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Nutrient Utilization and Food Conversion of Rainbow Trout, *Onchorhynchus mykiss*, Subjected to Mixed Feeding Schedules

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Abstract

Fish were offered either restricted feeding (5% of body weight or 1% body weight as maintenance requirement) or appetite feeding subdivided into three equal feeds. The best ($P<0.05$) growth response in terms of final body weight, percent weight gain and specific growth rate (SGR) was observed for feeding schedule I (control), for fish fed to appetite throughout. Feeding schedule II showed significantly the highest ($P<0.05$) growth response in terms of final body weight, percent weight gain and specific growth rate (SGR) in comparison with other feeding schedules. Growth rate and food conversion efficiency (FCE) in feeding schedule II were markedly higher during phase II in comparison with phase I. Phase I (0-4 weeks) growth rate slightly increased in fish fed restricted ration throughout (T-II). In contrast, in phase II (4-8 weeks) fish were fed to appetite throughout (T-II) showed a rapid increase in fortnightly growth response and higher growth rates, feed consumption and FCE.

Keywords: FCR, SGR, growth rate, *Onchorhynchus mykiss*, feed restriction, nutrient utilization.

Karma Yemleme Yapılan Gökkuşağı Alabalığında, *Onchorhynchus mykiss* Besin Kullanımı ve Gıda Dönüşümü

Özet

Balıklar, vücut ağırlıklarının %5'i ve %1'i oranında kısıtlı yemleme ve doyana kadar yemleme olmak üzere 3 ayrı gruba ayrılarak bir çalışma yürütülmüştür. Son vücut ağırlığı açısından en iyi (P<0,05) büyüme yanıtı, yüzde ağırlık kazancı ve spesifik büyüme oranı (SBO) balıkların doyana kadar yemlendiği I. yemleme programında (kontrol) gözlenmiştir. II. Yemleme programında, son vücut ağırlığı açısından, diğer yemleme programlarına kıyasla önemli derecede (P<0,05) en yüksek büyüme yanıtı, yüzde ağırlık kazancı ve spesifik büyüme oranı (SBO) gözlemlenmiştir. II. Yemleme programı, ikinci aşama boyunca, büyüme oranı ve yem dönüşümü (FCE) açısından I. aşamaya (0-4 hafta) kıyasla belirgin şekilde daha yüksektir. I. aşamada (0-4 hafta) büyüme oranı, sınırlı rasyonla beslenme (T-II) boyunca hafif artış göstermiştir. Buna karşılık, II. aşamada (4-8 hafta) doyana kadar yemlenen (T-II) balıklarda iki haftalık peryotlardaki büyüme tepkisinde hızlı bir artış ve daha yüksek büyüme hızı, yem tüketimi ve yem dönüşümü gözlemlenmiştir.

Anahtar Kelimeler: FCR, SBO, büyüme hızı, *Onchorhynchus mykiss*, kısıtlı yemleme, besin kullanımı.

Introduction

Aquatic animals are more sensitive to feed quality than terrestrial animals. This implies that closer attention must be given to aquafeed formulations. At the same time, the ingredients must also be cost effective (Akiyama, 1991) as feed alone bears the largest input cost (60-80%) in aquaculture (De Silva, 1985). The increasing cost of fish feed has focused intensive research not only on the manipulation of feed formulations but also on the economic feeding strategies for reducing feed input cost, thus making aquaculture operation more profitable. Feed deprivation followed by realimentation for compensatory growth may be economic feeding strategy suitable for aquaculture. Compensatory growth is defined as the increase in growth rate following a period of under nutrition (Qian *et al.,* 2000). Through this growth spurt, animals that have been subjected to previous nutritional restriction may partially or completely catch up in body size with those that have not undergone food restriction (Kim and Lovell, 1995). Under conditions of food scarcity in ponds resulting from overstocking and continuous unfavorable weather conditions, fish face starvation and meet their maintenance requirement on nutrient reserves in the organs deposited during feeding phase resulting in a retardation of growth. It is unknown whether fish can compensate for reduced growth rates following the restoration of a re feeding phase. With an intention to assess the effect of compensatory growth on growth parameters of trout, this research was initiated at Laribal trout culture farm, Dachigam National park, Srinagar Kashmir. Since this species has historically thrived in these waters, experiments relative to farming optimization are common place.

Materials and Methods

Experimental System

All experiments were carried out in 500 L capacity fibre glass tanks at hatchery units of the Laribal Trout Culture Farm, supplied with continuously flowing spring water with a temperature of 12±1°C and a water flow rate of 15 L/min. Rainbow trout, *Onchorhynchus mykiss* was used as a model for this research. Fish (average weight 8-13 g) were obtained for the experimental work from resident stock and randomly assigned into groups of 20 fish. Each fish group was placed in an individual experimental tank (300 L) in triplicates.

