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# Evaluation of different pressed and extruded fish meal based diets on the growth of gilthead sea bream, *Sparus aurata* L.

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**SUMMARY** - An experimental feeding trial was conducted concerning the effect of different sources of fish meal and feed manufacturing processes on the growth of gilthead sea bream, *Sparus aurata*. The feeding trial was conducted within indoor experimental tanks over a period of fourteen weeks using 60g juvenile gilthead sea bream. The fish were fed four different fish meal based diets, namely Chilean, Danish, Danish Aqua and Danish Low Temperature fish meals. Each formulation was processed by two forms of pellet manufacture, namely steam pressing and extrusion, giving a total of eight different feeds. A control pressed standard commercial diet was also given as the ninth diet. Fish fed the extruded feed were found to have performed better than the corresponding steam pressed feed in all the nutritional parameters studied, whatever the type of fish meal used and in some cases significantly so. The best overall performance was found in the fish fed the extruded Danish fish meal based diet, followed closely by the extruded Danish Low Temperature fish meal based feed. In the case of the steam pressed feeds the Standard control feed, the Danish Aqua meal feed and the Danish Low Temperature meal feed gave the best performance for different nutritional parameters. The Chilean feed gave an inferior performance whatever the manufacturing method used. Protein sparing was observed in the fish fed the extruded feed compared with fish fed the corresponding steam pressed feed, and protein digestibilities were slightly higher in fish fed the extruded feeds. A higher carcass lipid content was also found in the fish fed the extruded feeds. The results of this study clearly shows that extrusion had a positive effect on nutritional and growth performance compared to steam pressing, and that fish meal source and quality also had a profound effect on the nutritional value of the diet to gilthead sea bream.

**Key words:** Extrusion, fish meal , pressing, *Sparus aurata*

***RESUME*** *- "Evaluation de différents régimes basés sur des farines de poisson pressées et extrudées, sur la croissance de la daurade Sparus aurata." L'objectif de cette étude est de déterminer quelles farines de poisson ou combinaisons de farines de poisson et quelle forme d'aliment donnent les meilleures performances de croissance chez la daurade* Sparus aurata. *Quatre formulations contenant chacune une farine de poisson d'origine différente, chilienne, danoise, danoise "Aqua" et danoise "basse température" ont été réalisées. Des aliments pressés et extrudés ont été préparés à partir de chacune de ces formulations. Ces huit différents aliments ont été testés sur des daurades de 60g de poids moyen, pendant une durée de quatorze semaines. Un aliment pressé commercial a été utilisé comme témoin. Les valeurs des paramètres nutritionnels étudiés ont été meilleures lors de la distribution d'aliments extrudés par rapport à la distribution des aliments pressés correspondants, ceci de manière significative dans certains cas. En général, les meilleures performances d'élevage correspondent aux lots de poissons nourris avec l'aliment extrudé danois, suivi de près par l'aliment extrudé danois "basse température". Concernant les aliments pressés, les meilleurs résultats pour différents paramètres nutritionnels furent obtenus avec l'aliment commercial, l'aliment danois "Aqua" et l'aliment danois "basse température". L'aliment chilien a donné des résultats inférieurs quelle que soit la technique de fabrication de l'aliment. L'utilisation des protéines et leur digestibilité sont optimisées avec la distribution d'aliment extrudé, comparé à l'aliment pressé. Le taux de lipides des carcasses est supérieur pour les lots nourris avec les aliments extrudés. L'extrusion de l'aliment a un effet positif clair sur les résultats d'élevage de la daurade. La qualité des farines de poisson est également de première importance pour les performances d'élevage chez la daurade,* Sparus aurata.

***Mots-clés** : Extrudé, farine de poisson, pressé,* Sparus aurata

## INTRODUCTION

No one doubts that fish meal is a very good ingredient to put into fish food. Fish meal is still a very important part of many formulations due to its very good nutritional composition and its palatability. However, the quality of the fish meal makes a great deal of difference when it comes to the overall performance of the final feed as was shown clearly by Pike (1993). The demand for better quality fish meal is always increasing and is in fact being undertaken by numerous fish meal manufacturers (Anon, 1992, 1993, 1994a, b). On the other hand, increasing prices and competition for fish meal has led to the search, which is well under way, for alternate protein sources in feeds.

Another way around improving the efficiency of feed utilisation other than ingredient quality is through the manufacturing process. For example, extrusion is currently the main manufacturing process employed for salmon and trout feeds, and research into its use for other species is progressing. While more expensive as a technology, the advantages brought about by extrusion with regard to feed efficiency and reduced pollution have given the process the edge over steam pressing.

