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Effect of dietary crude fat to NFE ratio on growth, feed efficiency and quality traits in juvenile shi drum (*Umbrina cirrosa*)

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SUMMARY – *Umbrina cirrosa* is a candidate for Mediterranean aquaculture because of its very fast growth in captivity, even if its nutritional requirements are still unknown. Two isoproteic diets with different crude fat to N-free extract ratio (CF/NFE: L = 1.0 vs H = 1.5) were tested to evaluate juvenile shi drum productive and quality performance. The trial was conducted over summer 2001 using 4 groups of 200 fish (initial body weight = 83±25 g) fed 2% of the mean biomass. Considering a 4-month feeding period, L-diet fed fish showed significant greater weight gain due to higher specific growth rate and lower food conversion ratio. Whole body chemical composition resulted in higher crude protein and lower lipid contents for L-fish. This suggests that the better rearing performances obtained with fish fed on the L-diet are probably related to a more efficient utilization of dietary energy and crude protein. Colour and texture of flesh were not affected by dietary CF/NFE ratio.

Keywords: Shi drum, diet composition, NFE, feed efficiency, body chemical composition, fish quality.

RESUME – "*L'effet, chez la jeune ombrine côtière (*Umbrina cirrosa L.*) du rapport lipides/ extractif non azoté de l'aliment, sur la croissance, sur l'efficacité alimentaire et sur la qualité". L'ombrine côtière* (Umbrina cirrosa *L.) est un candidat exploitable par l'aquaculture (marine) de la Méditerranée parce que c'est un poisson qui a une croissance très rapide en captivité. De toute façon, les besoins nutritionnels de ce Sciaenidae sont inconnus. On a expérimenté deux régimes complets extrudés isoprotéiques, avec des rapports lipides/extractif non azoté différents (CF/NFE: L = 1.0 vs H = 1.5) dans le but d'évaluer les performances productives et la qualité de la production finale. L'expérimentation a été réalisée pendant l'été 2001, en employant 4 groupes de 200 poissons (poids corporel initial = 83±25 g), alimentés à 2% de la biomasse. Pendant une période de 4 mois, les poissons alimentés avec le régime L ont manifesté un accroissement de poids significativement plus grand que les autres, à cause d'un taux de croissance spécifique (SGR) plus élevé et d'un indice de conversion alimentaire (FCR) plus petit. La composition chimique du poisson entier a été plus élevée en protéines et plus basse en lipides chez les animaux de la thèse L. Ce qui suggère que, probablement, les meilleures performances chez les poissons alimentés avec le régime qui avait le plus bas rapport CF/NFE ont été en relation avec une meilleure efficacité de l'énergie et de la protéine du régime. Les principaux caractères qualitatifs mesurés chez les poissons à la fin de l'étude n'ont pas été influencés par le rapport CF/NFE.*

***Mots-clés* :** *Ombrine côtière, composition du régime, extractif non azoté, efficacité alimentaire, composition chimique du poisson, qualité des poissons.*

Introduction

Shi drum (*Umbrina cirrosa* L., Sciaenidae) is a potential new species for Mediterranean (marine) aquaculture. It is a common wild species in the Mediterranean Sea and it is often caught and sold at high trade prices (Barbaro *et al*., 1998). This fish seems to grow very fast both in intensive and semi-intensive rearing conditions (Borgoni *et al*., 1998; Andrighetto *et al*., 2001). Shi drum has a sub-terminal mouth and feeds on small fish and benthic invertebrates, even if it can consume aquatic vegetation too (Mylonas *et al*., 2000). However a very limited number of scientific studies on growth performance and diet utilization of this Sciaenidae are yet available. In the present study aiming at enlarging the knowledge about nutritional requirements, two isonitrogenous complete extruded diets with different crude fat to N-free extract (CF/NFE) ratio were tested in tank-cultured juvenile shi drum, in order to assess rearing performance and quality traits.