Experimental Diets

The pellet diet (100kg) was prepared using the composition depicted in Table 1. 0.5% chromium (III) oxide (BDH 277572Q) was used as inert indicator for digestibility studies. Dry ingredients were mixed for about 30 minutes in a Hobart mixer (Belle, Mini 150; England) to ensure that the mixture was well homogenized and then blended with oil for about 15 minutes. Water was added at 20-30% v/w to give a pelletable mixture. A steam conditioned Ottawinger Pellet Mill (Otta winger) was used to pellet the diets. An appropriate die was used to give pellets of desired sizes (1.0 to 3.0 mm) depending on fish size.

Table 1. Ingredient and nutrient compositions of experimental diet for Rainbow trout

Ingredient compositions	Amounts (kg/100 kg)
Fish meal	50
Soya meal	23
Whole Wheat	20
Minerals [a]	0.5
Yeast	1.0
DL Methionine	0.5
Choline Chloride	0.5
Vitamins [b]	0.10
Fish oil	4.00
Sodium Alginate	0.40
Total	100.00
Nutrient compositions	
CP (%, estimated)	36.93
EE (%, estimated)	7.51
CF (%, estimated)	6.21
Ash (%, estimated)	8.82
Calcium (%, estimated)	1.07
Phosphorous (%, estimated)	1.02

[a] Trace mineral premix supplied the following per Kg of diet:

Experimental Practices

Prior to initiation of each experiment, fish underwent a 2-week conditioning period. At the beginning of the experiment, fish were individually weighed followed by fortnightly intervals. Fortnightly bulk weights were used to adjust the daily feed ration for the following 2 weeks. All experiments were conducted for 8 weeks. Fish were offered either restricted feeding (5% of body weight or 1% body weight as maintenance requirement) or appetite feeding subdivided into three equal feeds at $10.^{00}$, $14.^{00}$ and $18.^{00}$ h every day as dictated by the experimental design. After a stipulated period of feeding (20 to 30 min.), unconsumed feed, if any, was collected on a fine mesh sieve, dried weighed and subtracted from food offered. Fecal matter was collected once a day at about $08.^{30}$ h before feeding. The faeces samples were collected by siphoning and dried for further analysis.

Experimental Analyses

General chemical analyses performed consisted of proximate analysis of feedstuffs, diets and carcass, as well as energy levels in diets, faeces, and chromium oxide in faeces and diets. Energy and protein determination in faeces and diets for digestibility studies used a CHNS/O series II combustion analyzer (Perkin Elmer) according to method of Pantazis and Jauncey (1996). Crude lipid analysis was done by Soxlet extraction method. Energy contents of whole fish samples were calculated using gross energy values of 23.6 and 39.5 kJ/g for protein and lipid, respectively. The feeding trial continued for 56 days according to the following mixed feeding schedules:

(I) Appetite 56 days + 0 (A56 + 0, control)
(II) Restricted 28 days + 28 days Appetite (R28+A28)
(III) Restricted 14 days + Appetite 14 days (R14+A14)
(IV) Restricted 7 days + Appetite 7 days (R7 + A7)
(V) Restricted 3 days + Appetite 4 days (R3 + A4)
(VI) Restricted 2 days + Appetite 2 days (R2 + A2)

Statistical Design

A completely randomized design (CRD) was applied in the present experiment. The mean values of different parameters (presented in results) were compared by One Way Analysis of Variance (ANOVA) where each of the different feeding schedule groups was the only source of variation. Duncan's test at 5% level of significance was used to find out the effect of length of feed deprivation on compensatory growth, feed utilization and activity in trout fingerlings.

Results

During the present experiment the results of growth performance and food utilizations was generally considered in three parts. The first deals with phase I (weeks 0-4), the second with phase II (weeks 4-8) and the third with a comparison of phase I and phase II as well as data for the overall (weeks 0-8) experimental period.

Growth, Survival and Feed Performance

The fortnightly growth response over phase I (weeks 0 - 4) is shown in Figure 1. Growth and feed response parameters are presented in Table 2 and graphically in Figures 2 and 3. The best (P<0.05) growth response in terms of final body weight, percent weight gain and specific growth rate (SGR) was observed for feeding schedule I (control), for fish fed to appetite throughout. In contrast, the growth response to feeding schedule II (4 weeks restriction) was significantly the lowest (P<0.05). No significant differences (P>0.05) in growth rate were observed in treatments III to VI. (Table 2 and Figure 2). Daily highest and lowest feed consumption per 100g fish was found to be significantly different (P<0.05) in the