During the present experiment a standard diet formulation was used in which four fish meals substituted the two fish meals of a standard steam pressed diet. The four formulations so obtained were processed by steam pelleting and extrusion to give, with the control standard diet, a total of nine experimental diets. These diets were fed to 60g gilthead sea bream, *Sparus aurata,* over a 14 week growth trial.

## MATERIALS AND METHODS

60g juvenile gilthead sea bream were obtained from the previously graded stock of a private fish farm and transported to the National Aquaculture Centre in Malta under anaesthetic (2-phenoxyethanol) with oxygenation. At the start of the experiment 40 fish were placed into each tank, with triplicate tanks for each diet. During the experiment the fish were weighed weekly. Each diet was set out in triplicate. The experiment lasted 16 weeks in all, including two weeks of acclimation.

27 0.27m$^3$ fibreglass tanks were used in this trial. Borehole water was introduced at a rate of 7.5L/min and aeration was provided by a single airstone, and used to maintain oxygen levels above 6ppm after feeding. Temperature throughout the experiment was 20.7$\pm$0.1$^{o}$C, and ammonia, nitrite and nitrate levels were always below 0.6, 0.15 and 10ppm respectively. The photoperiod maintained throughout the experiment was L:D 11:13.

All the feeds used were provided and processed by a commercial feed manufacturer. Nine feeds in all were used during the experiment, one of which was the standard pressed diet which had been in commercial production, and in which the bulk of the protein in the feed was provided by two fish meals. The other experimental feeds consisted of replacing the two fish meals in the standard diet with a single (whole) fish meal: Chilean, Danish, Danish Aqua or Danish LT, and both steam pressing and extruding these four new formulations, to give a total of eight diets.

While some ingredients and the inclusion levels were not disclosed, it is known that small percentages of meat meal, feather meal and toasted soya meal were included. Processed wheat also formed a part of the carbohydrate source. The special binder used for the extruded feeds was part carbohydrate, while the binder used in the pressed feeds contained little carbohydrate. Fish oil was used as were mineral and vitamin mixes. The temperatures reached during steam pressing was 60 to 70$^{o}$C and 80 to 90$^{o}$C during extrusion. Neither pelleting line utilised a conditioner and steam was added in the pelleting and extrusion barrels. The proximate analysis and partial amino acid profile of the fish meals used in the experiment are given in Table 1. The nutritional composition and the partial amino acid profile of the finished diets are given in Tables 2 and 3 respectively.

Table 1. Proximate composition and partial amino acid profile of the fish meals used in the experiment.

| *Fish Meal* | *Chilean* | *Danish* | *Danish Aqua* | *Danish LT* |
|---|---|---|---|---|
| | | | % | |
| Crude Protein | 67.10 | 69.00 | 71.40 | 72.20 |
| Crude Lipid | 10.10 | 12.60 | 10.80 | 9.70 |
| Crude Fibre | 0.30 | 0.50 | 0.50 | 0.70 |
| Crude Ash | 15.80 | 11.10 | 11.00 | 12.10 |
| | | | | |
| Arginine | 3.59 | 3.75 | 3.83 | 3.22 |
| Cysteine | 0.52 | 0.48 | 0.58 | 0.71 |
| Histidine | 2.82 | 1.89 | 1.65 | 1.93 |
| Isoleucine | 2.57 | 3.13 | 3.12 | 3.20 |
| Leucine | 5.01 | 5.05 | 5.65 | 5.51 |
| Lysine | 4.74 | 5.14 | 5.23 | 5.33 |
| Methionine | 1.79 | 1.91 | 2.00 | 1.91 |
| Phenylalanine & Tyrosine | 5.13 | 5.38 | 5.00 | 5.48 |
| Threonine | 2.79 | 2.93 | 3.36 | 3.13 |
| Tryptophan | 0.76 | 0.78 | 0.82 | 0.82 |
| Valine | 3.32 | 4.14 | 4.23 | 4.34 |

Table 2. Nutritonal composition of the feeds used during the experiment[1]

