The effect of feed ration on growth performance of rainbow trout, Oncorhynchus mykiss

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KQA319 Nutrition of Aquatic Organisms
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Abstract

Effects of six different feed rations (FR = 0.25, 0.5, 1.0,1.5, 2.0, 3.0 %BW/d) on specific growth rate (G), feed efficiency ratio (FER) and organ somatic index (OSI) in rainbow trout (Oncorhynchus mykiss) were studied in a six week growth trial at a water temperature of 17.7 ± 1.8 ºC (mean ± SD). The treatments were administered to two groups of rainbow trout initially weighing 117.6 ± 1.8g (mean ± SE). The relationship between FR and G was linear and G did not reach a plateau, it was concluded that the maximum FR and hence the maximum growth rate (Gmax) were not reached. The relationship between FR and FER was also linear and showed feed efficiency was not influenced by FR. However, FR had an influence on the OSI, higher liver, pylorus and stomach OSI were counteracted by a lower carcass OSI. Increased visceral OSI indicted a gain in condition over the experiment. This trial was significant in relation to optimising feed efficiency and growth. Under farm conditions similar data are determined to minimise wastage and maximise growth and the approach is important as a practical management tool.

Introduction

The primary objective of intensive fish farming is to maximise growth at minimal costs, understanding feed usage is critical as feed is the largest single cost in salmonid aquaculture (Hardy 1989). Overfeeding wastes feed, pollutes the environment and leads to decreased feed efficiency. Underfeeding results in reduced growth as well as decreased feed efficiency (Cho 1992; Talbot & Hole 1994; Einen et al. 1995). The feed efficiency ratio (FER) combines feed ration (FR, the input) with growth (G, the output). FER is a primary determinant of profitability in aquaculture and is calculated regularly for units of production such as tanks or cages (Tacon et al. 1995). FER has also been included in most breeding goals for farmed animals in aquaculture (Kolstad et al. 2004).

Two relationships that describe the relationship between FR and G and between FR and FER are used to assess farm performance (Carter et al. 2001). One predicts a curvilinear relationship and there are feeding rates at which feed efficiency will be highest (optimum) and at which growth will be maximum (maximum feeding level). In most feeding situations, feeding is at levels for maximum growth (R_{Gmax}) rather than for optimum feed conversion (R_{opt}), which is at a lower level, is usually economically desirable (Hardy 1989). It is therefore useful to investigate feeding rates for maximum growth, for the feed ration over R_{Gmax} would be considered wasteful and could result in increased production costs. In practice it is often difficult to balance R_{Gmax} and R_{opt} to achieve maximum growth and avoid food wastage at the same time. R_{main} is the amount of food required to be ingested by the fish to maintain bodily functions without either loss or gain of weight (Jobling 1994). The other model of fish growth predicts a linear increase in growth with ration up to the maximum ration and G_{max} after which there is no further growth and all feed remains uneaten and is wasted (Talbot & Hole 1994), FER is unchanged up to G_{max}.

The main aim of this study was to investigate the relationship between six different feed rations and growth performance of rainbow trout, *Oncorhynchus mykiss* (Walbaum), and also to compare the weight distribution and condition of the fish in each group and examine this in relation to the overall feeding regime. This experiment was organised so that it could be achieved on a farm with limited resources. Consequently the data points are not statistically independent but represent an approach to producing growth data from a cohort of fish that might be held in a tank or cage and measured on several occasions.

Materials and methods

Animals and facilities

This experiment was conducted in the Aquaculture Centre, University of Tasmania. Eighty rainbow trout (initial weight 117.63 ± 1.94g; mean ± SE) from an initial stock tank were distributed at random into two tanks (2x2x0.5 m). The experiment was split into three two-week blocks and was carried out from 10 March to 19 April 2005 (41 days). The tanks were supplied with continuous flow of aerated fresh water. The fish were exposed to natural variation in photoperiod and temperature (14.5 – 21.5 ºC), and the mean water temperature was 17.70 ± 1.81 ºC (mean ± SD).

