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ABSTRACT

A control diet (C) containing animal protein (mainly fish meal) was compared with 6 experimental diets containing different plant proteins (soybean meal, SM; rapeseed meal, RM; potato protein concentrate, PPC and a mix of the three vegetable protein sources, M). The plant protein replaced either 25 (1) or 50 (2)% of the animal protein with the exception of diet RM2 where the substitution rate was lowered to 35%, and in diet M where 55% of the total protein given was replaced in equal amounts by the three plant proteins. For the growth trial, which lasted 97 days, 528 European sea bass (initial live weight 107 ± 0,06g), distributed among 24 fibreglass tanks with three replicates per treatment, were used. The pelleted feed was distributed 5 times per day using an automatic dispenser. Energy, crude protein and crude fat digestibility values for fish meal and soybean meal were similar and not statistically different while the values for rapeseed meal and potato protein concentrate were significantly lower. Digestive utilization for NFE was higher in fish meal and decreased significantly in soybean meal, rapeseed meal and even more noticeably in potato protein concentrate. Diet digestibility values showed a similar trend with a clear worsening effect at the higher inclusion rates used. Diet M gave digestibility coefficients lower than those observed with diets C, SM_1, SM_2, RS_1 and RS_2 and higher than those of diets PPC_1 and PPC_2. Fish fed a diet in which 25% of the total protein was replaced by soybean had similar performances to those of the control group. On the other hand, sea bass fed diets SM_2, RS_1, RS_2 and M had lower growth rates and worse feed utilization than those observed with the control. Finally, specific growth rates and food conversion efficiency in sea bass fed diets containing potato protein concentrate were poor because of the low palatability. These results show that soybean meal can substitute up to 25% of the total protein of the diet without any negative effect on sea bass performance.

Key Words: Seabass, Alternative proteins, Nutrition.

RIASSUNTO
FONTI PROTEICHE ALTERNATIVE (FARINA DI SOIA, FARINA DI COLZA E CONCENTRATO PROTEICO) NELLE DIETE PER SPIGOLE

Una dieta di controllo costituita in prevalenza da farina di pesce venne confrontata con 6 diete sperimentali che contenevano diverse proteine vegetali (farina di soia, FS; farina di colza, FC e concentrato proteico di patata, PPC) e una dieta (M), dove vennero usate le tre farine proteiche vegetali. Le proteine di origine vegetale sostituivano il 25 (1) o il 50 (2)% delle proteine animali con l'eccezione di FC_2 dove la sostituzione era del 35% e della dieta M dove il 55% della proteina animale era sostituito in quote uguali dalle tre farine proteiche vegetali. Vennero utilizzati per la prova 528 branzini del peso vivo iniziale di 107± 0,06g distribuiti in 24 vasche con tre repliche per tesi. L'alimento veniva distribuito 5 volte al giorno per mezzo di un distributore automatico. La prova ebbe una durata di 97 giorni. La digeribilità dell'energia, della proteina grezza e dell'estratto etereo della farina di pesce e della farina di soia risultarono molto simili mentre i valori decrebbero significativamente nella farina di colza e ancor di più nel concentrato proteico di patata. L'utilizzazione digestiva degli estrattivi inazotati risultò più alta nella farina di pesce, diminuì nella soia e nella colza e ancor di più nel con-

centrato proteico di patata. I valori della digeribilità delle diete evidenziarono un comportamento simile con peggioramenti più marcati ai tassi di inclusione più elevati. La dieta M fece registrare valori di digeribilità leggermente superiori alle diete PPC_1 e PPC_2. I pesci che ricevevano le diete dove il 25% della proteina era sostituita dalla farina di soia ebbero delle performance simili a quelle rilevate con la dieta controllo. D'altro canto, con le diete FS_2 e FC_1 ed M i branzini evidenziarono tassi di accrescimento più bassi e peggiori indici di conversione rispetto al controllo ed alla dieta FS_1. Infine, i tassi di accrescimento dei pesci alimentati con le diete che contenevano il concentrato proteico di patata risultarono molto bassi ed addirittura negativi nella dieta PPC2 a causa della sua limitata appetibilità. I risultati della presente ricerca hanno evidenziato che la farina di soia può sostituire efficacemente il 25% delle proteine di origine animale.

