Hazelnut meal in diets for seawater farmed rainbow trout (*Oncorhynchus mykiss*): effects on growth performance and body composition

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**ABSTRACT**

A 77-day feeding trial was designed in order to assess the effect of partial or total replacement of soybean meal by hazelnut meal (HNM) on feed intake, growth performance, nutrient utilization and body composition of rainbow trout (initial mean body weight: 80.0±3.5 g) in seawater conditions. A control and three experimental diets were formulated in which soybean meal level (25.5%) in the control diet was replaced by hazelnut meal at 39.2 (HN 39), 78.4 (HN 78) and 100% (HN 100) to provide 44% crude protein and 20% crude lipid diets. Diets were fed to 125 rainbow trout to apparent satiation by hand twice daily at 09.00 and 16.00 hours under natural photoperiod conditions. At the end of the feeding trial, fish of all groups almost tripled their body weight and no significant difference (P>0.05) was revealed in final weight or specific growth rate between treatments. However, feed conversion ratio (FCR) of the HN100 group was significantly higher than other treatments (P<0.05). There was a slightly decreasing trend in protein efficiency ratio (PER) and net protein utilization (NPU) with increasing level of dietary hazelnut meal, but it was only significant in groups of fish fed HN100. All groups of fish displayed similar carcass and muscle compositions. According to the results of the present study, it can be stated that hazelnut meal can replace soybean meal at up to 200 g kg⁻¹ in grow-out diets of rainbow trout without any detrimental effects on growth performance.

**Key words:** Salmonids, Hazelnut meal, Soybean meal, Feed utilization.

**RIASSUNTO**

FARINA DI NOCCIOLA NELL’ALIMENTAZIONE DELLA TROTA IRIDEA (*ONCORHYNCHUS MYKISS*) ALLEVATA IN ACQUA MARINA: EFFETTI SULLE PERFORMANCE DI ACCRESCIMENTO E SULLA COMPOSIZIONE CORPOREA

La presente prova di alimentazione, durata 77 giorni, è stata svolta con il fine di valutare gli effetti della sostituzione parziale e totale della farina di soia con la farina di nocciola (HNM) sul mangime assunto dagli animali, sulle performance di accrescimento, sull’utilizzazione alimentare e sulla composizione corporea
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della trota iridea (con peso iniziale medio di 80,0±3,5 g) allevata in acqua marina. La dieta di controllo e le tre sperimentali sono state formulate sostituendo la soia, contenuta in ragione del 25,5% nel mangime di controllo, con percentuali crescenti di nocciola: 39,2% (HN 39), 78,4% (HN 78), 100% (HN 100), con la finalità di procurare un contenuto di proteine grezze pari al 44% ed un contenuto di lipidi grezzi del 20%. Le diete sono state somministrate a 125 trote, allevate in condizioni di illuminazione naturale, manualmente due volte al giorno (ore 09.00-16.00) fino a sazietà apparente. Alla fine della sperimentazione gli animali dei tre gruppi avevano triplicato il loro peso senza far registrare differenze significative (P>0,05) tra i gruppi per quanto concerne il peso finale e l’incremento ponderale. Tuttavia l’indice di conversione del mangime somministrato al gruppo HN100 è stato significativamente più alto rispetto agli altri trattamenti (P<0,05). È stata rilevata una lieve tendenza alla diminuzione per quanto concerne il rapporto di efficienza proteica (PER) e l’utilizzazione proteica netta (NPU) incrementando il livello di nocciola nella dieta, ma la significatività è stata messa in luce solamente nel gruppo di pesci alimentati con HN100. Tutti i gruppi hanno presentato una composizione simile della carcassa e del tessuto muscolare. I risultati di questo studio indicano che la farina di nocciola può essere utilizzata in sostituzione della farina di soia fino a 200 g/kg nelle diete da ingrasso della trota iridea senza effetti negativi sulle performances di accrescimento.

