Alternative plant protein sources in sea bass diets

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To cite this article: Domenico Lanari & Edo D'Agaro (2005) Alternative plant protein sources in sea bass diets, Italian Journal of Animal Science, 4:4, 365-374, DOI: 10.4081/ijas.2005.365

To link to this article: https://doi.org/10.4081/ijas.2005.365
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, SM1, SM2, RS1 and RS2 and higher than those of diets PPC1 and PPC2. 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 SM2, RS1, RS2 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.
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 saxatilis* 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 (SM1, SM2, soybean meal; RM1, RM2, rapeseed meal; PPC1, PPC2, 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 RM2 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 RM2 (rapeseed meal) followed by diet SM1 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

| Ingredients | Dry matter (%) | Crude protein | Ether extract | Ash | Crude fiber | N-free extract | Ca | P |
|-------------|----------------|---------------|---------------|-----|-------------|----------------|----|----|
| Fish meal   | 93.21          | 75.03         | 11.98         | 11.50| 1.31        | -              | 2.93| 2.36|
| Blood meal, spray | 90.00      | 87.00         | 11.50         | 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          | -   | -  |

\*: % DM
more elevated (0.61 g/kg) in diet SM₂ 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 SM₁ diet, intermediate in SM₃ and RM₁ treatments while lower values were observed with treatment RM₂. A further decrease in digestibility values was observed in diets PPC₁ 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 SM₁ had significantly bet-

| Diets | Ingredients | C | SM₁ | SM₂ | RM₁ | RM₂ | PPC₁ | PPC₂ | 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 | 14 | 18 |
| Fish oil | 15 | 16 | 15 | 15 | 15 | 17 | 15 |
| Binder | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Vit-min premix | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Chromium oxide | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| Diets | Ingredients | C | SM₁ | SM₂ | RM₁ | RM₂ | PPC₁ | PPC₂ | 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 |
Table 4. ANF’s content in the experimental diets.

| Diets       | C  | SM1 | SM2 | RM1 | RM2 | PPC1 | PPC2 | M  |
|-------------|----|-----|-----|-----|-----|------|------|----|
| TIA         | -  | 0.30| 0.61| -   | -   | 0.51 | 0.60 |    |
| Phytic acid | %  | 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               | Gross energy | Crude protein | Ether extract | N-free extract |
|---------------------------|--------------|---------------|---------------|----------------|
| Analytical parameters:    |              |               |               |                |
| Fish meal                 | 93.50        | 92.59         | 91.74         | 72.23          |
| Soybean meal              | 92.59        | 90.55         | 89.75         | 67.51          |
| Rapeseed meal             | 91.74        | 90.33         | 89.43         | 57.00          |
| Potato protein concentrate| 72.23        | 89.43         | 89.75         | 55.50          |
| Potato protein concentrate| 0.5683       | 0.6903        | 0.5167        |                |

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   | SM1  | SM2  | RM1  | RM2  | PPC1 | PPC2 | M  | SE |
|-------|-------------------------|-----|------|------|------|------|------|------|----|----|
|       |                         |     |      |      |      |      |      |      |    |    |
|       |                         | %   | 94.25| 93.58| 92.05| 92.25| 89.96| 90.45| 75.60| 80.16| 0.9656|
|       |                         | 92.59| 91.35| 90.55| 90.33| 89.43| 89.75| 85.75| 67.51| 55.50| 0.6712|
|       |                         | 91.74| 90.33| 89.75| 89.43| 89.75| 85.75| 85.75| 67.51| 55.50| 0.6712|
|       |                         | 72.23| 89.43| 89.75| 85.75| 85.75| 85.75| 85.75| 67.51| 55.50| 0.6712|
|       |                         | 0.5683| 0.6903| 0.5167| 0.6712| 0.6485| 0.6712| 0.6712| 1.4446|  |

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

Mater 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% substitution rate) showed a modest increase in body weight while fish fed PPC2 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 PPC2 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 PPC2 followed by fish fed PPC1 and by fish receiving the treatments M, SM2, RM1 and RM2; the lowest values were observed in fish fed
the control and SM1 diet. These results are clearly
due to the lower weight of the viscera and, partic-
ularly, 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 con-
taining potato protein concentrate and the mixed
diet M due to the low intake of these diets. The vis-
cerosomatic 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 dif-
ferent groups. The lowest value was observed with
diets PPC2 followed by PPC1, M, SM2 than RM1,
RM2 and finally diets C and SM1. The mesenteric
fat resulted more elevated in the subjects that
received diets C, SM1, RM1 and RM2 without sig-
nificant differences among them. In particular, the
lower percentage of fat was observed in fish fed
diet PPC2. 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 SM1
slightly but significantly lower in animals receiv-
ing diets SM2, RM1, RM2 and definitely lower with
treatments PPC1, PPC2 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, fol-
lowed by fish subjected to the mixed diet (M) and
rapeseed meal protein (RM1, RM2) and soybean

