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Compensatory growth of (*Sarotheroden galilaeus*) fingerlings after feed deprivation in association with *(Myriophyllum spicatum)* as a source of natural Food

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Abstract

This study was designed to investigate the effect of repeated unfed–fed cycles on the growth and feed utilization of the *Sarotheroden galilaeus* fingerlings. The trial was conducted in the cement ponds of the Barrage Fish Farm (30 Km-north of Cairo), which belongs to National Institute of Oceanography and Fisheries, Cairo, Egypt. The compensatory growth of *Sarotheroden galilaeus* fingerlings with an average initial body weight 4.61 ± 0.20 g. and body length 7.3 ± 0.15 cm, submitted to food deprivation followed by refeeding was evaluated for 12 weeks. A concrete pond (40 m^3) was divided into four equal compartments (10 m^3 each and stocked with 100 fingerlings). Continuous feeding for satiation twice a day was done throughout the experiment (Control group, D0), the other three groups were deprived of feed for 1, 2 and 3 days per week (D1), (D2), and (D3), respectively for 6 weeks followed by refeeding to satiation for 6 weeks as the control group during the full feeding period, in association with *Myriophyllum spicatum* as a source of natural food, for all treatment groups. The growth performance and physiological parameters indicated that there were no significant differences at food deprivation levels (D1) and (D2), as compared to the control group. Analysis of variance showed significant decreasing in growth measurements, at higher feed restriction regime (3 days, D3) as compared of the control. The present experiment showed that the feeding with moderate feed restriction deprivation regime (D2) in association with *Myriophyllum spicatum* as a source of natural food is recommended for good growth performance, optimal maturation and more economical for rearing of the freshwater cultured fingerlings of *Sarotheroden galilaeus*,.

Keywords: Tilapia, compensatory growth, *Myriophyllum spicatum*

1. Introduction

Sarotheroden galilaeus show a tendency to mature early, an undesirable trait for farmers as such fish disrupt the harvesting programmes and have a reduced value owing to their small size. There is evidence in several species of salmonids of a correlation between growth rate during the juvenile stage and eventual age of maturation, fast growth resulting in early maturation. (McCormick and Naiman 1984 and Heath *et al.,* 1991) showed that 1-1- male deprived *Oncorhynchus tshawytscha* (Walbaum) exhibited a bimodal size distribution in the spring.

Compensatory growth has been defined as a physiological process whereby an organism accelerates its growth after a period of restriction, to attain the weight of cohorts whose growth was never hampered (Hornick *et al*., 2000).Improved Interest in compensatory growth has increased because of its potential use in aquaculture; specifically to enhance feed efficiency. The contributions of an extending period of re-feeding to the recovery and activation of growth rate in *Sarotheroden galilaeus* are needed to investigate. Wasted nutrients from feed are direct losses, in terms of costs, and can later impact water quality, causing mortalities. Practical methods to decrease wasted feed or increase FE without adverse effects on growth would be useful to improve the economics and waste management of tilapia production.

Many studies have demonstrated that short-term food deprivation (Tian and Qin, 2003) or multiple periods of food deprivation and re-feeding increase feed efficiency and growth in various fish species (Hayward *et al*., 1997 and Zhu *et al*., 2004). Changes in digestive enzyme activities in response to periods of starvation reveal the most critical nutrient and energy reserves, and those metabolized or conserved in the face of increasing food deprivation (Johnston *et al*., 2004).

Compensatory growth may decrease production time while increased feed efficiency could reduce costs by enhancing nutrient utilization and assisting in water quality management, particularly in pond production. The fishes have different response for compensatory growth either complete or partial (Jobling *et al.,* 1994). Complete compensatory has been observed in relatively few studies (Quinton and Blake, 1990; Hayward *et al*., 1997; Xie *et al*., 2001 and Tian and Qin, 2003), however, partial compensatory was observed in Mozambique tilapia *Oreochromis mossambicus* reared in freshwater (Christensesn and Mclean, 1998), hybrid tilapia *O.mossambicus* X *O. nilotocus* reader in sea water (Wang *et al*., 2004), and hybrid tilapia (*Oreochromis mossambicus* X *O. niloticus*) reared in freshwater (Wang *et al.,* 2005), Gilthead sea bream (Eroldogan *et al.,* 2008), demonstrated compensatory growth attributed to improvement in feed intake but not for feed efficiency.

Seasonal variations of food supply in the aquatic environment cause many species of fish to endure periods of starvation (Van Dijk *et al*., 2005). Once food becomes available, some species exhibit compensatory growth, or periods of accelerated weight gain exceeding that of fish not exposed to food shortages (Hornick *et al.,* 2000). In some studies, increased growth rates have been reported to result in complete compensation; while in others the response only results in partial compensation (Ali *et al.,* 2003).

Compensatory growth is usually accompanied by hyberphagia (an increase in appetite). This phenomenon has been found in various fish species, such as cicheidis (Wang *et al*., 2000), cyprinids (Xie *et al.,* 2001). Gadoids (Jobling *et al.,* 1994), inctalurids (Gaylord and Gatlin, 2001), latids (Hayward and Wang, 2001) and pleuronectids (Paul *et al.,* 1995).

