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Effects of Starvation and Subsequent Refeeding on Growth and Biochemical Compositions of Gansu Golden Trout

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Abstract: The effects of starvation for different time (7, 14, 21 and 28 days, respectively) and refeeding on growth and body biochemical composition of Gansu golden trout were investigated. The trial was conducted for 56 days. The results showed that the compensatory growth occurred in refeeding fish after starvation, the body weight of starving 14 days was significantly higher than that of the control ($p<0.05$), the other groups had no significant differences ($p>0.05$). After being deprived of food, the content of lipid decreased and moisture increased significantly with the increasing of starvation period ($p<0.05$), returned to the level in the control group after refeeding except for the content of lipid. The specific growth rate, feeding rate and conversion efficiency in Gansu golden trout during recovery growth higher than that of the control ($p<0.05$), returned to the level in the control group as the starvation proceeded ($p>0.05$). It is suggested that over-compensatory growth occurred in group of starving 14 days in the course of recovery growth but the complete compensatory growth occurred in group of starving 7, 21 and 28 days It was due to the higher feeding rate and efficiency of food conversion after refeeding.

Key words: Gansu golden trout, starvation, refeeding, biochemical compositions, compensatory growth

INTRODUCTION

Fishes often suffer from hunger or undernourishment stress due to changes in seasons, environment, uneven distribution of food and other reasons and their survival, growth, development and reproduction of all will be affected by hunger. Fishes will make some adaptive regulations to hunger in its morphological, behavioral, physiological and ecological aspects (Weatherley and Gill, 1981). The tolerance and adaptability characteristics of fish to starvation are quite different with different in species, sex, lifestyle, environment and hunger extent and as an adaptive physiological ecology most fishes often show a growth rate of more than normal individuals when resume normal feeding following the hunger or undernourishment this is called compensatory growth phenomenon (Dobson and Holmes, 1984). Compensatory growth is a new field of research in fish nutrition physiology, researches in this area will help to understand the characteristics, rules and physiological mechanisms in the process of compensation growth following the hunger and provide a theoretical basis for fish growth studies.

Gansu golden trout (*Oncorhynchus mykis*) belongs to Clupeiformes Orders, Salmonids families, Trout genera, it is a new bred that was cultured from cold-water fish rainbow trout (*Oncorhynchus mykiss*) mutant (Zhang and Su, 2010) and is listed as the superior varieties suitable for breeding areas with cold water resources by Ministry of Agriculture of China in 2007. Gansu golden trout becomes the new darling of the cold-water fish with its individual large, fast growth, good color, nutrient-rich, high quality and highly social favored. The purpose of this study is to investigate the existence of compensatory growth phenomenon of Gansu golden trout to identify its condition, type, characteristics and mechanism and to reveal the law of physiology and ecology adaptation to starvation, providing a theoretical basis for the hunger physiological and scientific economic farming of it.

MATERIALS AND METHODS

About 75 juvenile Gansu golden trouts around 100 g were chosen to be experimental material from the breeding center of rainbow trout of yongdeng county, Gansu Province. The experiment was carried out in

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concrete ponds (6×6×1.6 m), the fish raised in cloth floating cages (80×60×60 cm) with 80 meshes in water, covered 20 polyethylene mesh to prevent the experimental fish escaping. The water for test was underground well water by aeration and the water temperature is of 10-12°C, pH value of 8.5, degree of hardness of 11, DO of 7.00-14.00%. The formal experiment was carried out after 2 weeks domestication. Experimental fishes were fed to the full price compound feed of Ningbo Tech Co.

Design of experiments: The experimental fishes were divided into five groups randomly each group of 15, respectively into the experimental pool for the control group N_0 (daily ration), hunger treated group N_7 (refeeding to experiment ends after 7 days hunger), treated N_{14} (refeeding to experiment ends after 14 days hunger), treated N_{21} (refeeding to experiment ends after 21 days hunger), treated N_{28} (refeeding to experiment ends after 28 days hunger). Each group was refed after certain starvation and experiments were conducted 56 days altogether. The fishes were Fed until satiation at 8:00 am and 18:00 pm every day twice, collecting the bait, drying and weighing, recording daily food intake data after 20 min.

Determination of the growth index: Each group of experimental fish weight was measured using an electronic balance (0.01 g) at the start of the experiment, the end of the hunger and the end of experiments, respectively obtained food intake by the difference between the amount of baits and the remnant, calculated Weight Gain Rate (WGR), Specific Growth Rate (SGR), Feeding Rate (FR) and Feed Conversion Ratio (FCR).

