E.Ü. Su Ürünleri Dergisi 2005
E.U. Journal of Fisheries & Aquatic Sciences 2005
Cilt/Volume 22, Sayı/Issue (1-2): 161–164

ISSN 1300 - 1590
http://jfas.ege.edu.tr/

Effects of Largely Varying Feeding Intensities on Growth, Weight Gain Composition and Fillet of Rainbow Trout, *Oncorhynchus mykiss* (Walbaum, 1792)

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Özet: ***Gökkuşağı alabalığının,*** Oncorhynchus mykiss ***(Walbaum, 1792) çeşitli beslenme yoğunluklarında büyüme, ağırlı kazanma ve fileto kompozisyonu değişimleri.*** Yüksek yağ ve düşük protein içeren yem (Yüksek yağ= yaklaşık 300 g/kg kuru maddede ve düşük protein= yaklaşık 400 g/kg kuru maddede), sekiz farklı besleme yoğunluğundaki (DFI- Günlük yem artışı) gruplara yedirildi. Her grupta her biri 101 gram başlangıç ağırlığındaki 20 balık vardı. Günlük yem tüketimi bir denklemle belirlendi: y=k*başlangıç BW*$(1+k)^d$, (d =deney gün sayısı, k = yem artışı oranı ve BW: Vücut ağırlığı). Sekiz besleme yoğunluğu için seçilen k değerleri 0.005 ve 0.02 aralığındaydı. Her besleme yoğunluğu için üç tekrar yapıldı. Her grup 3 kilogram yem tüketti. Deney süresi 229 gün ile 55 gün arasında değişti. Yem çevirim verimi, orta yoğunluktaki beslemede (0.010-0.0125) en yüksek değerdeydi ve yemleme yoğunluğu düştükçe artış gösterdi ve orta yoğunluktan aşağı seviyelerde azalışa geçti. Bu etki vücut ağırlık kazanımında da görüldü. Canlı ağırlık kazanımında protein konsantrasyonu yemleme yoğunluğu arttıkça düştü ancak canlı ağırlık yağ kazanımı arttı, enerji konsantrasyonu bu artışa bağlı olarak yükseldi. Sindirilebilir enerji kullanım verimi besleme yoğunluğu artışı ile 0.38'den 0.65'e bununla beraber sindirilebilir protein kullanım verimi en düşük besleme yoğunluğunda 0.40 iken, en yüksek değeri olan 0.48'e orta besleme yoğunluğunda ulaştı. Balık fileto kısmı deney sonu canlı ağırlığının yarısı kadardı. Kısıtlı besleme yoğunluğunda, filetonun yağ konsantrasyonu düşerken, protein konsantrasyonu sabit kaldı.

Anahtar Kelimeler: Yem çevirim oranı, Günlük yem artışı, kısıtlı besleme, Fileto verimi.

Abstract: High Fat Low Protein diet (High Fat = about 300 g/kg DM and Low Protein = about 400 g/kg DM) was fed at one of eight feeding intensities DFI (Daily Feed Increase), to groups of 20 trout, initially weighing on average 101 g per trout. Daily feed offer was determined by the equation: y = k*initial BW*$(1+k)^d$, (where d = the experimental day, k = the rate of feed increase and BW: Body weight). k-values chosen for the eight treatments ranged between 0.005 and 0.02. Three replicate groups were allotted to each treatment. 3 kg feed were fed to each group –this resulted in different durations ranging between 229 days at the lowest intensity and 55 days at the highest intensity. It is concluded that feed conversion efficiency increases by decreasing feeding intensity and peaks at moderate levels of feeding intensity (0.010-0.0125) then gently decreases with further increase. This effect is concurrently reflected in weight gain. Protein concentration in gain dropped by increasing feeding intensity, whereas lipid concentration and energy concentration in gain increased correspondingly. Efficiency of utilization of DE increased with increasing feeding intensity from 0.38 to 0.65, whereas that of DCP ranged between 0.40 at the lowest and 0.48 at half the highest rate of daily feed increase. Fillet corresponded to half of the whole body in all the treatments. Lipid concentration in fillet reduced by restrictive feeding intensity, whereas protein concentration appeared to be constant.

Key Words: Feed conversation efficiency, Daily feed increase, Restrictive feeding, Fillet yield.

