The Open Access Israeli Journal of Aquaculture – Bamidgeh

As from **January 2010** The Israeli Journal of Aquaculture - Bamidgeh (IJA) will be published exclusively as **an on-line Open Access (OA)** quarterly accessible by all AquacultureHub (http://www.aquaculturehub.org) members and registered individuals and institutions. Please visit our website (http://siamb.org.il) for free registration form, further information and instructions.

This transformation from a subscription printed version to an on-line OA journal, aims at supporting the concept that scientific peer-reviewed publications should be made available to all, including those with limited resources. The OA IJA does not enforce author or subscription fees and will endeavor to obtain alternative sources of income to support this policy for as long as possible.

Published under auspices of
The Society of Israeli Aquaculture and Marine Biotechnology (SIAMB),
University of Hawaii at Manoa Library
and
University of Hawaii Aquaculture Program in association with
AquacultureHub
http://www.aquaculturehub.org

ISSN 0792 - 156X

PUBLISHER:
Israeli Journal of Aquaculture - BAMIGDEH -
Kibbutz Ein Hamifratz, Mobile Post 25210,
ISRAEL
Phone: + 972 52 3965809
http://siamb.org.il

GROWTH, FEED UTILIZATION AND CARCASS COMPOSITION IN RAINBOW TROUT FED DIETS WITH A SIMILAR DIGESTIBLE ENERGY CONTENT AND DIFFERENT CARBOHYDRATE LEVELS

Ahmet Adem Tekinay*

Department of Aquaculture, Faculty of Fisheries, Onsekiz March University, Çanakkale, Turkey

Simon John Davies

Fish Nutrition Department, Biological Sciences, University of Plymouth, Plymouth, UK

Yusuf Güner

Department of Aquaculture, Faculty of Fisheries, Ege University, Ïzmir, Turkey

(Received 22.3.02, Accepted 21.6.02)

Key words: carbohydrate level, digestible energy, feed intake, nutrient utilization, rainbow trout

Abstract

Three diets including 13.2%, 22% or 30.5% carbohydrates as extruded wheat meal were fed to rainbow trout, *Oncorhynchus mykiss* (initial weight 34.8 g), for twelve weeks to investigate their influence on growth, protein and energy utilization and carcass composition. Daily feeding rates were 1.76, 2.05 or 2.17 g feed per 100 g body weight for the three diets, respectively, so as to reach a daily allowance of about 35.5 kJ digestible energy per 100 g body weight. No significant differences ($p>0.05$) in final mean weight or specific growth rate were observed between the treatments. Feed efficiency was negatively correlated to the dietary carbohydrate level. Utilized digestible protein and energy per kg growth were 365, 348, 358 g and 15.4, 15.9, 17.0 MJ, respectively, for the three diets. Apparent net protein and energy utilization of the groups fed a medium or high carbohydrate level were higher than those of the low carbohydrate group. Analysis of fish carcasses at the end of the trial revealed no significant ($p>0.05$) variations attributable to the carbohydrate level.

Introduction

Carbohydrate nutrition in rainbow trout has been studied in great detail (Phillips et al., 1948; Singh and Nose, 1967; Austreng et al., 1977; Bergot, 1979; Rychly and Spannhof, 1979; Bromley and Smart, 1981; Refstie and Austreng, 1981; Hilton and Atkinson, 1982; Spannhof and Plantikow, 1983; Bergot and Breque, 1983; Kaushik and Oliva-Teles, 1985; Beamish et al., 1986; Hilton et al., 1987; Kaushik et al., 1989; Takeuchi et al., 1990;

* Corresponding author. E-mail: aatekinay@comu.edu.tr

Pfeffer et al., 1991; Henrichfreise and Pfeffer, 1992; Brauge et al., 1994; Wilson, 1994; Pfeffer, 1995). More information is required on the digestible protein and energy requirements of trout fed different levels of dietary carbohydrate (Kim and Kaushik, 1990, 1992; Kaushik and Medale, 1994; Yomamoto et al., 2000, 2001).