| Fish meal | Standard | Chilean | Danish | Danish Aqua | Danish LT | Chilean | Danish | Danish Aqua | Danish LT |
|---|---|---|---|---|---|---|---|---|---|
| Pellet Type | Pressed | Pressed | Pressed | Pressed | Pressed | Extruded | Extruded | Extruded | Extruded |
| Moisture (%) | $8.65^{a}$ | $8.50^{a}$ | $8.85^{a}$ | 8.35 | $8.45^{a}$ | $3.60^{bc}$ | $4.15^{c}$ | $3.10^{b}$ | $3.65^{bc}$ |
| Crude Protein (%) | $53.45^{a}$ | $50.25^{a}$ | $52.55^{a}$ | $52.65^{a}$ | $53.30^{a}$ | $49.70^{a}$ | $52.55^{a}$ | $52.70^{a}$ | $53.50^{a}$ |
| Crude Lipid (%) | $11.50^{a}$ | $11.30^{a}$ | $11.45^{a}$ | $11.85^{a}$ | $11.70^{a}$ | $13.05^{a}$ | $12.70^{a}$ | $13.40^{a}$ | $12.75^{a}$ |
| Crude Ash (%) | $10.95^{ab}$ | $12.50^{c}$ | $11.35^{ab}$ | $11.10^{ab}$ | $11.05^{ab}$ | $11.65^{b}$ | $10.95^{ab}$ | $10.90^{ab}$ | $10.75^{a}$ |
| Crude Fibre (%) | $1.35^{a}$ | $1.25^{ab}$ | $1.25^{ab}$ | $1.40^{a}$ | $1.30^{a}$ | $1.10^{ab}$ | $1.15^{ab}$ | $0.95^{b}$ | $1.10^{ab}$ |
| Carbohydrate (%)[2] | $14.10^{a}$ | $16.20^{ab}$ | $14.55^{a}$ | $14.65^{a}$ | $14.20^{a}$ | $20.90^{c}$ | $18.50^{bc}$ | $18.95^{bc}$ | $18.25^{bc}$ |
| Gross Energy content (kJ/100 g wet diet)[3] | $1950.95^{a}$ | $1904.23^{a}$ | $1935.64^{a}$ | $1955.62^{a}$ | $1957.12^{a}$ | $2041.85^{b}$ | $2053.33^{b}$ | $2092.44^{b}$ | $2073.25^{b}$ |
| Protein/Gross Energy ratio (g/MJ) | $27.40^{a}$ | $26.39^{ab}$ | $27.15^{a}$ | $26.92^{a}$ | $27.23^{a}$ | $24.34^{c}$ | $25.59^{bc}$ | $25.19^{bc}$ | $25.80^{ab}$ |

1 Means in a row followed by the same superscript are not significantly different ($P < 0.05$).
2 Calculated as 100% - (%protein + %lipid + %ash + %fibre + %moisture).
3 Calculated using the following conversions: protein, 23.4kJ/g; lipids, 39.8kJ/g; carbohydrate, 17.2kJ/g.

Table 3. Partial amino acid profile of the diets used in the experiment.

| Diets | S | P1/E1 | P2/E2 | P3/E3 | P4/E4 |
|---|---|---|---|---|---|
| Fish meal | Standard | Chilean | Danish | Danish Aqua | Danish LT |
| | | | % in diet | | |
| Alanine | 2.86 | 2.79 | 2.95 | 3.10 | 2.88 |
| Arginine | 3.05 | 2.74 | 2.86 | 3.12 | 3.15 |
| Cysteine | 0.58 | 0.65 | 0.62 | 0.67 | 0.69 |
| Isoleucine | 1.88 | 1.76 | 1.85 | 2.01 | 1.95 |
| Glutamic acid | 6.99 | 6.38 | 7.00 | 7.15 | 6.99 |
| Glycine | 3.44 | 3.29 | 3.43 | 3.57 | 3.47 |
| Leucine | 3.62 | 3.13 | 3.48 | 3.55 | 3.63 |
| Lysine | 3.25 | 2.88 | 3.07 | 3.30 | 3.21 |
| Methionine | 1.08 | 0.96 | 1.08 | 1.15 | 1.15 |
| Threonine | 2.34 | 1.90 | 2.13 | 2.17 | 2.36 |
| Valine | 2.40 | 2.43 | 2.52 | 2.80 | 2.82 |

Three mm pellets were used and the daily feed given in two equal meals at 0830 and 1530 as follows: 1.5% body weight/day for fish of 50 to 80g, 1.3% body weight/day for fish from 80 to 100g, and 1.1% body weight/day over 100g. During the 14 day acclimation period, the fish were fed the standard diet to satiation except on the last two days during which the fish were fed their predesignated diet according to the tank. When sample weighing was to take place the fish were not fed the previous meal.

At the beginning and the end of the experiment fish samples were taken for carcass analysis and determination of hepatosomatic index and liver colour score. Faeces were collected during the last three weeks of the experiment; faeces were collected by inserting a thin mesh in the central outflow pipe and collecting retained material at 2 hour intervals and subsequently drying the material at 62$^{o}$C for 48 hours. However, only sufficient faeces were collected to perform a single crude fibre and crude protein analysis.