Introduction

Many factors contribute to the reduction of nutrient loss in feed and lower production cost of cultured fish in the last years. Improved diets and feeding strategies together have resulted in increased performance, better feed utilisation and carcass quality. Improved growth and feed efficiency with increased dietary lipid level (below 200 g/kg DM) have been reported in many studies (Reinitz, 1983; Beamish and Medland, 1986) with small rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792). Effects of high dietary lipid content (300 g/kg DM) have been reported on growth, feed conversion and body composition. These were reported from rainbow trout (Alsted, 1991) and small-sized Atlantic salmon in sea water (Hillestad and Johnsen, 1994). Short-term (Einen and Roem, 1997) and Long-term (Hillestad *et al.,* 1998) effects of dietary lipid has been examined in Atlantic salmon and in rainbow trout (Regost *et al.,* 2001). None of these studies have evaluated the effect of feeding intensity in fish fed with high dietary lipid level. This information is important for fish growers as a management tool which could be manipulated to achieve optimum growth and production. Objective of this experiment was to study the effect of varying feeding intensity in a broad range in trout fed on high dietary lipid level.

Materials and Methods

Experiments were carried out in a partial recycling Aquaculture System at the department of Animal Nutrition of Agricultural Faculty, Bonn University, Germany. The experimental system consisted of 24 circular shaped plastic culture tanks (in which the experimental fish were kept that were continuously supplied with water in parallel with about 70% of the outflowing water). Each culture tank had capacity of 250 l formed part of the culture system that had a water flow of 4-5 l per minute. Details of the system of circulation can be seen in Sanver (2004). A sedimentation unit is attached to each tank which allows collection of faecal samples. The water temperature is adjusted and maintained at about 15ºC. All the rainbow trout (*O. mykiss*) were selected from a homogenous population at the Department of Animal Nutrition in Bonn.

At the beginning of experiment, trout were sedated with clove oil (*Oleum Ceryophylli)*, hand graded, weighed in groups, 20 trout each initially weighing 101 g randomly allotted to culture tanks. Zero groups were killed by overdosed Benzocain (4-Ethyl-Aminobenzoat) and subsequently frozen for initial body composition analysis. Mean body weights per trout of these groups were similar to initial body weights of experimental trout. Data on mortality (weight, date, group) was recorded individually.

HFLP diet (High Fat= about 300 g/kg DM and Low Protein = about 400 g/kg DM) was fed. The diet consisted of fish meal, fish oil, soybean meal, wheat, vitamin and mineral premix of varying concentrations. The company Nutreco was responsible of the diet formulation and production. The feed ingredients were ground by using a hammer mill before mixing. Pellets were produced using a Wenger TX twin screw extruder. Oil was coated on the extruded pellets using a vacuum coater. Yttrium oxide was included as inert marker. The proximate composition of nutrient and energy experimental diet was analysed, per kg DM, ash =83 g, protein= 387 g, lipid=325, Gross energy = 25.40 MJ, Y_2O_3: 83.6 mg).

The experimental fish were offered feed at varying intensities. All the groups in the experiment consumed about 3 kg of feed which resulted in different experimental durations. The quantity of the feed to each group, corresponded to about 150% of its initial biomass, but the duration varied widely between treatments. The value of 3 kg feed fed to each group was drawn from the average consumption of groups fed to satiation in a previous experiment. Feeding schemes were calculated according to the equation below. All variables in this equation are known except the duration in days (d) which could be calculated:

Total consumption (g) = $(IBW*DFI)*(1+DFI)^d$

IBW: Initial body weight (biomass) at the beginning

DFI: Daily feed increase was from 2.00 until 0.5

At the highest feeding intensity experiment lasted 55 days while at the lowest intensity experiment lasted 229 days.

For instance; The amount of feed consumed on the first day of the experiment by the groups fed at the highest intensity (2.00% of IBW) and the groups fed at the lowest intensity (0.5% of IBW) is calculated as follows:

Feed consumption on day no.1= $(IBW*DFI)*(1+DFI)^d$

$= (2025\ g * 0.02)*(1+0.02)^1$

$= 41.3$ *g (highest intensity)*

in comparison to

$= (2092\ g *0.005)*(1+0.005)^1$

$= 10.5$ *g (lowest intensity)*

After killing and weighing the group biomasses, fish were weighed individually and then half of each group were sorted out on weight basis to represent the whole group; these were combined and used for whole body analysis. Half of the group was used for filleting. Each fish was put in plastic bags vacuumed and sealed. Afterwards, cooked at 60ºC for 10 minutes. Fillet was sampled for chemical analysis.

