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Research Article

Effects of Different Diets on the Growth Performance, Gonad Development and Body Composition at First Sexual Maturity of Rainbow Trout (*Oncorhynchus mykiss*)

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Abstract: Rainbow trout *Oncorhynchus mykiss* with an initial mean weight of 174 g (1+ year old) were fed on 3 different commercial diets (1 extruded pellet and 2 steam pellet) in the same environmental conditions until their first spawning. Changes in growth performance (weight gain, condition factor, specific growth rate and feed conversion rate), gonadosomatic index (GSI), hepatosomatic index (HSI) and body composition (protein, lipid, ash and dry matter) were investigated. The mean weight gain and condition factor for fish fed the extruded diet was significantly greater than for those fed the steam pellet diets ($P < 0.05$). There were no significant differences in specific growth rate, mean length increments and feed conversion rate among the groups, although the feed conversion rate for the extruded diet was slightly lower than the others. The HSI of the group fed an extruded diet was significantly greater than those of the others ($P < 0.05$). The GSI values of female and male fish at the end of the study (October) did not differ significantly among the groups. Similarly, diet had no significant effects on the muscle composition of the trial fish, except that the muscle lipid of the group fed the extruded diet was significantly higher than those of the other groups ($P < 0.05$).

Key Words: Broodstock, rainbow trout, growth, gonad development, diets, muscle composition

Farklı Rasyonların Gökkuşağı Alabalıklarının (*Oncorhynchus mykiss*) İlk Olgunlaşma Dönemindeki Büyüme, Gonad Gelişimi ve Kas Kompozisyonuna Etkileri

Özet: Başlangıç ağırlıkları 174 g olan gökkuşağı alabalıkları üç farklı ticari yem ile (1 ekstrude, 2 batar tip pelet yem) aynı çevre koşullarında ilk yumurtlama evresine kadar beslenmişlerdir. Bu çalışmada, balıkların büyüme performansı (canlı ağırlık artışı, kondüsyon faktörü, spesifik büyüme oranı, yem değerlendirme oranı), gonadosomatik indeks (GSI), hepatosomatik indeks (HSI) ve kas biokimyasal kompozisyonu (protein, yağ, kül ve kuru madde) incelenmiştir. Ekstrude pelet yemle beslenen balıkların ortalama canlı ağırlık artışı ve kondüsyon faktörü diğer yemlerle beslenen balıklardan farklı bulunmuştur ($P < 0,05$). Gruplar arasında spesifik büyüme oranı, ortalama boy artışı ve yem değerlendirme oranı bakımından istatiksel olarak fark görülmemesine rağmen yem değerlendirme oranı bakımından ekstrude yemle beslenen balıklarda diğer balıklara göre nisbeten düşük bulunmuştur. Ekstrude yemle beslenen grubun HSI değerinde diğer gruplara göre istatistiki olarak farklı bulunmasına ($P < 0,05$) karşın GSI bakımından gruplar arasında fark görülmemiştir. Farklı yemlerle beslenen balıkların kas kompozisyonlarında protein, kül ve kuru madde bakımından farklılık görülmemesine rağmen ekstrude yemle beslenen balıkların kaslarındaki yağ oranı yüksek bulunmuştur ($P < 0.05$).

Anahtar Sözcükler: Anaç gökkuşağı alabalığı, büyüme, gonad gelişimi, rasyon, kas kompozisyonu

Introduction

Salmon and trout farming began in the 19th century following the development of artificial fertilization by Jacobi in 1765 (1). In Turkey, the first rainbow trout farm was established in 1969 and now the number of rainbow trout farms has exceeded 1.000 (2). However, one of the most important problems facing farmers is the cost and quality of broodstock diets.

The egg and sperm quality of fish species may be improved through the nutritional quality of broodstock diets (3,5). Gonad development and fish fecundity are greatly affected by broodstock nutrition in several fish species and, during the last decade, increasing attention has been paid to the role of the different components of broodstock diets (6).

Quality of diet ingredients is very important with regard to nutritional composition and palatability. The demand for better quality fish feeds is constantly increasing in this sector. Another way of improving the efficiency of feed utilization other than ingredient quality is through the manufacturing process. For example, extrusion is currently the main manufacturing process employed for fish species, including salmonid feeds. Although the technology is quite expensive, the advantages provided by extrusion with regard to feed efficiency and reduced pollution have given the process the edge over steam pressing.