Proximate analysis were performed according to standard procedures (ISO, 1978; 1981; 1983; AOAC, 1990). Amino acid analyses of the fish meals used in the experimental diets and the final feeds was performed using a Perkin Elmer High Performance Liquid Chromatograph with a Merck RP80 column. The essential amino acid (EAA) profile of 1.05g *Sparus aurata* fingerling carcasses (Vergara, 1992) was used to obtain the EAA scores as a percentage of requirement. The EAA score was calculated by expressing the weight of EAA present in 100g of the diet as a percent of the weight of EAA required in 100g of the diet.

Statistical analysis consisted of multiple way analysis of variance using the Student-Newman-Keuls test, except in the cases where a homogeneity of variances in the samples was not found, in which case the nonparametric Kruskall-Wallis test was performed. To compare values obtained for carcass proximate analysis, hepatosomatic index and liver colour score at the end of the experiment with the value at the beginning, the Dunnett's procedure was used. The significance level for all the tests was taken as 0.05.

## RESULTS

The nutritional performance of the fish during the trail are shown in Table 4.

Higher specific growth rates (SGR) were obtained for the fish fed the extruded diet. The extruded Danish fish meal feed gave the fastest growth with 0.79%/day, followed closely by the extruded Danish LT meal feed. The SGR of these two feeds were significantly higher than the SGRs of the pressed Chilean and Danish meal diets (0.67 and 0.68%/day respectively). Of the pressed feeds the highest SGR obtained was by the Danish Aqua meal (0.72%/day) followed by the Standard and Danish LT meal diets with 0.71%/day. Survival was between 94.17% and 98.33%, with no significant differences between feeds.

As in the case of the growth parameters, the food conversion ratios (FCR) and feed efficiencies (FE) of the extruded diets were better than the corresponding pressed diets. The lowest FCR (1.50) and highest values of FE (66.58 and 66.70%) were obtained with the two extruded feeds containing Danish and Danish LT meal. The highest value of FCR obtained, 1.79, was given by the Chilean meal diet, a value which was if fact significantly higher than all the other diets except for the pressed Danish meal feed. The lowest FE was also given by the pressed Chilean meal feed at 53.37%, a value significantly lower than all the values obtained by the extruded feeds. The standard diet gave the best FCR and FE of the pressed diets with values of 1.69 and 59.51% respectively. The results for protein efficiency ratios (PER) can be clearly divided into two significantly different groups based on the pellet type. The extruded feeds gave significantly higher PERs, ranging from 1.23 (Danish Aqua meal) to 1.27 (Danish meal). As regards the pressed feeds, the lowest value was 1.07, obtained with the pressed Chilean meal feed, while the highest was 1.12, obtained with the Danish Aqua meal feed. The standard and the Danish LT meal feed obtained PERs only 0.01 lower than that obtained by the pressed Danish Aqua meal feed.

Table 4. Growth and feed utilisation of the diets during the experiment[1]

| Fish Meal | Standard | Chilean | Danish | Danish Aqua | Danish LT | Chilean | Danish | Danish Aqua | Danish LT |
|---|---|---|---|---|---|---|---|---|---|
| Pellet Type | Pressed | Pressed | Pressed | Pressed | Pressed | Extruded | Extruded | Extruded | Extruded |
| Initial Body Weight (g) | $57.44^{a}$ | $58.13^{a}$ | $58.64^{a}$ | $56.92^{a}$ | $57.43^{a}$ | $58.17^{a}$ | $58.21^{a}$ | $59.06^{a}$ | $59.51^{a}$ |
| Final Body Weight (g) | $115.70^{ab}$ | $111.84^{a}$ | $114.65^{ab}$ | $115.00^{ab}$ | $115.16^{ab}$ | $120.44^{bc}$ | $125.92^{cd}$ | $123.93^{cd}$ | $128.36^{d}$ |
| Specific Growth Rate (%/day) | $0.71^{ab}$ | $0.67^{b}$ | $0.68^{b}$ | $0.72^{ab}$ | $0.71^{ab}$ | $0.74^{ab}$ | $0.79^{a}$ | $0.76^{a}$ | $0.78^{a}$ |
| Survival (%) | $95.00^{a}$ | $95.83^{a}$ | $94.17^{a}$ | $95.00^{a}$ | $96.67^{a}$ | $96.67^{a}$ | $95.00^{a}$ | $98.33^{a}$ | $95.00^{a}$ |
| Food Conversion Ratio | $1.69^{ab}$ | $1.87^{c}$ | $1.79^{bc}$ | $1.70^{ab}$ | $1.70^{ab}$ | $1.62^{ab}$ | $1.50^{a}$ | $1.55^{a}$ | $1.50^{a}$ |
| Feed Efficiency (%) | $59.51^{abc}$ | $53.57^{a}$ | $56.03^{ab}$ | $58.96^{abc}$ | $58.96^{abc}$ | $61.73^{bcd}$ | $66.58^{d}$ | $64.56^{cd}$ | $66.70^{d}$ |
| Protein Efficiency Ratio | $1.11^{a}$ | $1.06^{a}$ | $1.07^{a}$ | $1.12^{a}$ | $1.11^{a}$ | $1.24^{b}$ | $1.27^{b}$ | $1.23^{b}$ | $1.25^{b}$ |
| Apparent Net Protein Utilisation (%) | $18.46^{ab}$ | $17.64^{a}$ | $17.69^{a}$ | $20.60^{bc}$ | $19.25^{ab}$ | $20.32^{bc}$ | $21.73^{c}$ | $19.63^{ab}$ | $19.51^{ab}$ |
| Apparent Net Lipid Utilisation (%) | $101.03^{bc}$ | $89.02^{d}$ | $106.46^{abc}$ | $98.04^{c}$ | $109.64^{ab}$ | $103.70^{abc}$ | $113.13^{a}$ | $108.15^{ab}$ | $114.07^{a}$ |
| Energy Efficiency (%) | $35.54^{a}$ | $31.92^{d}$ | $36.30^{ab}$ | $36.62^{ab}$ | $38.35^{abc}$ | $37.95^{abc}$ | $40.87^{c}$ | $39.14^{abc}$ | $39.70^{bc}$ |