Compensatory growth in fish is regulated by many environmental factors such as water temperature, water quality (Quinton and Blake, 1990), social aggression (Hayward *et al*., 2000) and dietary protein and energy contents (Gaylord and Gatlin, 2001) during re-alimentation period, also the abundant or lack of the natural food in ponds (Turano, 2006). The feed restriction in association with *Myriophyllum spicatum* as a source of natural food may help the fish at the highest starved rates. Roots and rhizomes, of most aquatic plants help to reduce erosion and facilitate colonization by benthic algae and invertebrates; their foliage offers shelter, support and, at least during daylight, locally enriched oxygen supply (Nakai *et al*., 2000). Macrophytes also provide a direct or indirect source of food for an immense variety of aquatic invertebrates and fishes, and for birds and mammals that frequent aquatic habitats (Godmaire and Nalewajko, 1989). Submersed aquatic macrophytes serve as important primary producers, using CO_2 and inorganic nutrients as raw materials for carbohydrate and protein production. Submerged macrophytes, including *M. spicatum*, act as nutrient buffers by using dissolved nitrogen and phosphorus for growth (Michelle *et al*., 2008). The submerged freshwater angiosperm *Myriophyllum spicatum* produces high amounts of polyphenols, especially gallotannins, having a broad biological activity against insect herbivores, algae, cyanobacteria and heterotrophic bacteria Tellimagrandin was present in apical meristems of *M. spicatum* (Schopfer and Brennicke, 2005). Xanthophylls are oil-soluble carotenoid pigments found in some aquatic plants (Choi *et al.,* 2002).

One of the methods, for controlling compensation is by food restriction and re-feeding, (Johansen and Overturf 2006). In the channel catfish (*Ictalurus punctatus*), overcompensation has been reported for deprivation periods of 1, 2, and 3 days (Chatakondi and Yant, 2001). Over compensation of various parameters upon re-feeding is noted in Atlantic salmon (Krogdahl and Bakke- McKellep, 2005) and Atlantic cod (Bélanger *et al.*, 2002) and has been proposed as a mechanism for compensatory growth. The gross growth efficiency of deprived fish is marginally higher than normally fed Chinese longsnout catfish (*Leiocassis longrostris*, Zhu *et al.*, 2004) and barramundi (*Lates calcarifer*, Tian and Qin, 2003). Re-feeding after deprivation has been reported to improve the feeding efficiency and induce growth in various fish species (Hayward *et al*., 1997; Tian and Qin, 2003; Zhu *et al.,* 2004 and Johansen and Overturf, 2006).

The major challenge facing the tilapia culture industry is the production of sufficient amounts of good quality seeds. The formulation of appropriate brood stock diets, in order to optimize reproductive outputs and seed production, is a key factor for achieving this objective.

This study aims to control the undesirable trait for farmers as a result of the early maturation of the freshwater cultured fingerlings *Sarotheroden galilaeus*, which gives poor production quality with low growth rates, also to investigate the optimum starvation periods to reduce these chronic problems in this species, and to reach to the optimum growth rate with minimum feed cost. Reducing feed input can be done by periodic feed deprivation which does not necessarily decrease the fish production. This study was designed to investigate the effect of repeated unfed-fed cycles on growth performance, feed utilization physiological conditions and the maturity rate of *Sarotheroden galilaeus.*

2. Materials and methods

The present study was established on 2 May 2007 to 8 August 2007 and conducted in the concrete ponds of the Barrage Fish Farm (30 Km-north of Cairo), which belongs to National Institute of Oceanography and Fisheries, Cairo, Egypt.

2.1. Experimental units and diets

A concrete pond (40 m^3) was divided into four equal compartments (10 m^3, each and stocked with 100 *Sarotheroden galilaeus* fingerlings). The pond was supplied with fresh water from Darawa canal, which originates from the River Nile. The control group was fed to satiation twice a day throughout the experiment. The other three groups were deprived of feed for 1, 2, and 3 days weekly, respectively for 6 weeks and then fed to satiation during the refeeding period (another 6 weeks) as the control group during the full feeding period, in association with *Myriophyllum spicatum,* which grow naturally in the pond, as a source of natural food, for all treatment groups. The artificial experimental ingredients (Table1) were mixed and formulated as dry pellets through pellet machine with 2 mm diameter and were dried at room temperature and kept frozen until experimental start. The compensatory growth of the experimental fish was evaluated biweekly in order to adjust the amounts of daily given feed rate which was 3 % of the total live biomass at two times/day (10.0 am, and 1.30, pm) for 84 days. At the end of the experiment, which lasted 12 weeks, fish in each pond were weighed and counted.

2.2. Experimental fish

Five hundred *Sarotheroden galilaeus* fingerlings were purchased from the local fish farm and mean fish body weight was 4.61 (g) and body length 7.3 (cm.). After acclimation in the concrete pond for 15 days, the experiment remained for 12 weeks. Four hundred fish were randomly assigned to four feeding groups. They were apparently healthy and free from any abrasions.

2.3. Water quality

Water temperature was recorded daily at 11 am., weekly, water analysis was carried out to determine pH values using Orion pH meter, while, dissolved oxygen and ammonia were determined according to standard methods (APHA, 1995).

2.4. Biochemical analysis

Analysis of the artificial ingredients and natural food (*Myriophyllum spicatum)*, and also fish body composition, were recorded at (Tables1 and 3). An initial sample of 10 fish per treatment were killed prior to the start of the experiment and subjected to proximate analysis, and a final sample of 20 fish per treatment was treated similarly. Chemical analyses of all the artificial ingredients and natural food (*Myriophyllum spicatum)* and also fish body composition were determined according to standard methods (A.O.A.C. 1997). The Gross energy content of the diets (artificial or natural) was calculated by using the factors of 5.65 Kcal/g proteins, 9.45 kcal/g lipids and 4.10 kcal/g diet (NRC, 1993). Blood was collected using heparinized syringes from caudal vein of the experimental fish at the end of the experiment. Blood was centrifuged at 3000rpm for 5 minutes. Plasma was subjected to determination of plasma total protein (PTP, g/dl) by the Biuret method (Wootton, 1964) and Plasma albumin (PTA, g/dl) by (Doumas *et al*., 1977).Blood glucose (mg/dl) was measured according to (Trinder, 1969).

