PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 11 (2): 104-109, 2012
ISSN 1680-5194

Effects of Pressed and Extruded Foods on Growth Performance and Body Composition of Rainbow Trout (*Oncorhynchus mykiss*)

Mustapha Aba[1], Belghyti Driss[1], Elkharrim Khadija[1], Benabid Mohammed[2] and Maychal Aziz[3]
[1]Biology and Health Laboratory, Environmental and Parasitology Team/UFR Doctoral "Parasitology compared: Medical and Veterinary Applications," Sciences Faculty, Ibn Tofail University, Kénitra B.P. 133, 14000, Morocco
[2]National Center of Hydrobiology and Pisciculture (NCHP)
[3]Agronomic and Veterinary Institute, Hassan II, Rabat, Morocco

Abstract: In order to compare the growth performance and quality of flesh of *Oncorhynchus mykiss*, with two types of food the pressed and extruded foods, an experimental test was conducted in a fish farm. The comparison of both foods with different formulation and different energy is performed in isoenergetic conditions. Following this study, two plans were formulated: the extruded food with 42% crude protein, 28% fat and 17% carbohydrate while the pressed food with 44.7% Crude Protein, 15% fat and 28.6 carbohydrates with digestible energy of 20.9 Mj and 16.48 Mj. The initial average weight of the trouts was 474 g and the fish were bred in two circular tanks supplied with fresh water in open circuit. Each group was fed twice a day. Within a 60 day-experiment, the final average weight of the extruded food group was 759 g (60.12% weight gain) and 724 g for the pressed food group (52.74 % weight gain). The best conversion rate was obtained with the extruded food with 1.17 v.s 1.56 with a survival rate of respectively 98.85 and 97.72%. The extruded feed resulted in more protein, more fat and less moisture in the fillets. Manufacturing technology and the formulation of both foods have had a major influence on the growth performance and flesh quality of rainbow trout.

Key words: Pelleted, extruted, trout, growth, nutrition, fillet composition

INTRODUCTION

In aquaculture feed is the main component of cost of production since it can reach 40 to 60% of the cost of production of farmed fish (Kaushik, 2000) and the development of this sector depends on the development formulation of a food economy but which meets the requirements of the fish in terms of quality and quantity (Kaushik, 1999). But the food fish is characterized by high levels of fishmeal (NRC, 1993) and the last two decades these meals tend to be partially replaced by vegetable products in order to have a savings protein (Medale, 2009) follows two major strategies: the first strategy is the replacement of fish meal by d other sources of vegetable protein and the second by increasing the energy input from non-digestible protein (Tacon, 1994; Cho and Bureau, 2001), this contribution is governed through better optimization of the use of food in addition to the quality of ingredients and what the process of manufacture (Kaushik, 2000). The concept of savings protein by lipids and carbohydrates, which, in addition to improving growth performance, reduces emissions of nitrogen, by limiting the oxidation of amino acids (Kaushik and Oliva-Teles, 1985; Cho and Bureau, 2001). The pressed food is characterized by a low digestibility of carbohydrates in rainbow trout (Krogdahl *et al*., 2005) and a low fat intake (Kaushik, 2000), therefore the energy provided by this pelleted food is low. The determination of protein and energy requirement of fish is essential on formulating nutritionally adequate and cost-effective feed, as growth performance and carcass composition of fish closely depend upon dietary protein and energy level.

New improvements in extruder technology have moved the upper limit of fat content in extruted feed from around 20 to 30%, an improved digestibility of starch and the energy content of food increase (Krogdahl *et al*., 2005) allowing good retention of protein and fish tissue becomes more fatty (Kaushik, 2000).

The objective of the present study was to evaluate the effects of pelleted and extruted food and to determine the interaction between these foods their formulation and their impacts on fish performance and body composition.

MATERIALS AND METHODS

Experimental design: The experiment was conducted between April 15, 2009 and June 27, 2009 at the fish farm located about 70 km from Azrou (Morocco). This test was conducted in two circular tanks of 22 m^3 volume at open circuit with an initial load of

Corresponding Author: Mustapha Aba, Biology and Health Laboratory, Environmental and Parasitology Team/UFR Doctoral "Parasitology compared: Medical and Veterinary Applications," Sciences Faculty, Ibn Tofail University, Kénitra B.P. 133, 14000, Morocco

14 kg fed by spring water at a constant temperature of around 14°C and a flow rate of 30 m^3/h, with a time of renewal of water 1.4 times per hour with oxygen levels above 80% saturation. The average content of dissolved oxygen in the outlet of the ponds was 7.1 ppm.