1 Means in a row followed by the same superscript are not significantly different ($P < 0.05$).

There is no clear-cut difference between the values for apparent net protein utilisation (ANPU) obtained with the extruded or pressed diets, although the former feeds, except in the case of Danish Aqua meal, where higher when compared to the corresponding pressed feed. The highest ANPU value (21.73%) was obtained with the extruded Danish meal feed, followed by the pressed Danish Aqua meal diet (20.60%) and then by the extruded Chilean meal diet (20.32%). The lowest value of 17.64% was again obtained by the pressed Chilean meal, followed immediately by the pressed Danish meal feed (17.69%) and then by the Standard diet (18.46%).

As with ANPU, no clear distinction can be seen in apparent net lipid utilisation (ANLU) between extruded and pressed diets, although in this case all the extruded feeds gave a higher value than the corresponding pressed feed. The extruded Danish LT meal gave the highest value for ANLU (114.07%), followed closely by the extruded Danish meal (113.13%) and pressed Danish LT meal (109.64%). While the Standard diet gave an ANLU of 101.03%, the pressed Chilean meal diet gave an ANLU value of 89.02%, which was significantly lower than all the other feeds used in the experiment. The value obtained for the pressed Danish LT feed (109.64%) was higher than both the extruded Chilean meal and Danish Aqua meal feeds (103.70 and 108.15% respectively).

Energy efficiency (EE) ranged from 31.92% (pressed Chilean meal feed) to 40.87% (extruded Danish meal feed). The pressed Chilean meal diet gave an EE significantly lower than all the other diets. The extruded feeds had overall better efficiencies than the pressed feeds, and each fish meal performed better in the extruded form compared to the pressed form; the EE obtained by the extruded Danish meal was significantly higher than the value obtained by the pressed Danish meal feed (36.30%). However, the pressed Danish LT diet which gave the highest efficiency of the pressed diets (38.35%), was higher than that EE obtained by the extruded Chilean meal diet. The Standard diet gave an EE of 35.54%, higher only than the pressed Chilean meal diet.

The moisture content of the fish decreased within the fish carcass over the experimental period (Table 5), and significantly so for all diets except for the Standard diet and the pressed Chilean meal diet. There was no significant changes in the crude protein or ash content of the fish over the experimental period. The initial crude lipid content was lower than was found in the fish carcasses at the end of the experiment. Moreover, fish fed the extruded diets had higher crude lipid contents than fish fed the pressed diets.

The hepatosomatic index value decreased from the beginning of the experiment to the end of the experiment in all diets, although there were no significant differences between the hepatosomatic indexes of the fish at the end of the experiment (Table 5). In addition, no significant differences were observed between the different diets at the end of the experiment with respect to the liver colour score, nor compared to the initial liver colour score.

