Turk J Vet Anim Sci
28 (2004) 851-856
© TÜBİTAK

Research Article

Effects of Spatially Localized and Dispersed Patterns of Feed Distribution on the Growth, Size Dispersion and Feed Conversion Ratio of the African Catfish (*Clarias gariepinus*)

Ferit RAD, Gülderen KURT, A. Sezai BOZAOĞLU
Department of Aquaculture, Faculty of Fisheries, University of Mersin, Mersin - TURKEY

Received: 05.02.2003

Abstract: The effects of spatially localized and spatially dispersed feeding patterns on the growth, size distribution and feed conversion ratio of the African catfish were investigated. Two groups of fish with an initial weight of 82.16 ± 4.80 and 82.40 ± 3.90 g were subjected to point source and scatter feeding patterns, respectively, for 2 months. Scatter fed fish reached a final mean weight of 192.69 ± 6.60 g while the mean final weight of point source fed fish was 169.67 ± 6.80 g ($P < 0.05$). The specific growth rates of scatter and point source fed fish were 1.51% day^{-1} and 1.29% day^{-1}, respectively. The feed conversion ratio of scatter fed fish was 1.86 and that of point source fed fish was 2.29. The difference between the coefficient of size variation for scatter and point source fed fish was statistically insignificant ($P > 0.05$). However, the final size distribution curve for the scatter fed group showed a more symmetrical pattern with the bulk of the fish clustering about the mean.

Key Words: African Catfish, feeding patterns, growth, size variation, feed conversion ratio

Lokalize ve Dağınık Yem Dağıtım Biçimlerinin Karabalığın (*Clarias gariepinus*) Büyüme, Ağırlık Dağılımı ve Yem Dönüşüm Oranı Üzerine Etkisi

Özet: Bu çalışmada lokalize ve dağınık yem dağıtım şeklinin karabalıklarının büyüme, ağırlık dağılımı ve yemden yararlanma oranı üzerindeki etkileri araştırılmıştır. Ortalama başlangıç ağırlıkları 82,16 ± 4,80 ve 82,40 ± 3,90 g olan iki grup balık iki aylık bir denemede sırasıyla nokta ve dağınık yemlemeye tabi tutulmuşlardır. Deneme sonunda dağınık yemlemeye tabi tutulan balıklar 192,69 ± 6,60 grama ulaşırken, nokta yemleme grubunda ortalama ağırlık 169,67 ± 6,80 g olarak bulunmuştur ($P < 0,05$). Spesifik büyüme oranı dağınık ve nokta yemleme gruplarında sırasıyla % 1.51 gün^{-1} ve % 1.29 gün^{-1} olarak hesaplanırken, yemden yararlanma oranı dağınık yemlenen grupta 1,86, nokta yemleme grubunda ise 2,29 olarak saptanmıştır. İki grubun ağırlık bakımından varyasyon katsayıları arasındaki fark istatistiksel olarak önemsiz bulunmuştur ($P > 0,05$). Ancak dağınık yemlemenin uygulandığı grupta ağırlık dağılım eğrisinin daha simetrik olduğu ve bireylerin büyük çoğunluğunun ortalama çevresinde kümeleştiği gözlenmiştir.

Anahtar Sözcükler: Karabalık, yemleme şekli, büyüme, ağırlık dağılımı, yemden yararlanma oranı

Introduction

Formation of dominance-based social hierarchies is a common phenomenon for many fish species, including the African catfish (*Clarias gariepinus*), and is thought to be a major reason for feeding growth variations among individuals. The spatial pattern of feed distribution can influence individual feeding success and growth homogeneity. Many animal species form social hierarchies where the relative social status of an individual can determine access to available resources (1). Teleost species utilized in aquaculture are often highly aggressive and form stable social hierarchies under captivity and rearing conditions (2,3). Intraspecific competition for a common resource in fishes ranges from exploitative competition, where individuals interact indirectly, to interference competition where one or few individuals actively prevent others from utilizing a resource (4). Individuals within social hierarchies possess different competitive abilities and the most aggressive ones are often more successful in exploiting a shared resource (5). Dominant aggressive behavior will result in disproportionate food acquisition, giving these individuals a growth advantage (1,3,5-10). Unwanted outcomes of farming fish that form social hierarchies are large variations in growth, and health and welfare problems like fin damage and stress (5). Jobling (11) suggested some tools for assessing the social environment by observing weight gain, size variation and feed conversion ratio. Accordingly, a high growth rate and little variation in body size indicate good rearing conditions with little or no depression of growth due to aggressive behavior. Suboptimal and disparate growth coupled to poor feed utilization reflect a poor social environment that may be the result of competition due to underfeeding or because of bad temporal or spatial distribution of feed.