2.5. Growth measurements such as biological and physiological parameters were calculated as follows:

Total weight gain (TWG) = mean final body weight – mean initial body weight

Daily weight gain DWG (g/fish/day) = Average final weight (g) - average initial weight (g)/days

Feed efficiency (g) = Body weight gain (g)/ feed intake (g)

Specific growth rate (SGR) = (Ln final weight -Ln initial weight (g)/experiment period x100.

Feed conversion ratio (FCR) = Total dry feed consumed (g) ÷ total wet weight gained (g).

Protein efficiency ratio (PER) = Wet weight gained (g) ÷ amount of protein consumed (g).

Condition factor (k) =100 (Wt/L^3), where Wt is fish body weight (g), L is total length (cm)

Gastro somatic index (G.S.I, %) = Gut weight /body weight) x 100

Hepato somatic index (HSI, %) = (Liver weight / body weight) x 100

Relative maturity = No. of males or females mature /total no of fish in every treatment

Gonado somatic index of male or female = Ovary or testes weight /body weight) x 100

Survival rate =No. of survive fish/total No. of fish at the beginning X100

Protein productive value PPV (%) Increase in fish body protein (g)/crude protein intake (g) x 100.

Fat retention value FRV (%) = [Final fish body fat (g)- initial fish body fat (g)/fat intake (g)] x100.

Intraperitoneal fat ratio IPF (%) = wet weight of fat x 100/body weight.

Energy retention value ERV (%) = (Energy increase in body Kcal /energy intake, Kcal) x100.

Plasma total globulins PTG (g/dl) = plasma total protein (PTP) - plasma albumin (PA) (g/dl).

2.6. Statistical analysis

All measurements were analyzed using one-way analysis of variance (ANOVA) to determine significant differences ($P<0.05$) among treatment means. All statistical analyses were conduced using the Statistical Analysis System (SAS, 2002, software version 8.2, Cary, NC, USA). Duncan's multiple range test (Duncan, 1955) was used to separate differences between treatment means at 5% significant level.

3- Results and discussion

During the 12 weeks feeding trial, average water temperature ranged from 25.5 ± 1.4 °C throughout the deprivation experiment and was 27.3 ± 2.1 °C, during the re-fed period. However water temperature throughout the whole experimental periods were within the normal rates according to (Ndong *et al.*, 2006), who stated that the optimal range is from 20 to 38°C for tilapia. Dissolved oxygen 5.5 ± 0.70 mg/l. and pH averaged 7.3 ± 0.30, whereas total ammonia concentration averaged 0.15 ± 0.04 mg /l during the

Table 1: Feed ingredient and nutrient composition of the artificial Ingredients and natural food *(Myriophyllum spicatum*) for tilapia submitted to different food deprivation levels reared in concrete pond (g/100g).

Ingredients (g/100g)		Chemical composition			
		Experimental artificial diet		*Myriophyllum spicatum.*	
			(%)	Dry material	(%)
Fish meal[2]	18.0	Moisture	9.7	7.1	92.9
Soybean meal	30.0	Crude protein	30	1.24	17.46
Wheat bran	40.0	Crude Lipid (Ether extract)	6.4	0.92	12.96
Corn gluten	5.0	Crude fiber	4.5	1.00	14.08
Soy & fish oil	3.0	Ash	6.5	1.29	18.17
Vit. & Min. Mix[1]	2.0	Nitrogen free extract(NFE)[3]	42.90		37.33
Starch	1.5	Gross energy Kcal/ 100g[4]	405.87		168.712
Chromic Oxide	0.5	Protein /Energy ratio[5]	73.92		7.349
Total	100.0	Lipid /Protein ratio[6]	21.33		0.74

1- Each Kg vitamin & mineral mixture premix contained Vitamin A, 4.8 million IU, D_3, 0.8 million IU; E, 4 g; K, 0.8 g; B_1, 0.4 g; Riboflavin, 1.6 g; B_6, 0.6 g, B_{12}, 4 mg; Pantothenic acid, 4 g; Nicotinic acid, 8 g; Folic acid, 0.4 g Biotin,20 mg , Mn, 22 g; Zn, 22 g; Fe, 12 g; Cu, 4 g; I, 0.4 g, Selenium, 0.4 g and Co, 4.8 mg.
2- Protien percent of fish meal; soybean meal; wheat bran and corn gluten were 60, 44, 8and, 56. respectively.
3- Nitrogen-free extract, determined by difference.
4- Gross energy content of the diets was calculated by using the factors of 5.65 Kcal/g proteins, 9.45 kcal/g lipids and 4.10 kcal/g diet (NRC, 1993)
5- Protein / Energy ratio = mg protein / Kcal.
6-Lipid /Protein ratio = mg lipid / Kcal.

experimental period. No specific diseases were noted and the best fish survival rates ranged from 96 to 98 % without significant difference as compared to the control fish group. These results are in closest agreement with (Chi-Ru *et al.,* 2008) who noted that no tilapia (*O. mossambicus*) died during the experimental periods in any starved or refeeding groups.