Tekinay and Davies (2001) fed rainbow trout different levels of extruded wheat meal (153, 322 or 435 g/kg diet) with a similar quantity of digestible protein (approximately 0.6 g per 100 g body weight per day) to evaluate the protein sparing effects of carbohydrate based diets. In that study, at the end of twelve weeks, the fish fed 322 g extruded wheat meal per kg diet had the highest growth performance and nutrient utilization. The same group utilized 19.7% less digestible protein and 10% less digestible energy per kg growth than the fish fed 153 g extruded wheat meal per kg diet. In our study, we investigate the influence of a digestible energy intake of approximately 35.5 kJ per 100 g body weight per day on growth, protein and energy utilization and carcass composition in trout, using the same experimental diets as Tekinay and Davies (2001).

Materials and Methods

Experimental fish and maintenance facilities. Rainbow trout, *Onchorynchus mykiss,* obtained from Mill Leat Trout Farm (Ermington, Devon, UK), were acclimatized to laboratory conditions (Biological Science, University of Plymouth) for three weeks prior to the start of the feeding trial. Batches of 40 trout with a mean weight of 34.8 g were placed into duplicate 400 l fiberglass tanks in a closed, fresh water recirculating system. Water flow through the tanks was 6.8 l per minute, producing a weekly water exchange of approximately 20%. Temperature was maintained at 15±0.2°C throughout the trial and a 12 hour light/12 hour dark photoperiod was established. The light intensity at the water surface was 480 lux.

Feeding and performance indicators. The ingredients and chemical compositions of the diets are given in Table 1. The dry powdered ingredients of each diet were weighed and mixed in the bowl of a Hobart A101 food processor (Hobart Manufacturing Company Ltd., London). Oil and, finally, distilled water were added during continuous mixing to yield a uniform paste sufficiently moist for extrusion. Using the food processor; the paste was extruded to a size of 3.16 mm. The feed was spread thinly onto trays and air dried at 44°C in a fan assisted drying cabinet and stored in black polyethylene bags. Samples of all experimental diets were removed directly after manufacture and stored at -20°C.

The daily feeding rates were adjusted to obtain a daily allowance of about 35.5 kJ digestible energy per 100 g body weight. Fish were hand fed daily at 09:00, 13:00 and 17:00 and the quantity of feed provided was recorded throughout the 12-week trial. Every two weeks, the trout were starved for 24 hours, then weighed individually, without being anesthetized. Parameters relevant to growth and feed utilization efficiency were calculated as explained by Tekinay and Davies (2001).

Sampling and analytical procedures. At the end of the feeding trial, ten fish from each treatment were withdrawn for carcass analysis. Proximate analysis of the diets and the fish carcass were performed according to the methods of the AOAC (1990). 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 550°C for 12 hours. Crude protein was analyzed by the automated Kjeldahl method after acid digestion, using the Gerhardt system. Lipid extractions were undertaken by a refinement of the original version of Folch et al. (1959). Carbohydrate in the feed was determined according to a modified method described by Morris (1994). Four ml HCl (2 mol/l) was added to 50 mg dry material. Following vortex mixing, samples were heated in a boiling water bath for two hours, then 2 ml of hydrolysate was sampled and neutralized with NaOH (0.5 mol/l) using phenol red as the indicator. The solution was then made up to a final volume of 10 cm^3 and 25 µl was withdrawn for glucose determination by the glucose oxidaze method. The glucose based car-

Table 1. Ingredients (%) and chemical composition (% dry matter) of experimental diets.

