OPTIMUM LIGHT WAVELENGTH AND LIGHT INTENSITY FOR THE SURVIVAL AND GROWTH OF JUVENILE OF ARFICAN CATFISH, *CLARIAS GARIEPINUS*

BY

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A thesis submitted in fulfilment of the requirement for the degree of Master of Science (Biotechnology)

Kulliyyah of Science
International Islamic University Malaysia

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ABSTRACT

The survival and growth rates of African catfish (*Clarias gariepinus*) were reported to be affected by light conditions. Most of the previous studies on African catfish had focused on the effects of light intensities, but the effects of light wavelengths are still poorly understood. Thus, the objectives of this study were to investigate the effect of different light wavelengths and light intensities on African catfish juveniles. In this study, three experiments were conducted which are rearing, behaviour and cortisol experiment. For fish rearing experiment, African catfish juveniles were reared for 14 days under five different light wavelengths (white, blue, green, yellow, and red) and three different light intensities (1.40, 0.014, and 0.0014 µmoles/m²/s) to determine their survival rates, growth rates, and production index. For the second experiment, the behaviour of the juveniles under different light and light wavelengths and light intensities were observed. Two types of behaviour (fish resting activities and fish biting activities) were analysed to determine the level of fish aggressiveness. For the third experiment, the cortisol levels of the juveniles were analysed using ELISA kit. The purpose of this experiment is to determine the stress level of the fish under different light conditions. Regarding the effects of light wavelengths, the juvenile showed the highest growth rates when reared under yellow light wavelength. Besides that, the lowest biting activities were observed when the juveniles reared under yellow light wavelength. Although the juveniles’ cortisol level under yellow light wavelengths was slightly higher than the juveniles reared under blue light wavelength, the increase in cortisol level were able to promote the juveniles’ feed intake, thus increasing their growth rates. Regarding light intensities, the results showed that light intensity had significant effect on the behaviour and the cortisol level of the juveniles. The juveniles reared under light intensity of 0.0014 µmoles/m²/s has lower aggressive behaviour and cortisol level than the juveniles reared under 1.40 µmoles/m²/s. However, there was an interaction between light wavelengths and light intensities. The juveniles reared under white light wavelength showed the highest growth rates at a light intensity of 0.0014 µmoles/m²/s, in contrast, the juveniles reared under yellow light wavelength showed the highest growth rates at a light intensity of 1.40 µmoles/m²/s. These indicate the effect of light wavelengths on the juveniles was differed under different light intensities. Among fifteen light conditions experimented, the juveniles showed the highest growth rates and production index and the lowest aggressive behaviour when reared under yellow light wavelength of 1.40 µmoles/m²/s. Therefore, rearing of African catfish juveniles under yellow light wavelength of 1.40 µmoles/m²/s is recommended.
خلاصة البحث

إن معدلات بقاء ونمو سمك السلّور الأفريقي (Clarias gariepinus) تتأثر، وفق آخر الدراسات، بحالات الضوء. ركزت معظم الدراسات السابقة على آثار شدة الضوء، ولكن آثار الأطوال الموجية للضوء لا تزال غير مفهومة. ولذلك هدف هذا البحث على دراسة آثار الأطوال الموجية المختلفة وشدة الضوء على صغار سمك السلّور الأفريقي. قامت هذه الدراسة على ثلاث استراتيجيات وهي تجربة التربية، والسلوك، والكيرتولا. تجربة التربية على صغار أسماك السلّور الإفريقية (متوسط الطول الكلي = 26.0 ± 5.0 سم، ومتوسط وزن الجسم = 0.15 ± 0.04 جم) لمدة 14 يومًا تحت خمسة أطوال موجية مختلفة (أبيض، أزرق، أخضر، أصفر، أحمر) وثلاثة مستويات مختلفة من شدة الضوء (1.4، 0.014، و0.0014 ميكرومول/م2 ثانية). وتم تحليل نوعين من السلوك (سلوك الراحة والسلوك العضوي) لتحديد مستوى عدوانية الأسماك. مع ذلك، كانت الأطوال الموجية بألوان الأصفر أظهرت أدنى مستوى لمستوى الكيرتولا، حيث أظهرت الأسماك أعلى معدلات للنمو عند الشدة الضوئية 1.40 ميكرومول/م2 ثانية. ومع ذلك، كانت هناك تداخل بين الأطوال الموجية وشدة الضوء. أظهرت الأسماك التي تم تربيتها تحت الأطوال الموجية الأحمر أعلى معدلات لنمو تحت الشدة الضوئية 0.0014 ميكرومول/م2 ثانية. وعلى النقيض من ذلك، أظهرت الأسماك التي تم تربيتها تحت الأطوال الموجية الأبيض أعلى معدلات لنمو تحت الشدة الضوئية 1.40 ميكرومول/م2 ثانية. ويرفض ذلك إلى اختلافات في الأطوال الموجية أو انخفاض في الشدة الضوئية. بين خمسة عشر حالة شديدة التي تم توريدها. أظهرت صغار سمك السلّور الإفريقية أعلى معدلات نموًا، ومصدر إنتاج، وأدنى سلوك عند تربيتها تحت الأطوال الموجية الأصفر وبقيادة 1.40 ميكرومول/م2 ثانية. لذلك، تنص هذه الدراسة على أن صغار سمك السلّور الإفريقية تحت الأطوال الموجية الأصفر وبقيادة 1.40 ميكرومول/م2 ثانية.
I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Biotechnology)