The rate of Weight Loss (BWL), Relative Growth Rate (WGR), Specific Growth Rate (SGR), Feeding Rate (FR) and Food Conversion Efficiency (FCR) calculated using the following equation:

$$\text{BWL (\%)} = 100 \times \frac{W_0 - W_1}{W_0}$$

$$\text{WGR (\%)} = 100 \times \frac{W_2 - W_1}{W_1}$$

$$\text{SGR (\%/day)} = 100 \times \frac{\text{Ln}W_2 - \text{Ln}W_1}{t}$$

$$\text{FR (\%/day)} = 100 \times \frac{C}{\frac{t \times (W_1 + W_2)}{2}}$$

$$\text{FCR (\%)} = 100 \times \frac{W_2 - W_1}{C}$$

Where:

W_0 = The body weight (g) of the begin of the trial
W_1 = The body weight (g) of the end of starvation
W_2 = The body weight (g) of the end of the trial
C = The total feeding amount (g)
t = The experimental time (days)

Measuring of biochemical parameters: Before the start of the experiment, the end of starvation and the end of the experiment, 3 Gansu golden trouts were randomly selected for anatomy in ice bath from each group for analysis of biochemical composition, the biochemical characteristics of each sample was repeated three times.

The moisture content was measured using a direct drying method, the acquired fish sample is dried to constant weight at 70°C to obtain moisture content and then ground into fine powder stored at -20°C for measuring body composition.

The crude protein content was determined by the improved Kjeldahl Method (GB/T5009, 5-2003) with sample size for 0.5-1.0 g measuring the total nitrogen content of the sample then obtained the content of crude protein from multiply the result by 6.25 (6.25×nitrogen amount).

The content of crude fat was measured using chloroform-methanol extraction, chloroform:methanol:H_2O (2:2:1) the determination of a sample amount of 1.0-2.0 g/parts.

The content of crude ash was measured by Gravimetric Method, igniting samples to constant weight using a muffle furnace at a high temperature of 550°C (is generally burn 12 for 24 h), the sample at the amount of 2.0-3.0 g (dry weight) and each sample measured three times and the average value as a measurement result.

Data processing: For the set of lines, nested Analyses of Variance (ANOVAs) were used to compare variation among strains, populations and the geographic regions. Variance components were computed by maximum likelihood using the VARCOMP procedure in SPSS for Windows (Ver. 10).

RESULTS

Changes of weight after starvation and refeeding: Seen from Table 1, the rate of weight loss of the starvation treatment group was gradually increased with the starvation time extended; N_{28} with the maximum of 9.14%. At the end of experiment, the weight of N_{14} group was significantly higher than that in the control group ($p<0.05$) and the other treatment groups had no significant difference from the control group ($p>0.05$).

Changes of WGR, FR, SGR and FCR after refeeding: Table 2 shows feeding rate of each group increased with increasing starvation to be the highest in N_{28}, reaching 16.57%, relative growth rate, specific growth rate and food conversion rate and food conversion efficiency to be the highest in N_{14}, reaching 57.50, 1.08 and 7.89%, respectively had a significant difference with the control group, ($p<0.05$) the specific growth rate of the starved group was significantly higher than that in the control group ($p<0.05$) and with extension of hunger time it was gradually elevated; starved group food conversion rates were significantly higher than that of control ($p<0.05$) but the starved groups showed no significant difference ($p>0.05$).

Changes on biochemical composition after refeeding: As can be seen from Fig. 1, Gansu golden trout muscle moisture content was gradually increased with the prolonged starvation, from 75.85% in N_0 rose to 77.64% in N_{28}; protein content did not change significantly ($p>0.05$) (Fig. 2); fat content was significantly decreased ($p<0.05$) which was 2.74% in N_0 and has been reduced to 1.48% in N_{28} (Fig. 3) ash content slightly elevated from 1.042-1.052% (Fig. 4). Refeeding to the end of the trial, moisture, ash, fat and protein content are basically returned to the control level.

Table 1: Weights and BWL on Gansu golden trout during starvation and after recovery growth

Groups	W_0 (g)	W_1 (g)	W_2 (g)	BWL (%)
N_0	96.98	96.98	132.15	0
N_7	97.35	94.90	135.76	2.51
N_{14}	96.75	91.67	144.38	5.25
N_{21}	97.82	89.54	127.07	8.46
N_{28}	98.09	89.12	119.28	9.14

Table 2: WGR, FR, SGR and FCR on Gansu golden trout during recovery growth

Groups	WGR (%)	FR (%)	SGR (%)	FCR (%)
N_0	36.27	11.27	0.55	4.86
N_7	43.06	12.95	0.73	5.58
N_{14}	57.50	13.48	1.08	7.89
N_{21}	41.91	15.50	1.00	6.38
N_{28}	33.84	16.57	1.04	6.24

