Effects of Photoperiod and Different Artificial Light Colors on Nile Tilapia Growth Rate

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Abstract: The objectives of the present study were to examine the effects of photoperiod and light colors on growth rate and activity of Nile Tilapia (Tilapia Niloticus). The fish were fed by hand a commercial feed (crude protein, 27%; crude lipid 5.06%; crude fiber 5.08%; total energy 4000 kcal/kg) for 60 days. The results indicated that photoperiod (24L:0D, 16L:8D and control) and light colors (white, red and blue) were significantly affected fish growth performance. The blue light was better than other colors lights, both at different photoperiods. The blue light and long light phase (24 light hours) produced the best fish percentage weight gain (WG = 1057.8%), specific growth rate (SGR = 4.05%), daily growth rate (DGR = 17.3%) and growth efficiency (GE = 0.29). On the other hand, the blue light and light cycle 16L:8D gave weight gain (WG = 890.4%), specific growth rate (SGR = 3.82%), daily growth rate (DGR = 14.84%) and growth efficiency (GE = 0.27). The lowest mean values of feed conversion ratio (FCR = 1.04) was observed in blue light and long light photoperiod. The highest mean values of feed conversion ratio (FCR = 1.19) was observed in blue light and 16L:8D light cycle.

Keywords: photoperiod, light colors, fish performance.

I. Introduction

Spectral composition is a main characteristic of light. In water light rays of different wavelength pass to different depths depending on light absorption and diffusion as well as on availability of admixtures and small organisms in a water body. Most species of fish have well-developed color sight, and are therefore very sensitive to colored light. For instant, the survival rate of haddock larvae (Melanogrammus aeglefinus L.) is higher with blue and green light (Downing 2002). The growth rate of silver carp larvae (Hypophthalmichthys molitrix Val.) and young carp (Cyprinus carpio L.) increased with green light (Radenk and Alimov 1991, Ruchin et al. 2002, Ruchin 2004).

The intensive culture of tilapia under controlled management systems is widely expanding to meet the increasing demands for these fishes, especially in developing countries. In this regard, the use of closed culture systems has received a considerable attention, and is becoming more common worldwide, particularly in arid areas that face shortage in fresh water or brackish water, or in areas where environmental parameters, such as salinity and temperature, are outside the tolerance range of tilapia (Muir et al., 2000; El-Sayed and Kawanna, 2004).

Photoperiod acts as an artificial Zeitgeber (cue or synchronizer), regulating the daily endogenous rhythms in fish and also affects fish growth, locomotor activity, metabolic rates, body pigmentation, sexual maturation and reproduction (Duston and Saunders, 1990; Gross et al., 1995; Silva-Garcia, 1996; Boeuf and Le Bail, 1999; Trippel and Neil, 2002; Biswas and Takeuchi, 2002; Biswas et al., 2002; Biswas et al., 2005). On the other hand, the growth and metabolic rates of several other species were not significantly affected by photoperiods (Imsland et al., 1995; Hallaräker et al., 1995; Purchase et al., 2000). Meanwhile, photoperiod may positively affect larval stages, but not juvenile stages (Barlow et al., 1995).

Adaptations of fish to their natural environment may also influence their response to the farming environment. As in nature, light intensity and background color can affect feed detection and feeding success of cultured fish, thus influencing fish growth and mortality. In general, the highest growth rates of fish larvae are achieved when light conditions and background color optimize the contrast between the feed and the background (Barahona-Fernandes, 1979; Hinshaw, 1986; Henne and Watanabe, 2003; Jentoft et al., 2006; Strand et al., 2007). Light intensity may also affect the size of prey preferred by juvenile fish (Mills et al., 1986). Tank colour has been shown to influence the success of larval swim bladder inflation (Martin-Robichaud and Petersen, 1998).

In most studies fluorescent lamps are used, resulting in what humans perceive as white light, despite the fact that: (a) in natural fish habitat, wavelength of light penetrating water varies greatly, (b) fish vision and spectrum perception are strongly adapted to each species natural habitat and living ethology (Chinen et al., 2005; Kusmic and Gualtieri, 2000; Neumeyer, 1992; Pointer et al., 2005), and (c) recent studies indicate that light spectrum affects farmed fish growth performance (Head and Malison, 2000; Karakatsouli et al., 2007, 2008).
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2008), behavior (Marchesan et al., 2005; Volpato et al., 2004) and physiological status (Head and Malison, 2000; Karakatsouli et al., 2007, 2008; Karakatsouli et al. 2010).