Parole chiave: *Spigola, Proteine alternative, Nutrizione.*

Introduction

Traditionally, fish meal is used in fish diets as the main protein source. In recent years, the increasing cost of this raw material in relation to its decreasing availability on the market and sometimes the rather poor quality of the product has stimulated several studies on its partial or complete substitution with alternative protein sources (Alliot *et al.*, 1979; Martinze *et al.*, 1988; Kaushik *et al.*, 1995; Watanabe *et al.*, 1997; Cheng *et al.*, 2000; Gouveia and Davis, 2000; Fournier *et al.*, 2004). *Leguminosae* seeds and their by-products, among which soybean and rapeseed meals, in particular, are widely used in animal nutrition because of their high protein content (40-50%) low cost and relative availability. The nutritive value of a plant depends upon its chemical composition, the content of essential amino acids, carbohydrates, minerals and their availability to fish during the metabolic process.

Among the several factors that can influence the digestion and absorption of nutrients, the presence of anti-nutritional substances is particularly relevant in the case of *leguminosae* seeds. Recent studies have shown that some by-products of soybean, although subjected to heat treatment, can show a residual anti-nutritional activity that reduces the activity of digestive enzymes and, therefore, the growth of fish (Alarcon *et al.*, 1999).

The results of several trials reported in literature on the substitution of fish meal with soybean meal in fish diets are discordant as far as the optimal rate of substitution. Growth performances and digestibility coefficients of single raw materials vary in relation to fish species, fish size and chemical characteristics of the other ingredients. Olli *et al.* (1994) used soybean meal at several substitution levels (0, 14, 28, 56% of dietary protein) in Atlantic salmon diets. The results showed that the substitution of fish meal with up to 56% of soybean meal did not have negative effects on fish performances, lipid deposition and nutrient digestibility. Gallagher (1994) observed that soybean meal could substitute fish meal up to 75% of the total in striped bass hybrids (*Morone sesatilis x M. chrysops*) while in sea bream diets Robaina *et al.* (1995) and Negas and Alexis (1995) did not observe any adverse effect on fish performances when using diets where 20-30% of dietary protein was given by soybean meal.

The rapeseed meal (RM) was used in Chinook salmon and tilapia diets in substitution of 20-30% fish meal (Higgs *et al.*, 1982, 1983) whereas Tibaldi *et al.* (1998) observed reduced growth performance in juvenile sea bass fed diets containing 30% of RM.

Xie and Jokumsen (1997) replaced 10, 20, 30 and 100% of the fish meal with potato protein concentrate in rainbow trout diets. These authors noticed a worsening of the productive performances with the lowest rate of substitution and observed a null growth rate with a substitution of 30%.

The scope of the present research was to evaluate the substitution of fish meal with increasing levels of several raw materials of plant origin like the soybean, rapeseed meal and potato protein concentrate in sea bass diets.

Material and methods

A total of 528 seabass (*Dicentrarchus labrax*) (initial weight: 107±0.06g) were randomly distributed among 24 fibreglass tanks (160 l) in a complete recirculated system (water salinity and temperature were, respectively, 13‰ and 22°C). Fish were fed by means of automatic dispensers, 5 times per day for 97 days, 8 isoproteic (47.8% d.m.)