Fish farmers aim to produce fish of a uniform size, and feeding regimes used in commercial fish farming have a considerable influence on the efficiency of production, growth homogeneity and size variation because of their effect on fish behavior, including competition for feed (12-14). The spatial patterns of food distribution can have profound effects on individual feeding success (1). If feed is delivered to a single location in the rearing unit, dominant fish are likely to defend and hold a position close to that area, giving them greater opportunities compared to lower ranked fish (5). Feed can be offered in a spatially dispersed fashion, for example uniformly distributed over the water surface, thereby making it indefensible and difficult for a dominant fish to monopolize. This results in greater feeding opportunity within the group and promotes uniformity of feeding and growth (1). It is clear that spatial pattern of feed delivery in rearing systems is an important managerial tool to overcome the negative impact of dominant hierarchies in fish farming. Considerable interest has been shown during the last decade in assessing how social conditions can be improved to promote uniformity of feeding and growth performance in commercial aquaculture (10).

The African catfish is an excellent species for aquaculture as it is omnivorous, grows fast, tolerates poor water quality and the methods for induced spawning are well established (12,15). This species is also a good candidate for species diversification of aquaculture in the Eastern Mediterranean region of Turkey. As for many other fish species the African catfish also exhibits sophisticated forms of social feeding behavior where dominant fish were observed to exclude the subordinates from obtaining food, thereby getting a relatively greater proportion of the food (16). To evaluate the possibility of overcoming dominance hierarchy related problems in African catfish on-growing, a growth experiment was conducted to investigate the effects of spatially localized “point source feeding” (i.e. defensible) and spatially dispersed “scatter feeding” (i.e. indefensible) patterns on the growth, size variation and feed conversion ratio of African catfish juveniles.

Materials and Methods

Fish

Wild African catfish juveniles were caught in Göksu delta, (Silifke/Mersin) and brought to the Aquaculture Research Unit of the University of Mersin, Faculty of Fisheries. Wild fish were allowed to acclimatize to captivity and artificial feed was given for 2 weeks prior to the experimental set-up.

Experimental Set-up

The experiment was carried out in 2 duplicates using 4 polyethylene tanks (200 x 50 x 50 cm). Each experimental tank was stocked with 25 African catfish juveniles. The mean initial weight of fish in each tank was arranged to be similar (82.12 ± 6.2 g, 82.20 ± 7.4 g, 82.76 ± 5.1 g, 82.04 ± 5.7 g, $P > 0.05$). Two tanks were randomly designated for spatially localized point source feeding and the other 2 for spatially dispersed scatter feeding. The mean initial fish weight in the point source feeding and scatter feeding groups were 82.16 ± 4.8 g and 82.40 ± 3.9 g, respectively ($P > 0.05$). The initial coefficient of weight variation and standard deviations were statistically similar for duplicates and treatments ($P > 0.05$).

The experiment was carried out indoors under ambient water temperatures (25.8 ± 0.09 ^{o}C). A static system was used where 50% of water was changed and renewed daily with dechlorinated tap water (17). The tanks were aerated and siphoned daily to remove uneaten feed and feces. Dissolved oxygen and pH were 4.08-6.44 mg/l and 7.40-7.80, respectively, throughout the experiment. The tanks were covered since the African catfish is photophobic and prefers low light intensity conditions (16). The covers were removed only for feed delivery.

Experimental procedures

The experiment was carried out over 2 months in 4 successive periods, each consisting of 2 weeks. The fish were fed extruded sinking pellets with a crude protein content of 47% and crude fat content of 12%. A feeding table recommended for the African catfish by De Graaf and Janssen (18) was used to determine the daily feeding rates, based on live body weight and water temperature. Daily feeding rates ranged from 3.6% (50-100 g fish) to 2.5% of live body weight (100-300 g fish). Ration size was calculated on a biomass basis for each tank in each period and was corrected at the beginning of each successive period according to final body weight measurements from the previous period (17).