Ingredient	*Diet*		
	Low carbohydrate	*Medium carbohydrate*	*High carbohydrate*
Fishmeal[1]	52.6	42.8	35.0
Poultry meat meal[2]	12.0	9.6	8.0
Blood meal[3]	3.0	2.4	2.0
Extruded wheat meal[4]	15.3	32.2	43.4
Fish oil[5]	10.81	8.6	7.2
Vitamin/mineral premix[6]	2.0	2.0	2.0
∝-cellulose[7]	1.89	-	-
Cr_2O_3[7]	0.4	0.4	0.4
Binder[7] (carboxy methyl cellulose)	2.0	2.0	2.0
Nutrient analysis			
Protein	48.7	41.7	37.3
Lipid	20.5	17.5	15.2
Ash	10.4	8.9	7.7
Carbohydrate	13.2	22.0	30.5
Digestible protein (%)	43.6	34.0	30.7
Digestible energy (MJ/kg)	20.2	17.3	16.4
Digestible protein/digestible energy (g/MJ)	21.6	19.7	18.7

[1] Low Temperature Fish Meal, Norsea Mink, LT 94. Donated by Trouw Aquaculture, Wincham, Cheshire, UK
[2] Int. Feed Number, 5-03-798, Trouw Aquaculture, Wincham, Cheshire, UK
[3] Int. Feed Number, 5-00-381, Trouw Aquaculture, Wincham, Cheshire, UK
[4] Int. Feed Number, 4-05-205, Trouw Aquaculture, Wincham, Cheshire, UK
[5] Atlantic Herring Oil (7-08-048), Seven Seas, Marfleet, Hull, UK
[6] Closed Formulation, Trouw Aquaculture, Wincham, Cheshire, UK
[7] Sigma Chemical Company, Poole, Dorset, UK

bohydrate content of the feed or feces (g/g wet weight) was then calculated as: carbohydrate in % = [(mg glucose in ml hydrolysate x 20 x 0.9)/weight of sample] x 100, where 20 is the dilution factor and 0.9 is the factor allowing the estimation of glycogen from the measured glucose content of the tissue. The energy content of freeze-dried samples of diets was determined by calorimetry (adiabatic bomb calorimeter, Gallenkamp) according to AOAC (1990).

Statistical analysis. The data were subjected to analysis of variance (ANOVA) and the multiple range test ($p < 0.05$) of Duncan (Steel and Torrie, 1960) using the statistical software package, Statgraphics 7 (Manugistics Incorporated, Rockville, MD, USA). Allometric analyses of the carcass of experimental fish were performed as outlined by Shearer (1994). The absolute weight of each parameter (protein, lipid and ash) in the body and the weight of the whole carcass or muscle were log transformed and plotted. Then, all slopes and intercepts were compared using multiple regression analysis in Statgraphics 7.

Results

No significant (p>0.05) differences were observed in growth performance of fish in terms of final mean weight or specific growth rate (Table 2). The feed efficiency of the trout fed the low carbohydrate diet was 14.15% and 31.1% better than that of the trout fed the medium or high carbohydrate diets, respectively. The apparent net energy utilization of the medium carbohydrate group was approximately 25% higher than that of fish fed the low carbohydrate diet but it was similar to that of the high carbohydrate group. Apparent net protein utilization followed a similar pattern; it was approximately 22% higher in the medium carbohydrate group than in the low. This can be attributed partially to the higher digestible protein content of the low carbohydrate diet.

The proximate compositions of the fish

Table 2. Growth of rainbow trout fed diets with different levels of carbohydrate for 84 days.

Parameter	*Diet*		
	Low carbohydrate	*Medium carbohydrate*	*High carbohydrate*
Initial mean weight (g)	34.7	34.8	34.8
Final mean weight (g)	149.2	145.2	139.8
Feed intake (g/100 g fish/day)	1.76[a]	2.05[b]	2.17[b]
Digestible protein intake (g/100 g fish/day)	0.77	0.70	0.67
Digestible energy intake (kJ/100 g fish/day)	35.6	35.5	35.6
Specific growth rate (%)	1.7	1.7	1.6
Feed efficiency (%)	112.1	98.2	85.5
Digestible energy utilized per kg growth (MJ)	15.4	15.9	17.0
Digestible protein utilized per kg growth (g)	365	348	358
Apparent net energy utilization (%)	40.4	50.5	48.8
Apparent net protein utilization (%)	42.3	51.7	50.3

Values in a row with a common superscript or no superscript are not significantly different from each other (p>0.05).

carcasses at the end of the trial are given in Table 3. There were no significant differences ($p>0.05$) between treatments in moisture content or protein, lipid and ash concentrations.