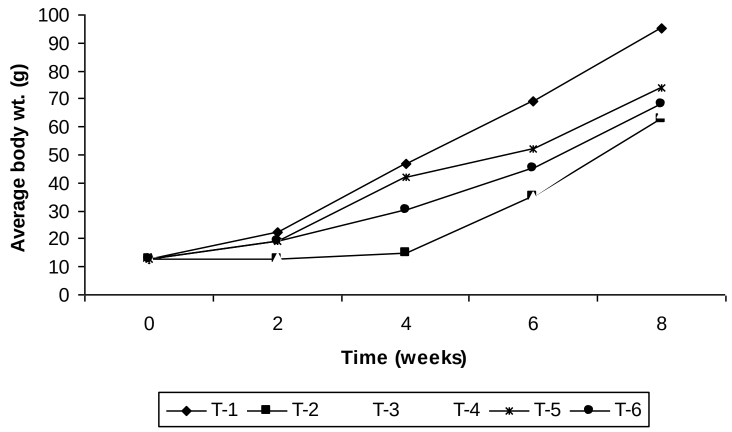

Figure 1. The mean fortnightly growth response of *Onchorhynchus mykiss* mixed feeding schedules over 8 weeks.

Table 2. Phase I (weeks 0-4). Growth performance, feed intake and feed utilization in *Onchorhynchus mykiss* maintained on mixed feding schedule

	Treatment (Feeding schedule)						
Treatment Parameters	T-1(Control)	T-2	T-3	T-4	T-5	T-6	±SEM
Initial body wt. (g)	12.99^a±0.06	12.91^a±0.08	13.05^a±0.13	12.91^a±0.08	13.01^a±0.05	12.92^a±0.10	0.02
Final body wt. (g)	40.60^c±0.83	15.57^a±0.24	28.89^b±0.75	29.23^b±0.67	30.31^b±0.90	29.64^b±0.44	1.77
Weight gain (g)	27.61^c±0.89	2.66^a±0.20	15.85^b±0.74	16.32^b±0.68	17.30^b±0.85	16.72^b±0.42	1.76
Weight gain (%)	212.57^c±7.77	20.61^a±1.47	121.47^b±5.81	126.36^b±5.53	132.99^b±6.09	129.38^b±3.40	13.6
Specific growth rate (SGR, % day)	4.07^c±0.09	0.67^a±0.05	2.84^b±0.10	2.92^b±0.09	3.02^b±0.10	2.97^b±0.05	0.25
Feed intake (g/100 g fish/day)	2.32^c±0.12	0.76^a±0.02	1.89^b±0.03	1.95^b±0.04	1.91^b±0.04	1.83^b±0.04	0.06
Food conversion efficiency (FCE)	1.05^b± 0.06	0.80^a± 0.06	1.04^b± 0.04	1.02^b± 0.04	1.07^b± 0.04	1.10^b±0.04	0.03
Protein efficiency ratio (PER)	3.02^b± 0.19	2.31^a±0.19	2.93^b±0.11	2.95^b± 0.12	3.06^b± 0.12	3.16^b±0.11	0.07
Apparent net protein utilization (ANPU, %)	48.43^b±5.36	37.39^a±2.30	47.17^b±3.23	47.86^b±2.04	48.96^b± 2.24	50.75^b± 0.67	1.21
Apparent net lipid utilization (ANLU, %)	89.86^b ±3.70	-5.13^a±29.57	73.32^b±4.36	54.96^b ±17.41	79.96^b±22.93	63.95^b±4.82	8.24
Apparent net energy utilization (ANEU, %)	45.31^b± 1.56	15.77^a± 6.89	40.43^b± 2.40	36.06^b± 5.40	42.97^b± 6.27	39.66^b± 1.15	2.54

Note: Values are means ± SD of three replicates. Means in the same row having different superscripts are significantly different (P < 0.05) and the values in the same row with the same superscript is not significantly different (P > 0.05). The treatments (feeding schedules) were viz., T-1 (control), T-2, T-3, T-4, T-5 and T-6 refers A 56, R28 + A28, R14 + A14, R7 + A7, R3+A4 and R2 + A2 respectively where R and A refers respectively to the restricted and appetite feeding and the numerical values refers to the number of days.