Parole chiave: Salmonidi, Nocciola, Soia, Utilizzazione alimentare.

Introduction

Fish meal is a quite expensive ingredient but still essential for commercial diets of aquaculture fish species because of its high protein content and well-balanced amino acid profile, a good source of essential fatty acids (EFA), minerals and vitamins (Gatlin et al., 2007). Alternative protein sources have been studied intensively during the last few decades due to shortages in fish meal supplies and consistent increases in prices. In the last decade, soy proteins have been one of the most utilized alternative non-animal protein sources to fish meal in diets of many aquaculture species because of its high protein content, reasonably good amino acid profiles, moderate price, and steady supply compared to fish meal among the various plant sources (Herrmann and Piedad-Pascual, 2000). Several studies have presented that soybean meal alone or in mix with other plant and animal protein sources can replace fishmeal protein in diets for many fish species, such as rainbow trout (Heikkinen et al., 2006; Barrows et al., 2007), gilthead sea bream (Venou et al., 2006), European sea bass (Tibaldi et al., 2006). On the other hand, the use of soybean products in aquafeed, especially in carnivorous fish species, still presents limitations due to the presence of anti-nutritional factors (Francis et al., 2001), limiting essential amino acids such as methionine and lysine (Vielma et al., 2004) and of course an increase in the market price globally.

Rainbow trout, *Oncorhynchus mykiss* is presently one of the most important fish species reared in Turkey due to its rapid growth, efficient feed conversion and increasing consumer demand. In trout rearing, feed costs represent between 50 to 60% of the total production costs. Global rainbow trout production increased in recent times from 427,329 in 1997 to 486,928 metric tonnes in 2005, respectively (FAO, 2006). However, the major obstacle to its culture is inadequate feedstuff to meet its dietary requirement in different culture systems, especially fresh water and marine environment (Krogdahl et al., 2004).

The common hazelnut, *Corylus avellana* is a popular nut that is fast gaining popularity all over the world. Turkey is the world’s largest producer of hazelnuts, contributing 74% to the total global production (FAOSTAT, 2007). Hazelnuts are rich in protein and unsaturated fat, and they con-
tain significant amounts of thiamine and pyridoxine. HNM could be an alternative to soybean meal in aquaculture feeds and has been marketed instead of soybean meal. Bilgin et al. (2007) and Buyukcapar and Kamalak (2007) have shown that soybean meal can be partially or totally replaced by hazelnut meal in rainbow trout diets reared in freshwater and in carps, respectively. To our knowledge, the inclusion of hazelnut meal in the diet of rainbow trout reared in seawater has not been studied previously. The aim of this study, therefore, is to evaluate the effects of substituting soybean meal (SBM) with HNM in commercial diets on growth performance, nutrient utilization and carcass-muscle compositions of *O. mykiss* reared in seawater.

**Material and methods**

**Fish and net cage facilities**

The feeding trial was carried out in the Net Cage Unit of the Faculty of Fisheries, Onsekiz Mart University (Çanakkale, Turkey). Rainbow trout were purchased from a local trout farm (Çanakkale, Turkey). After transportation, the fish were fed by hand to satiation with a commercial trout feed (Biomar) (crude protein: 40%, crude lipid: 18% as fed) in experimental net cages, and acclimatized until the beginning of the feeding trial. A total of 2000 rainbow trout (80.0 ± 3.5 g initial mean body weight) were randomly distributed into each of 8 experimental net cages (diameter: 2 m, depth: 2.5 m) with duplicate cages per diet. The fish were fed close to apparent satiation by hand twice daily. Water temperature was measured daily (09:00) and other water quality parameters weekly.