Discussion

Following the 12-week feeding trial, similar growth ($p>0.05$) was observed in all groups. Although not significantly different, the mean weight of the fish fed the low carbohydrate diet was higher than that of the other groups at the end of the trial. The SGRs were in accordance with the final mean weights. They also agreed with SGR data obtained by Tekinay and Davies (2001) in fish that received a daily digestible energy concentration of 30.3-34.4 kJ per 100 g body weight. Significant differences in final mean weight or SGR would probably have been recorded if the experiment had lasted longer. The SGRs of the groups fed 32.2% or 43.5% extruded wheat meal were better than that of Kaushik et al. (1989) who fed diets with 38% extruded wheat to rainbow trout at 18°C for 18 weeks and obtained an SGR of 1.3% per day. On the other hand, a much higher SGR of 2.6% was reported by Kim and Kaushik (1992) for fish that consumed a similar amount of digestible energy and protein but a higher carbohydrate level (38.2%). Growth performance reported by different workers may not be comparable since the experimental designs and dietary conditions of the studies differed.

The feed efficiency negatively correlated with the dietary carbohydrate level as previously demonstrated (Steffens, 1989; NRC, 1993; Tekinay and Davies, 2001). The feed efficiency values determined for the medium and high carbohydrate groups in this feeding trial were lower than those measured by Tekinay and Davies (2001). This is probably due to the higher daily food consumption in the present study. Takeuchi et al. (1990) fed a diet with a comparable level of extruded wheat meal (35%), digestible protein (399 g) and digestible energy (18.7 MJ per kg feed) to trout fry with an initial mean weight of 4.6 g for a six-week feeding trial. They obtained a feed efficiency of 109% and an SGR of 3.0%. The intake of digestible energy and protein of the experimental fish in that study were 50.5 kJ and 1.07 g per 100 g body weight. Yomatomo et al. (2001) fed trout (initial mean weight 28 g) diets with different levels of carbohydrates (9%, 18%, 27% or 36% potato starch or 34% dextrin) for eight weeks. Their SGR and apparent net protein utilization did not differ significantly ($p<0.05$) whilst their feed efficiency and protein efficiency ratio were higher in the trout fed the diets with 18% or 27% starch.

Digestible energy utilized per kg growth varied between treatments despite the fact

Table 3. Proximate composition (%) of the pooled carcass of experimental animals.

Carcass		*Diet*		
	Initial	*Low carbohydrate*	*Medium carbohydrate*	*High carbohydrate*
Moisture	72.0	70.8	71.1	71.2
Protein	16.2	17.1	16.7	16.5
Lipid	9.1	11.6	11.3	11.4
Ash	2.6	2.3	2.4	2.5

Values except initial composition are not significantly different from each other ($p>0.05$).

that all the experimental fish received the same amount of digestible energy per day (35.5 kJ per 100 g body weight). This was probably due to the fact that the trout utilized the feed with varying efficiency throughout the 12-week trial. Fish that received only 30.3, 31.14 or 34.44 kJ digestible energy per 100 g body weight per day (Tekinay and Davies, 2001) utilized 17.4, 15.9 and 17.9 MJ digestible energy per kg growth, respectively. Results of the high carbohydrate groups in both this study and Tekinay and Davies (2001) confirm the finding of Kim and Kaushik (1992) that 17.4 MJ of digestible energy was utilized per kg growth in trout grown at 18°C with a test diet including 38% gelatinized corn starch.

Digestible protein utilized per kg growth ranged 348-365 g but was as low as 312 g in the medium carbohydrate group (1.8 g daily feed, 0.61 g digestible protein intake per 100 g fish) in the study of Tekinay and Davies (2001). Kim and Kaushik (1992) calculated 390 and 460 g digestible protein per kg of trout produced. Adjustment of the daily feed intake is particularly important in order to obtain the most efficient protein sparing effect of diets containing high levels of digestible complex carbohydrates.