Diet and feeding

Each treatment was fed a commercial extruded pellet (Skretting salmon grower diet, 5 mm, 45 % crude protein, 22 % crude fat) twice per day (09.00 – 11.00 h and 15.00 – 17.00 h). The fish were fed three different rations in sequence: Tank 1, 0.25, 1.00. 2.00; Tank 2, 0.5, 1.50, 3.00 %BW). Each ration was calculated as a percentage of the mean wet body weight for each group and adjusted at the end of each two-week block after weighing the fish. Feed was delivered by hand, approximately five pellets at a time. The fish were fed until all the rations were eaten or until 5 pellets remained uneaten on the tank floor for 20 seconds, whichever came sooner. Any uneaten pellets were recorded and the average pellet weight subtracted from the ration. The quantity of feed dispensed, the amount eaten, personal observations concerning feeding behaviour, and water temperature were recorded for each tank. The tanks were cleaned most days after feeding by scrubbing the sides and bottoms, allowing the tanks to partially drain and re-fill. A check for adequate water flow and aeration was done daily.

Data collection

The fish were anaesthetized (benzocaine 50 ppm) and their wet weight and fork length recorded prior to distribution. From the initial stock tank, six fish were given a lethal dose of benzocaine at the start of the experiment prior to distribution into separate tanks and dissected to provide information about the wet weight, fork length, condition factor (K), and organ somatic indices (OSI) for liver (without gall bladder), pylorus (with fat), and the gutted carcass (with gills). Fifteen fish were dissected at the end of the experiment to give the same information as the initial six fish, stomach OSI was a further calculation.

Calculations and analysis

Specific growth rate (G) for each of the two-week blocks was calculated according to the formula:

G (%/d) = [LN (Final weight (g)/ Initial weight (g))] x 100/ d

where Final weight is the final weight at the end of a two-week block and initial weight is the initial weight at the start of a two-week block, and d the number of days in the two-week block (14 d).

There were 8 mortalities in tank 1 and 4 mortalities in tank 2 over the entire experimental period and these were taken into account in the calculation.

Feed efficiency ratio (FER) for each of the two-week blocks was calculated according to the formula:
FER (g/dry g) = Final weight (g) – Initial weight (g) / Total feed eaten (g)

where Final and Initial weights are defined as above and Total feed eaten is the total feed eaten over the two-weeks.

Condition index (K) was calculated for all fish according to the formula:
K (%) = (Weight (g)/Fork Length^3 (cm)) x 100

where weight and fork length were measured for all fish in a tank. Organ somatic indices (OSI) were calculated for liver, pylorus, stomach according to the formula:

OSI (%) = (organ weight (g)/ Weight (g)) x 100
Coefficient of variation (CV) was calculated according to the following formula:
CV (%) = (SD/ mean) x 100.

Six FR-G data points from the two-week periods in two tanks were used to construct one FR-G curve. This growth curve was intended to predict the maximum growth rate (G_{max}), maximum growth ration (R_{Gmax}) and maintenance ration (R_{main}). G_{max} is predicted from a plateau where increasing FR has no effect on G. A line of best fit can be drawn up from the pre-plateau FR-G data, the intersect with G_{max} is designated R_{Gmax}. R_{main} is the FR where G = 0. G_{max} was not reached in this experiment and the data showed the increase in G due to increasing FR, but not the plateau at G_{max}. Similarly FER was plotted against FR (FER that were less than zero (ie. below R_{main}) were omitted).

Results

No waste feed was collected after any meal, so feed intake was restricted by the feed delivery rates of 0.25 to 3.0 %BW/d and satiation not reached at these rations. There was an increase in weight, length and K for both of the tanks over the complete experiment (Table 1). The weight gain for tank 2 was higher than tank 1 despite the initial weight being lower. No statistical comparison was possible. CV of weight was higher for tank 1 both initially and at the end, it decreased in tank 1 but increased in tank 2 (Table 1).

The CV of length decreased in tank 1 and 2 (Table 1). In addition, it was found that the CV of weight was always higher than the CV of length. Tank 2 had a slightly higher length gain than tank 1, with tank 2 having a lower initial length but a higher final length than tank 1 (Table 1). Difference in initial mean K between the two tanks was 0.01 (%), but difference in final K was 0.15 %. Tank 1 had a higher initial K than tank 2 but tank 2 had a higher final K than tank 1 (Table 1).

Initial OSI values and those measured after six weeks are presented in Table 1. Carcass OSI decreased in tank 1 and 2 compared to the initial stock tank and was highest in tank 1 (Table 1). Carcass OSI decreased to 97.77 ± 15.08 % of the initial fish. Liver and Pylorus OSI were both higher for tank 1 and 2 compared to the initial stock tank (Table 1). Liver OSI increased to 239.66± 205.26 % and pylorus OSI increased to 183.91 ± 197.85 % for tank 1 and 2 compared with the initial stock tank.