Identical analysis was applied for diets, faeces and body as well as fillet homogenates. Dry matter was calculated weight loss after 24 h drying at 105ºC. Ash was analysed by overnight to constant weight at 550ºC. Crude protein was measured using the Dumas Method and multiplying N by 6.25. Total lipids were determined by HCl digestion of samples followed by petroleum ether extraction. Energy was measured by Adiabatic calorimetry principle (Bomb calorimetry). Yttrium analyses were done in feed and faeces by ICP-AES-Inductively Coupled Plasma-Atomic Emission Spectroscopy.

At the end of the experiment, the following parameters were calculated.

-Average Body weight (ABW) per fish:

ABW (g/fish) =Weight of group (g) / Fish number in the group

-Weight gain = Final weight (g/group)-Initial weight (g/group)

-DM feed consumption per fish (g):

DM consumption per group (g) / number of fish per group

-Feed conversion efficiency (FCE):

FCE = Weight gain (g) / dry matter feed intake (g)

-Nutrient (g/ kg) and energy (MJ/ kg) accretion:

[Final weight in kg per tank× concentration in body at the end]-

[Initial weight in kg per tank × concentration in body at the begin]

-Nutrient (g/ kg) and energy (MJ/ kg) accretion in Fillet:

Fillet weight at the end in kg per tank × concentration in Fillet at the final weight

-Energy as well as nutrient digestibility were calculated by the following equation (NRC, 1983)

$$100 - 100 \times \frac{\%\,Y_3O_2\ in\ feed}{\%\,Y_3O_2\ in\ faeces} \times \frac{\%\,nutrient\ in\ faeces}{\%\,nutrient\ in\ feed}$$

Statistical means in the experiment were compared in a one-way ANOVA by use of SPSS 6.1 for Windows statistical package.

Results

Growth, Lipid and protein accretion of trout in experiments overall, fish appeared in good health. 7 of the 480 trout were lost during the experiment for unidentified reasons, which did not appear to be related to feed or feeding intensity. Initial and final body weights as well as feed consumption of each group can be seen in Table 1. Rates of daily feed increase between 0.005 and 0.020 were reflected in the calculated average daily feeding intensities which ranged from 3.8 to 14.5 g dry matter per kg body weight. FCE increased by decreasing the feeding intensity, peaked at moderate feeding level and then decreased. Table 1 shows that digestibility of energy was constant at 93 - 94% for six of the eight feeding intensities and 91% at the highest two feeding intensities. The digestibility of crude protein averaged 94%. Energy and lipid concentrations of gain increased with increasing feeding intensity, whereas protein concentration decreased. Efficiency of utilization of DE increased with increasing feeding intensity from 0.38 to 0.65, whereas that of DCP ranged between 0.40 at the lowest and 0.48 at half the highest rate of daily feed increase.

Half of the whole body was fillet in all the treatments of the experiment. In Table 2, protein concentration of fillet appeared to be constant in all the treatments of experiment, whereas fillet lipid concentration dropped sharply by decreasing the feeding intensity. This tendency was reflected in the respective energy concentrations.

Table 1. Performance, digestibility of energy and proximate nutrients, composition of gain, and efficiency utilization of digestible energy (DE) and digestible crud protein (DCP) in rainbow trout fed diet HFLP with varying daily feed increases (means ± SD, 3 groups of 20 trout per treatment)[1]

DFI	0.005	0.006	0.0075	0.010	0.0125	0.0150	0.0175	0.020
Experimental days	229	176	144	107	88	74	64	55
Feed, g DM per trout	143 ±0.0	144±0.0	144±0.1	144±0.4	144±0.8	142±0.0	143±0.2	143±0.7
Gain, g per trout	123^{e}±7	137^{cd}±8	150^{bc}±5	161^{ab}±6	169^{a}±3	160^{ab}±6	159^{ab}±9	155^{bc}±7
FCE	0.86^{d}±0.05	0.95^{cd}±0.06	1.04^{bc}±0.03	1.12^{ab}±0.02	1.18^{a}±0.02	1.13^{ab}±0.04	1.11^{ab}±0.06	1.08^{bc}±0.06
F.I.,g DM.BW(kg)$^{-1}$.d^{-1}	3.8±0.1	4.8±0.2	5.7±0.0	7.3±0.2	8.9±0.05	10.6±0.3	12.5±0.3	14.5±0.3
Digestibility,%								
Energy	93^{a}±0.6	93^{a}±0.9	94^{a}±0.2	94^{a}±0.5	93^{a}±0.1	93^{a}±0.1	91^{b}±0.3	91^{b}±1.0
Crude protein	94±0.3	95±1.6	93±0.4	94±0.2	94±0.2	94±0.1	93±0.2	93±0.3
Lipids	88^{ab}±1.4	86^{ab}±3.5	91^{a}±0.6	90^{ab}±1.4	88^{ab}±0.7	85^{bc}±0.6	80^{cd}±0.6	78^{d}±3.7
Total carbohydrates	80^{a}±0.7	79^{ab}±4.4	80^{ab}±0.2	80^{a}±1.2	78^{ab}±0.3	77^{ab}±0.8	76^{ab}±0.3	75^{b}±1.5