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DECLARATION

I hereby declare that this thesis is the result of my own investigation, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Muhammad Firdaus bin Sallehudin

Signature…………………….. Date …………………
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Dedicated to my family and friends

For outstanding support and loves

Thank you Allah
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Equation 3.2  
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Equation 3.3  
\[ SGR = \frac{(\ln BW_f - \ln BW_i)}{D} \times 100 \]  30

Equation 3.4  
\[ PI = \frac{(BW_f - BW_i)}{D \times S} \]  31

Equation 3.5  
Average number of resting activities per minute  34

\[ = \frac{\text{total number of resting activities each minute for 30 minutes}}{30} \]

Equation 3.6  
Average number of biting activities per minute  35

\[ = \frac{\text{total number of resting activity each minute for 30 minutes}}{30} \]

Equation 4.1  
\[ y = -0.139x + 1.4994 \]  53
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>UV</td>
<td>Ultraviolet</td>
</tr>
<tr>
<td>ELISA</td>
<td>Enzyme-linked immunosorbent assay</td>
</tr>
<tr>
<td>LED</td>
<td>Light emitting diodes</td>
</tr>
<tr>
<td>CCD</td>
<td>Charge-coupled device</td>
</tr>
<tr>
<td>ADL</td>
<td>Average daily length gains</td>
</tr>
<tr>
<td>SGR</td>
<td>Specific growth rates</td>
</tr>
<tr>
<td>PI</td>
<td>Production index</td>
</tr>
<tr>
<td>PBS</td>
<td>Phosphate buffered saline</td>
</tr>
<tr>
<td>Rpm</td>
<td>Rotation per minute</td>
</tr>
<tr>
<td>HRP</td>
<td>Horseradish peroxidase</td>
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<tr>
<td>TMB</td>
<td>Tetramethylbenzidine</td>
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<table>
<thead>
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<tr>
<td>%</td>
<td>Percent</td>
</tr>
<tr>
<td>°C</td>
<td>Degree Celsius</td>
</tr>
<tr>
<td>μmoles/m²/s</td>
<td>Micromoles per square metre per second</td>
</tr>
<tr>
<td>μL</td>
<td>Microlitre</td>
</tr>
<tr>
<td>cm</td>
<td>Centimetre</td>
</tr>
<tr>
<td>g</td>
<td>Gram</td>
</tr>
<tr>
<td>Kg</td>
<td>Kilogram</td>
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<td>L</td>
<td>Litre</td>
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<td>M</td>
<td>Metre</td>
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<td>ml</td>
<td>Millilitre</td>
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<td>nm</td>
<td>Nanometre</td>
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<tr>
<td>ng</td>
<td>Nanogram</td>
</tr>
<tr>
<td>pg/g</td>
<td>Picogram per gram</td>
</tr>
<tr>
<td>Ppt</td>
<td>Parts per thousand</td>
</tr>
<tr>
<td>Rpm</td>
<td>Rotations per minute</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>SE</td>
<td>Standard error</td>
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CHAPTER ONE
INTRODUCTION

1.1 RESEARCH BACKGROUND

The human population in the world is growing at a breath taking pace. It is estimated that in the year of 2050, human population will reach 9.6 billion (Food and Agriculture Organization (FAO), 2010). As the global population increase, the demand for food will also be increased. One of the most promising sources of food is fish as it is widespread, affordable, and a healthy source of protein. Food and Agriculture Organization (FAO) of the United Nations stated that fish contributed about 17% of global population intake of animal protein consumed. However, in recent years, the amount of wild-captured fish is decreasing which indicate that the fish stocks have approached or even exceeded the point of maximum sustainable yield. Dramatic increase of human pollution, harmful fishing technique and overfishing have further decline the fish stocks (Beveridge et al., 2013). Aquaculture therefore remains the only viable alternative for increasing fish production in order to meet the protein need of the people (Adewumi & Olaleye, 2011). Thus, it is important to keep improving the culturing system used to prepare for the expected increase in the demand of the fish.