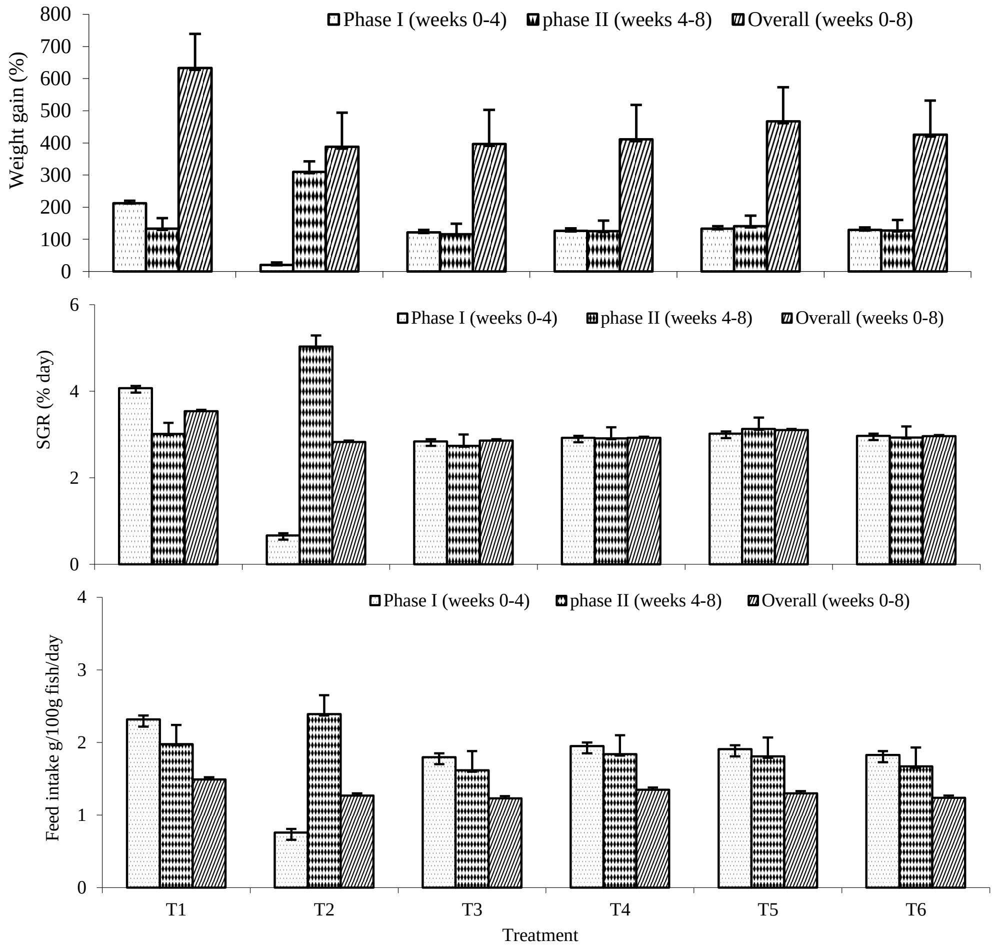

Figure 2. Growth performance (weight gain and SGR) and feed intake of *Onchorhynchus mykiss* maintained on mixed feeding schedules in different experimental periods.

Bars vertical are means of ± SD of three replicates. The treatments (feeding schedules) were viz., T-1 (control), T-II, T-III, T-IV, T-V, and T-VI refers A56, R28+A28, R14+A14, R7+A7, R3+A4 and R2+A2 respectively where, R and A refers respectively to the restricted and appetite feeding and the numerical values refers to the number of days.

feeding schedule I (control) and feeding schedule II, respectively. No significant difference (P>0.05) was observed between feeding schedules III to VI (Table 2 and Figure 2). From Table 2 it is seen that food conversion efficiency (FCE) did not vary significantly (P>0.05) among the feeding schedules I, III, IV, V and VI while feeding schedule II varied significantly (P<0.05). The fortnightly growth response during phase II (weeks 4-8) is also shown in Figure 1. Growth and feed response parameters are presented in Table 3 and graphically in Figure 2 and 3. Feeding schedule II showed significantly the highest (P<0.05) growth response in terms of final body weight, percent weight gain and specific growth rate (SGR) in comparison with other feeding schedules. No significant differences (P>0.05) in growth rate were observed in treatments I, III, IV, V and VI. (Table 3 and Figure 2). Daily feed consumption per 100 g fish was found to be significantly higher (P<0.05) in treatment I (control) and treatment II in comparison with other treatments. No significant differences (P>0.05) were observed between treatments III to VI. Food conversion efficiency (FCE) did not differ significantly (P>0.05) between feeding schedule groups (Table 3 and Figure 3).

Growth rate and food conversion efficiency (FCE) in feeding schedule II were markedly higher during phase II in comparison with phase I. Phase I (0-4 weeks) growth rates slightly increased in fish fed the restricted ration throughout (T-II). In contrast, in phase II (4-8 weeks) fish fed to appetite throughout (T-II) showed a rapid increase in fortnightly growth response (Figure 1) and higher growth rates, feed consumption and FCE (Tables 2 and 4).

The fortnightly growth response of *Onchorhynchus mykiss* overall (weeks 0 - 8) is shown in Figure 1. Growth and feed response parameters are summarized in Table 4 and graphically in Figures 2 and 3. Significantly higher (P<0.05) growth response in terms of final body weight, percent weight gain and specific growth rate (SGR) was observed in feeding schedule I (control), for fish fed to appetite throughout. No significant differences (P>0.05) in growth rate were observed between feeding schedule II to VI. Coefficients of variation (CV) for final weight in feeding schedule I (control) were