Materials and methods

Experimental conditions and fish

The trial took place in 2001 at "Bonello", a Veneto Agricoltura experimental centre nearby Porto Tolle (RO, Italy). On July 5th the fish were randomly divided into four groups (two groups per diet) of 210 subjects according to their weight (initial mean body weight: 83±25 g). The experimental period was 4 months long (124 days), divided into two subperiods: 1st (from 5 July to 11 September) and 2nd (from 12 September to 5 November). Shi drum were reared in 4.5 m^3 hemispheric fibreglass tanks (3.8 kg initial mean biomass/m^3) placed inside a greenhouse and supplied with a brackish water flow (on average: pH, 8.0; salinity, 30 ppt; flow rate, 1.1 $l \cdot s^{-1}$) on an open circuit. Water was continuously oxygenated by an oxygen compressor and till the end of September its temperature ranged between 19 and 30°C, then slowly dropped to 12°C in early November.

Diets and feeding

Two isonitrogenous complete extruded diets were formulated to obtain a different crude fat to N-free extract (CF/NFE) ratio: low (L) = 1.0 vs high (H) = 1.5 (Table 1).

Table 1. Formulation, chemical composition and gross energy of the experimental diets [Source: Hendrix S.p.A. (Skretting)]

	1st period (5 July to 11 Sept.)		2nd period (12 Sept. to 5 Nov.)	
	Low_1 diet	$High_1$ diet	Low_2 diet	$High_2$ diet
	CF/NFE = 1.1	CF/NFE = 1.5	CF/NFE = 1.0	CF/NFE = 1.5
Formulation (g/kg diet)				
Fish meal	545	550	475	480
Fish oil	150	180	165	205
Soybean meal	130	125	160	155
Wheat products	155	125	180	140
Vitamin-mineral mix	20	20	20	20
Chemical composition (% DM)				
Crude protein	48.7	48.2	46.5	46.1
Crude fat	21.1	24.0	21.7	26.5
N-free extract†	18.7	16.3	21.4	17.1
Ash	11.1	11.1	10.0	9.9
Crude fibre	0.4	0.4	0.4	0.4
Gross energy†† (MJ/kg DM)	22.8	23.4	23.0	24.0

†Calculated by: NFE = 100 – (CP+CF+ash+crude fibre).
††Calculated by (kJ/g): CP, 23.6; CF, 38.9; NFE, 16.7.

Samples of diets were analysed for chemical composition according to AOAC (1990): moisture, crude protein (CP: N-Kjeldhal·6.25), crude fat (CF: Soxhlet, diethyl ether) and ash. Crude fibre was analysed by ANKON methodology and NFE was calculated by difference as well as gross energy by energetic coefficients (kJ/g) according to Miglavs and Jobling (1989): CP, 23.6; CF, 38.9; NFE, 16.7. Except when they showed no more interest in food after eating any ration, fish were fed four times a day, seven days a week, to a daily 2% rate of the mean biomass. Each diet was slowly handfed to meet appetite and to minimise loss due to uneaten feed. Feed intake was daily recorded.

Working methods

At the end of each experimental subperiod, anaesthetised (2-phenoxy-ethanol, 200 ppm) fish were weighted in groups. The effect of CF/NFE ratio on performance was evaluated by calculating weight gain, specific growth rate (SGR), daily intake rate (DIR) and food conversion ratio (FCR). In addition, feed utilization efficiency was estimated by gross energy retention (GER) and gross protein retention (GPR) or protein productive value (PPV). At the beginning of the trial, on September 11th (1^{st} period) and on November 5th (2^{nd} period), samples of reared fish were sacrificed and submitted to morphometric, chemical and rheological analysis. Data of standard length (from extreme muzzle to the insertion of the tail fin) and total weight as well as viscera, liver, perivisceral (mesenteric + perinephric) fat weights were recorded and then used to calculate condition factor and hepatosomatic, viscerasomatic as well as perivisceral fat indexes (Fig. 1). After freeze-drying and grinding, chemical composition of whole body and fillet (dorsal white muscle) was determined as described for diets. Whole body gross energy was also calculated by the same energetic coefficients used with diets. After exposition to air (1 h, 2°C), fillet (dorsal portion) colour was measured by CR100 (Minolta, camera Co. Ltd, Japan) chromameter set on average daylight illumination (source '*C*') and data were expressed by Hunter-L*a*b* system (Mc Dougall, 1976). Cooking weight loss was determined on gutted trunk after heating procedure (adapted from Joseph, 1979). Trunks were cooked into polyurethane bags in a thermostatic bath (25 minutes, 75°C) and then cooled (50 minutes, running cold water). Warner-Bratzler (WB) max shear force (MSF) measurements were performed on cylindrical cores (n = 5 per fish) cut from the dorsal fillets of the cooked trunks. Cores had a 1.25 cm-diameter and their height corresponded to the fillet thickness; cuts were done perpendicularly to the muscle long axis; shear force was expressed in Newton (N).