Table 1: *Mean ± SD (standard deviation) and coefficient of variation (CV) for initial (stock tank) and final* (Tank 1 and 2) fish weight, length, condition factor (K), organ somatic index (OSI) for rainbow trout held in two tanks.

		Initial	Final	
		Stock tank	Tank 1	Tank 2
Initial weight (g)	Mean ± SD	117.64 ± 16.97	173.05 ± 26.45	195.39 ±28.92
	CV	14.42	15.29	14.80
Final weight (g)	Mean ± SD		173.05 ± 26.45	195.39 ± 28.92
	CV		15.29	14.80
Initial length (cm)	Mean ± SD		21.12 ± 1.25	20.80 ± 1.17
	CV		5.91	5.64
Final length (cm)	Mean ± SD		23.16 ± 1.28	23.25 ± 1.07
	CV		5.52	4.60
Initial K (%)	Mean ± SD		1.28 ± 0.11	1.27 ± 0.11
	CV		8.73	8.53
Final K (%)	Mean ± SD		1.40 ± 0.19	1.55 ± 0.11
	CV		13.48	7.26
Carcass OSI (%)	Mean ± SD	85.55 ± 9.02	84.47 ± 1.12	82.81 ± 1.60
	CV	10.54	1.33	1.96
Liver OSI (%)	Mean ± SD	0.87± 0.19	1.94 ± 0.29	2.23 ± 0.20
	CV	22.3	15.18	21.73
Pylorus OSI (%)	Mean ± SD	3.29 ± 0.93	4.49 ± 1.21	4.65 ± 1.26
	CV	28.33	26.97	36.37
Stomach OSI (%)	Mean ± SD	N/A	2.75 ± 0.89	3.50 ± 0.63
	CV		32.19	36.17

Feed Ration – Growth Analysis

There was a linear relationship between FR and G (Fig 1) but no relationship between FR and FER (Fig 2). This showed a constant FER as indicated by the linear relationship (constant gradient) for increasing FR and G (Fig 1). The relationship between FR and G was a simple linear one and G increased as FR increased (Fig. 1). R_{main} was calculated to be 0.11 %/d from y = 0.8445x - 0.0928. G_{max} was not predicted because a plateau was not observed even at the highest feed ration of 3 %BW/d (Fig.1.)

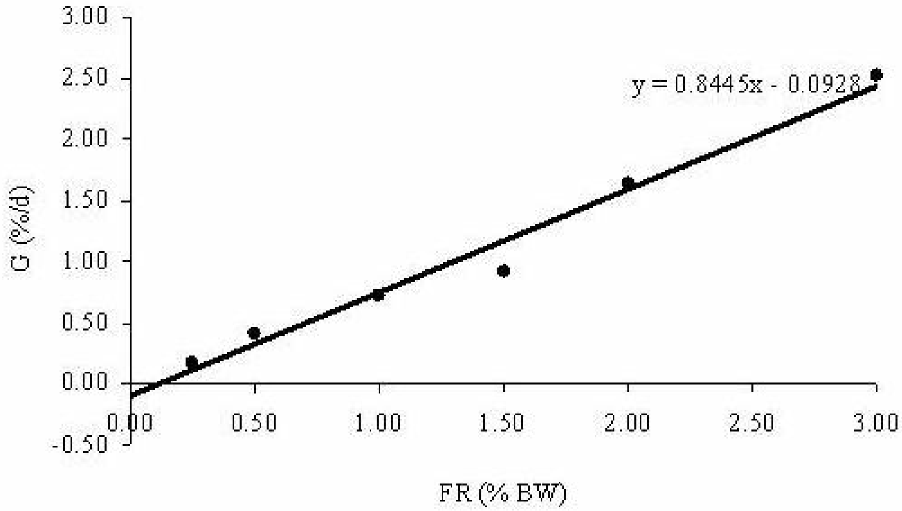

Figure 1: The relationship between feed rate (FR) and growth rate (G) of rainbow trout (Oncorhynchus mykiss) fed on six different rations for this study (2005)

The unpublished data in 2004 had a higher average total weight gain in the tank fed on average the higher ration (tank 2 and 3; 181.39 g) compared with the tank receiving the lower average ration (tank 1 and 4; 100.99 g) (Table 2). It was apparent was as ration increased so did FER to week 4 and decreased from week 4 to week 6 (Table2).