The objectives of the present study were to examine the effects of photoperiod and light color on growth rate and activity of Nile Tilapia (Tilapia niloticus)

II. Materials and Methods

The experiments were carried out through the period 1st October, 2012 to 1st December, 2012. The experiments were studied 70 Nile tilapia fingerlings with initial weight 0.5 g in glass tanks at Kom Elflos fish farm (31°06′N - 30°56′E), Krelsheikh Governorate, Egypt. Experimental tanks (glass, length height width: 70 cm 50 cm 35 cm, volume capacity 122.5 l), the tanks were provided with central drainage pipes surrounded by outer sleeves pipes, perforated at the bottom, to facilitate self-cleaning and waste removal. Continuous aeration through an air pump (Boyu, U -9900, 3.2 l/min) and heaters, with thermostats, to keep water temperature at 26 °C (Fig. 1). About 20% of the water was replaced daily by fresh water at the same temperature. Water quality parameters, including DO, ammonia and pH were recorded every ten days. The average values of these parameters throughout the study were: DO = 6.5 mg/l, ammonia = 0.049 mg/l and pH= 7.9.

The experiment was designed to study the effect of photoperiod and light color on Nile tilapia growth rates, feed utilization efficiency and survival of Nile tilapia. The fish were exposed to two photoperiod (light: dark, L: D) cycles (24L:0D and 16L:8D) by using fluorescent lamps and natural light – dark cycle (control, at experiment starting 11h 51mint L:12h 9mint D and experiment end 10h 21min L : 13h 39mint D). Light in each photoperiod tank was provided by two fluorescent lamps (36 W) suspended 100 cm above the water surface. On the other hand, the fish were exposed to three types of color light (white, red and blue). Light intensity was measured every five days at water surface (at tank center) by a digital Lux Meter (Digital light meter Nicety LX-802) and was constant at around 600 lx throughout the experiment in artificial photoperiod.

Fish were acclimated to experimental tanks for 1 day under room ambient light. After the acclimation period white, red and blue light color and photoperiod were applied and fish remained in these conditions for 60 days. Light color was achieved by covering light source. The fish were fed by hand a commercial feed (crude protein, 27%; crude lipid 5.06%; crude fiber 5.08%; total energy 4000 kcal/kg) for 60 days. The diet was offered twice a day at 10:00 h and 16:00 h. Daily feeding rates (% BW/day) were determined based on recommendations of different researchers (Morris and Mische, 1999; Al Hafedh, 1999; Coward and Bromage, 1999 and El-Sayed, 2002). Therefore, the daily rates were of 6 % BW/day for 30 days and reduced to 5 % BW/day for other 30 days. Fish were weighed at 10 days intervals (days: 0, 10, 20, 30, 40, 50 and 60) and feed intake were adjusted every 10 days also. Fish were weighed using an electronic balance (Shimadzu, EB-620SU ± 0.01 g sensitivity). The data collected every ten days and the growth rates were measured in terms of specific growth rate (SGR), weight gain (WG), feed conversion ratio (FCR) and condition factor (K) as the following:

![Diagram of experimental unit](image)

Fig. 1: experimental unit diagram.
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\[
SGR = \left( \frac{\ln FW - \ln IW}{\text{time (day)}} \right) \times 100 \quad \ldots \quad \ldots \quad (1)
\]

\[
WG = \left( \frac{FW - IW}{IW} \right) \times 100 \quad \ldots \quad \ldots \quad (2)
\]

\[
FCR = \frac{\text{dry feed given (g)}}{\text{wet weight gain (g)}} \quad \ldots \quad \ldots \quad (3)
\]

\[
DGR = \left( \frac{\text{experimental period} \times x \times 100}{100 \text{ (body weight, g)}} \right) \quad \ldots \quad \ldots \quad (4)
\]

\[
K = \frac{\text{condition factor}}{\text{total length, cm}^3} \quad \ldots \quad \ldots \quad (5)
\]

Where: SGR= specific growth rate, %. FW= final weight, g. IW= initial weight, g. WG= weight gain, %. FCR= feed conversation ratio. K= condition factor.

To evaluate energy expenditure, the energetic growth efficiency (GE) was calculated, where GE is the ratio between the energy of the weight increase of the fish and the total energy intake of the fish (Larsson and Berglund, 2005):

\[
GE = \left( \frac{J \times (FW - IW)}{(FI \times DE)} \right) \quad \ldots \quad \ldots \quad (6)
\]

where J is the conversion factor of mass to energy for percids (5.0 kJ g\(^{-1}\) wet weight) (calculated average from Hewet and Kraft, 1993 [P. flavescens] and Bryan et al., 1996 [P. flavescens and S. vitreum]), FW is the weight at time t (g), IW is the initial weight (g), FI is the feed intake (g), and DE is the digestible energy content of the feed (16.747 kJ·g\(^{-1}\), obtained from the manufacturer).