Recently, rainbow trout farmers have begun to use extruded pellet diets as well as steam pressed pellets. However, the use of extruded diets is still limited, mainly due to their high costs, which represent the major proportion of the production costs in salmonid culture. Thus, the objective of this study was to compare some commercial diets in terms of growth performance, gonad development and muscle composition.

Materials and Methods

This study was carried out at the Sapanca Inland Water Fish Research and Applied Station of the Faculty of Fisheries, İstanbul University, from September 1999 to October 2000. At the beginning of the trial, 3 groups of rainbow trout with 2 replicates, each of 200 fish [initial mean weight of 174 ± 10.27 g (mean ± SD) and mean length 24.42 ± 0.64 cm], were randomly placed in 3 m diameter and 65 cm deep circular fiberglass tanks (4.6 m^3, 7.5 kg/m^3, 43.5 fish/m^3) during the first seven months. Subsequently, because of increasing stocking density (30.8 kg/m^3, 28 fish/m^3) they were relocated to 12 x 3 x 0.70 m rectangular concrete ponds (25 m^3). The rearing system was single-pass, flow-through. Freshwater inflow to the tanks was regulated to maintain a constant water flow of 1.5 l/s during the first 7 months and 3 l/s at the later stage. The water temperature, dissolved oxygen and pH in the ponds were measured daily using a WTW Model OXI 330/SET oxygen meter and a 330/SET pH meter (Wissenschaftlich-Technische Werkstätten Weilheim, Germany), and the values varied from 6.9 to 17.9 °C and 7.5 to 9.5 mg/l (Figures 1 and 2) and 7.13 to 8.2.

The fish were fed twice a day (pellet size: 4-6 mm) with 3 commercial diets. The feeds, 1 extruded pellet and 2 steam pellet were provided by the manufacturers. The nutritional composition of the diets is given in Table 1. Feeding rates were adjusted monthly according to water temperature, feed intake and the age of the fish: 1.7% in the 1^{st} month, 1.5% (2^{nd} month), 1.2% (3^{rd} month), 1% (4^{th}-12^{th} months) and 0.7% (13^{th}-14^{th} months) of body weight/day in the last month.

Ten fish from each group were randomly selected at 30-day intervals during the study period of 13 months. The fish were sacrificed with 0.03% benzocain (saturated in acetone) before weighing them and measuring their length. The livers and gonads were removed and weighed individually, and the sex of each fish was recorded. Muscle samples from each group were pooled and ground in a mincer, and mixed sub-samples were taken from each

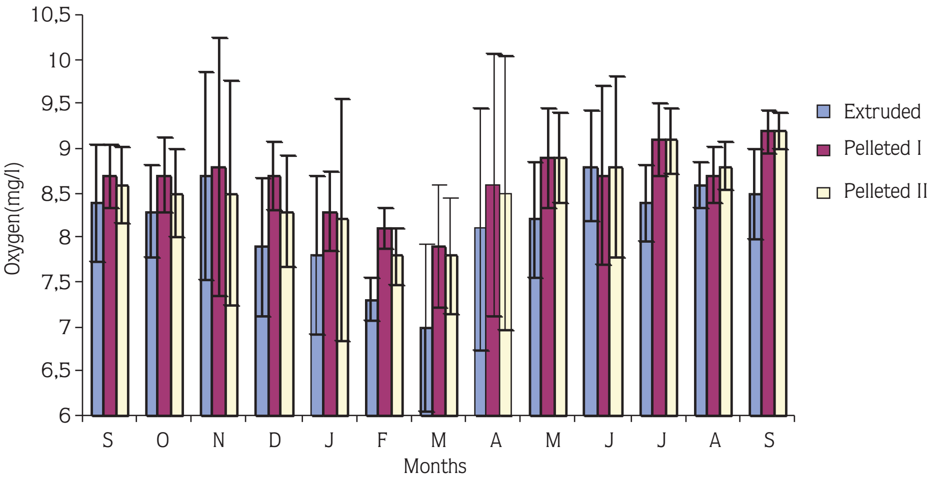

Figure 1. Mean monthly dissolved oxygen (mg/l) during the study. Error bars are 2 SD of the mean.