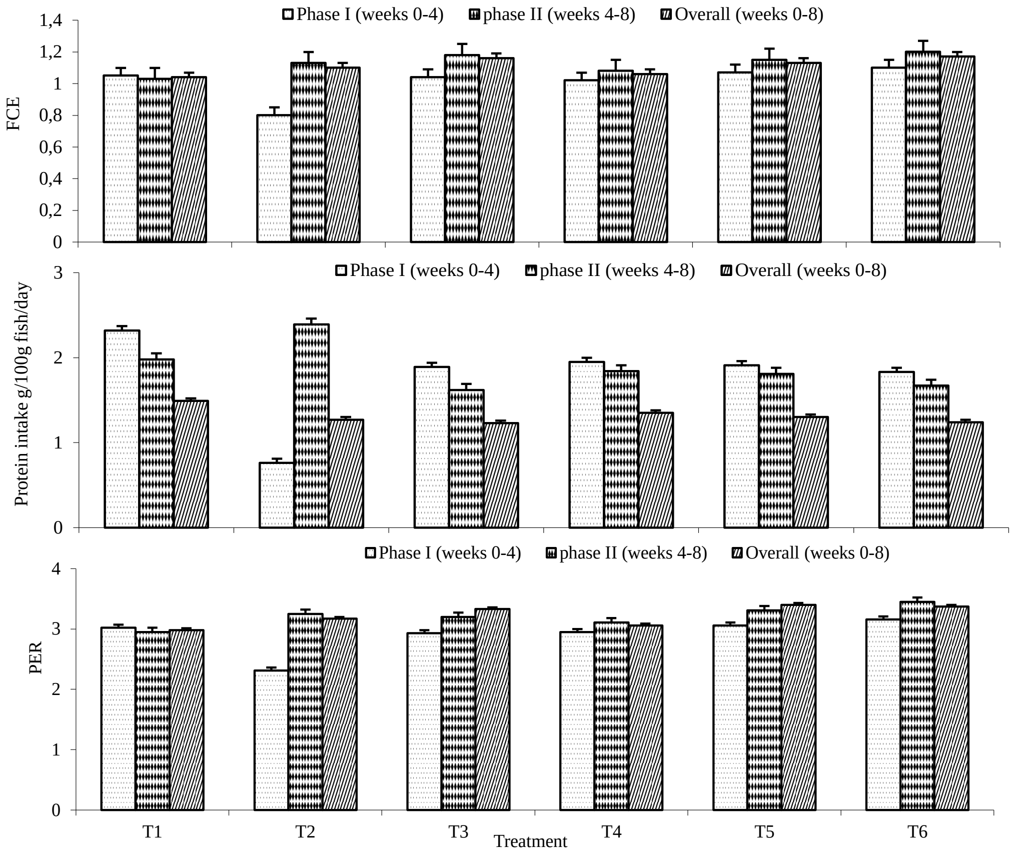

Figure 3. Food conversion efficiency (FCE), protein intake and PER of *Onchorhynchus mykiss* maintained on mixed feeding schedules in different experimental periods.

Bars vertical are means of ± SD of three replicates. The treatments (feeding schedules) were viz., T-1 (control), T-II, T-III, T-IV, T-V, and T-VI refers A56, R28+A28, R14+A14, R7+A7, R3+A4 and R2+A2 respectively where, R and A refers respectively to the restricted and appetite feeding and the numerical values refers to the number of days.

Table 3. Phase II (weeks 4-8). Growth performance, feed intake and feed utilization in *Onchorhynchus mykiss* maintained on mixed feeding schedule

Treatment	Treatment (Feeding schedule)						
Parameters	T-1(Control)	T-2	T-3	T-4	T-5	T-6	±SEM
Initial body wt. (g)	40.72^c±1.71	15.37^a±0.23	30.05^b±1.10	29.28^b±0.90	30.66^b±0.54	29.86^b±1.50	1.80
Final body wt. (g)	95.18^b±13.37	62.94^a±4.45	64.76^a±0.77	66.05^a±1.34	73.81^a±5.34	67.91^a±2.88	2.95
Weight gain (g)	54.45^b±11.67	47.57^{ab}±4.60	34.71^a±0.33	36.77^a±1.56	43.15^{ab}±5.06	38.04^a±1.50	1.76
Weight gain (%)	133.08^a±23.30	309.75^b±32.99	115.65^a±5.33	125.72^a±5.53	140.68^a±15.36	127.46^a±3.31	16.90
Specific growth rate (SGR, % day)	3.01^a±0.37	5.03^b±0.28	2.74^a±0.09	2.91^a±0.13	3.13^a±0.23	2.93^a±0.06	0.20
Feed intake(g/100g fish/day)	1.98^b±0.09	2.39^a±0.11	1.62^a±0.02	1.84^{ab}±0.06	1.81^{ab}±0.08	1.67^a±0.11	0.07
Food conversion efficiency (FCE)	1.03^a±0.12	1.13^a±0.08	1.18^a±0.01	1.08^a±0.07	1.15^a±0.10	1.20^a±0.09	0.02
Protein efficiency ratio (PER)	2.95^a±0.36	3.25^a±0.23	3.20^a±0.04	3.11^a±0.19	3.31^a±0.29	3.45^a±0.25	3.42
Apparent net protein utilization (ANPU,%)	50.75^a±10.53	52.34^a±5.11	55.27^a±4.28	51.25^a±7.88	57.12^a±9.53	54.85^a±1.80	1.56
Apparent net lipid utilization (ANLU,%)	93.97^a±20.90	103.51^a±14.14	103.15^a±10.35	103.68^a±15.95	88.32^a±21.81	126.38^a±13.16	4.36
Apparent net energy utilization (ANEU,%)	49.33^a±9.71	50.59^a±5.76	51.84^a±2.93	49.11^a±5.51	48.86^a±2.42	57.62^a±3.99	1.33