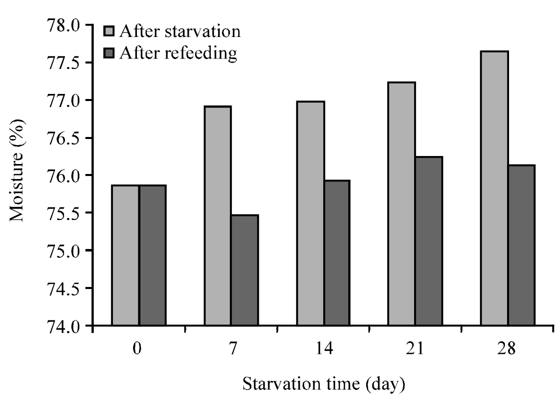

Fig. 1: Changes of moisture in Gansu golden trout after starvation and recovery growth

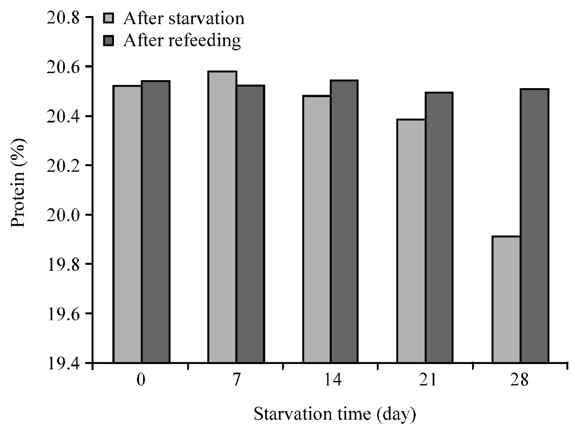

Fig. 2: The change of protein in Gansu golden trout after starvation and recovery growth

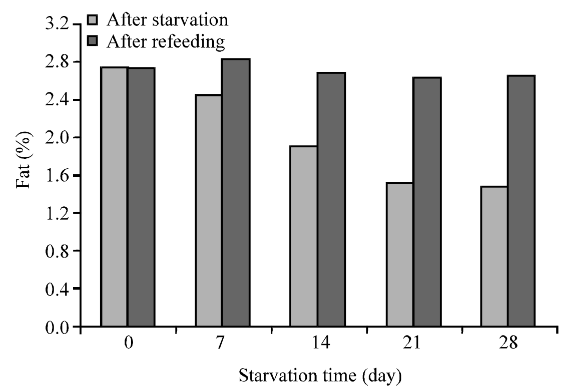

Fig. 3: The change of lipid in Gansu golden trout after starvation and recovery growth

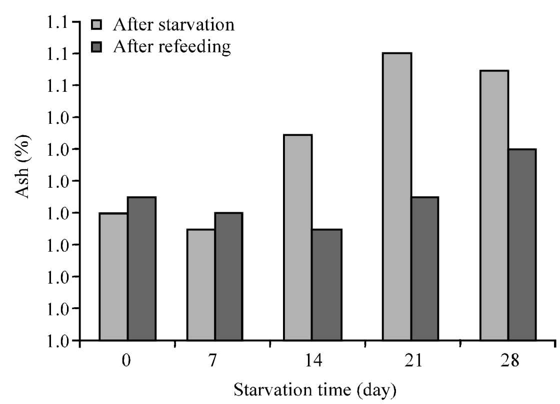

Fig. 4: The change of ash in Gansu golden trout after starvation and recovery growth

DISCUSSION

Phenomenon of compensation growth: Fish in the conditions of hunger or food restriction will show a downward trend in the weight of it, the decline depends on the length of time of hunger and food restriction. The growth rate of the fish in a certain period of time is much higher than that of individual sustained satiation after refeeding but this growth is not always maintained at all growth cycle to reach a certain level and gradually decreased and finally return to normal growth levels (Wu and Dong, 2001). In this experiment, the weight of N_{14} was significantly higher than that of the control group, the other treatment groups and the control group had no significant difference. With the extension of refeeding time, the growth rate for each treatment group was significantly higher than that of the control group which fully shows that the compensatory growth phenomenon is exist in Gansu golden trout. Rather than, hunger N_{14} exhibited an ultra compensation growth, N_7, N_{21} and N_{28} exhibited a full compensatory growth. During the recovery growth of fish, SGR amplitude is also some difference, the faster the SGR rising, the higher the level of the longer the duration, the better the effect of fish compensatory growth the greater the amount of compensation (Hayward *et al*., 1997). This study found that the SGR of N_{14} was significantly higher than that of the control group during recovery growth. The growth rate of individual animals after starvation or food restriction is higher than that of the sustained satiation but the growth rate of this increase has not always been maintained at a high level be gradually decreased and returned to normal levels after a period of time (Chatakondi and Yant, 2001). Miglaves and Jobling found that Arctic charr (*Saliveli nusal pinus*) increased rapidly over sustained satiation individual after 8 weeks of diet restriction treatment to the highest after 10 weeks (5 times as the end of food restriction >60% than sustained satiation individual), began to decline after 12 weeks although, still higher than the normal level at 16 weeks but the growth rate dropped to normal levels is a whole trend just a matter of time (Miglavs and Jobling, 1989a). Kim and Lovell (1995) made a similar report in channel catfish.