Table 2: Mean initial, week 2, week 4 and final fish weights, rations and feed efficiency ration (FER), total weight gain for rainbow trout (Oncorhynchus mykiss) held in four tanks (unpublished, 2004)

	Tank 1	Tank 2	Tank 3	Tank 4
Mean Initial Weight (g)	305.46	310.86	312.78	314.53
Ration 0-2 weeks (%BW/d)	0.25	0.50	0.50	0.25
FER (g/dry g)	-0.92	0.65	0.36	-0.11
Mean weight 2 weeks	295.64	324.98	320.61	313.33
Ration 2-4 weeks	1.00	1.50	1.50	1.00
FER (g/dry g)	0.84	0.96	0.97	0.91
Mean weight 4 weeks	330.22	390.28	386.12	353.07
Ration 4-6 weeks (%BW/d)	2.00	3.00	3.00	2.00
FER (g/dry g)	0.79	0.67	0.62	0.66
Mean Final Weight (g)	403.23	500.01	486.41	418.75
Total weight gain (g)	97.77	189.16	173.62	104.22

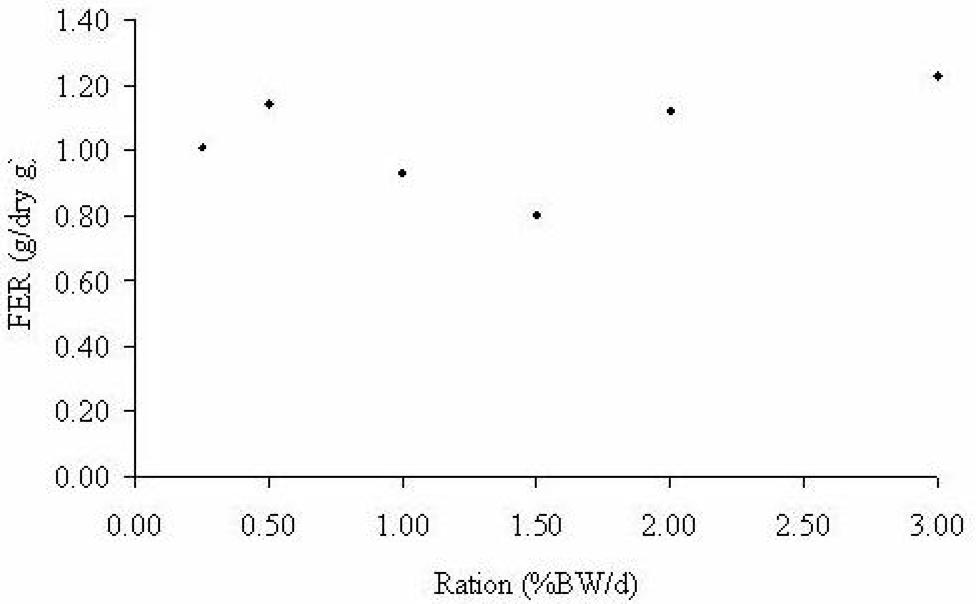

Figure 2: Relationship between feed efficiency ratio (FER) and ration for rainbow trout fed six different rations

The G data in a study done in 2004 on rainbow trout fed the same range of rations gave a Gmax of 1.56 at a RGmax of 3% BW/d and a Rmain of around 0.2 %BW/d (unpublished data) (Fig.3).The weight gain was half that of a similar study conducted in 2004 (unpublished data) on rainbow trout fed the same rations.