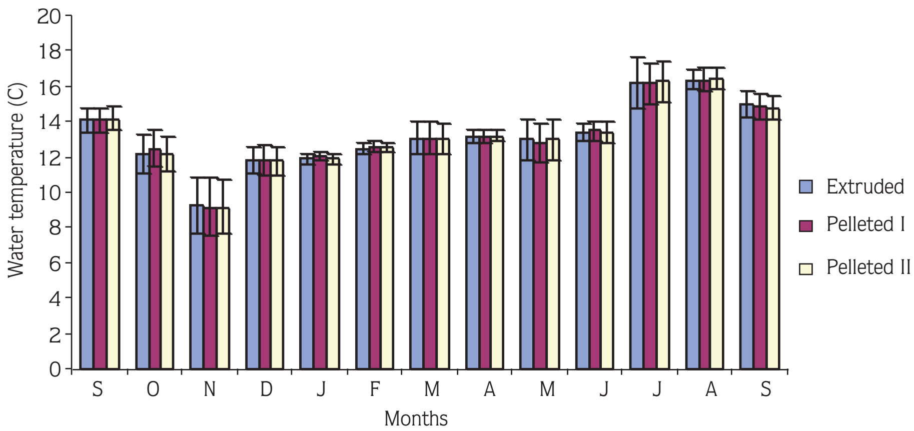

Figure 2. Mean monthly temperatures (°C) during the study. Error bars are 2 SD of the mean.

Table 1. The nutritional composition of the diets used during the study.

Pellet type	Extruded pellet	Steam pellet I	Steam pellet II
Proximate analysis			
Dry matter (%)	94.12	91.79	91.79
Moisture (%)	5.88	8.21	8.21
Crude protein (%)	46.65	43.82	46.86
Crude lipid (%)	20.42	14.03	11.30
Crude ash (%)	7.38	6.12	10.01
Crude fibre (%)	0.89	3.49	1.57
Carbohydrate (%)[a]	18.78	24.33	22.05
Gross energy[b]	5335	3945	4619
M.E.[c]	4223	2887	3084

[a] Calculated as 100%-(%protein + %lipid + %ash + %fiber + %moisture).
[b] (kcal/kg diet); based on 5.65 kcal/g protein, 9.45 kcal/g lipid, and 4.10 kcal/g carbohydrate (7).
[c] Metabolizable energy (kcal/kg diet); based on values given by Halver (7).

group for analysis of chemical composition (crude lipid, crude protein, dry matter and ash).

Feed conversion rate (FCR), specific growth rate (SGR), condition factor (K), gonadosomatic index (GSI) and hepatosomatic index (HSI) were calculated as follows:

FCR = Total feed given (kg)/total weight gain (kg) (8); SGR (%day^{-1}) = [100(lnW_2-lnW_1)/t], where W_2 is the final weight of the fish, W_1 is the initial weight and t is the number of days between sampling events (30 days) (1); K = 100W/L^3, where W is weight (g), L is total length (cm) (1); GSI = 100[gonad weight (g)/total body weight (g)] and HSI = 100[liver weight (g)/ body weight (g)] (9).

Dry matter was determined by drying at 100-102 °C, crude protein (N x 6.25) was measured according to the Kjeldahl method and ash was determined at a temperature of 550 °C (10). Crude fat in feeds was analyzed by using the ether extraction procedure (Soxtec System HT6 Tecator AB, Sweden). Fat in fish tissue was analyzed using the Soxtec System with a hydrolyzing unit (Soxtec System HT6, 1047 hydrolyzing unit, Tecator AB, Sweden). All samples were analyzed in triplicate.

Analysis of variance (ANOVA) was used to compare the mean values of the factors measured (N = 2), using Excel Office 2000 and SPSS 10.0. When a significant difference was found ($P < 0.05$), the ANOVA was followed by Duncan's multiple range test to identify which groups were different (11).