Biological materials: 1400 juveniles trout females triploid of average weight of 474 g from the same batch of eggs were divided randomly into two circular tanks. The test was conducted in monoculture, fish were fed manually and the daily ration was split into two meals distributed at 09 am and 03 pm, seven days a week for 60 days, according to the feeding table provided by the supplier of food (71 *E. coli* of Biomar). Every two weeks 30 fish of each batch have been anesthetized after 24 h of fasting in order to measure the size and the weight of each fish for measurements of weight and size. The quantities of food distributed were weighed to estimate the consumption by the fish between two weighings.

Experimental foods: Formulation and chemical composition of experimental diets are shown in Table 1a, 1b and 2.

The rate of feeding: The experimental test was aimed at comparing two non-isoenergetic foods to different formulations on their growth performance of fish and their flesh quality in isoenergetic condition. The amount of food distributed is consistent with the feeding tables of extruded and pressed foods that have different digestible energy 20.90 Mj, 16.48 Mj, respectively. These rates of rationing depends on the temperature of the water closely of the site, we have set the rates according to the temperature of the site which is about 14° so that the quantitative ratio for the same food energy intake is: amount of food extruded 1.27 = amount of pressed food (or amount of food extruded 0.78 = amount of pelleted food). Gross energy was calculated using the following values: crude protein = 23.7 kJ/g, crude lipids = 39.5 kJ/g and carbohydrate = 17.2 kJ/g proposed by Brett and Groves (1979). The calculation of digestible energy is obtained by the coefficient of digestibility of protein, fat and carbohydrates gelatinized or raw (Guillaume and Medale, 2001).

Body measurements: Body mass, length and organ mass were recorded to evaluate the Condition Factor (CF) = ([total body weight (g)] / [total body length (cm)]3 viscerosomatic index (VSI) = ([viscera weight (g)] / [total body weight (g)] x 100) (Ricker, 1979).

Zootechnical parameters

Calculations: The following variables were calculated:

Weight gain (WGR, %) = 100 x (final body weight - initial body weight) / initial body weight

Table 1a: Ingredient and proximate compositions (g/100 g dry matter) of the Extruted diets

Ingredients	Extruted diet
Fish meal	30%
Soybean meal	15%
Rapeseed oil	12%
Fish oil	10%
Soy concentrate	8%
Wheat	6%
Rapeseed meal	6%
Krill meal	5%
Vitamin A - (UI/kg)	5000
Vitamin D_3 - (UI/Kg)	1000
Vitamin E - (mg/kg)	180
Vitamin C - (mg/kg)	100
Astaxanthin	50 ppm
Ashes	7%

Table 1b: Ingredient and proximate compositions (g/100 g dry matter) of the pelleted diet

Ingredients	Pressed diet
Fish meal	41.5%
Fish oil	11.5%
Corn gluten	15%
Wheat Flour	30%
Vitamin complex	2%
Cantaxanthin	40 ppm
Ashes	6.1%

Table 2: Proximate composition of diets (%)

	Extruted diet	Pressed diet
Dry matter	96%	93.2%
Proteins	42%	44.7%
Lipids	28%	15%
Carbohydrates	17%	28.6%
Fiber	2%	2%
Ash	6%	6.1%
Moisture	4%	6.80%
Phosphorus	1%	1.15%
Gross energy (GE, Mj/kg)	24.28	21.58
Digestible energy (DE, MJ/kg)	20.90	16.48
DP/DE (g/MJ) (DP:Digestible Prtoein)	18.08	24.41
Ratio P/L	42/28	44.7/15

Survival (%) = 100 x (final amount of fish / initial amount of fish)

Average daily growth (g) = (final wt - initial wt) / no. of days

Feed conversion ratio (FCR) = Feed fed (g, DW)/body weight gain (g)

Specific growth rate (SGR) = [ln final mean body wt. (g)] - [ln initial mean body wt. (g)]/days x100

Feed conversion ratio (FCR) = g feed consumption / (g final biomass - initial biomass)

Food conversion ratio (FCR) = Diet fed (g) / total wet weight gain (g)

Specific Growth Rate (SGR) = 100 (Ln final weight (g) - Ln initial weight (g)) / time (days)

Chemical analysis: At The ventral muscle was determined, crude protein, crude fat and ash, according to AOAC (1990).