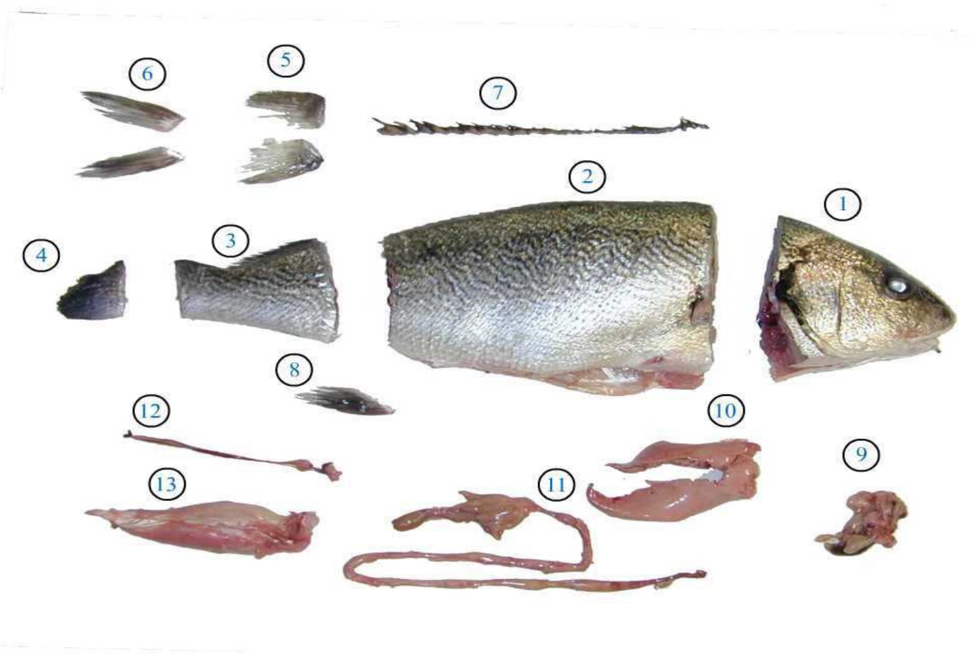

Fig. 1. Shi drum dissection regions along reference points and organs. Legend: 1, head; 2, trunk; 3, tail peduncle; 4, tail fin (incomplete because of microbial erosion); 5, breast fins; 6, abdominal fins; 7, trunk dorsal fin; 8, anal fin; 9, mesenteric fat; 10, bilobate liver; 11, viscera (duct + spleen); 12, gonads; 13, perinephric fat.

The feeding trial was designed according to a factorial design with two levels of the diet factor and two replicates for level. All variables were checked for normality and variance homogeneity. The variance analysis (ANOVA) was supported by general linear model (GLM) procedure of SAS (1999).

Results and discussion

Growth and feed efficiency

Within the range of environmental temperature recorded shi drum showed a normal feeding behaviour and a physiological surviving rate, especially for higher one (30-32°C). The effect of the dietary CF/NFE ratio on weight gain, specific growth rate (SGR), food conversion ratio (FCR) and daily intake rate (DIR) were reported in Table 2. The best weight gain was obtained by the diet with the low CF/NFE ratio (L-diet) because of its higher SGR (1.28 vs 1.23 %/d; P<0.01) and lower FCR (1.33 vs 1.61; P<0.1). The best performances were due to L-diet (L_1 and L_2) also referring to the two subperiods of the trial (Table 3).

Table 2. Effect of dietary CF/NFE ratio on rearing performance and feed efficiency referred to the overall trial (5 Jul. – 5 Nov.)