3.1. Growth performance

After 6 weeks deprivation period, the fish in the high starved periods (D3) grew significantly less than the control, while the moderate deprivation groups (D1 and D2) were nearly the same and did not differ significantly from the full feeding regime (D0) group. Whereas the best total body weight gain TWG at the end of the whole experimental period was achieved by the fish fed the lower and moderate deprivation regime (D1& D2.) and grew better than the highest starvation group. Moreover, the fish fed with (D1) revealed higher TWG (33.68±0.23) value than the full feeding regime Do (33.59±0.25). Table (2) indicated that TWG in (D1 and D2) nearly the same, but D3, (31.34±0.12) had lower significantly TWG ($P<0.05$) than the other groups. Based on this result, daily weight gains DWG (g/fish/day) was not different in the control D0 (0.40±0.04) and D1 (0.40±0.03) but the lowest daily gain was recorded in D3 (0.37±0.02).

Analysis of variance for SGR values followed the same trend as in TWG and DWG, so the fish groups fed on moderate deprivation D1, had significantly ($P<0.05$) higher SGR than the D3 group. However, at the end of the trial, SGR values were 2.52 ± 0.14; 2.50 ± 0.17and 2.52 ± 0.15 %/d for fish groups fed on moderate regime (D1, D2) and (Do, the full feeding fish group), respectively. No significant differences ($P<0.05$) were found between the treatments in condition factor (K), except in treatment D3 (1.71) which was the lowest one.

3.2. Feed utilization

3.2.1. Feed consumption and feed conversion ratio

Feed utilization parameters illustrated in Table (2) indicated that slightly increases were found in feed intake (FI) with the increasing of deprivation levels, the highest values of FI was detected for fish fed 4 days weekly (D3, 56.97) without significant difference with those fed to satiation (Do, 57.14) while similar values were recorded for the lower and moderate deprivation levels D1, D2 56.96 and 56.93 g, respectively.

Feed conversion ratio in D0, D1, D2 and D3 was found to be 1.70; 1.70; 1.73 and 1.82, respectively, so, 6 weeks period was apparently short for full compensation for the fish fed 4 days weekly (D3). These results indicate that *Sarotheroden galilaeus* fingerlings may be capable partially to growth compensation by increasing gut volume (Table 2) and consequent increased feed consumption (FI) and slightly change in feed conversion ratio. These results are in agreement with those obtained by (Chatakondi and Yant, 2001) who recorded that catfish fingerlings were fed daily to satiation (controls) and growth was compared with those deprived of feed for one, two, or three days and then refed for as long as feed consumption was statistically higher than that of control fish.

3.2.2. Protein, fat and energy ratios; energy productive values and feed efficiency

The same trend was observed in protein efficiency ratio (PER), intraperitoneal fat ratio (IPF) and energy retention value (ERV %). The best results detected at the lowest and moderate starvation periods D1 and D2, while the highest deprivation periods (D3) was lower significantly ($P<0.05$) than the control (D0). The fish in both moderate groups D1 and D2 exhibited clear compensation for the reduced number of feeding days by increasing feed consumption and consequently weight gain during the days when they were fed, and the compensation increased towards the end of the experiment by increases in FI, FE, and SGR. Response continued for the full 6-weeks of the refeeding period. It is possible that if the last refeed period of the cycle had been extended when the compensatory growth response persisted, treatment fingerlings at D3 may have achieved a final body weight closer to that of control fish. The compensatory growth response observed during the refeeding period may have resulted from the increased amount of weight loss experienced during the feed deprivation period, as it has been reported by (Quinton and Blake, 1990) who stated that the compensatory growth response depends on the length and severity of feed deprivation. The extended compensatory growth response could also be a learned response to previous feed deprivation periods. Similar responses have been reported in experiments using repetitive feeding cycles, in which increases in SGR (Zhu *et al.,* 2004), FI (Wu *et al*., 2003 and Zhu *et al.,* 2004) and FE (Wu *et al*., 2003) were improved with each cycle.

Also, the present findings exhibited modest improvements in (FE) at the termination of the trial for fish fed 6 and 5 days per week (D1,D2) as compared to the fish fed 7 days weekly (D0)or with those fed 4 days only. These results confirm the findings reported by (Kim and Lovell, 1995 and Li *et al*., 2005), and further demonstrate the potential for catfish to overcome periods of feed restriction by regaining lost weight. However, treated fish in the study by (Chatakondi and Yant, 2001) showed increased FE at the termination of the trial, whereas (Kim and Lovell, 1995) did not report improvements in FE and (Li *et al*., 2005) showed moderate improvements, albeit not statistically different from control fish. If the feeding regimes in pond studies could yield increases in FE and full growth compensation, farmers would benefit from both reductions in feed cost and water quality issues without sacrificing production. Boujard *et al*. (2000) suggested that increases in FE during refeeding are responsible for the compensatory growth response. Fish may utilize feed more efficiently following periods of feed deprivation and growth rates increase without hyperphagia