The African catfish *Clarias gariepinus* is one of the essential species for aquaculture throughout the world. This freshwater fish is currently being intensively cultured in developing countries such as Mali, Ghana, Nigeria, and South Africa (De Graaf & Janssen, 1996). Its rapid growth, tasty flesh, and the fish abilities to withstands disease and poor water quality make African catfish an excellent candidate
for aquaculture (Adamek, Kamler, & Epler, 2011; Adewolu, Adeniji, & Adejobi, 2008; Appelbaum & Kamler, 2000). However, the main problem in culturing this fish species is inadequate supply of fish seed to fish farmers due to large-scale mortalities of fish that occur in the early life stages (Appelbaum & Kamler, 2000). High mortality during larvae and juveniles stages of African catfish is mainly associated with the fish aggressive behaviour (Appelbaum & Kamler, 2000). It has been reported that the aggressive behaviour of African catfish contribute to 70 – 83% of total mortality accumulated during 46 – 50 days of rearing (Appelbaum & Damme, 1988; Appelbaum & Kamler, 2000; Hecht & Appelbaum, 1987).

To increase the production of the fish, it is important to improve the fish culture method. Providing optimum environmental conditions in fish rearing facilities can improve the survival and growth of the fish. One of the environmental conditions that can influence fish survival and growth rates is lighting condition (Shin, Lee, & Choi, 2012; Delabbio, 2015; Boeuf & Le Bail, 1999). Light environment in aquatic habitats are quite different from those on the land (Chang et al., 2009). In aquatic environment, light is attenuated by both scattering and absorption; as a result, the intensity of light is reduced with increasing water depth. Besides that, the wavelengths of light are absorbed selectively dependent on the optical properties of the water. In clear ocean water, the wavelength that is best transmitted is 470 - 480nm, while near the coast is 500 - 530nm and in the freshwater is 550 - 560nm or longer (Bone et al., 1995).

The effects of light intensity on the survival and growth of larvae and juveniles has been studied in flatfish larvae (Bone, Marshall, & Blaxter, 1995), cod larvae (Huse, 1994), Australian giant carb larvae (Gardner & Maguire, 1998), larval haddock (Downing & Litvak, 2001), Atlantic cod larvae (Puvanedran & Brown, 2002), sea
bass post-larvae (Cuvier-Péres, Jourdan, Fontaine, & Kestemont, 2001), and juvenile haddock (Tripple & Neil, 2002). Light intensity was also reported to affect swimming activity (Petrell & Ang, 2001), aggressive behaviour (Hecht & Pienaar, 1993), feed intake (Mukai, Tuzan, Lim, & Yahaya, 2010), stress level (Karakatsouli et al., 2008), skin colour (Rotllant et al., 2003), physiological hormone (Boeuf & Le Bail, 1999), metabolism (Appelbaum & Kamler, 2000) and metamorphosis (Puvanedran & Brown, 2002) of the fish. Other than the intensity of the light, light wavelengths also could influence the physiology of the fish. Studies showed that different fish species require different light wavelength to optimize their survival and growth rates. For example, the optimum light wavelength for growth of Yellowtail clownfish (Shin et al., 2012) and Atlantic halibut (Sierra-flores et al., 2015) is blue and green light wavelengths, while yellow light wavelength is optimum for the growth of rainbow trout (Heydarnejad, Parto, & Pilevarian, 2013).

To optimize the condition in fish culture, light conditions including light intensity and light wavelength should be designed to address the specific light requirement of the fish under culture (Delabbio, 2015). Therefore, in this study, the effects of light intensity and light wavelengths on the survival, growth, aggressive behaviour and stress level of African catfish juveniles were examined. The data from the present study is important to determine the optimum light condition for rearing of this fish species.
1.2 PROBLEM STATEMENTS

African catfish showed high aggressive behaviour during larval and juvenile stages (Appelbaum & Kamler, 2000). This aggressive behaviour leads to low survival and growth of the fish. To increase the survival and growth rates of the fish, African catfish juveniles should be reared under its optimal environment conditions. According to Boeuf & Le Bail, (1999), light intensities and light wavelengths could affect the growth and survival of the fish. Additionally, the effect of light conditions on fish is dependent on fish species and fish developmental stages. Previous studies on the effect of light intensity on African catfish showed that the larvae have low aggressive behaviour when reared under low light intensity (Mukai et al., 2013). In another study, the larvae showed higher survival and growth rates when reared under continuous dark condition (Appelbaum & Kamler, 2000). At present, the studies on the effect of light conditions on African catfish were mostly focused on the effect of different light intensities (Almazán-Rueda, Schrama, & Verreth, 2004; Britz & Pienaar, 1992; Hossain, Beveridge, & Haylor, 1998; Mukai & Lim, 2011; Mukai et al., 2013), thus, the information on the effects of different light wavelengths on the survival and growth rates of the African catfish are still inadequate. Therefore, present study was conducted to examine the effects of different light wavelengths and light intensities on the survival rate, growth rate, behaviour and stress level of the juveniles of African catfish.