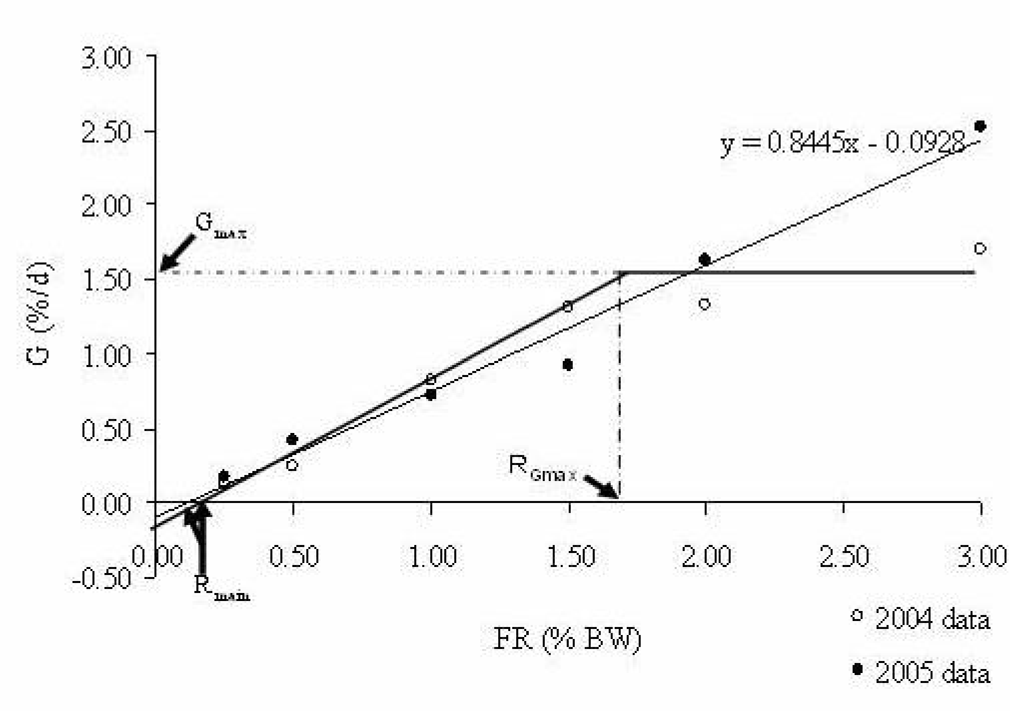

Figure 3: Comparing the relationship between feed rate (FR) and growth rate (G) of rainbow trout *Oncorhynchus mykiss* fed on six different rations for this study (2005) and a similar study conducted in 2004 (unpublished dataSubmission Categories

Discussion

There are different approached to modelling the relationship between feed ration and growth (Carter et al. 2001). According to Jobling (1994) the relationship between growth rate and feed ration is curvilinear. However, a linear relationship is often observed and equally applicable (Talbot et al. 1994; Carter et al. 2001). The maximum growth rate could be obtained at the level which the growth rate tends to level off with increasing ration. However, levelling off was not found in this study and this suggests that the rations were insufficient to give maximum growth rate. Due to this reason R_{Gmax} was not determined. The R_{main} was 0.11 %BW/d in this study which was lower than that found by Storebakken et al. (1991) of 0.3 %BW/d at a lower temperature of 15 ºC.

Temperature may have played a part in influencing G_{max} of rainbow trout, *Oncorhynchus mykiss*, as temperatures used in this study was towards the high end compared to previous studies (McCarthy et al. 1992; Boujard et al. 2002; Storebakken et al. 1991; Talbot et al. 1999) and on many occasions was higher than the optimum temperature of 17 ºC for rainbow trout (Jobling 1994). Temperature influences both ingestion and metabolism and will therefore affect growth rates (Jobling 1994). As temperature increases, G_{max} increases to a certain point then decreases (Jobling 1994). As temperature increases metabolism increases and the amount of feed required to support metabolism and maintain a given rate of growth increases with temperature (Jobling 1994).This may have contributed to the fish in this study not reaching G_{max}.

Combined 2004 and 2005 Analysis

The R_{main} in the study conducted in 2004 (unpublished) almost two times higher than in this study. It is presumed that the R_{Gmax} may be higher than 3 %BW/d under the present experimental conditions in order to give G_{max}, which should be higher than 3.0 %BW/d (the maximum growth rate for the present study). Compared with a previous study (2004 unpublished data), the weights of the fish in this study was about two and a half times lower at the beginning and about 2.3 times lower at the end for tank 2 and 2.6 times lower for tank 1. In their study (unpublished 2004), initial mean fish weight (310.91 ± 3.93 g; mean ± SD) of fish was more than two times the weight of fish in this study. This could be another reason the fish in the former study reached G_{max} and not in the present study even though the rations were identical. As larger fish usually require proportionally less food than smaller animals (growth on a percentage body weight is larger in smaller fish). As Jobling (1994) states that when expressed in relative terms (ie. food intake per g body weight, or as a percentage body weight consumed per day) food intake (and thus ration required) declines with increasing body weight (Jobling 1994).

It is also evident that the optimum ration (R_{opt}) was also not reached, as R_{opt} is the highest point in a FER-rations graph after a plateau just before decreasing (Jobling 1994). In this study there was no relationship between FER and ration, no plateau was observed and therefore it is assumed that R_{opt} and R_{Gmax} is higher than 3 %BW/d, the highest feed ration in this study.

Both G_{max} and maximum FER are not achieved under the same conditions (Jobling 1994), and this fact could not be demonstrated in this study. It can be seen from the results that neither the R_{opt} ration nor the G_{max} was provided as the FER-ration graph was a horizontal relationship.