Table 5. Initial and final carcass proximate composition, hepatosomatic index and liver colour score, and apparent protein digestiblities of fish fed the experimental diets[1]

| Fish Meal | | Standard | Chilean | Danish | Danish Aqua | Danish LT | Chilean | Danish | Danish Aqua | Danish LT |
|---|---|---|---|---|---|---|---|---|---|---|
| Pellet Type | Initial | Pressed | Pressed | Pressed | Pressed | Pressed | Extruded | Extruded | Extruded | Extruded |
| Moisture (%) | $63.74^{a}$ | $62.40^{abc}$ | $63.10^{ac}$ | $60.00^{bc}$ | $59.35^{b}$ | $59.15^{b}$ | $59.55^{bc}$ | $61.30^{bc}$ | $61.40^{bc}$ | $61.50^{bc}$ |
| Crude Protein (%) | $16.61^{a}$ | $16.55^{abc}$ | $16.60^{abc}$ | $16.60^{abc}$ | $17.45^{c}$ | $16.95^{abc}$ | $16.50^{abc}$ | $16.90^{abc}$ | $16.25^{ab}$ | $16.10^{ab}$ |
| Crude Lipid (%) | $16.32^{a}$ | $17.85^{abc}$ | $17.50^{ab}$ | $18.85^{bc}$ | $17.95^{bc}$ | $19.00^{bc}$ | $19.15^{bc}$ | $19.10^{bc}$ | $19.50^{c}$ | $19.20^{bc}$ |
| Ash (%) | $3.38^{a}$ | $3.70^{a}$ | $3.50^{a}$ | $3.45^{a}$ | $3.45^{a}$ | $3.40^{a}$ | $3.70^{a}$ | $3.40^{a}$ | $3.20^{a}$ | $3.40^{a}$ |
| Hepatosomatic Index | $1.97^{a}$ | $1.33^{b}$ | $1.70^{ab}$ | $1.49^{ab}$ | $1.25^{b}$ | $1.19^{b}$ | $1.61^{ab}$ | $1.43^{ab}$ | $1.55^{ab}$ | $1.29^{b}$ |
| Average Colour Score[2] | $1.91^{a}$ | $2.6^{a}$ | $2.8^{a}$ | $1.6^{a}$ | $1.8^{a}$ | $1.4^{a}$ | $2.8^{a}$ | $1.8^{a}$ | $2.6^{a}$ | $1.8^{a}$ |
| Apparent protein digestibility (%) | | 93.03 | 92.54 | 92.91 | 92.07 | 92.49 | 92.60 | 93.43 | 94.85 | 94.16 |

1 Means in a row followed by the same superscript are not significantly different ($P < 0.05$).

2 Analysis performed using the Kruskal Wallis test.

As shown in Table 5, the observed apparent digestibility coefficients (ADC) for protein were high for all the diets, the lowest value being 92.07% for the pressed Danish Aqua meal feed. The results appear to show a slightly higher digestibility for protein within the extruded feeds compared to the corresponding pressed feeds. The Standard diet gave an ADC higher than the extruded Chilean meal feed.

The calculated amino acid scores for the amino acids tested all exceeded 100% with two exceptions (Table 6). The scores for isoleucine in all the diets except the Danish Aqua meal diets were below 100% but were all above 93%. The methionine score for the Chilean meal feed was 96.04%.

Table 6. Amino acid scores of the experimental diets

| Fish Meal Used In Diet | | Standard | Chilean | Danish | Danish Aqua | Danish LT |
|---|---|---|---|---|---|---|
| Diet/s | | S | P1/E1 | P2/E2 | P3/E3 | P4/E4 |
| Essential Amino Acid | Requirement of EAA as % of protein[1] | | | Score (%) | | |
| Arginine | 4.35 | 131.18 | 126.03 | 125.11 | 136.15 | 135.61 |
| Isoleucine | 3.75 | 93.79 | 93.90 | 93.88 | 101.75 | 97.38 |
| Leucine | 5.25 | 129.00 | 119.29 | 126.14 | 128.36 | 129.48 |
| Lysine | 5.50 | 110.55 | 104.77 | 106.22 | 113.90 | 109.30 |
| Methionine | 2.00 | 101.03 | 96.04 | 102.76 | 109.15 | 107.68 |
| Threonine | 3.68 | 118.97 | 103.30 | 110.14 | 111.94 | 120.09 |
| Valine | 3.28 | 136.90 | 148.23 | 146.20 | 162.05 | 161.00 |

1 From Vergara, 1992. EAA profile of 1.05g Sparus aurata fingerling carcasses.

## DISCUSSION

From the results of the nutritional analyses, differences have been observed between the different fish meals tested and the improvement brought about by extrusion on fish performance compared to the corresponding pressed feeds is also clearly seen. The reasons behind the differences seen in this experiment could be put down to fish meal quality in one case and the effect of feed manufacture by extrusion on energy and nutrient availability in the other.