[1]Values that do not share a common superscript letter in the same row are significantly different (p<0.05).

Table 2. Proximate nutrients, composition of gain, and efficiency utilization of digestible energy (DE) and digestible crud protein (DCP) in rainbow trout fed diet HFLP with varying daily feed increases (means ± SD, 3 groups of 20 trout per treatment)[1]

DFI	0.005	0.006	0.0075	0.010	0.0125	0.0150	0.0175	0.020
Experimental days	229	176	144	107	88	74	64	55
Feed, g DM per trout	143±0.0	144±0.0	144±0.1	144±0.4	144±0.8	142±0.0	143±0.2	143±0.7
Composition of gain								
Energy, MJ.(kg)$^{-1}$	10.4^{d}±0.5	10.6^{cd}±0.8	11.0^{cd}±0.6	11.4^{cd}±0.2	12.0^{abc}±0.1	11.7^{bc}±0.5	13.2^{ab}±0.8	13.7^{a}±0.1
Crude protein, g.(kg)$^{-1}$	167^{a}±1	164^{a}±5	162^{a}±10	157^{ab}±5	146^{bc}±4	144^{c}±3	145^{bc}±1	145^{bc}±2
Lipids, g.(kg)$^{-1}$	171^{d} ±3	171^{d}±18	197^{cd}±11	207^{bc}±3	223^{abc}±7	235^{ab}±16	250^{a}±20	256^{a}±4
Efficiency of utilization								
DE	0.38^{f}±0.03	0.42^{ef}±0.03	0.48^{de}±0.04	0.54^{cd}±0.02	0.60^{abc}±0.01	0.56^{bc}±0.03	0.63^{ab}±0.04	0.65^{a}±0.03
DCP	0.40^{b}±0.02	0.43^{ab}±0.04	0.47^{ab}±0.03	0.48^{a}±0.03	0.47^{ab}±0.02	0.45^{ab}±0.03	0.45^{ab}±0.03	0.43^{ab}±0.02

[1]Values that do not share a common superscript letter in the same row are significantly different (p<0.05).

Table 3. Fillet composition in final weight in rainbow trout fed diet HFLP with varying daily feed increases (means ± SD, 3 groups of 20 trout per treatment)[1]

DFI	0.005	0.006	0.0075	0.010	0.0125	0.0150	0.0175	0.020
Experimental days	229	176	144	107	88	74	64	55
F.I., gDM.BW(kg)$^{-1}$.d^{-1}	3.8±0.1	4.8±0.2	5.7±0.0	7.3±0.2	8.9±0.05	10.6±0.3	12.5±0.3	14.5±0.3
Proportion of Fillet to Whole body (g/kg)	0.480^{a}±0.02	0.453^{c}±0.00	0.472^{ab}±0.01	0.465^{ab}±0.01	0.457^{c}±0.01	0.472^{ab}±0.03	0.467^{ab}±0.01	0.467^{ab}±0.03
Composition of Fillet								
Energy, MJ.(kg)$^{-1}$	6.53^{de}±0.3	6.88^{d}±0.2	6.98^{d}±0.1	7.41^{c}±0.3	7.21^{c}±0.4	7.49^{ab}±0.1	7.49^{ab}±0.1	7.83^{a}±0.1
Crude protein,g.(kg)$^{-1}$	219^{ab}±5.5	221^{a}±2.0	221^{a}±6.6	213^{bc}±4.1	217^{b}±1.2	218^{ab}±5.4	214^{bc}±0.8	213^{bc}±2.4
Lipids, g.(kg)$^{-1}$	40.6^{d}±3.1	48.0^{cd}±4.3	52.2^{c}±1.9	62.9^{b}±6.6	63.5^{b}±5.1	64.0^{b}±3.1	66.9^{ab}±4.1	73.8^{a}±3.5

[1]Values that do not share a common superscript letter in the same row are significantly different (p<0.05).