and isolipidic (19.4% d.m.) diets with three replicates per treatment. The dispenses were fitted to distribute an amount close to 1% of live weight and were adjusted according to the average fish live weight. It was not possible to evaluate the amount actually ingested so the feed conversion ratio was calculated on the basis of the quantities distributed. Diets were as follows: control (C) where animal proteins (fish meal, blood meal brewer yeast) were used and seven diets (SM_1, SM_2, soybean meal; RM_1, RM_2, rapeseed meal; PPC_1, PPC_2, potato protein concentrate and M), where 57% of total protein was given by SM, RM and PPC. The animal protein substitution rate was 25 (1) and 50% (2) in all treatments with the exception of RM_2 where the substitution rate was of 35%. Fish were weighed every two weeks; mortality was recorded daily and water analysis was performed weekly. At the beginning of the experiment 20 fish were sacrificed and 12 per treatment were sacrificed at the end. To determine the apparent digestibility coefficients of single ingredients and of the experimental diets following the procedures proposed by Cho and Kausik (1990) 9 groups of fish were used. During the digestibility trial, fish were fed *ad libitum* diets containing $10g/kg^{-1}$ dm of chromium oxide. Faeces were collected for a week by means of sedimentation columns and stored according to the procedures suggested by Cho *et al.* (1982). Proximate analysis of feed, faeces and fish were performed according to A.O.A.C. (1995) and gross energy by adiabatic bomb calorimeter. The phytic acid content was determined following the methods reported by Davies and Reid (1979), TIA (trypsin inhibition factor) according to Smith *et al.* (1980), glucosinolates according to Sorensen (1990) and water analyses were carried out according to the methods reported by APHA (1980). Data were submitted to one-way ANOVA and the comparison among means was performed with the Newman-Keuls test (Snedecor & Cochran, 1982). Carcass chemical composition means were submitted to statistical analysis after adjusting them for the body weight (covariable).

Results

The chemical composition of ingredients is reported in Table 1. It should be noted that the fibre content of the rapeseed meal was quite high for an ingredient to be used in fish nutrition. The potato protein concentrate was characterized by a high protein content, close to 80%, a medium level of ash and a balanced content in phosphorus and calcium. The composition of the experimental diets are summarized in Table 2. The inclusion rate of precooked starch varied according to the characteristics of the other raw materials and limited variations were made to the fish oil added. Dietary concentrations of some anti-nutritional factors are reported in Table 3. The highest content in phytic acid (1.31% d.m.) was observed in diet RM_2 (rapeseed meal) followed by diet SM_1 and by the mixed protein diet (M). Lower values were found in the diet containing soybean meal, potato protein concentrate and control. The concentration of the trypsin inhibition factor (TIA) turned out to be

Table 1. Chemical composition of ingredients.

Ingredients	Dry matter (%)	Crude protein[1]	Ether extract[1]	Ash[1]	Crude fiber[1]	N-free extract[1]	Ca[1]	P[1]
Fish meal	93.21	75.03	11.98	11.50	1.31	-	2.93	2.36
Blood meal, spray	90.00	87.00	9.50	3.50	-	-	0.33	0.28
Soybean meal	89.44	52.93	2.20	7.02	4.72	33.13	0.34	0.60
Rapeseed meal	91.32	40.74	1.50	8.20	10.50	39.01	0.84	1.18
Potato protein concentrate	89.48	79.89	2.04	14.50	2.07	14.50	0.87	1.35
Yeast brewers	91.69	52.44	0.46	7.51	0.69	38.90	0.15	1.48
Precooked corn starch	95.00	0.30	-		-	99.70	-	-

[1]: % DM

Table 2. Composition of the experimental diets (%).

	Diets							
Ingredients	C	SM_1	SM_2	RM_1	RM_2	PPC_1	PPC_2	M
Fish meal	50	35	20	35	30	35	20	20
Blood meal, spray	5	5	5	5	5	5	5	5
Yeast brewers	5	5	5	5	5	5	5	5
Soybean meal	-	21	43	-	-	-	-	15
Rapeseed meal	-	-	-	28	39	-	-	17
Potato protein concentrate	-	-	-	-	-	14	28	18
Precooked corn starch	20	13	7	7	-	21	20	-
Fish oil	15	16	15	15	16	15	17	15
Binder	2	2	2	2	2	2	2	2
Vit-min premix	2	2	2	2	2	2	2	2
Cromium oxide	1	1	1	1	1	1	1	1

Table 3. Proximate analysis, mineral and energy content of the experimental diets.