Fish meal quality has always been regarded as a very important parameter affecting performance (Nose, 1979; Chou, 1985), and the work by Pike (1993) clearly shows this. For example, Pike (1993) fed 90g Atlantic salmon, *Salmo salar*, three feeds with fish meal processed from fish 12 hours after capture, two days after storage and one week after storage. The fish meal prepared just after capture gave an SGR of 1.65%/day compared to the fish meal prepared after one week which gave an SGR of 1.29%/day. The former fish meal gave an FCR of 0.89 compared to 1.47 by the latter fish meal. By contrast, the meal prepared after two days storage gave an SGR of 1.52%/day and an FCR of 0.95.

Unfortunately, no information was disclosed by the manufacturer concerning the source or catch site of the different meals used during this study.

The pressed Chilean meal feed gave the worst performance in all parameters studied compared to the other pressed feeds. Inclusion of this fish meal also gave the feed with the lower performance in nearly all parameters in the extruded feeds. However, the extruded feed gave a significantly marked improvement in all parameters studied compared to the pressed Chilean fish meal feed.

The effect of extrusion on the feeds based on the other three fish meals was similar to that seen in the Chilean meal, where better performance was obtained as a result of the extrusion. However, the increased improvement was more marked in the case of the Danish fish meal than in the Danish Aqua or Danish LT meals, indicating that some other parameter could be having an effect when passing from steam pressing to extrusion.

The extruded Chilean fish meal feed performed clearly better than the pressed feeds in the parameters studied except in ANPU, ANLU and EE. The difference between the SGR of the extruded Chilean meal feed and that of the pressed Danish meal was only 0.02 (a 2.7% difference). Similarly, the FE of the extruded Chilean meal feed was less than 3% higher than that obtained by the pressed Danish Aqua and Danish LT meal feeds. This clearly shows that a pressed good quality fish meal based feed can almost equal, and even better, the performance of an extruded fish meal based feed of lower quality.

Considering the pressed feeds, the feed containing the Danish meal feed performed better than the Chilean fish meal, but worse than the pressed Standard, Danish Aqua and Danish LT meal feeds in all parameters except the ANLU in the case of the Danish Aqua meal and EE in the case of the Standard diet. The best performance was not given by a single fish meal or feed, but was given by either the Standard, Danish Aqua or Danish LT meals for different nutritional parameters. Similarly within the extruded feeds, no fish meal stood out by itself. The Danish fish meal gave the best overall performance, followed by the Danish LT meal feed. However, unlike the pressed feeds, the Danish Aqua meal did not perform as well as the Danish LT meal but still performed better than the Chilean fish meal.

It appears clear from the proximate analysis of the feeds used in the experiment that the protein content was sufficient to meet the protein requirement of the gilthead sea bream, at least according to the results quoted by various authors (40% by Kissil et al., 1982; 42% and 46% by Vergara, 1992). In fact, from the results of the PER and ANPU it can be concluded that the level of protein used in the feeds in this experiment were probably too high, and could well have been reduced.

The amino acid scores available for the various diets show no important deficiency, with all amino acid scores being above 93%. With respect to the other three amino acids not available for calculation of the scores (i.e. histidine, phenylalanine and tryptophane) the amino acid profiles of the fish meals used indicated that it was not likely that any deficiencies would arise from these amino acids.

The property of protein sparing is well known. During the present experiment, the extruded feeds had a slightly higher carbohydrate and lipid content on a wet basis compared with the pressed feeds. In consequence the gross energy content of the extruded feeds were higher and the protein to energy ratio lower than the corresponding pressed feeds. However, although the crude lipid and crude protein contents in the feeds used were not significantly different. However, the carbohydrate contents of the extruded feeds were significantly higher than the pressed feeds. It is well known that fish have different carbohydrate digestibilities, and other factors having a major effect on carbohydrate digestibility include the degree of polymerisation (Spannhof and Plantikow, 1983), carbohydrate inclusion level, and the technological treatment used in preparation of the feed (Bergot and Breque, 1983).

During the manufacture of extruded feeds, the feed mixture is cooked to higher temperatures than during steam pelting. The higher temperatures lead to increased carbohydrate availability due to gelatinisation of the starch component in the diet during the process (Hilton et al., 1981; Hilton and Slinger, 1983). The wheat used in the manufacture of the diets as part of the carbohydrate source had a gelatinisation temperature in the region of 80$^{o}$C, a temperature reached during the extrusion process employed for the present diets.

The higher energy content, lower protein to energy ratio and energy availability of the extruded feeds could partly explain the improved performance of the these feeds over the pressed feeds. Increased FCR, FE and EE as a result of better feed utilisation for growth is clear in the extruded diets, while the higher PER and ANPU values give evidence of protein sparing, all contributing to better growth and better protein utilisation, as seen in numerous other trials (Kaushik et al., 1989; Joeng et al., 1991; Cho, 1992; Silver et al., 1993, Robert et al., 1993).