The data obtained from the experiment were subjected to one-way analysis of variance (ANOVA) (using SPSS program) to test the effect of photoperiod and light color on the growth rates, feed utilization efficiency. When ANOVA identified significant difference among groups. Least significant difference (LSD) was used to compare means at P < 0.05.

### III. Results and discussion:

3.1. Effect of light period:

Data and illustrations on growth patterns of Nile tilapia exposed to two long-day artificial photoperiod are presented in Tables 1 and 2 and Fig.2. The results of experiment indicated that photoperiod (24L:0D and 16L:8D) and ambient light regime (control) significantly affected fish growth performance (Table 1 and Fig. 2). The highest mean final weight (48.62 ± 0.30 g) was reached in fish maintained under continuous light regime (24L:0D). Mean final weights of fish exposed to 16L:8D and control photoperiods were measured as 45.30 ± 0.20 and 41.15 ± 0.20 g, respectively. At the end of experiment, there are significant differences between photoperiods \((p < 0.05)\). Significant differences in mean body weights of photoperiod groups and control were only detectable during the second month (days 30–60) of the experiment. Throughout this stage, mean body weight of fish at constant light regime (24L:0D) was significantly different and higher than that of other photoperiod regime (16L:8D) and control \((p<0.05)\). Moreover, mean body weights of fish exposed to 16L:8D photoperiod groups were also found to be significantly different from that of control during this development stage (Table 1).

<table>
<thead>
<tr>
<th>Time (day)</th>
<th>24L:0D</th>
<th>16L:8D</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (initial)</td>
<td>5.00 ± 0.02</td>
<td>5.00 ± 0.02</td>
<td>5.00 ± 0.02</td>
</tr>
<tr>
<td>10</td>
<td>7.31 ± 0.12(^a)</td>
<td>7.24 ± 0.11(^a)</td>
<td>7.10 ± 0.11(^a)</td>
</tr>
<tr>
<td>20</td>
<td>10.69 ± 0.21(^a)</td>
<td>10.48 ± 0.15(^a)</td>
<td>10.07 ± 0.14(^a)</td>
</tr>
<tr>
<td>30</td>
<td>15.63 ± 0.25(^a)</td>
<td>15.17 ± 0.15(^a)</td>
<td>14.29 ± 0.15(^a)</td>
</tr>
<tr>
<td>40</td>
<td>22.86 ± 0.28(^a)</td>
<td>21.96 ± 0.20(^a)</td>
<td>20.28 ± 0.19(^a)</td>
</tr>
<tr>
<td>50</td>
<td>33.43 ± 0.31(^a)</td>
<td>31.80 ± 0.19(^b)</td>
<td>28.77 ± 0.19(^b)</td>
</tr>
<tr>
<td>60</td>
<td>48.62 ± 0.30(^a)</td>
<td>45.30 ± 0.20(^b)</td>
<td>41.15 ± 0.20(^b)</td>
</tr>
</tbody>
</table>

*Values in the same row with different superscripts are significantly different \((P < 0.05)\) from each other.
The results indicated that photoperiod significantly affected fish growth performance (Table 2). The long light phase (24 light hours) produced the best fish percentage weight gain (WG= 872.4 %), specific growth rate (SGR = 3.79 %), daily growth rate (DGR = 14.54 %) and growth efficiency (GE = 0.26). The control treatment produced the lowest values of weight gain (WG = 723 %), specific growth rate (SGR = 3.51 %), daily growth rate (DGR = 12.05 %) and growth efficiency (GE = 0.24). The lowest mean values of feed conversation ratio (FCR = 1.14) and condition factor (K = 2.21) were observed in long light photoperiod. The highest mean values of feed conversation ratio (FCR = 1.24) and condition factor (K = 2.38) were observed in control.

![Graph showing effect of photoperiod on Nile tilapia growth](image)

**Fig. 2.** Effect of photoperiod regimes on the growth performance of Nile tilapia.

The present study demonstrated that the growth and feed efficiency of Nile tilapia were significantly affected by photoperiod. Mean final weights and growth performance (SGR, WG, DGR and GE) of fish exposed to different artificial photoperiods and ambient natural light cycle in this study (Tables 2) reveal that growth in Nile Tilapia is enhanced under constant long-day artificial photoperiods (24L:0D and 16L:8D) when compared to natural light regime. Long-day photoperiods have been reported to stimulate growth in a number of fish species (Boeuf and Le Bail, 1999; Randall et al., 2001). Biswas and Takeuchi, 2003; Biswas and Takeuchi, 2002 and Biswas et al., 2002) have similarly reported clear effect of photoperiod manipulation on growth in Nile tilapia.