Eight fillets of final fish carcasses and muscles were sampled and stored at -25°C for proximate analyses, which were performed according to AOAC. Dry matter was determined after drying at 105°C until a constant weight was obtained. Ash content was measured by incineration in a muffle furnace at 525°C for 12 h. Crude protein was analyzed by the Kjeldahl method after acid digestion using the Gerhardt system. Lipid was determined by folch method (1957).

Statistical studies: Our results are compared statistically (R Development Core Team, 2011). All parameters of growth and yield were subjected to Analysis of Variance test (ANOVA). The results were subjected to analysis of variance and any differences estimated by the Duncan test (1955) at the 0.05 level.

RESULTS

During the experiment no mortality and no disease were recorded. The two experimental diets were well accepted by fish throughout the trial, the water temperature varied during the test between 13.9° and 14.1°C. Our experimental test shows that the performance of zootechnical parameters vary significantly ($p < 0.05$) between the two dietary treatments (Table 3). Indeed the final weights of fish are between 724 and 759 g for diets extruded and pressed and Duncan's test shows a significant difference between the final weights ($p<0.05$). The percentage weight gain was 52.74 for the pelleted food, when he was in the extruded feed 60.12. There is a significant difference between the two values of the two systems ($p<0.05$). The TCS is calculated by 0.7% for fish fed with the diet in a pressed feed and 0.8% for the extruded diet, there was a significant difference ($p<0.05$). The VI was 7.88 for the pressed food and 10.29 for the extruted food; The condition factor was 1.16 and 1.24 respectively for the presse and the extruted food. The survival rate was 97.72% for pelleted food and 98.85% for the extruded food the difference between the two groups was not significant. The rainbow trout fed with extruded feeds had high levels of lipid and low levels of moisture compared with rainbow trout fed with pelleted feeds ($p<0.05$), probably due to high fat level in the extruded feed. The crude protein levels of the fish fillet differ ($p>0.05$) among fish fed with extruded and pelleted feeds.

DISCUSSION

For the determination of optimum growth rates and body composition of rainbow trout, it is necessary to determine the protein and energy requirement of this fish. Since the protein content in finfish diets usually constitutes the largest single cost factor in feeds (Watanabe, 2002).

Table 3: Results of Rainbow trout performances obtained during this experimental test

	Prelleted diet	Extruted diet
Initial average weight (g)	474.00	474.00
Final average weight (g)	724.00	759.00
Weight gain (%)	52.74^a	60.12^b
Specific growth rate (%)	0.70^a	0.80^b
Feed conversion ratio	1.56	1.07
Viscerosomatic index	7.88^a	10.29^b
Protein efficiency ratio (PER)		
Condition factor K	1.16^a	1.24^b
Survival (%)	97.72	98.85

Table 4: Filet composition (g/100 g DM)

	Pelleted diet	Extruted diet
Protein	17.78^a	19.72^b
Fat	5.58^a	8.35^b
Moisture	72.50^b	68.85^a

A significant improvement in growth performance due to the sparing effect of lipid and carbohydrate on dietary protein and the manufacturing technology has been reported for the same fish species (Guroy, 2006; Aba *et al.*, 2011) and in the sea bass (Chebbaki, 2010) and in silver perch (Booth *et al.*, 2002).

The difference performance observed between the tested foods (Pressed and Extruded) would result from the best degree of convertibility by the fish, the ingredients incorporated into foods. In our study the weak growth performance observed in the batch fed with the pelleted food could be explained by their different levels of protein, fat and carbohydrates and also by the manufacturing technology of that food (Aba *et al.*, 2011). The pelleted food contains significant levels of protein, more raw starch and the salmonids in general are characterized by a low digestibility in raw starch and this results from a failure in specific enzyme (Krogdahl *et al.*, 2005). The pressed food contains less fat because its physical structure does not allow incorporation of these fats (Kaushik, 2000) and thus the energy of the food is low compared to that of extruded one.

In salmonids, the digestive and metabolic utilization of carbohydrates depends on their nature or complexity while the technological treatments (extrusion, gelatinization) improve the digestibility of starches (Spannhof and Plantikow, 1983; Bergot and Breque, 1983; Kaushik, 2000). Therefore, the diets containing gelatinized starch provide more digestible energy than the diets containing raw starch. The low digestibility of the raw starch is due to the amylase (Spannhof and Plantikow, 1983; Silas and Trono, 1994), which is lacking in the rainbow trout (*Oncorhynchus mykiss*).