	L-diet	H-diet	P	SEM
	CF/NFE = 1.0	CF/NFE = 1.5		
Initial body weight (g)	83.1	82.8	ns	0.3
Final body weight (g)	401.1	374.2	**	2.8
Weight gain (g/fish)	318.1	291.4	**	2.5
Specific growth rate (%/d)	1.28	1.23	***	0.01
Offered feed (g/fish)	421.6	412.0	ns	3.0
Food conversion rate	1.33	1.41	*	0.02
Daily intake rate (%/d)	1.42	1.47	ns	0.02
Gross energy retention† (%)	32.1	30.0	ns	1.2
Gross protein retention†† (%)	30.8	27.8	*	0.7

*P<0.1; **P<0.05; ***P<0.01 [Data represent means of 2 replicates (200 fish/replicate)].
†GER: Gross energy retention = (fish energy gain, kJ) / (energy intake, kJ) · 100.
††GPR: Gross protein retention = (fish protein gain, g) / (protein intake, g) · 100.

Table 3. Effect of CF/NFE ratio on rearing performance and feed efficiency in the 1st and 2nd period

	1st Period (5 July to 11 Sept.)				2nd Period (12 Sept. to 5 Nov.)			
	L_1-diet	H_1-diet	P	SEM	L_2-diet	H_2-diet	P	SEM
	CF/NFE = 1.1	CF/NFE = 1.5			CF/NFE = 1.0	CF/NFE = 1.5		
IBW (g)	83.1	82.8	ns	0.3	252.9	244.5	**	0.9
FBW (g)	252.9	244.5	**	0.9	401.1	374.2	**	2.8
WG (g/fish)	169.8	161.2	**	0.9	148.3	129.7	**	2.6
SGR (%/d)	1.64	1.59	**	0.01	0.84	0.77	*	0.01
OF (g/fish)	185.9	185.3	ns	0.3	235.7	226.6	ns	2.8
FCR	1.09	1.15	**	0.01	1.59	1.75	*	0.04
DIR (%/d)	1.63	1.67	**	0.01	1.31	1.33	ns	0.02
GER (%)	39.9	36.3	***	0.1	25.9	25.0	ns	2.0
GPR (%)	35.7	33.8	ns	0.8	26.8	22.7	ns	1.7

See Table 2 for acronyms. *P<0.1; **P<0.05; ***P<0.01 [Data represents means of 2 replicates (200, 188 fish/replicate)].

The feed efficiency was affected by dietary CF/NFE according to different patterns among experimental periods (Tables 2 and 3). With reference to the overall experimental period feed efficiency was influenced by dietary treatments only for gross protein retention (GPR) with the best result corresponding to the L-diet (30.8 vs 27.8%; P<0.1). Moreover, if we consider each subperiod of the trial, data on feed efficiency showed instead only a significant higher dietary energy retention (GER) with L_1-diet than with H_1-diet in the smallest fish (39.9 vs 36.3%; P<0.01).

In relation to the overall feeding period, probably fish fed with L-diet grew more than H-fed fish because of more efficient utilization of crude protein. On the basis of experimental data reached in the present study it is not possible to detect if this result was due to the different CF and/or NFE levels of the two checked diets. In juvenile red drum (*Sciaenops ocellatus*), another Sciaenidae, Craig *et al*. (1999) found a decrease in weight gain when fish were fed diets with more than 14% lipid on a dry-weight basis. Shi drum could also be a species not tolerating high dietary lipid concentrations, according to the results of the present trial with higher CF diet (>24% DM). The best performances, reached with L-diet were probably due to a partial substitution of some crude fat with NFE as an energetic source, that could have improved the anabolic use of dietary crude protein. Energy from carbohydrates is available in a longer time than that one from lipids; so a greater inclusion of this feed source could result in a better protein sparing effect. L-diet fed fish showed both higher gross protein retention and higher whole body crude protein content (Table 4). This may also explain the better weight gain of L-diet because protein tissue (muscle) has a higher moisture content (water holding capacity) than the lipid one.