The daily ration was offered in a single meal at 09:00 for both groups, since feeding activity is higher in the first half of the day for the African catfish (19). In the point source feeding groups, the daily ration was offered in the same corner of the tank throughout the experiment. This defensible feeding regime allowed the possibility for the corner and thus the food resource to be monopolized by the dominant individual(s) in the tanks (1). In the scatter feeding groups, the feed was distributed randomly across the surface of the water, several pellets at a time, rendering the food resource indefensible (1).

All fish were individually weighed every 2 weeks to monitor growth and feed utilization and to correct the daily ration size for each successive period (20). Growth was computed in terms of weight gain (RWG) and specific growth rate (SGR) as follows (20):

Relative weight gain (%) = (final weight – initial weight / initial weight) x 100

Specific growth rate (% day^{-1})= [(In final weight – In initial weight) / no. of days] x 100.

Feed utilization was calculated in terms of feed conversion ratio (FCR) as follows (15):

$$FCR = WtA / (Bf - Bi)$$

where Bf and Bi are the final and initial biomass of the tank, respectively, and WtA is feed provided. Since all fish were weighed individually initial and final biomass was calculated based on mean body weight and the number of fish in each tank.

Statistical analysis

An independent t-test was used for comparing mean body weights (± SE) for the 2 feeding regimes. The effect of point source and scatter feeding on size variation was investigated by comparing the coefficient of size variation (live weight) and standard deviations of mean body weight in each treatment (9,14,21). The coefficient of size variation was computed as follows (21):

CV = (Standard deviation) x 100 / Mean body weight

Initial and final size distribution of fish in each treatment was further studied using histograms (22). Standard deviations were compared using Levene's test. Size distribution curves were tested by 1-sample Kolmogorov-Smirnov test for normality (14). For all statistical tests, differences present at the 5% level were considered significant. All statistical analyses were carried out by SPSS version 10.

Results

Descriptive statistical data on the mean final weight of fish for each treatment are given in Table 1. The mean final weight of fish in the scatter fed group was higher than that of the point source fed group and was statistically significant ($P < 0.05$). The mean final weights of fish in the scatter and point source feeding tanks were 192.69 ± 6.6 g and 169.67 ± 6.8 g, respectively. Two mortalities were recorded during the third period of the experiment, each from 1 treatment. The final number of fish in each treatment was therefore 49.

Table 1. Descriptive statistical data on mean final weight of fish for each treatment and period.

Treatment	Fish number	Body weight Mean±se (g)	Standard deviation	Coefficient of variance (%)
Point source feeding				
Initial	50	82.16 ± 4.80	34.60	42.10
Final	49	$^{\Upsilon}$169.67 ± 6.80	48.34	28.50
Scatter feeding				
Initial	50	82.40 ± 3.90	27.67	33.50
Final	49	$^{\varphi}$192.69 ± 6.60	47.08	24.40

A significant difference between final mean body weights is shown by different symbols ($P < 0.05$)

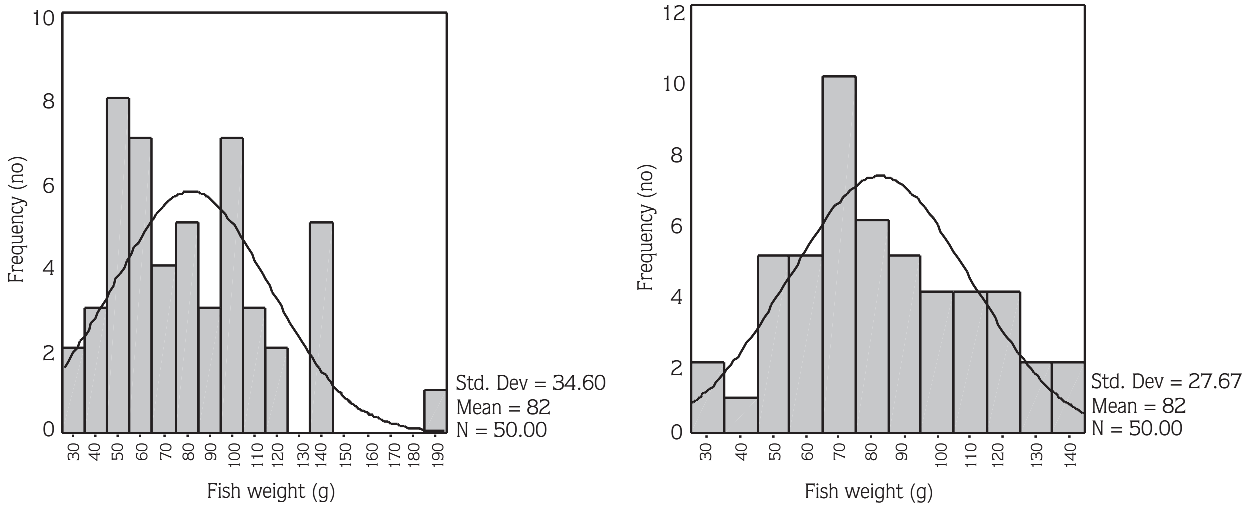
The differences between the final coefficient of size variation and the standard deviation of mean body weights for the 2 treatments were statistically insignificant ($P > 0.05$). The results of the 1-sample Kolmogorov-Smirnov test indicated that the size frequency curves for both treatments showed normal distributions. However, the final size distribution in the scatter fed group showed a more symmetrical pattern, indicating that a greater number of fish are clustered about the center and a more homogeneous size distribution was achieved in the scatter fed group at the end of the experiment. The final size distribution curve of point source fed fish was skewed to the right, indicating a less symmetrical distribution (Figure).