Results

Growth parameters evaluated during the study are summarized in Table 2. Initial length and weight values were not different among the groups. Fish fed the extruded pellet diet grew faster than the other groups and had a significantly higher final weight ($P< 0.05$, Table 2, Figure 3). A similar trend ($P < 0.05$) was observed for condition factor. However, the feed conversion and specific growth rates did not differ significantly among the groups.

The mean GSI of the female groups started to increase from May on, but rapid increments occurred during the last 3 months (Figure 4). At the beginning of the study mean GSI for females was 0.01, and increased to a maximum value of 6.67 for the group fed the steam pellet diet I (Table 3).

The HSI of the mature females in all groups fluctuated during the trial periods (Figure 5), from 1.46 in September to 0.86 in May. The values for the group fed the extruded diet were considerably higher than those of the other groups and the final values for males and females differed significantly among the groups ($P < 0.05$). The HSI fell towards the spawning period in both male and female fish (Table 3, Figure 5).

Body composition (dorsal muscle of fish) is given in Table 4. Initial values were determined just before the study. Dry matter, crude protein, crude lipid and ash were 22.16%, 19.16%, 8.64% and 1.34%, respectively. There were no significant changes in the mean percentage crude protein, dry matter and ash content of the fish body over the study period, while the lipid content of fish fed the extruded pellet diet was higher than that of the other groups (Figure 6) ($P < 0.05$).

Table 2. Growth performance of rainbow trout fed 3 different commercial diets. Values are means ± SD of replicates (N = 2). Means in each row followed by different superscripts differed at the 0.05 probability level according to Duncan's multiple range test.

	Extruded pellet	Steam pellet I	Steam pellet II
Duration of trial (days)	390	390	390
Initial weight (g)	174 ± 10.27[a]	174 ± 10.27[a]	174 ± 10.27[a]
Initial length (cm)	24.42 ± 0.64[a]	24.42 ± 0.68[a]	24.42 ± 0.64[a]
Final weight (g)	2346 ± 273[a]	1218 ± 168.8[b]	1326 ± 194.3[b]
Final length (cm)	53.85 ± 2.33[a]	44.20 ± 2.47[a]	46.00 ± 2.26[a]
Condition factor	1.38 ± 0.12[a]	1.25 ± 0.08[b]	1.25 ± 0.13[b]
Specific growth rate	0.67 ± 0.37[a]	0.50 ± 0.32[a]	0.52 ± 0.33[a]
Feed conversion ratio	1.7 ± 1.11[a]	2.8 ± 1.78[b]	2.4 ± 1.72[b]

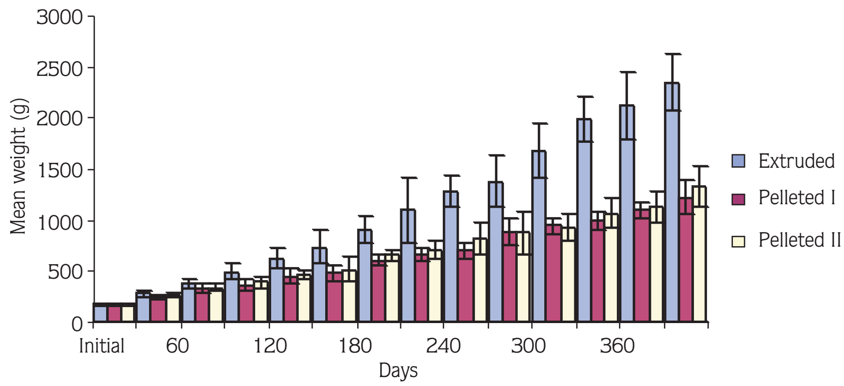

Figure 3. Changes in mean increase in weight in groups during the study. Error bars are 2 SD of the mean.