**Experimental diets**

The experimental diets were formulated to meet all known nutritional requirements of rainbow trout (Hardy, 2002). Extruded diets (3 mm diameter), containing 440 g kg⁻¹ crude protein and approximately 200 g kg⁻¹ crude lipid (dry matter), were prepared at a commercial feed plant (Bagci Gida ve Yem San. Tic. Ltd., Aydin/Turkey). Anchovy fish meal, soybean meal and hazelnut meal were the main protein sources. Chemical compositions of protein sources used in this study are presented in Table 1. Formulation and chemical composition of the experimental diets are presented in Table 2. Experimental diets were formulated by replacing soybean meal (SBM) with HNM at levels of 39.2%, 78.4% or 100%, respectively.

**Sampling and chemical analysis**

At the beginning of the feeding trial, a pooled sample of 10 fish was collected to be used as an initial carcass and muscle sample. At the end of the feeding trial, 6 (six) fish were sampled from each cage and frozen at -25°C for the subsequent whole-body and muscle proximate analysis. Following the feeding trial, all fish were counted and weighed after 24 hours of starvation and then 6 fish from each net cage were with-

| Table 1. Proximate composition of fish meal, soybean meal and hazelnut meal. |
|---------------------------------|-------|-------|-------|
| Proximate analyses (%)          | Fish meal | Soybean meal | Hazelnut meal |
| Moisture                        | 9.34   | 10.05  | 10.35  |
| Protein                         | 67.10  | 46.80  | 44.20  |
| Lipid                           | 7.40   | 1.30   | 3.00   |
| Ash                             | 16.80  | 7.37   | 2.37   |
drawn and stored at -20°C until the determination of whole-body and muscle proximate composition. Dried samples of the feed and fish were ground into fine powder with a laboratory mill. Dry matter, crude protein, lipid, fibre and ash contents of the feed and fish were analyzed using standard methods as described in AOAC (2000). Nitrogen-free extract (NFE) was computed by taking the sum values for crude protein, lipid, ash, crude fibre, and moisture and then subtracting this from 100. Gross energy in diets was calculated using the conversion factors of 23.7 kJ g for protein, 39.5 kJ g for lipid and 17.2 kJ g for carbohydrate, respectively (Brett and Groves, 1979).

**Evaluation of fish performance**

Feed efficiency and fish nutrient utilisation were calculated according to the formulae given below:

- Specific growth rate (SGR) = 100 × (ln final fish weight) − (ln initial fish weight))/experimental days
- Feed Conversion Ratio (FCR) = feed intake (g)/weight gain (g)
- Protein Efficiency Ratio (PER) = weight gain (g)/protein fed (g)
- Net Protein Utilisation (NPU) (%) = [(final body protein (g)−initial body protein (g))/dietary protein consumption (g)]×100
- Net Energy Utilisation (NEU) (%) = [(final body energy-initial body energy)/dietary energy consumption (g)]×100
- Condition Factor (CF) (%) = (fish weight (g)/(fish length)³ (cm))×100

**Statistical analysis**

All data were analyzed using Statgraphics 7.0 (Manugistics Incorporated, Rockville, M. D., USA) for statistical significance (P<0.05) by ANOVA (Zar, 2001). Individual differenc-
es between dietary treatments were determined by Duncan’s new multiple range test. Allometric analyses of the carcass of fish were performed as explained by Tekinay et al. (2003) and Güroy et al. (2006).

**Results**

Water temperature, dissolved oxygen, pH and salinity during the experimental period varied between 10.0 and 16.1°C; 8.3 and 9.7 mg l\(^{-1}\); 7.4 and 8.1; and 23.6 and 27.1‰, respectively.

Feed intake data, growth performance and nutrient utilization are presented in Table 3. All diets were readily consumed by experimental fish throughout the feeding trial. Fish fed diet HN100 group displayed (P<0.05) the highest feed intake (FI), whereas FI of other groups were similar (P>0.05). The growth performance at 77 days showed no marked differences in the final body weight and specific growth rate (SGR) among all the experimental groups (P>0.05). Feed conversion ratio (FCR) ranged from 0.77 to 0.88 (Table 3) with an increasing trend corresponding to levels of dietary HNM substitutions. Protein efficiency ratio (PER) values ranged from 2.58 (HN 100) to 2.96 (HN 39) and it demonstrated a decreasing trend with increasing level of dietary hazelnut meal (Table 3). There was no difference between PER of control and HN39 groups (P>0.05), but PER of HN100 was significantly lower than other treatments (P<0.05). Similar to PER, net protein (NPU) and energy utilization (NEU) of fish decreased significantly (P<0.05) as dietary hazelnut meal increased. Condition factor of fish showed similar patterns (P>0.05). Carcass and muscle compositions of rainbow trout were not affected by dietary treatments (P>0.05) (Table 4).