The energy content, with a low ratio between digestible protein and digestible energy (DP/DE) could explain the improved performance Plan extruded (Guillaume and Medale, 2001) as a result of better utilization of food, while contributing to better growth and better use of proteins, which saves the proteins as indicated in numerous studies (Kaushik *et al.*, 1989; Cho, 1992). However, we can reduce the rate of protein in food by increasing the intake of digestible energy as fat (Cho and Kaushik, 1990) or as digestible carbohydrates such as starch gelatinized (Kaushik and Oliva-Teles, 1985). Hence improving the digestibility of starch and therefore there is an increase of the digestible energy of the food. The increase in the amount of digestible energy in fish feed by incorporating a rate well digestible carbohydrates by the extrusion process (Kaushik, 2000) and a high rate of lipids is a nutritional strategy applied in order to have a sparing protein without compromising the growth of trout (Cho and Bureau, 2001). This sparing effect by supplementation of fat and carbohydrates has been well demonstrated for salmonids and catfish (Dias *et al.*, 1999; Torstensen *et al.*, 2001; Aba *et al.*, 2011), perch Scortum barcoo (Song *et al.*, 2009).

Dietary PD/ED is an important criterion in fish feed formulation. Optimum dietary DP/ED ratios for rainbow trout at temperature between 15° and 18° were investigated and the estimated ratios range from 17 to 19 Mj/kg (Medale, 2010). In the present study, the maximum growth and feed efficiency ratio was obtained in the group with the extruted food.

The growth observed in this study represented by the weight gain are comparable to those obtained by Pfeffer *et al.* (1991) and those reported by Pokniak *et al.* (1999) and these results are consistent with those reported by Zoccarato *et al.* (1996) and Aba *et al.* with their experimental work concerning the trout, the pressed and extruded foods, since the extruded food is high in fat and thus provides more energy than the pressed one and then the fish is gains more weight.

Similar results were observed in the silver perch (*Bidyanus bidyanus*) by Booth *et al.* (2002) and in the Nile tilapia (*Oreochromis niloticus*) by Ammar (2008) whose body has known a significant gain with the extruded food compared to the pressed food. Guroy (2006) and Chebbaki (2010) in their work on Dicentrarchus labrax, even with isoenergetic diets for pressed and extruded diets have observed a better performance in weight.

In addition, we can say that in the diet can be extruded to have a greater incorporation of lipids, which probably increased by the IVS increased visceral fat is seen in the viscera that there are more deposition of fat in the rainbow trout (Richard *et al.*, 2006; Medale, 2009) and IV obtained in this study is almost consistent with the results of Gelineau *et al.* (2001).

It is now well known that decreasing dietary energy supply reduces fish growth, feed efficiency and protein retention by increasing protein catabolism (Watanabe, 1982; Medale *et al.*, 1995).

Our results for fillet composition are similar to those reported by Quillet *et al.* (2007), including the energy content of food plays an essential role in the retention of protein and fat and moisture and are consistent with those of Yildiz (2007) whose work is carried out on the sea bass. the low content of protein in the net can only be explained by a large protein catabolism in trout fed with the pelleted food to have the energy for growth (Medale, 2009).

Lipid concentration in fish body (fillets), reflected dietary lipid concentration (Chaiyapechara *et al.*, 2003; Medale, 2009). Increasing the lipid concentration in the feed from 15-28% increased the fillet lipid concentration from 5.58-8.35%. The trout composition at the end of the test shows an increased content of lipids independently of protein levels (Dias *et al.*, 1999).

The studies indicated (Lupatsch *et al.*, 2001) that only dietary fat level may influence the carcass fat level, whereas the protein of the diet does not affect the same elements of the filet when the fish weight is taken into account.

Increasing dietary energy intake leads, in almost all species, an increase in body fat accompanied by a decrease in water content (Medale, 2010).

Moisture content, inversely correlated to lipid content (Quillet *et al.*, 2007). According to studies by De Francesco *et al.* (2004), Quillet *et al.* (2007), the moisture content increases as the fat content of fillet is low, Similar results were obtained for Sea bass by Yildiz (2007) and these results are consistent with results obtained in this trial.

Conclusion: The control of growth performance and fillet composition of fish is related to the composition of the food and method of manufacture. The extruded food offers the best trout growth performance of its energy content, its buoyancy, its digestibility and the ratio of digestible protein/digestible energy and protein energy levels not decisive. In intensive fish farming using extruded diets despite their price can be justified by the savings resulting from their feed efficiency, for better conversion and their contribution to sustainable aquaculture.