3.2.3 Protein /energy utilization

Protein productive values PPV (%) in D1 and D3 (14.68 and 14.69) were nearly the same, while significant highest value was detected in D2 (14.98) as compared with the control (D0) (14.24). Analysis of variance of the present results indicate that moderate starvation group were able to compensate the growth retardation during the feed deprivation period and came to almost the same final weights on the control group (D0), while the group under highest deprivation (D3) failed to compensate the growth retardation with lower final weights, even with the aquatic *Myriophyllum spicatum* as a source of natural food. These results are in the same line with (Turano, 2006) who reported that the presence of natural prey in ponds could alter the compensatory growth response when it is dependent on periodic feed deprivation, This problem would likely be compounded in studies using smaller fish, because fish consume both natural and artificial feed (Kelly and Kohler, 1996).Although the present work was conducted in concrete ponds, the small fish initial weight was used because smaller fish may benefit more from natural prey, and utilize this source during deprivation periods. Li *et al*. (2005) reported no difference in net production between channel catfish offered cyclic feeding regimes of 1:6, 1:4, and 2:5 (days not fed: days fed) and normally fed control fish. Since pond culture is conducted in a dynamic and biologically diverse environment, as opposed to more controlled aquaria experiments, additional factors must be taken into consideration in the design of the study. Specifically, because of the availability of natural prey, extended periods of feed deprivation may be necessary to obtain a similar metabolic state as fish exposed to shorter feed deprivation periods in aquaria. Additionally, seasonal fluctuations in temperature can influence the amount of time necessary to reduce metabolism, and may also affect growth during the refed. The present result is at the same suggestion of (Ndong *et al*., 2006) who stated that the use of cyclic feeding regimes may also have an overall effect on pond water quality, particularly if FE is increased. Enhancements in FE may help to improve overall nutrient utilization, while periods of feed deprivation could be used during periods of maximal feeding to assist in management of phytoplankton, thereby reducing the risk of dissolved oxygen (DO) depletion. Additionally, prolonged cyclic feeding regimes would likely have a greater effect on water quality as phytoplankton, the major producers of dissolved oxygen, relies on nutrients (Turano, 2006). The more short-term restriction (Li *et al.,* 2005) is applied to increase FE and decrease costs associated with labor. Similarly, in another study using extended feed deprivation, full growth compensation was observed with hybrid tilapia, *Oreochromis mossambicus* x *O. niloticus* (Wang *et al.*, 2000).When fish deprived of feed for one, two, or four weeks followed by four weeks of refeeding were compared to control fish fed to satiation, those deprived of feed for one week were not statistically different in weight following the completion of the 8- week trial. No difference was observed in FE, or protein and energy retention efficiency between control and treatment fish during refeeding. Similar results were also observed by (Xie *et al*., 2001) with gibel carp (*Carassius auratus gibelio*).

3.3. Biological and physiological measurements

3.3.1 Natural feed and gut indices

The growth performance and physiological parameters indicated that there were no significant differences at food deprivation levels (D1) and (D2). Analysis of variance showed significant decreasing in growth measurements, at higher feed regime (3 days, D3) as compared to the control. The closest results between the two moderate feeding and the control may be due to the presence of the aquatic freshwater plant (*Myriophyllum spicatum*) as a source of natural food, for all treatment groups. Analysis (Table 1) indicates that although, *Myriophyllum spicatum* is low in protein and carbohydrates and high in moisture, it contains lower crude fiber and Lipids than the protein content, ash content was 18.17 % (1.29 dry materials). Cronin *et al.* (2002) noted that populations of benthic invertebrates beneath submersed vegetation can be more than 100 times larger than those in none vegetative openings within plant beds. Water milefoil (*M. spicatum*.) has been shown to provide a better habitat for invertebrates and for fish (Cronin and Lodge, 2003). The open water is known to affect aquatic plant communities by out competing native species, but it should also have effects on fish by altering food and habitat type.Production of fish and invertebrates appears to increase directly with increasing macrophyte biomass, small fish hide invigitation while adult fish remain long at edges of macrophyte (Godmaire and Nalewajko, 1989). Extensive reduction in sediment ammonium levels within *M. spicatum*, beds in conjunction with its seasonal growth (Carignan and Kalff, 1982) attest to the importance of its roots. Besides to xanthophylls contents in excess of 660 mg/kg, photosynthesis in higher plants, algae and photosynthetic bacteria converts light energy into chemical energy, building up organic matter out of CO_2 and water. This organic matter then serves as the basis for the food of the heterotrophic organisms. (Schopfer and Brennicke, 2005). The growth parameters of *Sarotheroden galilaeus* fingerlings which exposed for 12 weeks to period of repeated unfed–fed cycles shown in Table (2) revealed that both moderate groups (1, 2 days/week) enable tilapia to compensate the growth retardation almost successfully.

The fish in both moderate groups exhibited clear compensation for the reduced number of feeding days by increasing food consumption (artificial or natural), thus the gastro somatic indices (G.S.I) of the starved groups were significantly higher than those of the control group, since G.S.I of the starved group D1, D2, and D3 were 2.98, 2.99 and 3.11 %, respectively (Table 2). Krogdahl and Bakke-McKellep (2005) reported that fasting caused extensively rapid decreases in the tissue mass, protein, and enzyme capacities of Atlantic salmon (*S. salar*) within 2 day fasting period. However, intestinal wasting slows down during long-term starvation periods. Protein degradation in other tissues, particularly white muscle, apparently levels up at such a time to provide more amino acids for vital body functions (Navarro and Gutierrez, 1995).By feeding a meal after 6 d fasting period, fractional rates of protein synthesis in the intestines are higher than that 3 h after feeding, and these were brought about by an increase in protein synthesis per unit of RNA (Krogdahl and Bakke-McKellep, 2005).