**Discussion**

The objective of this study was to investigate the partial or total replacement of soybean meal by hazelnut meal in rainbow trout diets at grow-out stage in seawater.
conditions. Results obtained from this investigation revealed that hazelnut meal could be incorporated into diets formulated for rainbow trout at up to 30% by total replacement of soybean meal in grow-out feed. Only a few studies have reported that hazelnut meal could partially replace fish meal or soybean meal without detrimental effects on growth performance in European sea bass (Emre et al., 2008), carp (Buyukcapar and Kamalak, 2007) and rainbow trout (Bilgin et al., 2007).

Trout of all groups in this investigation almost tripled their body weight and no significant difference (P>0.05) was revealed in final weight or specific growth rate between treatments. The growth performance of the fish in this study was in line with a previous study carried out in the same facility using approximately same size of rainbow trout (Tekinay et al., 2009).

Replacement of soybean meal by 78% of HNM did not cause any adverse effect on FCR. However, total replacement of soybean meal with hazelnut meal resulted in significantly lower FCR when compared to the other experimental diets (P<0.05). The altered feed efficiency in fish fed the diet with high levels of hazelnut meal has also been reported by Buyukcapar and Kamalak (2007) who evaluated the effects of replacement of fish meal and soybean meal proteins with hazelnut meal protein in the diets of mirror carp fingerlings. They suggested that hazelnut meal could be incorporated into the diet at 35% and 40%, however, dietary inclusion of HNM above these levels caused reduction in feed utilization. On the other hand, Emre et al. (2008) declared that European sea bass (Dicentrarchus labrax) fed diets including varying levels of HNM displayed similar FCR to the control group fed the fish meal-based diet.

Trouts fed diets with high inclusion (30% of the diet) of hazelnut meal showed a higher feed intake. Feed intake of fish can be influenced by digestible energy density, palatability, nutrient digestibility and deficiencies in amino acids of formulated diets (Houlihan et al., 2001). Increased feed intake can be attributed to high palatability of hazelnut meal, whereas suppressed feed

Table 4. Carcass and muscle composition of rainbow trout fed with the experimental diets.

|                      | Initial | Control       | HN 39       | HN 78       | HN 100      |
|----------------------|---------|---------------|-------------|-------------|-------------|
| Carcass composition (%)|         |               |             |             |             |
| Moisture             | 70.34   | 72.95 ± 1.34  | 71.61 ± 0.79| 72.97 ± 0.38| 71.33 ± 1.28|
| Protein              | 17.51   | 17.29 ± 0.52  | 17.08 ± 0.36| 16.51 ± 0.21| 16.49 ± 0.09|
| Lipid                | 4.65    | 5.03 ± 0.19   | 5.95 ± 0.55 | 5.16 ± 0.62 | 4.73 ± 0.28 |
| Ash                  | 3.17    | 2.83 ± 0.23   | 2.55 ± 0.14 | 2.63 ± 0.16 | 2.94 ± 0.10 |
| Muscle composition (%)|         |               |             |             |             |
| Moisture             | 71.87   | 73.57 ± 0.37  | 72.93 ± 0.74| 72.29 ± 1.04| 74.29 ± 1.22|
| Protein              | 17.87   | 17.43 ± 0.24  | 17.62 ± 0.32| 16.78 ± 0.68| 16.52 ± 0.52|
| Lipid                | 3.58    | 4.63 ± 0.22   | 5.59 ± 0.26 | 5.01 ± 0.49 | 4.04 ± 0.29 |
| Ash                  | 3.34    | 2.59 ± 0.18   | 2.48 ± 0.09 | 2.47 ± 0.13 | 2.35 ± 0.05 |
efficiency of fish fed high levels of HNM could be the different apparent digestibility coefficients between soybean and hazel nut meals.