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

| Diets | C        | SM1      | SM2      | RM1      | RM2      | PPC1     | PPC2     | M        | SE |
|-------|----------|----------|----------|----------|----------|----------|----------|----------|----|
|       | 107.2    | 107.1    | 107.2    | 107.1    | 107.1    | 107.1    | 107.1    | 107.2    |    |
| Initial weight |         |          |          |          |          |          |          |          |    |
| Final weight  | 191.6    | 189.5    | 170.2    | 180.1    | 172.0    | 136.2    | 103.8    | 148.7    |    |
| SGR          | 0.60     | 0.59     | 0.47     | 0.54     | 0.49     | 0.15     | 0.03     | 0.34     |    |
| Feeding rate  | 1.06     | 1.07     | 1.07     | 1.06     | 1.08     | 1.05     | 1.05     | 1.08     |    |
| FCR          | 1.69     | 1.73     | 2.16     | 1.88     | 2.13     | 7.39     | -        | 3.20     |    |
| PER          | 1.49     | 1.47     | 1.18     | 1.35     | 1.17     | 0.35     | -0.07    | 0.78     |    |

SGR = \((\text{ln final weight} - \text{ln initial weight}) \times 100 / \text{days})
FCR = (\text{feed intake, g} / \text{fish weight gain, g})
PER = (\text{fish weight gain, g} / \text{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          | SM1        | SM2        | RM1        | RM2        | PPC1       | PPC2       | M         | SE |
|-------|------------|------------|------------|------------|------------|------------|------------|-----------|----|
|       | 90.21      | 90.90      | 92.11**    | 91.31**    | 91.27**    | 93.44**    | 94.53**    | 92.35**   |    |
| Carcass yield |        |           |            |            |            |            |            |           |    |
| Viscerosomatic index | 9.79     | 9.10**    | 7.89**    | 8.72**    | 8.72**    | 6.64**    | 5.47**    | 7.65**    |    |
| Mesenteric fat | 5.98**    | 5.40**    | 4.43**    | 5.02**    | 5.06**    | 2.70**    | 1.37**    | 3.91**    |    |
| Hepatosomatic index | 3.00**   | 2.52**    | 1.81**    | 2.35**    | 2.24**    | 2.07**    | 1.62**    | 1.80**    |    |

Means within the same row not sharing a common superscript are significantly different (A,B,C: P < 0.01).
meal at the highest inclusion rate (SM2). 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 PPC1 and PPC2 diets and the highest level in fish subjected control and SM1 and SM2 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

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

|          | Initial | Final |
|----------|---------|-------|
|          | C       | SM1   | SM2   | RM1   | RM2   | PPC1  | PPC2  | M SE 87 df |
| Dry matter |         |       |       |       |       |       |       |       |
| %        | 39.56   | 40.09 | 39.40 | 37.24 | 37.95 | 38.92 | 34.96 | 34.59 | 35.06 | 1.95 |
| Crude protein |         |       |       |       |       |       |       |       |       |
| % DM     | 44.4    | 45.18 | 46.73 | 45.34 | 47.48 | 46.08 | 51.00 | 51.78 | 47.94 | 2.29 |
| Crude fat | *       | 39.5  | 40.17 | 38.51 | 38.34 | 35.88 | 38.37 | 30.94 | 28.12 | 35.62 | 3.51 |
| Ash      | *       | 15.0  | 13.50 | 12.84 | 14.02 | 14.45 | 13.42 | 16.75 | 18.85 | 14.92 | 1.71 |
| Gross energy | KJ g-1 DM | 24.61 | 26.68 | 26.20 | 26.23 | 25.77 | 26.49 | 24.83 | 23.96 | 25.94 | 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       | SM1  | SM2  | RM1  | RM2  | PPC1  | PPC2  | M SE 88 df |
|-------|---------|------|------|------|------|-------|-------|-----------|
| GER % | 33.50   | 29.27 | 22.54 | 20.11 | 24.46 | 0.44  | -7.61 | 13.64 | 8.9956 |
| GPR   | 25.01   | 24.54 | 15.85 | 21.04 | 18.19 | 5.82  | 0.77  | 12.13 | 2.2188 |
| GLR   | 49.39   | 38.46 | 31.30 | 26.31 | 31.39 | -15.49 | -28.14 | 13.55 | 8.1855 |
| Ash   | 24.18   | 20.61 | 21.64 | 21.14 | 16.75 | 17.41 | 14.15 | 18.31 | 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).
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 PPC1 evidenced a modest growth rate while using diet PPC2 the growth rate was negative. Only limited research has been carried out on the utilization of this product in fish nutrition. 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 PPC2 and PPC1 followed by diet M, then diets RM1, RM2 and SM2, finally the control and diet SM1. 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 SM3 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 Raghman, 1972; Papoustsoglou and Paparakaske-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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