Compared with the study done in 2004 on rainbow trout with same rations, the weight gain in this study was about half that (141.19 ± 46.92 g; mean ± SD). This may be due to larger fish used in the 2004 study (310.91 ± 3.93 g; mean ± SD) (Table 6).

The higher weight gain for tank 2 in the present study was probably due to the higher rations fed to that tank. This was consistent with the unpublished data in 2004.

The lower CV of weight in tank 2 could be due to the higher rations that were fed to tank 2 in each of the two-week trial. McCarthy et al. (1992) found that increasing group ration resulted in a decrease in individual CVs in daily feed intake. As the CV of food intake decreases, the CV of weight should decrease as well as the strength of the feeding hierarchy and the variability in individual consumption decreases as food availability increases (Storebakken et al. 1991).

Fish Condition

Storebakken et al. (1991) conducted a similar study on rainbow trout fed 0.0 – 2.0 %BW/d and found that carcass OSI decreased as feed ration increased after six weeks [91.20 ± 1.70 g, 88.70 ± 1.90 g, 86.30 ± 3.10 g and 83.00 ± 1.80 g (mean ± SD) for 0.0, 0.3, 1.0 and 2.0 % BW/d respectively]. This seems to agree with the present findings, as species (rainbow trout) and ration sizes except for 0.0 % BW/d) was similar to this study and carcass OSI was lower in tank 1 (which was fed on average a lower ration than tank 2).

Liver OSI was higher in the tank fed on average the higher ration (tank 2) and this again agrees with Storebakken et al. (1991) as they also had an increase in liver OSI with increasing ration after six weeks (0.71 ± 0.10, 0.90 ± 0.20, 1.00 ± 0.10 and 1.40 ± 0.20 (mean ± SD) for 0.0, 0.3, 1.0 and 2.0 %BW/d). Liver OSI at 2.0 %BW/d was double that of 0.0 %BW/d after six weeks and this reflects the doubled liver OSI in tank 1 and 2 compared with the stock tank for the present study.

The higher pylorus OSI with the higher ration tank suggests that pylorus OSI (with fat) increases with increasing feed ration. This may be a direct result of storage fat as fat ingestion was higher with higher feed rates in a separate study (Storebakken et al. 1991). To some extant the storage of fat represents an important energy store, which can be mobilized for maintenance of essential body functions, supply energy, and reproductive purposes such as egg production.

The pylorus and stomach comprise a large proportion of viscera in rainbow trout and will be used for comparisons. Both pylorus and stomach OSI were higher in tank 2 (average higher ration tank). Storebakken et al. (1991) found an increase in viscera to body weight ration as ration increased, this corresponds to the higher pylorus and stomach OSI in tank 2 for the present study.

Limitations

Several limitations in the present study were identified. Mortalities in the experiment gave artificial values when calculating growth rate. OSI information was not collected for weeks two and four and this did not allow for comparisons of each two-week block. Individual fish weight was only measured at the start and end of the experiment and this did not provide detailed information necessary for some calculations. Initial dissection of fish was taken from the stock tank and this did not allow for comparison between the two tanks for initial FDS. Three distinct rations were applied to each tank and this may have affected the growth performance of the subsequent rations. The feeding of higher rations at the end of the experiment may have caused compensatory growth whereby previously underfed fish can rapidly gain condition to match that of fish continually fed an optimal ration (Jobling et al. 1994). Therefore under experimental conditions and not following a farm-type situation there should be at least 3 replicates for each treatment (Carter & Hauler 2000).

Conclusions

In the present study the effects of feed ration on growth, feed efficiency and percent carcass, liver, stomach and pylorus have been quantified. The relationship between feed ration and growth was linear and the G_{max} is likely to be greater than 2.5 %/d while R_{Gmax} was greater than 3 %BW/d under the experimental conditions, although exact values could not be determined for this experiment. No relationship was found between feed ration and feed efficiency ratio. The greater increase in body weights due to higher feed rate in tank 2 was associated with higher liver, pylorus and stomach OSI and a lower carcass OSI. Ration size is important in determining growth, feed efficiency and variation in body size (Talbot et al. 2004). Future work should focus on the determination of G_{max}, R_{Gmax} for rainbow trout at a range of body weights and temperatures. It is likely that feeding strategies can be developed, based on these physiological parameters, which allow for more efficient production and/or reproduction of fish (Storebakken et al. 1991), and this should also be the focus of future studies.

Acknowledgements

We acknowledge the contribution of other students in KQA319 involved maintenance of fish and data collection. We would also like to thank the students doing the same unit in 2004 for providing their data for comparisons.

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