One of the most common problems when plant protein products are used can sometimes be acceptability due to the low palatability of the diets (Burel et al., 1998; Glen-cross et al., 2007). In the present experiment, feed consumption has been carefully monitored every day and no palatability problem was encountered in any treatments. Similar results have been reported by Bilgin et al. (2007), Ergun et al. (2008) and Emre et al. (2008) in rainbow trout, black sea turbot (Scophthalmus maeoticus) and sea bass, respectively.

Proximate composition of whole body and muscle (moisture, protein, lipid and ash) of rainbow trout were not affected by the inclusion level of hazelnut meal. These results are in agreement with the findings of Emre et al. (2008) in the European sea bass. However, body protein, lipid and ash were influenced by dietary hazelnut meal levels in rainbow trout reared in freshwater (Bilgin et al., 2007). Buyukcapar and Kamalak (2007) reported a reduction in carcass lipids in mirror carp fed diets containing various levels of hazelnut meal.

Conclusions

In conclusion, it can be suggested that hazelnut meal can partially substitute soybean meal in the diet of rainbow trout without any detrimental effect on growth performance. Formulated diets including up to 10-20% of HNM were palatable and readily consumed by fish in seawater environment. Growth performances of all experimental groups were quite similar irrespective of the inclusion level of HNM. Only FCR related to feed intake increase should be taken into consideration when HNM inclusion levels in the diets exceed 20%.

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REFERENCES

AOAC, 2000. Official Methods of Analysis. 17th ed. Association of Official Analytical Chemist, Arlington, VA, USA.

Barrows, F.T., Stone, D.A.J., Hardy, R.W., 2007. The effects of extrusion conditions on the nutritional value of soybean meal for rainbow trout (Oncorhynchus mykiss). Aquaculture 265:244-252.

Bilgin, Ö., Turker, A., Tekinay, A.A., 2007. The use of hazelnut meal as a substitute for soybean meal in the diets of rainbow trout (Oncorhynchus mykiss). Turk. J. Vet. Anim. Sci. 31:145-151.

Brett, J.R., Groves, T.D.D., 1979. Physiological energetics. In: W.S. Hoar, D.J. Randall and J.R. Brett (eds.) Fish Physiology. Vol. VIII., Academic Press, New York, NY, USA, pp 279-352.

Burel, C., Boujard, T., Corraste, G., Kaushik, S.J., Bœuf, G., Mol, K.A., Van Der Geyten, S., Kuhn, E.R., 1998. Incorporation of high levels of extruded lupin in diets for rainbow trout (Oncorhynchus mykiss): nutritional value and effect on thyroid status. Aquaculture 163:325-345.

Buyukcapar, H.M., Kamalak, A., 2007. Partial replacement of fish and soyabean meal protein in mirror carp (Cyprinus carpio) diets by protein in hazelnut meal. S. Afr. J. Anim. Sci. 37:35-44.

Emre, Y., Sevgili, H, Sanli, M., 2008. A preliminary study on the utilization of hazelnut meal as a substitute for fish meal in diets of European sea bass (Dicentrarchus labrax L.). Aquac. Res. 39:324-328.

Ergun, S., Yigit, M., Turker, A., Harmantepe, B., 2008. Incorporation of Soybean Meal and Hazel-
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nut Meal in Diets for Black Sea Turbot (Scophthalmus maeoticus). Isr. J. Aquacult.-Bamid. 60:27-36.

FAO, 2006. Aquaculture Production Statistics 2004. Food and Agriculture Organisation ed., Roma, Italy.