REFERENCES

Aba, M., D. Belghyti, K. Elkharrim, M. Benabid, Y. Elguamri and A. Maychal, 2011. Effects of two pressed and extruded foods on growth performance and flesh quality of rainbow trout (*Oncorhynchus mykiss)*. Sciencelib Editions Mersenne, volume 3 N°111004.

Ammar, A., 2008. Effect of extruded and non extruded fish pellet on growth performance and total production of nile tilapia and grey mullet fingerings reared in a polyculture system in earthen ponds, 8ème Symposium sur l'aquaculture du tilapia October 12-14, 2008 Cairo, Egypt.

AOAC (Association of Official Analytical Chemists), 1990. Official methods of analysis of the Association of Official Analytical Chemists, 15th edition. AOAC, Arlington, Virgina, USA.

Bergot, F. and J. Breque, 1983. Digestibility of starch by rainbow trout: Effects of the physical state of starch and the intake level. Aquaculture, 34: 203-212.

Booth, M.A., G.L. Allan, A.J. Evans and V.P. Gleeson, 2002. Effects of steam pelleting or extrusion on digestibility and performance of silver perch *Bidyanus bidyanus*. Aquac. Res., 33: 1163-1173.

Brett, J.R. and T.D.D. Groves, 1979. Physiological energetics. Pages 279-352 In W.S. Hoar, D.J. Randall and J.R. Brett. (eds.). Fish Physiology. Volume 8. Bioenergetics and Growth. Academic Press, New York.

Chaiyapechara, S., M.T. Casten, R.W. Hardy and F.M. Dong, 2003. Fish performance, fillet characteristics and health assessment index of rainbow trout (*Oncorhynchus mykiss*) fed diets containing adequate and high concentration of lipid and vitamin E. Aquaculture, 219: 715-738.

Chebbaki, K., 2010. Effect of fish meal replacement by protein sources on the extruded and pressed diet of European sea bass juvenile (*Dicentrarchus labrax*). Agric. Biol. J. North America, 1: 704-710.

Cho, C.Y., 1992. Feeding systems for rainbow trout and other salmonids with reference to current estimates of energy and protein requirements. Aquaculture, 100: 107-123.

Cho, C.Y. and S.J. Kaushik, 1990. Nutritional energetics in fish: protein and energy utilization in rainbow trout. In: Bourne GH, Ed. Aspects of food production, consumption and energy values. World Rev. Anim. Nutr., 61: 132-172.

Cho, C.Y. and D.P. Bureau, 2001. A review of diet formulation strategies and feeding systems to reduce excretory and feed wastes in aquaculture. Aquac. Res., 32: 349-360.

De Francesco, Giuliana Parisi, Françoise Medale and Paola Lupi, 2004. Effect of long-term feeding with a plant protein mixture based diet on growth and body/fillet quality traits of large rainbow trout (*Oncorhynchus mykiss*). Aquaculture, 236: 413-429.

Dias, J., G. Corraze, J. Arzel, M.J. Alvarez, J.M. Bautista, C. Lopez-Bote and S.J. Kaushik, 1999. Nutritional control of lipid deposition in rainbow trout and European seabass: Effect of dietary protein/energy ratio. Cybium, 23: 127-137.

Duncan, D.B., 1955. Multiple range and Multiple F test. Biometrics, 11: 1- 42.

Gélineau, A., G. Corraze, T. Boujard, L. Larroquet and S. Kaushik, 2001. Relation between dietary lipid level and voluntary feed intake, growth, nutrient gain, lipid deposition and hepatic lipogenesis in rainbow trout. Reproduction, Nutrition, Development, 41: 487-503.

Guroy, D., 2006. Influence of feeding frequency on feed intake, growth performance and nutrient utilization in European Sea Bass (*Dicentrarchus labrax*) fed pelleted or extruded diets. Turkish J. Vet. Anim. Sci., 30: 171-177.

Guillaume, J. and F. Medale, 2001. Nutrition and feeding of fish and crustaceans, Nutritional énergétics, pp: 59-79.

Kaushik, S.J. and A. Oliva-Teles, 1985. Effect of digestible energy on nitrogen and energy balance in rainbow trout. Aquaculture, 50: 89-101.

Kaushik, S.J., F. Medale, B. Fauconneau and D. Blanc, 1989. Effect of digestible carbohydrates. On protein/energy utilization and on glucose metabolism in iainbow trout (*Salmo gairdneri* R.). Aquaculture, 79: 63-74.

Kaushik, S.J., 1999. Nutrition glucidique: Intérêt et limites des apports de glucides, In: Nutrition et alimentation des poissons et crustacés INRA Editions, pp: 171-186.