		Diets							
Ingredients		C	SM_1	SM_2	RM_1	RM_2	PPC_1	PPC_2	M
Dry matter	%	91.4	91.0	90.7	90.8	90.6	91.2	91.5	91.6
Crude protein	% DM	46.06	47.70	48.00	47.75	49.00	47.20	48.15	48.30
Ether extract	"	20.30	20.20	18.65	19.05	20.45	18.25	19.75	18.55
Ash	"	9.90	9.10	8.00	10.55	10.65	8.10	7.95	8.25
Crude fibre	"	0.90	2.40	3.35	3.60	5.30	1.00	1.10	3.30
N-free extract	"	22.84	20.60	22.00	19.05	14.60	25.45	23.05	21.60
Ca	"	1.60	1.60	1.39	1.36	1.20	1.54	1.38	1.30
P	"	1.24	1.15	1.10	1.10	1.20	1.30	1.20	1.24
Gross energy	MJ/g DM	21.18	21.27	21.13	21.22	21.26	21.22	21.18	21.26

more elevated (0.61 g/kg) in diet SM_2 and M. Tables 5 and 6 report the apparent digestibility coefficients of energy, protein, crude fat and N–free extract of single ingredients and of the experimental diets. The apparent digestibility coefficients of energy, protein and lipid of soybean meal resulted similar to those of fish meal. In rapeseed meal, energy and N-free extract coefficients were similar to those observed in soybean meal, while significantly lower values were obtained for protein and fat. Finally, nutrient digestibility in potato concentrate was significantly lower than the other protein sources tested. Digestibility coefficients of the protein, fat and energy of the experimental diets, according to the results of the statistical analysis, can be separated into 5 groups. High values were evidenced in the control diet and SM_1 diet, intermediate in SM_2 and RM_1 treatments while lower values were observed with treatment RM_2. A further decrease in digestibility values was observed in diets PPC_1 and M and the lowest values were obtained with PPC2 diet. Growth and feed efficiency indices are summarizing in Table 7. Total growth, daily gain and specific growth were clearly influenced by dietary treatments. In particular, fish fed control and diet SM_1 had significantly bet-

Table 4. ANF's content in the experimental diets.

Diets		C	SM_1	SM_2	RM_1	RM_2	PPC_1	PPC_2	M
TIA	g/kg	-	0.30	0.61	-	-	-	0.51	0.60
Phytic acid	% DM	0.17	0.40	0.66	0.99	1.31	0.30	0.32	0.90
Glucosinolates	"	-	-	-	0.27	0.37	-	-	-

Table 5. Apparent digestibility coefficients (%) of ingredients.

	Ingredients				
Analytical parameters:	Fish meal	Soybean meal	Rapeseed meal	Potato protein concentrate	SE 20 df
Gross energy	93.50^{A}	92.59^{AB}	91.74^{B}	72.23^{C}	0.5683
Crude protein	91.38^{A}	91.00^{A}	89.75^{B}	51.60^{C}	0.6903
Ether extract	98.55^{A}	98.00^{A}	89.83^{B}	67.51^{C}	0.5167
N-free extract	-	61.33	60.16	-	-

Means within the same row not sharing a common superscript are significantly different (A,B,C: P < 0.01).
df: degree of freedom.

Table 6. Apparent digestibility coefficients of the experimental diets.

		Diets								
Analytical parameters:		C	SM_1	SM_2	RM_1	RM_2	PPC_1	PPC_2	M	SE 40 df
Gross energy	%	94.25^{A}	93.58^{AB}	92.05^{C}	92.25^{BC}	89.96^{D}	80.45^{E}	75.60^{F}	80.16^{E}	0.9656
Crude protein	"	92.25^{A}	91.35^{AB}	90.55^{B}	90.33^{BC}	89.43^{C}	57.00^{E}	55.50^{F}	85.75^{D}	0.6712
Ether extract	"	99.00^{A}	98.85^{A}	97.36^{B}	98.80^{A}	97.75^{B}	93.78^{C}	78.00^{E}	92.71^{D}	0.6485
N-free extract	"	82.50^{A}	73.38^{B}	71.63^{B}	71.16^{B}	57.50^{C}	54.50^{D}	45.10^{E}	56.16^{CD}	1.4446

Means within the same row not sharing a common superscript are significantly different (A,B,C : P < 0.01).

ter performances (P<0.01) than those obtained with the diets where 50% or 25% and 35% were substituted with soybean and rapeseed meal, respectively. With diet M, where over 50% of the total protein came from a mixture of soybean meal, rapeseed meal and potato protein concentrate, performances were lower. Fish fed diets containing potato protein concentrate (25% of substitution rate) showed a modest increase in body weight while fish fed PPC_2 diet lost weight. The result could be explained by low ingestion that could be related to the low palatability of the diet. The amount ingested by fish did not cover the maintenance requirement. The feed conversion ratio evidenced the same trend observed for growth performances (P<0.05). The value for PPC_2 was not reported as being very high as fish lost weight. Slaughter indices are reported in Table 8. The dressing percentage was significantly higher in fish fed diet PPC_2 followed by fish fed PPC_1 and by fish receiving the treatments M, SM_2, RM_1 and RM_2; the lowest values were observed in fish fed

Table 7. Growth and feed efficiency of European seabass fed the experimental diets for 97 days.