The present study found that the gut weight to body weight percentages increased by increasing the deprivation rate, feeding treatments induced clear changes in the maximum gut volume by the end of the experiment, measured under constant conditions. This was a slight increase with the increasing of deprivation rate, D3 group exhibited the largest gut volume than the rest groups, the values were found to be D0, 3.36 ± 0.53; D1, 3.86± 0.78; D2; 4.16± 0.70 and D3, 4.74 ± 0.83 ml, (Table 2).The present results are in agreement with whom demonstrated that variable food intake and re-feeding lead to increase in tissue mass, protein content, and enzyme activities synchronous with the response of fasting, possibly due to a combination of increased cellular proliferation higher rates of protein synthesis, and lower levels of protein degradation, (Krogdahl and Bakke-McKellep, 2005 and Chi-Ru *et al.,* 2008). Recent data have demonstrated that starvation or a shortage of food may lead to increases in enzyme activities in different sections of the intestines (Harpaz *et al*., 2005 and Krogdahl and Bakke-McKellep, 2005). Starvation inhibits the growth of tilapia according to the relationship between specific growth rates and trypsin specific re-feeding after deprivation has been reported to improve the feeding efficiency and induce growth in various fish species (Tian and Qin, 2003; Zhu *et al*., 2004 and Johansen and Overturf, 2006).

The results also suggest that intermittent feeding could be used for rearing *galilaeus* and thereby potentially decreasing costs of a fish farm. These results indicate that *galilaeus* is capable of growth compensation partially through increasing stomach volume and consequent increased feed intake without a change in feed conversion ratio, however, 6 weeks was apparently too short for full compensation for those deprived 3 days weekly. The results showed that reducing feed input by repeating unfed–fed cycles induced compensatory growth of the fish. Application of this feeding regime provides flexibility in feeding management and may reduce organic discharge into the environment. Reduction of organic pollution should help the sustainable use and conservation of the *galilaeus* ecosystem.

The basis for this discrepancy in weight loss is unclear, but may reflect the presence of an internal biological clock. Evidence for an internal clock was reported by (Van Dijk *et al.*, 2005). Despite holding temperature and photoperiod constant, juvenile roach, *Rutilus rutilus*, exposed to a 21 day feed deprivation period during the winter season had a significantly larger liver mass, and higher liver lipid content, white muscle protein and glycogen content than fish used in the same study conducted during the summer. Ali *et al.* (2003) reported that the compensatory growth may be an internal adjustment mechanism for animal to adapt to often dramatically varied environment. The animal that withstands a period of nutrition restriction could retain to a normal growth. Similarly, *S. galilaeus* in this study may be better prepared for feed deprivation periods during the experimental periods, because the experiment was started in early summer.

3.3.2. Hepatic indices

In order to better understanding the physiological basis of compensatory growth, measures of energy HSI and IPF ratio were monitored throughout the experiment (Table 3). Measurements of energy reserves such as HSI, IPF and fat retention may offer some understanding of metabolic state and may be useful in predicting a compensatory growth response. Higher deprivation (D3) resulted in precipitous declines in HSI (1.40) and IPF (1.91%). While the values were closest in the other two deprivation levels D1 and D2 as compared to the control. Similar changes in HSI and fat retention have been observed in channel catfish (Gaylord and Gatlin, 2000). The shift in metabolism, as proposed by (Broekhuizen *et al.,* 1994) could contribute to the compensatory growth response. If low metabolic rates are maintained from the period of starvation into the initial realimentation period, more energy could then be directed toward growth. Small *S. galilaeus* required six weeks of refeeding to replenish energy stores to control levels. It seems that larger-sized *S. galilaeus* fingerlings may preferentially mobilize energy stores from the liver, rather than fat stores following periods of feed deprivation. Replenishment of energy stores coincided with the compensatory growth response of both feed cycles. However, restoration of energy parameters during the refeeding period resulted in a compensatory growth response lasting the full 6-weeks of refeeding. Hence, although a compensatory growth response can be predicted by a sufficient reduction in HSI to a value of at least 1.4 (Table 2).

3.4. Blood measurements

Plasma levels (plasma total protein; total albumin and plasma total globulins) as shown in (Table 2) were measured in this study to characterize the possible function of immunity during the compensatory growth response. This study reports for the first time that feed deprivation causes a concomitant increase in PTP although no significant increase in plasma protein was observed between the low and moderate starvation periods. These results are in agreement with those reported by Small *et al*. (2002) who reported a significant increase in plasma protein in striped bass. During the feeding cycle, increases in plasma protein were accompanied by a reduction in energy stores, specifically liver and intraperitoneal fat, or blood glucose. Although the reduction in HSI is likely due to glycogen mobilization (Gaylord and Gatlin, 2000), similar to results on plasma protein reported in juvenile coho salmon (Duan and Plisetskaya, 1993).Similarly the present results (Table 2) revealed that Plasma albumin increased and plasma total globulins decreased gradually with the increasing in the deprivation levels, the values of albumin and globulins recorded in control groups were (1.46 & 2.28); D1(1.47& 2.29); D2(1.51& 2.18) and D3 (1.7 & 1.84) (g/dl), respectively. Moreover, blood glucose values decreased significantly and depended on the deprivation rate increase, the minimum and maximal values were (74.56±1.49 and 105.51±4.18 mg/dl) at D3 and D0, respectively.