The improvement in the performance of Nile tilapia the present study with increasing light period may also have been related to the reduction of standard metabolic rate. In support, Biswas et al. (2002) and Biswas and Takeuchi (2002) studied the effects of photoperiod on the metabolic rate of fed and unfed young and adult Nile tilapia. They found that metabolic rate and energy loss were negatively correlated with light periods. They concluded that Nile tilapia conserve energy when raised under photoperiods with longer light phases. However, these authors suggested that growth studies must be conducted under different photoperiod cycles in order to further evaluate the effects of photoperiod regimes on these fish. The reduction of fish metabolic rate with increasing light phases has also been reported with marine fish species (Boehlert, 1981).

**Table: 2. Effects of Photoperiod on Nile Tilapia Growth Parameters (mean ± SD)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>24L:0D</th>
<th>16L:8D</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial weight (IW), g</td>
<td>5.00 ± 0.02</td>
<td>5.00 ± 0.02</td>
<td>5.00 ± 0.02</td>
</tr>
<tr>
<td>Final weight (FW), g</td>
<td>48.62 ± 0.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45.30 ± 0.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>41.15 ± 0.20&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Weight gain (WG), %</td>
<td>872.4 ± 6.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>806 ± 4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>723 ± 4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Specific growth rate (SGR), %</td>
<td>3.79 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.67 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.51 ± 0.01&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Daily growth rate (DGR),</td>
<td>14.54 ± 0.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.43 ± 0.07&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.05 ± 0.07&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Feed conversation ratio (FCR)</td>
<td>1.14 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.19 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.24 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Condition factor (K)</td>
<td>2.21 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.32 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.38 ± 0.01&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Growth efficiency (GE)</td>
<td>0.26 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.25 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.24 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Values in the same row with different superscripts are significantly different (P < 0.05) from each other.
3.1. Effect of color light:

Data and illustrations on growth patterns of Nile tilapia exposed to three types of light colors and two long-day artificial photoperiod are presented in Tables 3 and 4 and Fig. 3 and 4. The results of experiment indicated that light colors (white, red, and blue) significantly affected fish growth performance (Table 3 and Fig. 4). The highest mean final weight (56.89 ± 0.4 g) was reached in fish maintained under blue light and continuous light regime (24L:0D). While the mean final weight for fish exposed to blue light and 16L:8D was 49.52 ± 0.4 g. Mean final weights of fish exposed to white and red light under 24L:0D cycle were 48.62 ± 0.3 g and 51.81 ± 0.5 g respectively. On the other hand, the mean final weight of fish exposed to white and red light under 16L:8D cycle were 45.3 ± 0.2 g and 47.89 ± 0.4 g respectively. There are significant differences between light colors (p < 0.05). Throughout this experiment, mean body weight of fish at blue light was significantly different and higher than that of other light colors (p < 0.05) both at two photoperiods (Table 3).

<table>
<thead>
<tr>
<th>Time (day)</th>
<th>24L:0D</th>
<th>16L:8D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>white</td>
<td>red</td>
</tr>
<tr>
<td>0 (initial)</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>10</td>
<td>7.31</td>
<td>7.38</td>
</tr>
<tr>
<td>20</td>
<td>10.69</td>
<td>10.91</td>
</tr>
<tr>
<td>30</td>
<td>15.63</td>
<td>16.11</td>
</tr>
<tr>
<td>40</td>
<td>22.86</td>
<td>23.79</td>
</tr>
<tr>
<td>50</td>
<td>33.43</td>
<td>35.14</td>
</tr>
<tr>
<td>60</td>
<td>48.62</td>
<td>51.81</td>
</tr>
</tbody>
</table>

The results indicated that light colors significantly affected fish growth performance (Table 4). The blue light was better than other colors lights, both at different photoperiods. The blue light and long light phase (24 light hours) produced the best fish percentage weight gain (WG = 1037.8 %), specific growth rate (SGR = 4.05 %), daily growth rate (DGR = 17.3 %) and growth efficiency (GE = 0.29). On the other hand, the blue light and light cycle 16L:8D gave weight gain (WG = 890.4 %), specific growth rate (SGR = 3.82 %), daily growth rate (DGR = 14.84 %) and growth efficiency (GE = 0.27). The lowest mean values of feed conversion ratio (FCR = 1.04) was observed in blue light and long light photoperiod. The highest mean values of feed conversion ratio (FCR = 1.19) was observed in blue light and 16L:8D light cycle.