		Diets								
		C	SM_1	SM_2	RM_1	RM_2	PPC_1	PPC_2	M	SE 16 df
Initial weight	g	107.2	107.1	107.2	107.1	107.1	107.1	107.1	107.2	0.0933
Final weight	"	191.6^{A}	189.5^{A}	170.2^{C}	180.1^{B}	172.0^{C}	123.6^{E}	103.8^{F}	148.7^{D}	3.7806
SGR		0.60^{A}	0.59^{A}	0.47^{C}	0.54^{B}	0.49^{C}	0.15^{E}	-0.03^{F}	0.34^{D}	0.0224
Feeding rate	% LW	1.06	1.07	1.07	1.06	1.08	1.05	1.05	1.08	0.1123
FCR		1.69^{a}	1.73^{a}	2.16^{b}	1.88^{ab}	2.13^{b}	7.39^{d}	-	3.20^{c}	0.1936
PER		1.49^{A}	1.47^{A}	1.18^{C}	1.35^{B}	1.17^{C}	0.35^{E}	-0.07^{F}	0.78^{D}	0.0490

SGR = (ln final weight – ln initial weight) x 100 / days
FCR = (feed intake, g / fish weight gain, g)
PER = (fish weight gain, g / protein intake, g)
Means within the same row not sharing a common superscript are significantly different (A,B,C: P < 0.01; a,b: P < 0.05).

Table 8. Slaughter variables of European seabass fed the experimental diets.

		Diets								
		C	SM_1	SM_2	RM_1	RM_2	PPC_1	PPC_2	M	SE 88 df
Carcass yield	%	90.21^{F}	90.90^{EF}	92.11^{CD}	91.31^{CDE}	91.27^{DE}	93.44^{B}	94.53^{A}	92.35^{C}	0.97
Viscerosomatic index		9.79^{A}	9.10^{AB}	7.89^{CD}	8.72^{BC}	8.72^{BC}	6.64^{E}	5.47^{F}	7.65^{DE}	0.96
Mesenteric fat	%	5.98^{A}	5.40^{AB}	4.43^{BC}	5.02^{AB}	5.06^{AB}	2.70^{D}	1.37^{E}	3.91^{CD}	0.97
Hepatosomatic index		3.00^{A}	2.52^{B}	1.81^{DE}	2.35^{BC}	2.24^{BC}	2.07^{CD}	1.62^{E}	1.80^{DE}	0.36

Means within the same row not sharing a common superscript are significantly different (A,B,C: P < 0.01).

the control and SM_1 diet. These results are clearly due to the lower weight of the viscera and, particularly, of mesenteric fat and liver weight whose importance was inversely related to the dressing percentage. It is worth noting the low percentage of mesenteric fat measured in fish fed diets containing potato protein concentrate and the mixed diet M due to the low intake of these diets. The viscerosomatic index showed a trend exactly opposite to that of the carcass yield. In fact, also in this case, data can be grouped in four statistically different groups. The lowest value was observed with diets PPC_2 followed by PPC_1, M, SM_2 than RM_1, RM_2 and finally diets C and SM_1. The mesenteric fat resulted more elevated in the subjects that received diets C, SM_1, RM_1 and RM_2 without significant differences among them. In particular, the lower percentage of fat was observed in fish fed diet PPC_2. Whole body chemical composition is reported in Table 9. Final body composition was significantly modified by treatments. Dry matter content was similar in fish fed control and SM_1 slightly but significantly lower in animals receiving diets SM_2, RM_1, RM_2 and definitely lower with treatments PPC_1, PPC_2 and M. Also crude protein content was significantly modified by treatments. The highest content was observed in sea bass fed diets containing potato protein concentrate, followed by fish subjected to the mixed diet (M) and rapeseed meal protein (RM_1, RM_2) and soybean

Table 9. Whole body composition of European seabass fed the experimental diets (means adjusted for live body weight).