The values obtained in this experiment with gilthead sea bream for SGR, FCR, PER, ANPU, ANLU and EE compare well with the results obtained by other workers on gilthead sea bream (Marais and Kissil, 1979; Kissil et al., 1982; Vergara, 1992). Compared to some other species, there is a great deal to be done to improve FCR and FE (Lie et al., 1988; Schweder et al., 1989; Garcia-Riera et al., 1993; Johnsen et al., 1993), PER and ANPU (Viola et al., 1981/1982; Chou, 1985; Lie et al., 1988; Garcia-Riera et al., 1993; Silver et al., 1993). However the values of EE obtained in this trial were quite high compared to some results in other species (Viola et al., 1981/1982; Viola and Arieli, 1983; Silver et al., 1993).

It is a commonly observed phenomenon that there is an increase in lipid composition in the fish carcass with increasing body size, with a corresponding decrease in the moisture content of the fish with the lipid more or less replacing the water in the body (Reinitz and Hitzel, 1980; Andersen and Alsted, 1993; Robert et al., 1993). A look at the carcass compositions show that this was observed during the present experiment.

Andersen and Alsted (1993) and Garcia-Riera et al. (1993) concluded that the accumulation of lipid takes place in the body with protein sparing. During this experiment there was an increase in carcass lipid content in both the pressed and extruded feeds, but fish fed the extruded feeds showed a higher increase than the corresponding pressed feeds. The fish fed the extruded feeds also had higher ANLUs. The values of ANLU were almost all above 100%, indicating that there was a transformation of other dietary components into lipids.

An increase in the energy content of diets as occurs in aquaculture can affect the liver of fish adversely and generally results in an increase in size and a change in colour to one which is lighter than what is normally found in the wild. Furthermore, feeding of high fat diets may cause fatty infiltration of the liver and excessive obesity with fatty deposition in the body (Adron et al., 1976; Roberts, 1989; Hedia, 1991; Cowey, 1993). The effect of increased energy on hepatosomatic index and liver colour score is not clear from the literature (Refstie and Austreng. 1981; Kaushik et al., 1989; Johnsen et al., 1993; Robert et al., 1993). In this trial the final hepatosomatic indexes generally decreased compared to the original value, without any noticeable trends. The decrease could have been due to the higher level of feeding prior to the restricted feeding regime used throughout the experiment. The results obtained with the liver colour scores during this experiment were not clear, and further work should be carried out to see whether this score is of any practical use and of significance in ascertaining the health status of fish.

Although the digestibility study carried out did not supply sufficient material for a complete analysis and study, the trend seen in the limited results available show higher protein digestibilities in fish fed the extruded feeds. This could have been due to the beneficial effect of extrusion on antinutritional factors present or some other factors related to the higher heat used in the extrusion process.

During this experiment, no additional lipid was added to the extruded feeds, even though the addition of higher lipid levels is a possibility with extrusion. A number of commercial extruded bream feeds do already contain higher levels of lipid. However, further studies should be carried out to investigate the effect of increased energy availability on sea bream carcass composition, in view of marketing considerations and fish health.

## CONCLUSIONS

The results of the present study clearly indicate the improvement brought about by extrusion of the diets on the performance of the gilthead sea bream, *Sparus aurata*, compared to conventional steam pressed feeds, whatever the fish meal source used in the formulation.

Although there is still a great deal of further work to be done to improve the overall growth performance of gilthead sea bream, the use of extrusion technology seems to be a step in the right direction, although it must be taken with practical caution.

Of the fish meals tested, the most obvious observation was the poorer performance of the Chilean fish meal. However, it must be emphasised that this does not imply that all Chilean fish meals are of poor quality (since no information was provided on the source and quality of the Chilean fish meal used). On the other hand, the best performance was observed using the extruded Danish meal feed followed by the extruded Danish LT meal feed. However, as mentioned previously, it must be pointed out that a great deal of data was missing concerning the fish meals used and certain details of the formulations tested. The results also showed different improvements by extrusion depending on the fish meal, indicating that other factors and interactions were also involved.

The higher energy content of the extruded diets and the increased carbohydrate availability of these diets partly explain the improved growth, protein utilisation and feed utilisation seen in this trial, although other parameters played a part. In view of this, protein sparing within the gilthead sea bream should be investigated further in order to reduce the protein content of diets with the aim of obtaining more balanced diets. However, caution is called for in the use of higher energy diets in view of the increased lipid contents of the fish carcass, and the health of the fish, an area which clearly has to be studied in depth.

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