Kaushik, S.J., 2000. Feed formulation, diet development and feed technology CIHEAM, pp: 43-51.

Krogdahl, A., G.I. Hemre and T.P. Mommsen, 2005. Carbohydrates in fish nutrition: Digestion and absorption in postlarval stages. Aquac. Nutr., 11: 103-122.

Lupatsch, I., G.W. Kissil and D. Sklan, 2001. Optimization of feeding regimes for European sea bass *Dicentrarchus labrax*: A factorial approach. Aquaculture, 202: 289-302.

Médale, F., C. Brauge, F. Vallée and S.J. Kaushik, 1995. Effects of dietary protein/energy ratio, ration size, dietary energy source and water temperature on nitrogen excretion in rainbow trout. Water Science and Technology, 31: 185-194.

Medale, F., 2009. Protein sources in feed for farmed fish. Agricultures, 18: 103-111.

Medale, F., 2010. Nutritional quality of fish flesh lipids as affected by farming practices. Cahiers de Nutrition et de Diététique, 45: 267-273.

National Research Council (NRC), 1993. Nutrient Requirements of Fish. Washington, DC: National Academy Press.

Pfeffer, E., J. Beckman-Toussaint, B. Henrichfreise and H.D. Jansen, 1991. Effect of extrusion on efficiency of utilisation of maize starch by rainbow trout *Oncorhynchus mykiss*. Aquaculture, 96: 293-303.

Pokniak, J., S. Cornejo, C. Galleguillos, C. Larrain and J. Battaglia, 1999. Effects of pelletization or extrusion of the fattening diet on production performance of pan size rainbow trout (*Oncorhynchus mykiss*). Archivo. medicina. vetirinaria, 31: 141-150.

Quillet, E., S. Guillou, J. Aubin, L. Labbé, B. Fauconneau and F. Médale, 2007. Response of a lean muscle and a fat muscle rainbow trout (*Oncorhynchus mykiss*) line on growth, nutrient utilization, body composition and carcass traits when fed two different diets. Aquaculture, 269: 220-231.

R Development Core Team, 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing.

Richard, N., S.J. Kaushik, L. Larroquet, S. Panserat and G. Corraze, 2006. Replacing dietary fish oil by vegetable oils has little effect on lipogenesis, lipid transport and tissue lipid uptake in rainbow trout (*Oncorhynchus mykiss*). Br. J. Nutr., 96: 200-309.

Ricker, W.E., 1979. Growth Rates and Models. W.S Hoar, D.J. Randall and J.R. Brett (Eds.) Fish Physiology, Vol.8. Academic Press, New York: XVII+786 pp.

Silas Hung, S.O. and S. Trono, 1994. Carbohydrate utilization by rainbow trout is affected by feeding strategy. J. Nutr., 124: 223-230.

Song, L.P., L. AN, Y.A. Zhu, X. Li and Y. Wang, 2009. Effects of dietary lipids on growth and feed utilization of jade perch, *Scortum barcoo*. J. World Aquac. Soc., 40: 266-273.

Spannhof, L. and H. Plantikow, 1983. Studies on carbohydrate digestion in rainbow trout. Aquaculture, 30: 95-108.

Tacon, A.G.J., 1994. Feed ingredients for carnivorous fish species: Alternatives to fishmeal and other fishery resources. FAO Fish. Circ., pp: 81, 35.

Torstensen, B.E., Ø. Lie and K. Hamre, 2001. A factorial experimental design for investigation of effects of dietary lipid content and pro- and antioxidants on lipid composition in Atlantic salmon (*Salmo salar*) tissues and lipoproteins. Aquac. Nutr., 7: 265-276.

Watanabe, T., 1982. Lipid nutrition in fish. Comparative Biochemistry and Physiology, 73: 3-15.

Watanabe, T., 2002. Strategies for further development of aquatic feeds. Fish Sci., 68: 242-52.

Yildiz, M., 2007. Effects of variations in feed and seasonal changes on body proximate composition of wild and cultured sea bass (*Dicentrarchus labrax* L.). Turk. J. Fish. Aquatic Sci., 7: 45-51.

Zoccarato, I., B. Sicuro, L. Gasco, G.B. Palmegiano, M. Boccignone and M.L. Bianchini, 1996. Use of pelletised or extruded diet at two feeding levels: Effect on performance and body composition in rainbow trout (*Oncorhynchus mykiss*). Rivista Italiana Acquacoltura, 31: 107-118.