Specific growth rates (SGRs) and relative weight gains (RWGs) computed for each treatment are shown in Table 2. Based on initial and final mean weights, fish in the scatter fed tanks showed a higher SGR. SGRs in the scatter and point source feeding tanks were 1.51% day^{-1} and 1.29% day^{-1}, respectively. Naturally, relative weight gain showed a similar pattern, where fish in the scatter feeding tanks gained more weight (133.84%) than those

Point source fed fish

Scatter fed fish

a. Initial



b. Final

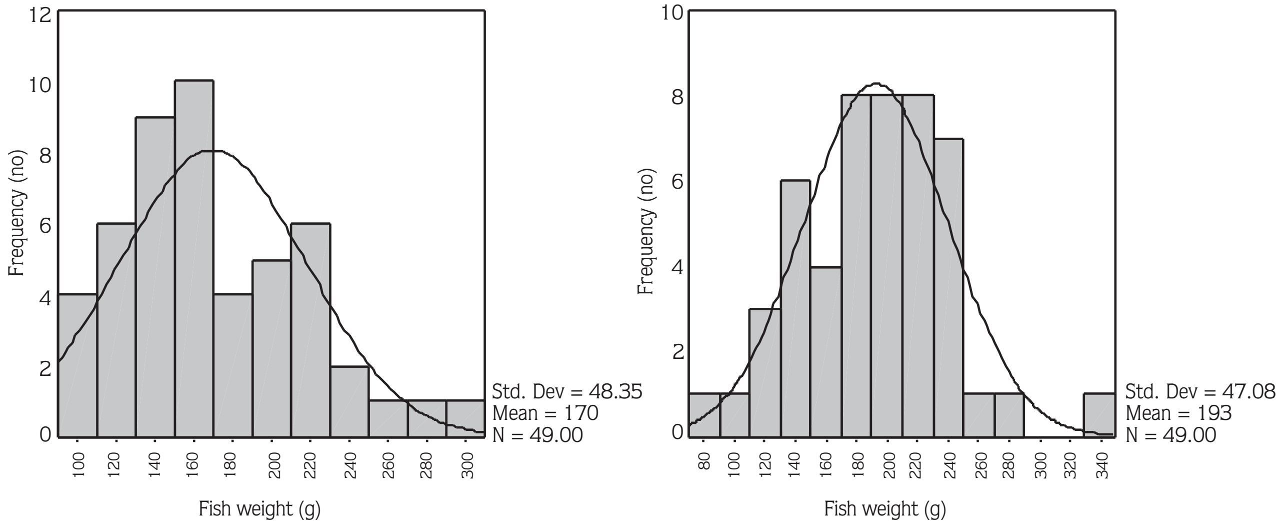


Figure. Size distribution of fish in point source and scatter feeding tanks.

in the point source feeding tanks (106.51%). The scatter pattern of feed distribution also led to a better feed conversion ratio. The feed conversion ratio for the scatter fed group was 1.86, whereas it was 2.29 for the point source fed fish.

Discussion

Different feed consumption or feeding success between individuals appears to be a common phenomenon in fish either in the wild or in captivity (1,23-26). The ranges of meal size taken by a fish within a group (inter-individual variation) and the consistency of feeding over time appear to be influenced by a number of factors, such as the mix of individuals within the group, the pattern of food distribution, group size and ration level. The spatial localization of food delivery allows the more aggressively dominant fish to intimidate their conspecifics, defend the position close to the point of food input and therefore monopolize the food resource, resulting in a stable feeding hierarchy. In contrast, the spatial dispersion of food reduces its defensibility by dominant individual(s) in the group and promotes uniformity of feeding opportunity (1). Uniform feeding opportunity within the group leads to higher growth rates and little variation in body size within the group (4,11,24).