Fig. 3. Effect of light color on the growth performance of Nile tilapia.
The present study demonstrated that the growth and feed efficiency of Nile tilapia were significantly affected by light colors. Mean final weights and growth performance (SGR, WG, DGR and GE) of fish exposed to different light colors in this study (Tables 4) reveal that growth in Nile Tilapia is enhanced under blue light when compared to white and red lights. Light colors have been reported to stimulate growth in a number of fish species (Ruchin, 2004; Marchesan et al., 2005; Strand et al., 2007 and Luchiari and Freire, 2009).

Table 4. Effects of Photoperiod and Light Color on Nile Tilapia Growth Parameters (mean ± SD)

<table>
<thead>
<tr>
<th>Light cycle</th>
<th>Parameters</th>
<th>Light color</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial weight (IW), g</td>
<td>White</td>
<td>5.00 ± 0.02</td>
<td>5.00 ± 0.02</td>
</tr>
<tr>
<td>24L:0D</td>
<td>Final weight (FW), g</td>
<td>Red</td>
<td>48.62 ± 0.315</td>
<td>51.81 ± 0.55</td>
</tr>
<tr>
<td></td>
<td>Weight gain (WG), %</td>
<td>Blue</td>
<td>872.4 ± 6.1^a</td>
<td>936.2 ± 10^b</td>
</tr>
<tr>
<td></td>
<td>Specific growth rate (SGR), %</td>
<td></td>
<td>3.79 ± 0.01^a</td>
<td>3.9 ± 0.01^ab</td>
</tr>
<tr>
<td></td>
<td>Daily growth rate (DGR),</td>
<td></td>
<td>14.54 ± 0.1^a</td>
<td>15.6 ± 0.16^a</td>
</tr>
<tr>
<td></td>
<td>Feed conversation ratio (FCR)</td>
<td></td>
<td>1.14 ± 0.01^a</td>
<td>1.1 ± 0.01^a</td>
</tr>
<tr>
<td></td>
<td>Condition factor (K)</td>
<td></td>
<td>2.21 ± 0.02^a</td>
<td>2.25 ± 0.02^a</td>
</tr>
<tr>
<td></td>
<td>Growth efficiency (GE)</td>
<td></td>
<td>0.26 ± 0.01^a</td>
<td>0.27 ± 0.01^a</td>
</tr>
<tr>
<td>16L:8D</td>
<td>Initial weight (IW), g</td>
<td>White</td>
<td>5.00 ± 0.02</td>
<td>5.00 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>Final weight (FW), g</td>
<td>Red</td>
<td>45.3 ± 0.2</td>
<td>47.89 ± 0.4</td>
</tr>
<tr>
<td></td>
<td>Weight gain (WG), %</td>
<td>Blue</td>
<td>806 ± 4^a</td>
<td>857.8 ± 8^b</td>
</tr>
<tr>
<td></td>
<td>Specific growth rate (SGR), %</td>
<td></td>
<td>3.67 ± 0.01^a</td>
<td>3.77 ± 0.01^a</td>
</tr>
<tr>
<td></td>
<td>Daily growth rate (DGR),</td>
<td></td>
<td>13.43 ± 0.07^a</td>
<td>14.3 ± 0.13^a</td>
</tr>
<tr>
<td></td>
<td>Feed conversation ratio (FCR)</td>
<td></td>
<td>1.19 ± 0.01^a</td>
<td>1.15 ± 0.01^a</td>
</tr>
<tr>
<td></td>
<td>Condition factor (K)</td>
<td></td>
<td>2.32 ± 0.01^a</td>
<td>2.28 ± 0.02^a</td>
</tr>
<tr>
<td></td>
<td>Growth efficiency (GE)</td>
<td></td>
<td>0.25 ± 0.01^a</td>
<td>0.26 ± 0.01^a</td>
</tr>
</tbody>
</table>

*Values in the same row with different superscripts are significantly different (P < 0.05) from each other.

It has been suggested that freshwater fish species are more sensitive to photoperiod than marine and diadromous species (Imsland et al., 1995). However, the response of marine species to photoperiods has been well investigated, while less information is available on freshwater species.

In conclusion, the present results revealed that photoperiods and color light were significantly affect the growth of Nile tilapia. A 24L:0D cycle and blue light were suggested for optimal performance of fish. These results have a significant application in tilapia aquaculture in indoor recirculating systems, as they improve our understanding of the role that photoperiod and light color plays in fish growth and metabolism. Adopting the optimum photoperiod in case of tilapia will also reduce the amount of energy used for standard metabolism, and in turn increase fish growth and profitability (El-Sayed and Kawanna, 2004).
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