Table 4. Effect of CF/NFE on whole body chemical composition and gross energy (/100 g wet weight)

	5 July	11 September				5 November			
		L_1-diet	H_1-diet	P	SEM	L_2-diet	H_2-diet	P	SEM
		CF/NFE = 1.1	CF/NFE = 1.5			CF/NFE = 1.0	CF/NFE = 1.5		
Moisture (g)	68.5 ± 0.8	66.1	66.2	ns	0.4	66.3	65.5	*	0.3
Crude protein (g)	18.7 ± 1.0	17.9	17.6	ns	0.1	18.0	17.4	**	0.1
Crude fat (g)	7.6 ± 1.0	11.1	10.8	ns	0.5	11.3	12.1	*	0.3
Ash (g)	4.3 ± 0.6	3.8	4.1	ns	0.1	3.7	4.0	**	0.1
NFE† (g)	0.9 ± 0.1	1.1	1.3	ns	0.2	0.8	1.0	ns	0.1
GE†† (kJ)	754 ± 29	873	857	ns	19	876	898	ns	12

*P<0.1; ** P<0.01 [Data represent means of 24 fish (12 fish/tank) except for 5 Jul. (6 fish/tank)].
†Calculated as complement to 100.
††Gross energy, calculated by (kJ/g): CP, 23.6; CF, 38.9; NFE, 16.7.

Quite apart from the effects due to the different tested CF/NFE ratios, shi drum showed good performance if compared to other common marine cultured species (Company *et al*., 1999). On average this Sciaenidae respectively showed over 1st and 2nd feeding subperiod a weight gain of 166 and 139 g, a FCR of 1.12 and 1.67, a GER of 38.1 and 25.5%, a GPR of 34.8 and 24.8%. So, rearing performances were better in the former subperiod, corresponding to the youngest animals, than in the latter one. Decreased efficiency of feed utilization can be explained by environmental factors, such as the lowering of the water temperature. In addition, fish lipids storage was greater in absolute term in the last part of the experimental feeding period: whole body CF content was on average below 10% over 1st subperiod and upper 11% over the 2nd one (Table 4).

Whole body chemical composition

Chemical composition of fish was influenced by dietary treatments only during the 2nd experimental subperiod (Table 4). At the end of trial, whole body proximate composition of the L-diet fish fed was characterized by higher value of crude protein than fish fed the H-diet (18.0 vs 17.4%; P<0.01), while crude fat (11.3 vs 12.1%; P<0.1) and ash (3.7 vs 4.0%; P<0.01) contents were lower in L-fish. As with other marine fish species (Craig *et al*., 1999; Company *et al*., 1999), this research pointed out that an increase in dietary fat content generally resulted in a raised body lipids deposition. Shi drum evidenced a rather low whole body lipid (ether extract) content if compared with cultured fish of similar size (350-400 g) and fed diet with 22-26% crude fat level such as European sea bass (Lanari *et al*. 1999; Segato *et al*., 2002) and gilthead sea bream (Vergara *et al*., 1999). The result regarding the lower ash content in L-fish, can be explained considering that after the juvenile phase the percentage of mineral elements seems to decrease more and more as muscle mass weight increases faster than length does (Shearer, 2001). In fact, in the present research trunk fillet weight was higher for L-diet fed fish (Table 5).

Table 5. Effect of CF/NFE ratio on morphometric traits, proximate composition (g/100 g wet weight) of fillet (dorsal white muscle) at the end of trial

	5 July	5 November			
		L_2-diet	H_2-diet	P	SEM
		CF/NFE = 1.0	CF/NFE = 1.5		
Morphometric traits (n)†		(36)	(36)		
Standard length (cm)	16.0 ± 0.9	26.8	26.3	ns	0.3
Trunk fillet (g)	29.9 ± 4.7	172.2	163.2	*	2.6
Condition factor†† (100 g/cm^3)	1.96 ± 0.13	2.17	2.23	ns	0.07
Hepatosomatic index (%)	1.9 ± 0.3	2.8	2.8	ns	0.1
Viscerasomatic index††† (%)	2.0 ± 0.2	1.4	1.6	*	0.1
Perivisceral fat index†††† (%)	0.8 ± 0.3	3.5	3.5	ns	0.1
Fillet proximate composition (n)		(12)	(12)		
Moisture (g)	-	75.2	75.9	*	0.2
Crude protein (g)	-	21.2	20.6	**	0.1
Crude fat (g)	-	1.9	1.8	ns	0.1
Ash (g)	-	1.3	1.3	ns	0.1

*P<0.05; **P<0.01.
†n: Number of fish per level.
††Referred to standard length.
†††Viscera = duct + spleen.
††††Perivisceral fat = mesenteric fat + perinephric fat.