Fish subjected to a scatter feeding regime reached a higher mean final weight and showed a higher growth rate (SGR) than those in the point source feeding group (Tables 1 and 2). The mean final weights of the 2 groups were significantly different ($P < 0.05$, Table 1). The lower mean final weight and reduced growth rate in point source fed fish seem to be associated with disproportionate feed acquisition due to the spatial pattern of feed distribution in this group. The spatially localized pattern of feed distribution in point source feeding tanks probably allowed dominant fish to defend and monopolize the feeding area. This resulted in a disproportional distribution of feed and heterogeneous growth performance within the group (Figure). In contrast, in scatter fed tanks the spatially dispersed and uniform pattern of feed distribution over the water's surface made it indefensible and difficult for dominant fish to monopolize. This pattern of feed distribution likely promoted uniformity of feeding opportunity and success, resulting in higher growth and a more homogeneous size distribution within the group (Tables 1 and 2, Figure). Even though size distribution frequencies in both treatments (Figure) showed a normal distribution curve, the final size distribution of fish in the scatter fed group clearly indicated a more symmetrical distribution around the mean and a uniform size distribution. In contrast, the final size distribution of fish in the point source fed group is a skewed curve where the bulk of the fish are clustered to the left of the population mean, indicating a less homogeneous size distribution. A uniform size distribution and small size variation are particularly desirable in aquaculture (12,21,24). On the other hand a reduced or skewed growth rate is considered an important sign of behavioral problems associated with social hierarchies in farming conditions (11). The establishment of a dominance hierarchy in a group of fish is thought to be a major reason for the development of size heterogeneity, with greater variation indicating stronger hierarchy formation (25). The skewed final size distribution in the point source fed group in this experiment is therefore an indicator of the establishment of feeding hierarchies.

It is known that when aggression or stress levels are high, fish usually show higher maintenance energy requirements, which in turn leads to a decrease in feed conversion efficiency and growth (16,26). Furthermore, Jobling (11) attributed sub-optimal and disparate growth coupled with poor food utilization to poor social environment due to bad temporal or spatial distribution of feed. The reduced growth and poor FCR for fish in the point source feeding group (Tables 1 and 2) could be associated with high levels of stress within individual fish due to the establishment of feeding hierarchies and therefore sub-optimal social conditions.

Our findings indicate that as far as growth rate and feed conversion ratio are concerned a spatially dispersed (i.e. indefensible) feeding pattern is more appropriate for feeding the African catfish than spatially localized (i.e. defensible) point source feeding.

Table 2. Specific growth rate, relative weight gain and feed conversion ratio of fish in the 2 different feeding regimes.

Treatment	SGR (% day^{-1})	RWG (%)	FCR
Point source feeding	1.29	106.51	2.29
Scatter feeding	1.51	133.84	1.86