Note: Values are means ± SD of three replicates. Means in the same row having different superscripts are significantly different (P < 0.05) and the values in the same row with the same superscript is not significantly different (P>0.05).

The treatments (feeding schedules) were viz., T-1 (control), T-2, T-3, T-4, T-5 and T-6 refers A 56, R28 + A28, R14 + A14, R7 + A7, R3+A4 and R2 + A2 respectively where R and A refers respectively to the restricted and appetite feeding and the numerical values refers to the number of days.

Table 4. Overall (weeks 0-8). Growth performance, feed intake and feed utilization in *Onchorhynchus mykiss* maintained on mixed feeding schedule

Treatment Parameters	Treatment (Feeding schedule)						
	T-1(Control)	T-2	T-3	T-4	T-5	T-6	±SEM
Initial body wt. (g)	12.99^{a}±0.06	12.91^{a}±0.08	13.05^{a}±0.13	12.91^{a}±0.08	13.01^{a}±0.05	12.92^{a}±0.10	0.02
Final body wt. (g)	95.18^{b}±13.37	62.94^{a}±4.45	64.76^{a}±0.77	66.05^{a}±1.34	73.81^{a}±5.34	67.91^{b}±2.88	2.95
CV (%) of final wt.	54.84^{b}±9.88	44.98^{ab}±3.29	36.59^{a}±7.07	34.63^{a}±3.43	35.55^{a}±2.38	42.08^{ab}±1.78	2.02
Weight gain (%)	633.03^{b}±106.26	387.84^{a}±37.62	396.36^{a}±5.75	411.54^{a}±13.23	467.28^{a}±39.82	425.43^{a}±20.87	22.70
Specific growth rate(SGR, % day)	3.54^{b}±0.26	2.83^{a}±0.13	2.86^{a}±0.02	2.92^{a}±0.05	3.10^{a}±0.12	2.96^{a}±0.07	0.06
Feed intake(g/100g fish/day)	1.49^{b}± 0.14	1.27^{a}±0.06	1.23^{a}±0.01	1.35^{ab}±0.03	1.30^{ab}±0.06	1.24^{a}±0.08	0.05
Food conversion efficiency (FCE)	1.04^{a}± 0.11	1.10^{a}±0.08	1.16^{a}±0.02	1.06^{a}±0.03	1.13^{a}±0.08	1.17^{a}±0.09	0.02
Protein efficiency ratio (PER)	2.98^{a}± 0.33	3.17^{a}±0.22	3.33^{a}±0.04	3.06^{a}±0.08	3.40^{a}±0.22	3.37^{a}±0.24	0.05
Apparent net protein utilization (ANPU, %)	51.71^{a}± 9.54	51.10^{a}±4.68	53.69^{a}±2.04	48.66^{a}±4.58	54.94^{a}±7.50	53.72^{a}±1.90	1.24
Apparent net lipid utilization (ANLU,%)	85.45^{a}± 14.50	93.45^{a}±12.07	87.43^{a}±8.14	83.62^{a}±11.12	79.28^{a}±14.78	100.71^{a}±8.26	2.88
Apparent net energy utilization (ANEU,%)	45.65^{a}± 7.47	47.37^{a}±5.11	47.07^{a}±2.54	43.78^{a}±2.68	45.54^{a}±0.79	50.49^{a}±2.69	0.96

Note: Values are means ± SD of three replicates. Means in the same row having different superscripts are significantly different (P < 0.05) and the values in the same row with the same superscript is not significantly different (P>0.05).
The treatments (feeding schedules) were viz., T-1 (control), T-2, T-3, T-4, T-5 and T-6 refers A 56, R28 + A28, R14 + A14, R7 + A7, R3+A4 and R2 + A2 respectively where R and A refers respectively to the restricted and appetite feeding and the numerical values refers to the number of days.