Quality traits

Morphometric traits and indexes were not influenced by diets, except for fillet weight and viscerasomatic index (VSI) (Table 5). Particularly, L-diet fed fish showed lower VSI value than H-fish (1.4 vs 1.6%; P<0.05). This data is in (apparent) contrast with the results found by Lanari *et al.* (1999) and Jover *et al*. (1999) which observed in European sea bass and Mediterranean yellowtail respectively a significant decrease of VSI values in fish fed with increasing dietary crude fat level. However, Lanari *et al.* (1999) observed a significant increase of VSI value for decreasing dietary NFE level too. Moreover, the percentage of viscera seems to be negatively correlated with the growth rate.

Proximate composition of fillet (dorsal white muscle) is reported in Table 5. As dietary CF/NFE ratio increased, crude protein content of muscle decreased while moisture increased; instead lipids (ether extract) of this portion of fillet were similar between L and H thesis. In this sense, neither perivisceral nor intramuscular fat was affected by dietary treatments. So the higher CF content observed in whole body H-diet fed fish (Table 4) is probably due to a storage of lipids in other organs (i.e. liver) and/or tissues (subcutaneous or intermuscular adipose tissue). However, lipids content of trunk flesh was also the same in the two fish groups (4.3 vs 4.5%; P>0.1; not tabulated). Thus, the levels of dietary CF tested in this research seemed not to be able to enhance the lipid content of dressed carcass (gutted trunk) while they could increase the liver lipid as a result of nutritional imbalance (Vergara *et al*., 1999; Craig *et al*., 1999).

Dorsal raw fillet colour was not affected by dietary treatments (Table 6). Texture properties (cooked trunk loss, maximum shear force of cooked fillet) were also not influenced by dietary treatments. Rheological parameters seemed not to be affected by feed CF and NFE content, probably because the diet with the highest fat level (H-diet) was not able to modify flesh lipid amount (Torrisen *et al*., 2001; Segato *et al*., 2003).

Table 6. Effect of CF/NFE ratio on raw fillet colour, cooked loss of trunk and max shear force (MSF) of cooked fillet at the end of trial (n = 12)

	5 July	5 November			
		L_2-diet	H_2-diet	P	SEM
		CF/NFE = 1.0	CF/NFE = 1.5		
Raw fillet colour					
Lightness (L*)	45.9 ± 1.9	43.6	43.1	ns	0.6
Redness (a*)	3.2 ± 0.7	0.1	0.3	ns	0.1
Yellowness (b*)	0.1 ± 0.6	-4.1	-3.8	ns	0.2
Texture properties					
Cooked trunk loss (%)	-	12.5	11.8	ns	0.9
MSF cooked fillet (N)	-	5.9	6.0	ns	0.3

Conclusions

The present research indicates shi drum as a good candidate for Mediterranean marine aquaculture because of its rearing performance, also obtained by diets formulated on the basis of nutritional requirements of other species (European sea bass and gilthead sea bream). The most efficient dietary CF/NFE ratio, obtained with 18-22% both of crude fat and non-structural carbohydrates (N-free extract), was able to maximize the use of feed energy and protein to plastic growth as values of gross protein retention showed. Furthermore, the diet with lowest CF/NFE ratio (1.0) showed the highest specific growth rate (SGR) and the lowest food conversion ratio (FCR). Differences between checked diets were not able to affect the main tested quality traits, except for whole body lipid (ether extract) content and fillet weight. The higher body lipid content, obtained when fish were fed the diet with the highest CF/NFE ratio (1.5), did not influenced neither intramuscular (dorsal fillet) nor intermuscular (flesh) fat storage. So, rheological properties (fillet colour and tenderness) probably were not affected by different CF/NFE ratios. In short, diet with higher fat substitution with non-structural carbohydrates may be performed in future trials, even if this kind of formulation could determine some trouble in the extrusion process regarding physical characteristics (sinking) of the pellet.

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