References

1. McCarty, D., Gair, D.J., Houlıman, D.F.: Feeding rank and dominance in *Tilapia rendalli* under defensible and indefensible patterns of food distribution. J. Fish Biol., 1999; 55: 854-867.
2. Höglund, E., Qverli, O., Balm, P.H.M., Winberg, S.: Neuroendocrine correlates of social stressin fish. Second Cost Workshop on the feeding behavior of fish in culture. Sweden 1996.
3. Sloman, K.A., Armstrong, J.D.: Review paper physiological effects of dominance hierarchies laboratory artefacts or natural phenomena. J. Fish Biol., 2002; 61: 1-23.
4. Staffan, F., Magnhagen, C., Alanara, A.: Variation in food intake within groups of juvenile perch. J. Fish Biol., 2002; 60: 771-774.
5. Brannas, E., Alanara, A., Magnhagen, C.: The social behaviour of fish. In: Keeling, L., Gonyo, H., Eds. Social Behaviour in Farm Animals. CAB International, 2001; 273-302.
6. Bailey, J., Alanara, A., Brannas, E.: Methods for assessing social status in arctic charr. J. Fish Biol., 2000; 57: 258-261.
7. Brannas, E., Linner, J., Ericsson, L.O.: Aggression and growth as an effect of size composition in groups of arctic charr. J. Fish Biol., 2002; 60: 1331-1334.
8. Sloman, K.A., Taylor, A.C., Metcalfe, N.B., Gilmour, K.M.: Effects of an environmental perturbation on the social behaviour and physiological function of Brown trout. Anim. Behav., 2001; 61: 325-333.
9. Winberg, S., Carter, C.G., McCarthy, I.D., He, Z.Y., Nilsson, G.E., Houlihan, D.F.: Feeding rank and brain serotonergic activity in Rainbow trout *Oncorhynchus mykiss*. J. Exp. Biol., 1993; 179: 197-211.
10. Moutou, K.A., McCarty, I.D., Houlihan, D.F.: The effect of ration level and social on the development of fin damage in juvenile Rainbow trout. J. Fish Biol., 1998; 52: 756-770.
11. Jobling, M.: Physiological and social constraints on growth of fish with special reference to Arctic charr, *Salvelinus alpinus*. Aquaculture, 1985; 44: 83-90.
12. Ewa-Oboho, I.O., Enyenihi, U.K.: Aquaculture implications of growth variation in the African catfish: *Hetorobranchus longifilis* (Val.) reared under controlled conditions. J. Appl. Ichthyol. 1999; 15: 111-115.
13. Talbot, C., Corneillie, S., Korsoen, O.: Pattern of feed intake in four species of fish under commercial farming conditions: implications for feeding management. Aquac. Res., 1999; 30: 509-518.
14. Kristiansen, H.R.: Discrete and multiple meal approaches applied in a radiographic study of feeding hierarchy formation in juvenile salmonids. Aquac. Res., 1999; 30: 519-527.
15. Appelbaum, S., Mcgeer, J.C.: Effect of diet and light regime on growth and survival of African catfish (*Clarias gariepinus*) larvae and early juveniles. Aquac. Nutr., 1998; 4: 157-164.
16. Hecht, T., Uys, W.: Effects of density on feeding and aggressive behaviour in juvenile African catfish, *Clarias gariepinus*. South African J. Sci., 1997; 93: 537-541.
17. Lim, P.K., Boey, P.L., Ng, W.K.: Dietary palm oil affects growth performance, protein retention and tissue vitamin E concentration of African catfish, *Clarias gariepinus*. Aquaculture., 2001; 202: 101-112.
18. De Graaf, G., Janssen, J.: Artificial Reproduction and Pond Rearing of the African Catfish *Clarias gariepinus* (Burchell 1822) in Sub Saharan Africa. FAO Fisheries Technical Paper no 362. 1996.
19. Hossain, M.A.R., Batty, R.S., Haylor, G.S., Beveridge, M.C.M.: Diel rhythms of feeding activity in African catfish, *Clarias gariepinus* (Burchell 1822). Aquac. Res., 1999; 30: 901-905.
20. Fagbenro, O.A., Davies, S.J.: Use of soybean flour (dehulled, solvent-extracted soybean) as a fish meal substitute in practical diets for African catfish, *Clarias gariepinus* (Burchell 1822): growth, feed utilization and digestibility. J. Appl. Ichthyol., 2001; 17: 64-69.
21. Pirhonen, J., Forsman, L.: Effect of prolonged feed restriction on size variation, feed consumption, body composition, growth and smolting of brown trout, *Salmo trutta*. Aquaculture., 1998; 162: 203-217.
22. McClave, J.T., Dietrich II, F.H.: Statistics (Sixth edition). Macmillian College Publishing Company. 1994.
23. Brannas, E.: Individual variation in distribution, activity and growth rate of Arctic charr kept in a three- tank system. J. Fish Biol., 1998; 53: 795-807.
24. Gelineau, A., Corraze, G., Boujard, T.: Effects of restricted ration, time-restricted access and reward level on voluntary food intake, growth and growth heterogeneity of Rainbow trout (*Oncorhynchus mykiss*) fed on demand with self-feeders. Aquaculture., 1998; 167: 247-258.
25. Petursdottir, T.E.: Influence of feeding frequency on growth and size dispersion in Arctic charr *Salvenilus alpinus*. Aquac. Res., 2002; 33: 543-546.
26. Olsen, R.E., Ringo, E.: Dominance hierarchy formation in Arctic charr *Salvenilus alpinus* (L): nutrient digestibility of subordinate and dominant fish. Aquac. Res., 1999; 30: 667-671.