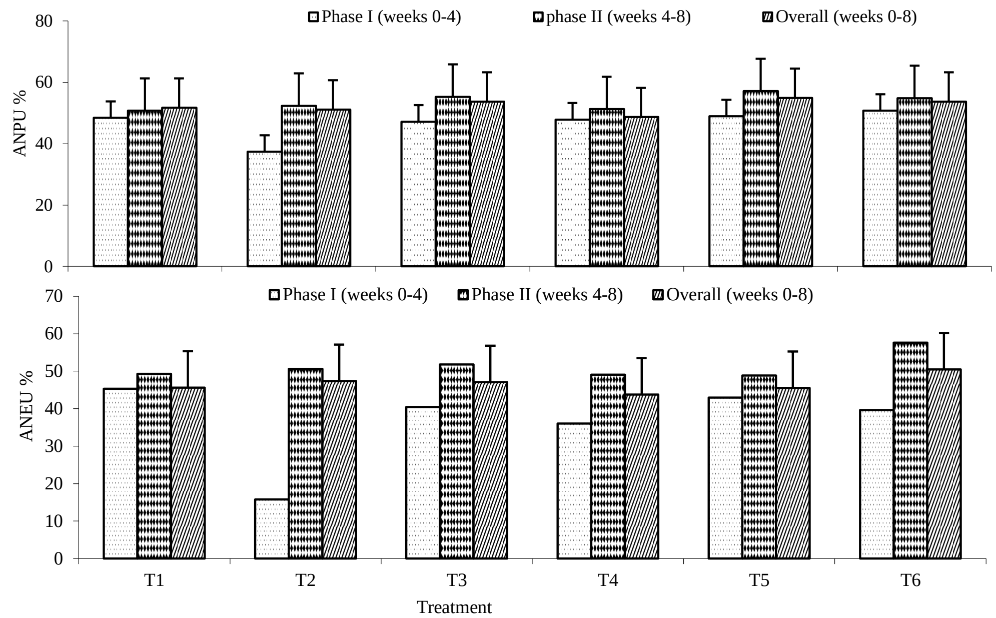

Figure 4. Apparent net protein utilization (ANPU) and apparent net energy utilization (ANEU) of *Onchorhynchus mykiss* maintained on mixed feeding schedules in different experimental periods.
Bars vertical are means of ± SD of three replicates. The treatments (feeding schedules) were viz., T-1 (control), T-II, T-III, T-IV, T-V, and T-VI refers A56, R28+A28, R14+A14, R7+A7, R3+A4 and R2+A2 respectively where, R and A refers respectively to the restricted and appetite feeding and the numerical values refers to the number of days.

significantly higher (P<0.05). Improved growth rates were accompanied by lower CV for final weight feeding schedules III, IV and V and there were no significant differences (P>0.05) between them (Table 4). Daily feed consumption per 100g fish was found to be significantly higher (P<0.05) in feeding schedules I (control). Fish in feeding schedules II to VI did not show statistical differences (P>0.05). Food conversion efficiency (FCE) in any feeding schedule did not differ significantly (P>0.05) (Table 4). For treatment III, it is possible to calculate both food intake and growth rate for the 2-week periods of maintenance and appetite feeding as this corresponds to the 2-week weighing interval. The average SGR (%, day) and food intake (g/100 g fish/day) for the two appetite feed periods were 4.89% day and 3.15%

day respectively.

Apparent Nutrient and Energy Utilization

The protein efficiency ratio (PER) and apparent net protein utilization (ANPU) for phase I (weeks 0 - 4) are presented in Table 2 and graphically in Figures 3 and 4. Fish on feeding schedule II had significantly lower (P<0.05) PER and ANPU while feeding schedules I, III, IV, V and VI did not vary significantly (P>0.05). As shown in Table 2, a significantly lower (P<0.05) Apparent Net Lipid Utilization (ANLU) value of –5.13% was found in fish fed schedule II. However, no significant differences (P>0.05) were noticed in other groups. Similarly, apparent net energy utilisation (ANEU) was lowest (P<0.05) for feeding schedule II with no significant differences (P>0.05) between the other group (Table 2). In phase II (weeks 4 - 8) PER and ANPU are shown in Table 3 and graphically in Figures 3 and 4. PER ranged from 2.95 to 3.45 and did not show significant differences (P>0.05) amongst groups. ANPU ranged from 50.75 to 57.12% and did not vary significantly (P>0.05) between treatments. However, comparatively higher PER and ANPU values were recorded in the feeding schedules II to VI than for the control (T-I). As shown in Table 3, ANLU and ANEU also did not differ significantly (P>0.05) between groups. In phase II, feeding schedule II displayed considerable changes in PER, ANPU, ANLU and ANEU value in comparison to phase I (Figure 4; Table 2 and Table 3). PER and ANPU of *Onchorhynchus mykiss* in the overall experimental period (weeks 0 - 8) are presented in Table 4 and graphically in Figure 4. PER and ANPU did not differ significantly (P>0.05) amongst groups. However, slightly higher PER and ANPU values were observed for feeding schedule V (R3 + A4). As shown in Table 4, ANLU and ANEU did not show significant differences (P>0.05).

