traits.

Period	June	October			
		Vegetable	Control	P	SEM
Dietary treatment n.	40	40	40		
Length (cm):					
Standard	14.3 ± 0.3	25.3	26.0	*	0.2
Head	-	7.0	7.0	ns	0.1
Trunk	6.9 ± 0.4	12.5	12.8	ns	0.1
Maximum height	-	7.9	8.0	ns	0.1
Maximum thickness	-	3.3	3.7	*	0.1
Maximum girth	-	19.9	19.8	ns	0.1
Weight (g):					
Head	-	85.3	80.8	ns	1.1
Trunk	32.5 ± 2.2	213	219	ns	2
Liver	1.3 ± 0.1	7.3	8.1	ns	0.2
Viscera	1.3 ± 0.3	5.2	4.9	†	0.1
Celomatic fat:					
- mesenteric	-	4.1	2.7	*	0.1
- perinephric	-	10.9	12.5	ns	0.4

†: $P < 0.1$; * $P < 0.05$

Table 4. Effects of dietary treatment on juvenile shi drum morphometric indexes.

Period	June		October			SEM
			Vegetable	Control	P	
Dietary treatment n.	40	40	40			
DI	%	95.6 ± 0.4	92.5	92.4	ns	0.1
AI		2.55 ± 0.18	2.35	2.41	ns	0.2
CF	10 ³ .g cm ⁻³	1.41 ± 0.16	2.31	2.16	*	0.03
HSI	%	2.14 ± 0.29	1.96	2.14	ns	0.05
VSI	"	2.21 ± 0.40	1.40	1.29	*	0.03
CFI	"	-	3.99	4.01	ns	0.11

*: $P < 0.05$ DI, dressing index: $100 \times (\text{viscera} + \text{liver} + \text{celomatic fat weight}/\text{body weight})$ AI, agility index: $\text{trunk and peduncle length}/\text{max height}$ CF, condition factor: $100 \times (\text{body weight}/\text{standard length}^3)$ HSI, hepatosomatic index: $100 \times (\text{liver weigh}/\text{body weight})$ VSI, viscerasomatic index: $100 \times (\text{viscera weight}/\text{body weight})$ CFI, celomatic fat index: $100 \times (\text{celomatic fat weight}/\text{body weight})$ Table 5. Whole body and dorsal fillet proximate composition (g 100g⁻¹ wet weight).

Period	June		October			SEM
			Vegetable	Control	P	
Dietary treatment n.	16	12	12			
Whole body:						
Moisture		70.7 ± 0.3	65.3	65.0	ns	0.3
Crude protein		19.0 ± 0.2	18.0	18.6	**	0.1
Ether extract		5.0 ± 0.3	11.3	11.2	ns	0.4
Ash		4.7 ± 0.2	3.8	3.9	ns	0.1
Dorsal fillet:						
Moisture		-	76.4	76.2	ns	0.2
Crude protein		-	19.8	20.3	*	0.3
Ether extract		-	2.2	1.9	ns	0.2
Ash		-	1.2	1.3	ns	0.1

*: $P < 0.05$; **: $P < 0.01$

Table 6. Rheological and colour traits 24 hours post mortem on raw and cooked fillet.

Period	June		October			
	Dietary treatment n.		Vegetable 14	Control 14	P	SEM
Raw fillet:						
pH		6.25 ± 0.06	6.29	6.27	ns	0.01
Lightness	L	47.7 ± 1.5	43.4	43.2	ns	0.3
Redness	a	0.3 ± 0.5	-0.1	-0.1	ns	0.1
Yellowness	b	-1.2 ± 0.7	-3.9	-3.7	ns	0.1
Cooked fillet:						
Cooking losses	%	-	6.3	6.5	ns	0.3
Max shear force	N	-	5.9	5.4	ns	0.2
Lightness	L	-	82.5	81.9	ns	0.3
Redness	a	-	0.2	0.4	ns	0.1
Yellowness	b	-	8.8	7.7	*	0.2

*: $P < 0.05$

diets, the CPR and PER were similar.

Raw and cooked fillet rheological traits were not affected by dietary treatment, probably as a consequence of similar fillet lipids content (Table 6). Regarding this trial, Corato *et al.* (2004) reported that the increase in dietary vegetable sources did not even modify sensory traits, except for skin appearance and fillet colour. Fillet yellowness was higher in vegetable thesis (8.8 *vs.* 7.7; $P < 0.05$), showing a significantly different b^* value only after the heating procedure. Robaina *et al.* (1997) reported that dietary pigments could induce a yellow-orange colour in muscle and skin in gilthead sea bream. Parisi *et al.* (2004) also found a significant increase in b^* value in rainbow trout fed a total fish meal replaced with a diet of plant products, although these authors suggested an interaction between vegetable sources and the pigments used in diet formulation.

Conclusions

Summarizing, the results of this study indicated that a relatively high inclusion of dietary plant products (soybean and cereal) could be tolerated for shi drum growth with no effects on feed efficiency. A limited influence was observed on body shape and fillet colour. Finally, the study noticed that shi drum could be reared successfully under the same conditions used for other common marine fish.

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