Ways of energy utilization: Hunger or under nutrition, fish first consumes its own stored energy to sustain life. The adaption to hunger is different in different kinds of fish due to differences in food habits, lifestyle, feeding, food quality and body structure (Cheng and Fang, 2007). The situation is not the same to utilization of the physical storage of energy. To most fish, the actual content of water decreased with decomposition of the basic nutrients after starvation but increased in the content of percentage (Miglavs and Jobling, 1989b), as an material of energy storage, saccharide first be decomposed in a short time then using fat and less use of protein and generally after consuming a lot of fat (Lou and Shi, 2008). Grass carp (*Ctenopharyngodon idellus*) can make better use of sugar as an energy material (Shen *et al*., 1999) under hunger; the American redfish (*Sciaenops ocellatus*) (Jiang *et al*., 2002) and tiger sharks (*Panaceas polyuranodon*) (Zheng and Wang, 2003) first use fat and protein as metabolic energy few types of fish during hunger mainly make consumption of protein Mehner and Wieser reported the hungry perch (*Perca fluviatilus linnaeus*) juveniles mainly use protein (Mehner and Wieser, 1994).

The results of this study showed that change in protein content was not obvious but the content of fat decreased, suggesting that the fat to be used as a main energy supplement during starvation of Gansu golden trout. Biochemical analysis also showed that biochemical components could be recovered in the short term to the same level as the control group did not show a component increases too many or too few after compensatory growth in Gansu golden trout. That is hunger then refeeding does not affect the nutritional quality of fish which is coincident with Zhang-Bo findings (Zhang *et al*., 2000).

Mechanisms of compensatory growth: Currently, many researchers made a lot of researches on mechanism of compensatory growth and still remained controversial about the action of compensatory growth in animal. Studies have shown that the factors of eco-physiology led to compensatory growth is more complex including the developmental stages of the shortage of food in response to intra-specific and inter-specific differences and abiotic environmental impact (Quinton and Blake, 1990). Here is mainly the following three viewpoints. The first view: the fish after hunger reduced basal metabolic rate when resumed eating, low metabolic level can be maintained for some time, this reduction of metabolic expenditure increases the proportion of energy in growth and improves the efficiency of food conversion then the compensation growth happens. The compensatory growth of United States redfish is mainly achieved by lowering the standard metabolic rate and improving food conversion rate (Jiang *et al*., 2002). The second point of view: animals will immediately make a large number of syntheses and metabolite levels will rise rapidly after starvation, compensating for the growth of produce, animals resume growth by increased appetite and achieved substantial increase in feeding level. Reimers found that Atlantic salmon significantly improved food conversion rate in restoring growth after two months of starvation (Reimers *et al*., 1993). Deng *et al*. (1999) reported that Southern catfish recovered compensatory growth by significant increasing ingestion level after 50 days of starvation; seawater tilapia compensatory growth is mainly achieved by increasing the feeding level also (Wang, 2001). The third view: the fish not only increases the appetite and feeding level and at the same time improves the food conversion efficiency in recovery feeding stage, therefore, compensatory growth is the result of the interaction of these two physiological factors (Bilton and Robins, 1973). This test showed that the feeding rate and food conversion rate were higher in 14, 21 and 28 days groups of Gansu golden trout than the control group, researchers considered that with the extension of starvation time, Gansu golden trout increased appetite and food intake one hand on the other hand reduced the level of basal metabolism after refeeding which is in line with the third view.

Compensatory growth is a new field of research in fish nutrition physiology, researches in this area will help to understand the characteristics, rules and physiological mechanisms of compensation process of fish following starvation and provide a theoretical basis for fish growth studies. Researchers can improve the efficiency of feed utilization, reduce farming costs and environment pollution caused by the animal waste by rationally utilizing the effect of compensation growth in Gansu golden trout while has important practical significance in improving growth performance.

CONCLUSION

However, the research on compensatory growth of aquatic animal is still in experimental stage and the vast majorities were carried out in a controlled temperature indoor conditions need to continue to improve on the theories and methods and to be verified in practice. In particular, must figure out the influence on disease-resistant immunity of aquatic animal under hunger or inadequate nutrition. Therefore, the production practice to improve economic efficiency by compensatory growth in farmed animals requires a process of exploration.

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