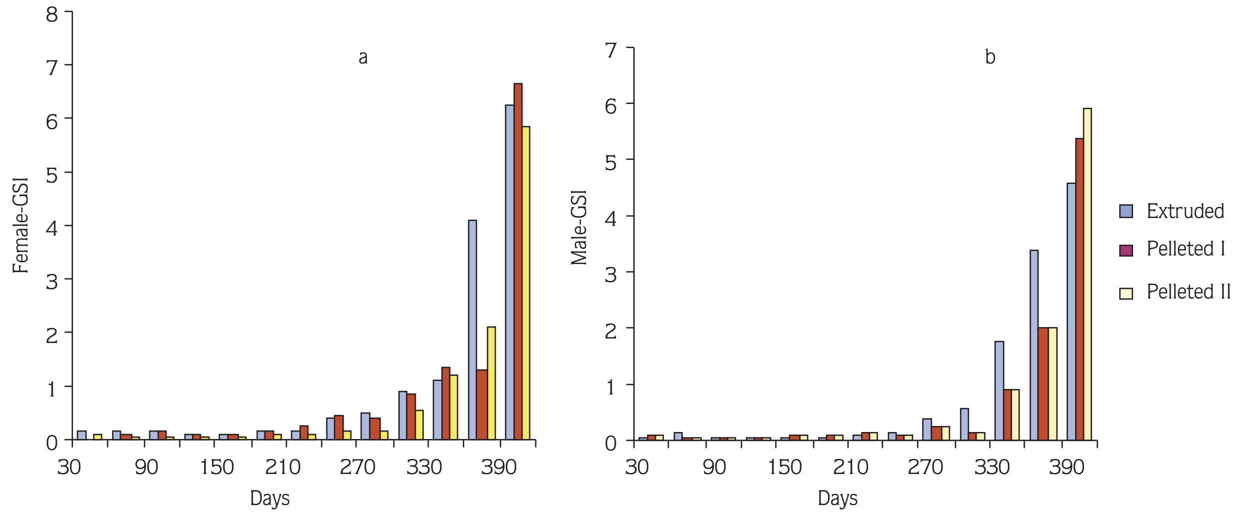

Figure 4. Variations in mean GSI values of females (a) and males (b).

Table 3. Mean gonad weight, liver weight, GSI and HSI, for male and female rainbow trout fed 3 different commercial diets. Values are means ± SD of replicates (N = 2). Means in each row followed by different superscripts differ at the 0.05 probability level according to Duncan's multiple range test.

	Extruded pellet		Steam pellet I		Steam pellet II	
	Female	Male	Female	Male	Female	Male
Initial gonad weight (g)	0.44 ± 0.04	0.16 ± 0.04	0.03 ± 0.03	0.19 ± 0.15	0.36 ± 0.10	0.27 ± 0.02
Final gonad weight (g)	146.5 ± 46.4	106.3 ± 36.6	83.0 ± 25.3	63.3 ± 10.6	85.4 ± 29.6	72.0 ± 30.0
Initial liver weight (g)	4.28 ± 0.99	3.63 ± 0,66	2.49 ± 0.09	2.70 ± 0.12	2.55 ± 0.26	2.17 ± 0.06
Final liver weight (g)	32.8 ± 5.95	24.1 ± 3.12	17.9 ± 3.75	11.6 ± 3.15	17.3 ± 4.38	8.95 ± 2.59
Initial GSI%	0.15	0.06	0.01	0.08	0.14	0.11
Final GSI%	6.23[a]	4.55[a]	6.67[a]	5.39[a]	6.13[a]	5.83[a]
Initial HSI%	1.46	1.30	1.04	1.10	0.96	0.89
Final HSI%	1.40[a]	1.03[b]	1.43[c]	0.99[c]	1.24[c]	0.73[c]