		Initial	Final								
			C	SM_1	SM_2	RM_1	RM_2	PPC_1	PPC_2	M	SE 87 df
Dry matter	%	39.56	40.09^{A}	39.40^{A}	37.24^{B}	37.95^{B}	38.92^{AB}	34.96^{C}	34.59^{C}	35.06^{C}	1.95
Crude protein	% DM	44.4	45.18^{C}	46.73^{BC}	45.34^{C}	47.48^{BC}	46.08^{BC}	51.00^{A}	51.78^{A}	47.94^{B}	2.29
Crude fat	"	39.5	40.17^{A}	38.51^{AB}	38.34^{AB}	35.88^{B}	38.37^{AB}	30.94^{C}	28.12^{C}	35.62^{B}	3.51
Ash	"	15.0	13.50^{CD}	12.84^{D}	14.02^{CD}	14.45^{CD}	13.42^{CD}	16.75^{B}	18.85^{A}	14.92^{C}	1.71
Gross energy	KJ g^{-1} DM	24.61	26.68A	26.20^{A}	26.23^{A}	25.77^{A}	26.49^{A}	24.83^{B}	23.96^{B}	25.94^{A}	0.97

Means within the same row not shearing a common superscript are significantly different (A,B,C: $P < 0.01$).

Table 10. Nutrient retention efficiency of seabass fed the experimental diets.

		Diets								
		C	SM_1	SM_2	RM_1	RM_2	PPC_1	PPC_2	M	SE 88 df
GER	%	33.50^{a}	29.27^{a}	22.54^{ab}	20.11^{ab}	24.46^{a}	0.44^{c}	-7.61^{c}	13.64^{b}	8.9956
GPR	"	25.01^{a}	24.54^{ab}	15.85^{de}	21.04^{bc}	18.19^{cd}	5.82^{f}	0.77^{g}	12.13^{e}	2.2188
GLR	"	49.39^{a}	38.46^{ab}	31.30^{b}	26.31^{bc}	31.39^{b}	-15.49^{d}	-28.14^{d}	13.55^{c}	8.1855
Ash	"	24.18^{a}	20.61^{ab}	21.64^{ab}	21.14^{ab}	16.75^{b}	17.41^{b}	14.15^{c}	18.31^{ab}	3.6982

GER: (fish energy gain,kJ) / (energy intake, kJ) x 100
GPR: (fish protein gain,kJ) / (protein intake, kJ) x 100
GLR: (fish lipid gain,kJ) / (lipid intake, kJ) x 100
Ash: (fish ash gain,kJ) / (ash intake, kJ) x 100
Means within the same raw not shearing a common superscript are significantly different (A,B,C: $P < 0.05$).

meal at the highest inclusion rate (SM_2). The lowest values are noted in fish receiving the control diet and soybean meal at the lowest substitution rate. Fat level was inversely related to protein content with the lowest value in sea bass fed PPC_1 and PPC_2 diets and the highest level in fish subjected control and SM_1 and SM_2 diets. Gross energy values had the same trend noted in fat content.