The apparent net energy and protein utilization of the medium and high carbohydrate treatments were more efficient than those of the low carbohydrate treatment. The apparent net protein retention negatively correlated with the digestible protein content of the diet. Both utilization rates were superior to those of Kim and Kaushik (1992) who fed rainbow trout with diets containing 38% digestible carbohydrates of different sources. This can be explained by the higher levels of carcass lipid in the present study due to the higher levels of dietary lipid.

The carcass composition indicates that the body protein, lipid and ash contents were not influenced when trout consumed varying carbohydrate concentrations as long as the diet contained a similar level of digestible energy. This is supported by the allometric analysis of carcass data explained by Shearer (1994) and applied by Tekinay et al. (2000) and Tekinay and Davies (2001). Thus, it can be suggested that diets containing digestible carbohydrate and energy concentrations between 16.4 and 20.2 MJ per kg do not significantly ($p>0.05$) alter the proximate composition of the trout carcass.

From a practical point, a diet with 40% protein including approximately 30% extruded wheat meal and a daily intake of 0.6-0.7 g digestible protein and 35 kJ digestible energy per 100 g body weight produces acceptable growth and nutrient and energy utilization in rainbow trout. This is supported by Yomamoto et al. (2001) who recommended a 40% protein diet with either 18% fat and 18% starch or 11% fat and 27% starch for juvenile trout under voluntary feeding conditions.

It could be suggested from the results that optimum growth and nutrient utilization can be achieved by adjusting the dietary lipid and carbohydrate levels to the digestible energy requirement of the fish under examination. However, the present and previous studies demonstrated that fish size, water temperature and dietary factors such as feeding rate, duration of feeding trial, and digestible protein and energy concentrations of the test diets affect the growth, feed intake and utilization significantly (Kaushik and Medale, 1994).

References

AOAC, 1990. K. Helrich (ed.). *Official Methods of Analysis,* 15th ed. Assoc. Official Analytical Chemists, Arlington, VA. 1298 pp.

Austreng E., Risa S., Edwards DJ. and H. Hvidsten, 1977. Carbohydrate in rainbow trout diets. 2. Influence of carbohydrate levels on chemical composition and feed utilization of fish from different families. *Aquaculture,* 11:39-50.

Beamish F.W.H., Hilton J.W., Niimi E. and S.J. Slinger, 1986. Dietary carbohydrate and growth, body composition and heat increment in rainbow trout (*Salmo gairdneri*). *Fish Physiol. Biochem.*, 2:85-91.

Bergot F., 1979. Carbohydrate in rainbow trout diets: effects of the level and source of carbohydrate and the number of meals on growth and body composition. *Aquaculture,* 18:157-167.

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

Brauge C., Medale F. and G. Corraze, 1994. Effect of dietary carbohydrate levels on growth, body composition and glycaemia in rainbow trout, *Oncorhynchus mykiss*, reared in seawater*. Aquaculture*, 123:109-120.

Bromley P.J. and G. Smart, 1981. The effect of the major food categories on growth, composition and food conversion in rainbow trout (*Salmo gairdneri* Richardson). *Aquaculture,* 23:325-336.

Folch J., Lees M. and G.H. Sloan-Stanley, 1959. A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem.,* 226:497-509.

Henrichfreise B. and E. Pfeffer, 1992. Wheat and wheat starch as potential sources of digestible energy for rainbow trout (*Oncorhynchus mykiss*). *J. Anim. Physiol. Anim. Nutr*., 67:143-147.

Hilton J.W. and J.L. Atkinson, 1982. Response of rainbow trout (*Salmo gairdneri*) to increased levels of available carbohydrate in practical trout diets. *Brit. J. Nutr.,* 47:597-607.

Hilton J.W., Atkinson J.L. and S.J. Slinger, 1987. Evaluation of the net energy value of glucose (cerelose) and maize starch in diets for rainbow trout (*Salmo gairdneri*). *Brit. J. Nutr.,* 58:453-461.