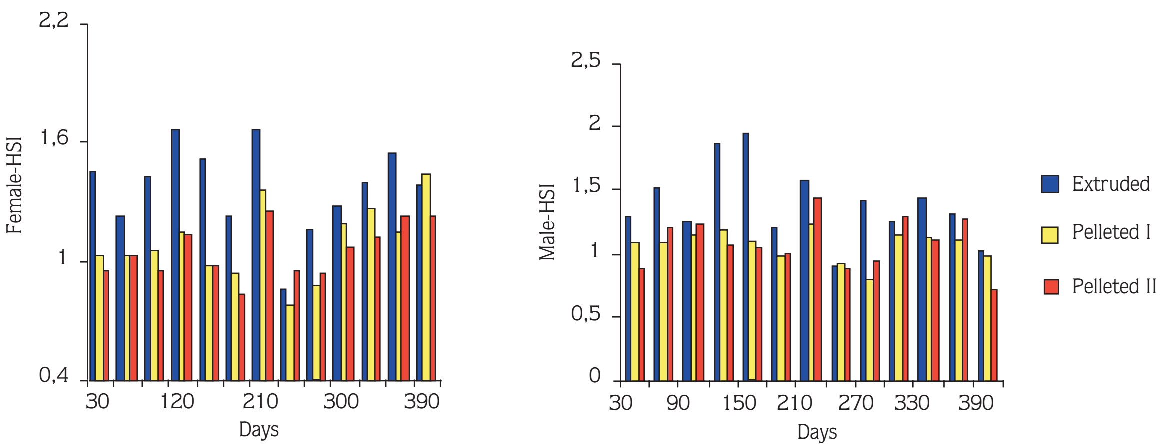

Figure 5. Variations in mean HSI values of females (a) and males (b).

Table 4. Average body composition (dorsal muscle; % dry weight basis) of rainbow trout fed different commercial diets during the experiment. Values are means ± SD of dorsal muscle of replicate groups (n = 10). Means in each row followed by different superscripts differ at the 0.05 probability level according to Duncan's multiple range test.

	Initial	Extruded pellet	Steam pellet I	Steam pellet II
Proximate analysis				
Dry matter (%)	22.16 ± 0.17	26.58 ± 0.36[a]	24.78 ± 0.55[a]	25.09 ± 0.39[a]
Crude protein (%)	19.16 ± 0.27	21.09 ± 0.52[a]	21.46 ± 0.36[a]	21.34 ± 0.66[a]
Crude lipid (%)	8.64 ± 0.46	15.70 ± 1.18[a]	9.33 ± 0.61[b]	9.27 ± 0.46[b]
Ash (%)	1.34 ± 0.005	1.46 ± 0.03[a]	1.41 ± 0.02[a]	1.41 ± 0.03[a]

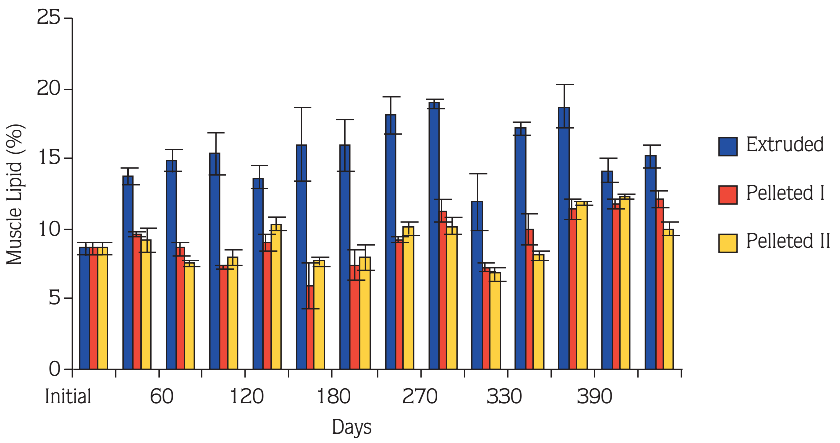

Figure 6. Variations in mean muscle lipid levels (% of dry matter). Error bars are 2 SD of the mean.

Discussion

Approximately 50% of the production costs in salmonid farming are related to feeds and feeding. Thus, the aim of the fish farmer is usually to cause the fish to grow rapidly, whilst keeping feed costs as low as possible. In deciding on feeding practices appropriate to given conditions, feeding rate, feeding frequency, pellet type and size and method of feed delivery should be considered, since all of these factors affect growth rates and efficiency of food utilization. Food intake is also influenced by season, photo-period, stocking density, water quality and abrupt changes in the rearing conditions and reproductive status of the fish. Growth increases until the fish reaches sexual maturity, at which time the rate of growth starts to slow down. The growth rate of fish is controlled by food intake and environmental conditions (12-17).

Jobling (14) observed the effects of feeding rate on digestibility of dietary energy in rainbow trout. He found that the higher growth rate and higher digestibility of dietary energy of extruded diets were due to an increased availability of dietary carbohydrate. There was no difference in protein digestibility between pelleted and extruded diets.