3.5. Indices of maturation

Results of female Gonado Somatic Indices (GSI), in D0, 2.88% and (D1, 3.00 %) and (D2, 2.93 %) were significantly higher than (D3, 2.42 %) these results may explain the importance of the moderate starvation periods to reduce the incidence of early maturation in freshwater cultured fingerlings *galilaeus*. This result is closest with (Reimers *et al*., 1993 and Hopkins and Unwin, 2008) who reported that springtime fasting was used as a means to reduce the incidence of early maturation in cultured male *Oncorhynchus tshawytscha* which show a tendency to mature early, an undesirable trait for farmers as such fish disrupt the harvesting programmes and have a reduced value owing to their small size. In other expression, the relative maturity of deprived males and females fingerlings *S.galilaeus* reduced significantly by increasing in deprivation days as shown in Table (2). The males and females *S.galilaeus* full fed group (D0) have a significantly ($P<0.05$) higher incidence (49.28 and 52.94 %) while

Table 2: Growth performance and biological parameters of fingerling *Sarotheroden galilaeus* fed daily to satiation (control) or different periods of feed deprivation/refeeding during a twelve week study in cement ponds (Means ±SE)

Growth parameters	Starvation periods*. (D0)	(D1)	(D2)	(D3)
Mean Initial weight (g)	4.62 ± 0.35 [a]	4.60±0.30 [a]	4.59± 0.30 [a]	4.60± 0.29 [a]
Mean finial weight (deprivation) g	21.62 ± 0.23 [a]	21.16± 0.19[ab]	20.98± 0.20 [b]	19.94±0.12 [c]
Mean finial weight (refeeding) g	38.21±0.21 [a]	38.2 ± 0.27 [a]	37.50±0.21 [b]	35.94 0.20[c]
TWG (g fish $^{-1}$)	33.59±0.25 [a]	33.68±0.23 [a]	32.91±0.14 [b]	31.34±0.12 [c]
DWG. (g/fish/day)	0.40±0.04 [a]	0.40±0.03 [a]	0.39±0.01 [b]	0.37±0.02 [c]
Mean initial length (cm)	7.3±0.15	7.3±0.09	7.3±0.11	7.3±0.16
Mean final length (cm)	12.7± 0.24	12.7±0.18	12.6±0.20	12.8±0.23
Condition factor (K)	1.87 [a]	1.87 [a]	1.88 [a]	1.71 [bc]
SGR (%/d).	2.52 ±0.15 [a]	2.52±0.14 [a]	2.50±0.17 [ab]	2.45±0.21[b]
Feed intake FI (g fish $^{-1}$)	57.14 [a]	56.96 [b]	56.93 [b]	56.97[b]
FCR	1.70 [a]	1.70 [a]	1.73 [ab]	1.82 [c]
PER (%)	1.95 [a]	1.96 [a]	1.93[ab]	1.88 [b]
FE (g)	0.588 [a]	0.591 [a]	0.578 [b]	0.550 [bc]
PPV (%)	14.24[c]	14.68 [b]	14.98 [a]	14.69[b]
FRV (%)	19.53 [a]	17.34 [b]	16.1 [b]	9.38 [d]
IPF (%)	3.45 [a]	3.44 [a]	3.37 [a]	1.91[b]
ERV (%)	8.9 [a]	7.34 [b]	5.22 [c]	2.33 [d]
Survival rate (%)	97 % [a]	98 % [a]	96 % [a]	96% [a]
Physiological parameters:				
HSI (%)	1.47 [a]	1.48 [a]	1.45 [a]	1.40 [b]
Gut volume. (ml)	3.36 ± 0.53 [d]	3.86± 0.78[c]	4.16± 0.70 [b]	4.74 ± 0.83[a]
G.S.I (%)	2.93 [bc]	2.98 [b]	2.99 [b]	3.11 [a]
Relative maturity of males	49.28 ± 2.04 [a]	41.38 ± 3.14 [b]	38.00 ± 2.52 [bc]	24.18 ± 1.80 [d]
Relative maturity of females	52.94 ± 2.04 [a]	45.60 ± 2.04 [b]	41.18 ± 2.04 [bc]	23.53 ± 2.04 [d]
Gonado somatic index of male (%)	1.95 [a]	1.87 [b]	1..63 [c]	1.22 [d]
Gonado somatic index of female (%)	2.88 [b]	3.00 [a]	2.93 [a]	2.42 [c]
PTP (g/dl)	3.74 [a]	3.76 [a]	3.70 [a]	3.54 [b]
PA(g/dl)	1.46 [bc]	1..47[bc]	1.51 [b]	1.70 [a]
PTG(g/dl)	2.28 [a]	2.29 [a]	2.18 [b]	1.84 [c]
Blood glucose (mg/dl)	105.51±4.18 [a]	96.49±1.58 [b]	87.75±1.58 [c]	74.56±1.49 [d]

a,b,c…Means in the same row have different superscripts are significantly different ($P \leq 0.05$)

*Starvation periods: (D0) Control full feeding; (D1) deprived for 1 day; (D2) deprived for 2 days and (D3) deprived for 3 days weekly, respectively.

the minimum values (24.18 and 23.53 %), were detected for those fed the highest deprivation rate (D3). On the other hand, fish in the two groups that had been fasted for 1 or 2 days weekly (D1and D2) recorded the optimum rates. Similar results from restricted spring feeding have been obtained with older Atlantic salmon, in their second year also Thorpe *et al.* (1990) found that maturing male Atlantic salmon *Salmo salar* L. pan had higher condition factors in spring than nonmaturing parr. They concluded that inadequate springtime growth activated a physiological switch to suppress the onset of maturation. Rowe and Thorpe (1990) were able to reduce the incidence of male parr maturation experimentally by reducing food rations during spring.

Although hyperphagia reoccurred in highest deprivation fish (D3) at the end of the whole experiment, fish final weight did not reach that of the control fish. Body lipid/protein ratio in D3 was (0.346) and lower significantly than that of the (D1& D2), since the fish body protein value for D3 (15.28 %) was slightly higher than that of the control one, while the fish body lipid for D3 (5.29 %) was significantly ($P<0.05$) lower than the other treatments (Table 3). On the other hand, the moisture and ash contents slightly fluctuated throughout all treatments, however, relative gains in protein, lipid and ash as proportions of total body weight gain, did not differ significantly among (D1, D2) and D3 groups.