Kaushik S.J. and F. Medale, 1994. Energy requirements, utilization and dietary supply to salmonids*. Aquaculture*, 124:81-97.

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

Kim J.D. and S.J. Kaushik, 1990. Additive nature of digestible energy and relative energy values of different energy yielding nutrients in practical trout diets. *AJAS,* 3:231-242.

Kim J.D. and S.J. Kaushik, 1992. Contribution of digestible energy from carbohydrates and estimation of protein/energy requirements for growth of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture,* 106: 161-169.

Morris P.C., 1994. *The Water Soluble Vitamin Nutrition of Gilthead Sea Bream (Sparus aurata)*. Ph.D. Thesis. Univ. Plymouth, UK. 285 pp.

NRC, 1993. *Nutrient Requirements of Fish.* Natl. Res. Council, Natl. Acad. Sci., Washington, DC. 114 pp.

Pfeffer E., 1995. Carbohydrate utilization and its determination. *J. Appl. Ichthyol.,* 11:175-182.

Pfeffer E., Beckmann-Toussaint J., Henrichfresie B. and H.D. Jansen, 1991. Effect of extrusion on efficiency of utilization of maize starch by rainbow trout (*Oncorhynchus mykiss*). *Aquaculture,* 96:293-303.

Phillips A.M., Tunison A.V. and D.R. Brockway, 1948. *The Utilization of Carbohydrates by Trout*. Fish. Res. Bull., no. 11. New York State Conservation Dept., Bureau of Fish Culture, Albany, NY. 44 pp.

Refstie T.E. and E. Austreng, 1981. Carbohydrate in rainbow trout diets. III. Growth and chemical composition of fish from different families fed four levels of carbohydrate in the diet. *Aquaculture,* 25:35-39.

Rychly J. and L. Spannhof, 1979. Nitrogen balance in trout. I. Digestibility of diets containing varying levels of protein and carbohydrate. *Aquaculture,* 16:39-46.

Shearer K.D. 1994. Factors affecting the proximate composition of cultured fishes with emphasis on salmonids. *Aquaculture,* 119:63-88.

Singh R.P. and T. Nose, 1967. Digestibility of carbohydrates in young rainbow trout. *Bull. Freshwater Fish. Res. Lab.,*17(1):21-25.

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

Steel R.G.D. and J.H. Torrie, 1960. *Principles and Procedures of Statistics: a Biometric Approach*, 2nd ed. McGraw Hill, New York. 633 pp.

Steffens W., 1989. *Principles of Fish Nutrition*, Ellis Horwood, London. 383 pp.

Takeuchi T., Jeong K.S. and T. Watanabe,

1990. Availability of extruded carbohydrate ingredients to rainbow trout (*Oncorhynchus mykiss*) and carp (*Cyprinus carpio*). *Nipp. Suis. Gak.*, 56:1839-1845.

Tekinay A.A. and S.J. Davies, 2001. Dietary carbohydrate level influencing feed intake, nutrient utilization and plasma glucose concentration in the rainbow trout, *Oncorhynchus mykiss*. *Turk. J. Vet. Anim. Sci.,* 25:657-666.

Tekinay A.A., Alpaslan M., Usta A. and P. Akyüz, 2000. The effects of dietary fat levels on carcass composition of rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792). *J. Fish. Aquat. Sci*., 17(3-4):95-104.

Wilson R.P., 1994. Utilization of dietary carbohydrate by fish. *Aquaculture,* 124:67-80.

Yomamoto T., Shima T., Unuma T., Shiraishi M. and M. Tabata, 2000. Voluntary intake of diets with varying digestible energy contents and energy sources, by juvenile rainbow trout, *Oncorhynchus mykiss*, using self-feeders*. Fish. Sci.,* 66(3):528-534.

Yomamoto T., Konishi K., Shima T., Furuita H., Suzuki N. and M. Tabata, 2001. Influence of dietary fat and carbohydrate levels on growth and body composition of rainbow trout, *Oncorhynchus mykiss*, under self-feeding conditions. *Fish. Sci*., 67(2):221-227.