Discussion

The results of the current study demonstrate that the length of restricted feeding and subsequent appetite feeding periods influenced growth performance and feed efficiency in rainbow trout, *Onchorhynchus mykiss*. Unsurprisingly, during phase I, the highest and lowest growth rates in terms of final body weight, % weight gain and SGR were observed in fish fed either to appetite (A28 + 0) or a restricted ration (R28 + 0), respectively. In groups III to VI, fish fed alternate periods restricted and appetite feeding, showed partial growth recovery. However, they did not fully compensate since these groups showed significantly lower growth rates than the control treatment that was fed to appetite throughout (Table 2). Thus, it is feasible to suggest that the 4-week period was not sufficient to induce any marked compensatory growth response in rainbow trout. It has been reported that the hyperphagic response and compensatory growth are dependent upon the severity and duration of feed restriction (Jobling *et al.*, 1993; Jobling and Koskela, 1996). During phase II (weeks 4 - 8) fish fed feeding schedule II (that had suffered the greatest growth deprivation during 4 weeks feed restriction in phase I) became hyperphagic and the previously restricted feeding fish displayed markedly greater growth rates (Table 3, Figure 1 and Figure 2). This type of growth response is generally referred to as compensatory or catch-up growth as has been described previously for a variety of fish species and hyperphagia is often observed during the period of compensation (Dobson and Holmes, 1984; Miglavs and Jobling, 1989a; Jobling *et al.*, 1993; Jobling *et al.*, 1994; Jobling and Koskela, 1996; Saether and Jobling, 1999). The next major compensatory growth responses were for feeding schedule V (R3 + A4). Growth responses following a period of feed restriction may be more variable, possibly because of the inequalities that arise within groups (McCarthy *et al.*, 1992; Jobling and Koskela, 1996; Damsgaard *et al.*, 1997). Jobling and Koskela (1996) reported that compensatory growth responses were higher in those rainbow trout that had suffered the greatest growth deprivation during a period of feed restriction.

The results for *Onchorhynchus mykiss* in this study are similar to those in Arctic charr, where alternating periods of feeding restricted and satiation rations did not induce complete compensatory growth over a 16-week experimental period (Miglavs and Jobling, 1989a, 1989b). These authors concluded that the restricted – satiation feeding regime employed did not have any beneficial effect with regard to energetic efficiency or growth improvement. In contrast, other studies reported for Atlantic cod, *Gadus morhua* L., and Arctic charr, *Salvelinus alpinus* L., that deprivation periods of up to 3 weeks in duration were not sufficient to induce compensatory growth (Jobling *et al.*, 1993; Jobling *et al.*, 1994). In these latter studies, Atlantic cod and Arctic charr were returned to adequate feeding conditions following 8 weeks and 24 weeks, respectively, of restricted feeding. This return to adequate feeding gave rise to a compensatory growth response, with the degree of compensation being directly related to the severity and duration of the food restriction previously imposed (Jobling *et al*., 1993; Jobling *et al.*, 1994). Thus, larger fish may require longer periods of feeding restriction before the 'nutritional stress' becomes sufficiently severe to induce a compensatory growth response. Partial compensation is the response most often recorded in both domestic animals (Wilson and Osbourn, 1960; O'Donovan, 1984;) and fish (Weatherley and Gill, 1981, 1987; Miglavs and Jobling 1989a; Jobling *et al.*, 1993; Jobling *et al.*, 1994), although complete compensation has previously been recorded in some studies carried out on fish (Bilton and Robins, 1973; Dobson and Holmes, 1984; Quinton and Blake, 1990; Rueda *et al.*, 1998; Saether and Jobling 1999).

The present experiment appears to disagree with the results reported by Bilton and Robins (1973) and Dobson and Holmes (1984) where salmonids showed marked improvement in growth efficiency during periods of recovery from feeding restriction or under nutrition. Similarly, the findings of this study also appear to differ from some other studies reported for fish (Wieser *et al.,* 1992; Russell and Wootton, 1992) and homeotherms (Plavnik and Hurwitz, 1985; Jones and Farrell, 1992). To what extent animals show complete or partial recovery following return from restricted to appetite feeding seems to depend upon the age at which the restriction is applied, and upon the severity and duration of restricted feeding (Summers *et al*., 1990; Yu *et al*., 1990; Leeson *et al.*, 1991; Jones and Farrell, 1992; Jobling *et al*., 1993; Jobling *et al*., 1994).

Apparent Nutrient and Energy Utilization

Fish fed shorter alternating schedules (groups V and VI) in phase I (weeks 0-4) showed comparatively better PER and ANPU whereas in phase II (weeks 4-8) groups II to VI displayed improved PER and ANPU compared to fish fed to appetite throughout (control). Over the 8-week experimental period fish fed alternating feeding schedules exhibited higher PER and ANPU than the control. Miglavs and Jobling (1989b) reported that the weight gained in Arctic charr fed on a restricted feeding regime for 8 weeks throughout was in the form of comparatively low-energy carcass tissue comprised mostly of moisture and protein, whilst there was a decrease in high-energy lipid stores. Thus, FCE was relatively higher during the period of food restriction but ANEU was poor.

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