Table 3: Chemical composition of whole body *Sarotheroden galilaeus* fingerlings submitted to different food deprivation levels reared in cement pond.(As wet weight basis)

Items	Deprivation days				
	Initial	Control	D1	D2	D3
Moisture (%)	78.27	75.12^{a}	75.77^{b}	75.63^{b}	76.14^{c}
Crude protein (%)	12.77	15.21^{b}	15.28^{b}	15.35^{a}	15.28^{b}
Ether extract (%)	4.69	5.85^{a}	5.80^{a}	5.72^{ab}	5.29^{c}
Ash (%)	4.27	3.82^{a}	3.15^{c}	3.30^{bc}	3.29^{bc}
Lipid/Protein Ratio	0.367	0.385^{a}	0.379^{a}	0.373^{ab}	0.346^{c}
Energy(Kcal/100g)	116.47	141.22^{a}	141.14^{a}	140.78^{b}	136.32^{c}

a,b,c…Means in the same row have different superscripts are significantly different ($P \leq 0.05$)

4. Conclusion

It can be concluded that moderate feed restriction (2 days deprivation / week) for 6 weeks resulted in complete compensatory growth and optimal maturity rates, while a severe feed restriction (4 days, satiation) did not lead to complete compensatory growth. Moreover, the biological and physiological results explain the importance of the moderate starvation periods to reduce the incidence of early maturation in freshwater cultured fingerlings *S. galilaeus.*

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النمو التعويضي لإصبعيات البلطي الجاليلي عند تقييد الغذاءِ مع (الميريوفيلام) كمصدر للغذاء الطبيعي

راقي فخري عطا الله

المعهد القومي لعلوم البحار والمصايد بالقاهرة

هذه الدراسة بهدف مقارنة أداء النمو ومعدلات الإعاشة المثلى وكفاءةِ الغذاءِ، و القياسات البيولوجية والفسيولوجية، ومعدلات النضج للوُصُول إلى معدل النمو القصوى بكلفةِ الغذاءِ الدنيا وأيضاً للسَيْطَرَة على الميزةِ غير المرغوبةِ للمزارعين كنتيجة النضوجَ المبكّر لأصبعيات البلطي الجاليلي، وما ينتج عنه من إنتاجَ ضعيفَ، بمعدلات النمو المنخفضةِ، أيضاً لتَحرّي فتراتِ التجويع القصوى عند تغذيتها بمستويات مختلفة من تقييد الغذاء (التغذية و الحرمان) مع الغذاء الطبيعي بالأحواض الخرسانية بمزرعة الأسماك بالقناطر الخيرية التابعة للمعهد القومي لعلوم البحار والمصايد، القاهرة. بدأت التجربة بمتوسطات وزن 4.61 وطول 7.3 سم ، و قد تم عمل أربعة معاملات، المجموعة القياسية غُذّيتْ إلى الإشباع مرّتين في اليوم (مجموعة الكنترول) طوال فترة التقييم لمدة 12 أسبوعا . والمجموعات الأخرى الثلاث حرمان من الغذاء بمعدل (1 ، 2 ،3) أيامِ أسبوعيا، على التوالي لمدة 6 أسابيعِ وبعد ذلك غَذّيت إلى الإشباع لمدة 6 أسابيع أخري كالمجموعة القياسية حتى نهايةِ التجربةِ .، وذلك في تواجد النبات المائي (الميروفيلام) الذي ينمو طبيعيا بأحواض التجربة كمصدر غني للغذاء الطبيعي.

وقد أشارت القياسات البيولوجية و الفسيولوجيةَ و أداء النمو إلى أنه ليس هناك اختلافات هامّة في مستويات حرمانِ الغذاءِ (2,1) يوم ، بمُقارنتها بالمجموعة القياسيةِ (الكنترول). كما أوضح تحليلُ التباينِ نَقْص معنوي في مقاييسِ النمو، في نظامِ تقييدِ الغذاءِ الأعلى (3 أيامِ) بمُقارنتها بالكنترول، وأكدت التجربة أنّ الإطعام بنظامِ تقييدِ الغذاءِ المعتدلِ (يومان حرمان/أسبوع) وفي وجود النبات المائي كمصدر جذب للغذاءِ الطبيعي، موصّى بهُ لأداءِ النمو الجيدِ والأكثرِ اقتصادية لتَرْبية أصبعيات البلطي الجاليلي و بمعدلات النضج المناسبة كحل مناسب لإنتاج الذريعة المحسنة. و بذلك يُمْكِنُ أن نستنتج أنّ نظام تقييدِ الغذاءِ المعتدلِ (حرمان يومين / أسبوع) لمدة6 أسابيع أدّتْ إلى نمو تعويضي كاملِ ونِسَبِ نضج معتدلة، بينما تقييد غذاءِ حادٍّ (4 أيام، إشباع/أسبوع) لَمْ يُؤدّ إلى نمو تعويضي كامل.و علاوة على ذلك تُوضّحُ النَتائِجُ الحيويةُ والفسيولوجيةُ أهميةُ تطبيق نظام فتراتِ التجويع المعتدلةِ في تغذية أسماك البلطي الجاليلي بالمزارع السمكية لتَخفيض حادثةِ النضوج المبكّرِ في الماء العذبِ للحصول علي إنتاج عالي الجودة.