Discussion

Results of the present trial indicate that soybean meal can replace up to 25% of the fish meal in sea bass diets with no significant differences in growth performance compared to the control. This conclusion is in agreement with those of Cowey *et al.* (1975) for the hen-sparrow (*Pleuronectes platessa*). Authors remarked that some fish like the hen-sparrow do not appreciate a high level of vegetable protein in the diets in relation to the lower palatability. Similar results were also obtained by Viola *et al.* (1982) with carp, by Jakson *et al.* (1982) with tilapia, by El-Sayed (1994) with sea Silver bream (*Rhabdosargus saraba*), by Robaina *et al.* (1995) and Negas and Alexis (1995) with sea bream. Only a limited amount of work has been carried out on the substitution of fish meal with the soybean meal in sea bass nutrition. The optimal rate of substitution found in the present research is lower than the value reported by Gallagher (1994) in diets for hybrid striped bass where soybean meal substituted 44% of fish meal without evidencing a negative effect on the feed intake and higher than those reported by Alliot *et al.* (1979) which ranged between 5 and 15%. The results reported in literature for rapeseed meal, like those for the soybean meal, vary in relation to the species, fish size and plant variety. Growth performances obtained with diets containing 25% rapeseed meal turned out lower than those found with the control diet and the diet containing 25% of SM. These results are in contrast to the conclusions of Yurowski *et al.* (1978) and Higgs *et al.* (1982, 1983) on the utilization of rapeseed meal in tilapia diets. In fact, in their experiments rapeseed meal was substituted to levels that comprised between the 20 and 25% of the protein without a negative effect on fish growth and digestibility. With diet M, the increase in weight of the fish was very modest. The low rate of growth is probably imputable to the presence of the PPC. Fish fed diet PPC_1 evidenced a modest growth rate while using diet PPC_2 the growth rate was negative. Only limited research has been carried out on the utilization of this product in fish nutriton. Xie and Jokumsen (1997) replaced fish meal in rainbow trout diets with 10, 20, 30 and 100% of potato protein concentrate. These authors noticed a worsening of the productive performance with the lowest rate of substitution and observed a null growth rate with a substitution of 30%. Parova and Par (1979) reported that the use of diets containing 10% of PPC did not determine a negative effect on growth and health of carps. Results of this study have clearly showed that this product cannot be used in sea bass nutrition because of the low palatability.

Slaughter indices were significantly influenced by the experimental diets. Carcass yield was higher with treatment PPC_2 and PPC_1 followed by diet M, then diets RM_1, RM_2 and SM_2, finally the control and diet SM_1. This result is not surprising because of the high correlation with the amount of mesenteric fat deposited that showed an opposite trend. These observations are in agreement with those of Ballestrazzi *et al.* (1994) and Ballestrazzi and Lanari (1996). Moreover, other authors have confirmed the increase of the mesenteric fat with increasing feed intake levels (Watanabe *et al.*, 1993). The viscerosomatic index showed a similar trend observed for the mesenteric fat. Fish fed diets containing PPC evidenced a significant decrement of the hepatosomatic index in relation to the utilization of glycogen, stored as an energy source.

Effects of the experimental diets on protein body concentrations were very small with the exception of fish fed diet SM_2 which showed a significant difference compared to the other treatments. Body fat content evidenced a lower value in fish fed diets containing potato protein concentrate compared to the other diets. The low percentage of fat stored with PPC diets is due to the limited ingestion of the feed or to a probable use of the body fat like an energy source. Other authors reported that the percentage of body fat is positively correlated with the dietary energy and the ration level (Cowey and Sargent, 1972; Pandian and Raghaman, 1972; Papoustsoglou and Papaparaskeva-Papoustsoglou, 1978; El Sayed, 1994). According to several reports (Olli *et al.*, 1994; Robaina *et al.*, 1995), soybean seeds contain various anti-nutritional factors such as the antitrypsin and antichimotrypsin factors, lectine, oligosaccharides of low digestibility and a low level of metionine. In the present study, the value of TIA in the soybean meal was low indicating a reduced antitrypsin activity. It is not clear, therefore, which factor was responsible for the reduced growth of fish fed diets containing 50% vegetable protein even if the presence of oligosaccharides and fibres of low digestibility have certainly exercised a negative effect. The genetic improvement of some rapeseed varieties in recent decades has reduced the necessity to use the heat treatments on these meals in order to eliminate the glucosinolates and hastened the introduction of new varieties in fish nutrition. Results of the present experiment have shown that the rate of growth of the diet where the rapeseed meal replaced 25% or 35% of the protein was significantly lower than the control diet. The reduction of growth rate is probably due to the presence in these diets of a residual amount of glucosinolates or a high fibre content. This phenomenon was also observed in other species like chinook salmon and tilapia (Higgs *et al.*, 1982, 1983). In this case the low growth was attributed to the presence of glucosinolates or to the inactivation of mironase enzyme.

Conclusions

Results of the present experiment are in agreement with the observations reported by other authors. Soybean meal can substitute up to 25% of the total protein of the diet without any negative effect on sea bass performance.

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