FAOSTAT, 2007. Food and Agriculture Organization of The United Nations. Home page address: http://faostat.fao.org/

Francis, G., Makkar, H.P.S., Becker, K., 2001. Anti-nutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. Aquaculture 199:197-277.

Gatlin, D.M., Barrows, F.T., Brown, P., Dabrowski, K., Gaylord, T.G., Hardy, R.W., Herman, E., Hu, G., Krogdahl, A., Nelson, R., Overturf, K., Rust, M., Sealey, W., Skonberg, D., Souza, E.J., Stone, D., Wilson, R., Wurtele, E., 2007. Expanding the utilization of sustainable plant products in aquafeeds: a review. Aquac. Res. 38:551-579.

Glencross, B.D., Booth, M., Allan, G.L., 2007. A feed is only as good as its ingredients - a review of ingredient evaluation strategies for aquaculture feeds. Aquacult. Nutr. 13:17-34.

Güroy, D., Deveciler, E., Güroy Kut, B., Tekinay, A.A., 2006. Influence of feeding frequency on feed intake, growth performance and nutrient utilization in European sea bass (Dicentrarchus labrax) fed pelleted or extruded diets. Turk. J. Vet. Anim. Sci. 30:171-177.

Hardy, R.W., 2002. Rainbow trout, Oncorhynchus mykiss. In: C.D. Webster (ed.) Nutrient Requirements and Feeding of Finfish for Aquaculture. CAB International, New York, NY, USA, pp 184-202.

Heikkinen, J., Vielma, J., Kemilainen, O., Tiirila, M., Eskelinen, P., Kiuru, T., Navaia-Paldanius, D., von Wright, A., 2006. Effects of soybean meal based diet on growth performance, gut histopathology and intestinal microbiota of juvenile rainbow trout (Oncorhynchus mykiss). Aquaculture 261:259-268.

Hertrampf, J.W., Piedad-Pascual, F., 2000. Handbook on Ingredients for Aquaculture Feeds. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Houlihan, D., Boujar, T., Jobling, M., 2001. Food Intake in Fish. Blackwell Science, Oxford, UK.

Krogdahl, A., Sundby, A., Olli, J.J., 2004. Atlantic Salmon (Salmo salar) and rainbow Trout (Oncorhynchus mykiss) digest and metabolize nutrients differently. Effects of water salinity and dietary starch level. Aquaculture 229:335-360.

Tekinay, A.A., Davies, S.J., Güner, Y., 2003. Growth, feed utilization and carcass composition in rainbow trout fed diets with a similar digestible energy content and different carbohydrate level. Isr. J. Aquacult-Bamid. 55:31-38.

Tekinay, A.A., Deveciler, E., Güroy, D., 2009. Effects of dietary tuna by-products on feed intake and utilization of rainbow trout Oncorhynchus mykiss. J. Fish. Inter. 4:8-12.

Tibaldi, E., Hakim, Y., Uni, Z., Tulli, F., de Francesco, M., Luzzana, U., Harpaz, S., 2006. Effects of the partial substitution of dietary fish meal by differently processed soybean meals on growth performance, nutrient digestibility and activity of intestinal brush border enzymes in the European sea bass (Dicentrarchus labrax). Aquaculture 261:182-193.

Venou, B., Alexis, M.N., Fountoulaki, E., Haralabous, J., 2006. Effects of extrusion and inclusion level of soybean meal on diet digestibility, performance and nutrient utilization of gilthead sea bream (Sparus aurata). Aquaculture 261:343-356.

Vielma, J., Ruohonon, K., Gabaudan, J., Vogel, K., 2004. Top-spraying soybean meal-based diets with phytase improves protein and mineral digestibilities but not lysine utilization in rainbow trout, Oncorhynchus mykiss (Walbaum). Aquac. Res. 35:955-964.

Zar, J.H., 2001. Biostatistical Analysis. Prentice-Hall Inc., Upper Saddle River, NJ, USA.