In the present study higher growth rates (Figure 3) were observed in fish fed the extruded pellet diet rather than those on steam pellet diets. The specific growth rates in the groups varied from 0.15 to 1.64 in different periods. Feed conversion rates (FCRs) in groups also varied from 0.8 to 6 in different periods. These variations are related to water quality, environmental conditions (Figures 1 and 2), physiological state and age of fish sampling and/or food intake in periods. Thus, at the end of the study, the mean FCR values in the groups were 1.7, 2.4 and 2.8 (Table 2). Priede and Secombes (13) reported that fish approaching sexual maturation and swelling with eggs have a very high condition factor, 1.4 or over, and that this falls to well below 1 after spawning.

At the beginning of the current study, the mean condition factor of the groups was 1.19, while the final values rose to 1.38 in the group fed the extruded pellet diet and 1.25 in the other groups fed steam pellet diet II (Table 2).

Watanabe (3) reported that dietary protein levels did not affect pre-spawning mortality, spawning success or the duration of spawning, nor did they have a significant effect on the absolute or relative number of eggs spawned, relative egg size or embryo survival. High energy levels, however, had a greater effect on broodstock spawning.

The extruded pellet diet had a high level of energy. It can therefore, affect gonad, and liver development and the nutritional value of broodstock. The mean GSI increased towards the spawning period in female fish (Figure 4). There were no significant differences in GSI among the experimental groups. However, HSI in the group fed the extruded pellet diet was higher than that in the groups fed pellet diets ($P < 0.05$) (Table 3). The HSI of the mature females in the groups fluctuated from September to May, possibly due to seasonal changes. The mean HSI of the groups started to increase again for the females from summer-autumn which normally takes place during the breeding season (Figure 5).

Lincoln and Scott (9) reported on diploid male and female GSI and HSI in their study, and found higher HSI in diploid females because the livers are engaged in the synthesis of vitellogenin. Tveranger (4) noted that the HSI of females fell during the spawning period, approaching the same levels as those of male and immature fish. HSI in maturing females is significantly higher in the period before spawning than that in males. HSI increased towards spawning and then subsequently decreased.

The composition of the diet determines, to a large extent, the fat content of fish. The higher the ratio between the metabolizable energy and protein in the diets, the higher the fat content in the tissue. Whole-body composition was also affected by season, water temperature and sexual maturation (18).

In the present study, a higher muscle lipid level was observed in the group fed the extruded diet than in the other groups until the end of the study (Figure 6). This indicates that the high lipid in the extruded pellet diet has more effect on muscle lipid than the other pellet diets.

A similar result was obtained by Reintz and Hitzel (19), Reintz (20) and Zoccarato et al. (21). In addition the protein, lipid and water content of immature rainbow trout growing at different rates were examined by Weatherley and Gill (22). In fingerlings, protein, lipid and caloric contents tended to increase as a percentage of body composition, whereas above fingerling size, protein decreased whilst lipid and caloric contents continued to increase. Rowe et al. (23) reported that mesenteric fat is needed for maturation. Fat levels continued to increase in non-maturing parr during autumn months, but had declined in maturing parr by September.

The mean feed costs in the groups were: extruded diet, \$0.67/kg x 1.7(FCR) ~ \$1.1 per kg fish; steam pellet diet I, \$0.60/kg x 2.8(FCR) ~ \$1.7 per kg fish; steam pellet diet II, \$0.56/kg x 2.4(FCR) ~ \$1.6 per kg fish. Although the extruded diet is more expensive than the other steam pellets, producing 1 kg of fish with this diet cost less due to the better feed conversion. Even though the feed conversions were not significantly different, the fish fed the extruded feed had a lower feed conversion, which made the diet cost effective.

In conclusion, the results of this study show that extruded feeds improved growth performance, feed conversion, gonad weight and lipid content in fish flesh compared to those achieved with steam pellet diets. The higher energy content of the extruded diet may partly explain the improved growth performance of fish. During the study there was an increase in body lipid content in the group fed the extruded diet compared to those on the steam pellet diets. High energy due to the extruded feeds did not adversely affect the deposition of proteins. On the applied side, future studies for extruded feeds should focus on the effects of unwanted intraperitonal lipid in broodstocks. More studies are also needed on the content of broodstock feeds in terms of nutritional ingredients.

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