Discussion

The feeding intensity of DFI 0.0125 which was the moderate feeding level gave the optimal growth performance. The FCE in this study show that overfeeding is not necessary for a fast growth of rainbow trout. On the contrary maximum weight gain and a good product result can be obtained by using 1.0 kg dry matter from a balanced ration for more than 1.0 kg gain. Increased FCE due to restricted feeding was reported by a number of studies performed with Atlantic salmon (Hillestad *et al.,* 1998), rainbow trout (Storebakken *et al.,* 1991; Braun 1998). A comparable study to this experiment regarding to the variation in feeding intensity by Storebakken and Austreng (1987) reported that the rainbow trout (*Salmo gairdneri* Richardson) fed at six different ration levels for two periods of 21 days found the FCE the highest at the moderate ration level where values obtained were an FCE of 1 kg growth per kg dry feed.

Increasing feeding intensity had obvious influence on accretion of nutrients. Lipid in gain increased drastically, where the concentration was almost doubled at the highest feeding level that of the lowest feeing intensity. Storebakken (1987), Huisman (1976) stated the decrease in lipid deposition while decreasing feeding rate and results concerning protein indicate that protein is preserved in the carcass even with scanty rations.

It was reported that the increase in percent carcass and visceral fat was a direct result of storage fat as fat ingestion was higher with increased feeding rates (Storebakken *et al.,* 1991). The increase in lipid deposition by increasing feeding level represents an important energy store which can be mobilized during periods of underfeeding or in times of negative energy balance, for maintenance energy requirements or for reproductive purposes. This increase in lipid deposition in gain was reflected in the energy accretions of the treatments.

Although the protein deposition in gain increased by the reduction of feeding intensity, this could be pronounced in a slight manner rather than significant.

Almost half of the body weight yielded as fillet without being affected by such strict restrictive feeding levels. The lipid gain of fish showed a drastic drop at the lowest feeding intensity, corresponding an almost a half decrease of the fish fed at the highest intensity. In fillet, obvious influence of restrictive feeding in this experiment was seen in lipid accretion of fillet which decreased by restrictive feeding. The decrease of lipid in fillet is not dramatic as it is in the drop of lipid concentration in weight gain. This such lipid loss from the fish body could be explained by the fat depots in the visceral cavity without the sacrifice of fillet yield and fillet quality.

By starvation prior to slaughter in Atlantic salmon (Einen *et al.,* 1998), fillet fat content was slightly lower after 58 days of starvation compared with normally fed fish on the other hand fillet protein content was higher in fed fish than in fish starved for 86 days. Fillet was used most, followed by viscera and liver. Long-term starvation seem to produce only marginal changes in body composition of big Atlantic salmon, but rather a shrinkage of the total body mass illustrated by weight loss and less fillet-yield. The reduced fillet-yield after long-term starvation could be explained by a lower proportion of muscle mass compared to bones, fins and head.

Buyers of salmonids ranked body shape and fatness as important quality criteria (Koteng, 1992), hence the reduced fat content would be preferred in market. However, the perception of fatness may be somewhat different than fat content of fillet or body homogenates. During the evaluation of fatness, the size of visible fat depots is probably more important than the total fat content.

Reduced fatness from the body without decreasing fillet yield could be best achieved by applying a broad range of restrictive feeding rather than starvation, may emerge as an emerging strategy in the long run.

Conclusion

High fat diets (dietary fat ≥ 300 g.kg^{-1} DM) with reasonably low dietary protein levels (from about 500 g.kg^{-1} DM to around 400 g.kg^{-1} DM) could be of economic advantage due to their favourable performance in nutrients as well as energy gain, DE and DCP utilization. This stands out even more especially with protein sources being among the most expensive feed ingredients in production. Adapting this way of feeding not only saves money but also gives the farmer the possibility of determining at what time he wants to get his stock into the market as such leaving him the flexibility that is demanded by the current wavy market situations. This method of feeding also gives the farmer the possibility to vary the nutrient composition of the fish in accordance to the demands of the market.

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