1.3 RESEARCH OBJECTIVES

1.3.1 General Objective

To determine the optimum light wavelength and light intensities for the survival and growth of African catfish juveniles.
1.3.2 Specific Objectives

- To determine the survival rates, growth rates and production index of African catfish juveniles under different light wavelengths and intensities.
- To determine the fish aggressive behaviour of African catfish juveniles under different light wavelengths and intensities.
- To determine the stress level of African catfish juveniles under different light wavelengths and intensities.

1.4 SIGNIFICANCE OF STUDY

This experiment is essential to determine the optimum light wavelength and light intensity for African catfish rearing. By obtaining the optimum light condition for rearing of juvenile African catfish, the survival and growth of this fish species could be increased. The results from this experiment shall then be used by farmers to increase the production of African catfish at juvenile stages.

1.5 RESEARCH HYPOTHESIS

i. Survival and growth rates of the African catfish juveniles will be higher under the optimum light wavelength and light intensity.

ii. Under optimum light wavelength and light intensity, African catfish juveniles will have less aggressive behaviour.

iii. Lower cortisol level will be observed when juvenile African catfish is reared under optimum light wavelength and light intensity.
CHAPTER TWO
LITERATURE REVIEW

2.1 AFRICAN CATFISH BIOLOGY

2.1.1 Taxonomy and Morphology of African Catfish

Taxonomic study conducted by Teugels (1996) listed about 33 families with 412 genera and 2584 species of catfish. One of the catfish species that is economically important in the world is African catfish. The African catfish belongs to the family of Clariidae and genus of Clarias. There are two species under this genus which are C. anguillaris and C. gariepinus (Teugels & Adriaens, 2003).

<table>
<thead>
<tr>
<th>Kingdom: Animalia</th>
</tr>
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<tbody>
<tr>
<td>Phylum: Chordata</td>
</tr>
<tr>
<td>Class: Actinopterygii</td>
</tr>
<tr>
<td>Order: Siluriformes</td>
</tr>
<tr>
<td>Family: Clariidae</td>
</tr>
<tr>
<td>Genus: Clarias</td>
</tr>
<tr>
<td>Species: C. gariepinus</td>
</tr>
</tbody>
</table>

**Figure 2.1:** Scientific classification of African catfish, *C. gariepinus* (Teugels, 1996)

The external morphology of African catfish is characterized by elongated cylindrical body, flattened head and darkly pigmented body with scale-less skin. It has dorsal and anal fins that made of soft rays that elongate nearly reaching the caudal fin while the pectoral fin has a strong spine. In addition, they have four pairs of barbels that primarily function as prey detection. Apart from that, African catfish has
suprabranchial organs that enable it to utilize the atmospheric air. The sexual characteristic of African catfish is easily distinguished as the male has distinct sexual papilla that is located behind the anus whereas it is absent in females (De Graaf & Janssen, 1996).

Figure 2.2: Morphological characteristics of African catfish, *C. gariepinus* (De Graaf & Janssen, 1996)
2.1.2 Geographical Distribution, Habitat and Production of African Catfish

The African catfish is widely distributed in Africa. Its native range extends from South Africa through Central, West and North Africa into the Middle East and Eastern Europe (Food and Agriculture Organization (FAO), 2010). This fish species is aneurytopic species that inhabit varieties of inland waters including streams, lakes, rivers, swamps, and floodplains (Akeem Saka, 2015; Marimuthu, Cheen, Muralikrishnan, & Kumar, 2010; Bruton, 2010). Besides that, African catfish is adaptive to extreme environmental conditions (Bazyli, Ewa, Adrianna, & Janusz, 2013). It can survive in wide range of water temperature (8-35 °C) (Teugels, 1989), pH (6.5 - 8.0) (Ndubuisi, Chimezie, Chinedu, Chikwem, & Alexander, 2015) and salinity (0 - 10 ppt) (Teugels, 1989). Moreover, this fish also can live in very turbid and poorly oxygenated water which is uninhabitable by other fish species (Mustapha, Okafor, Olaoti, & Oyelakin, 2012; Nwakanma & Okwum, 2016).

During 1980s, African catfish is introduced throughout Asia, Europe and South America for fish farming purposes (Food and Agriculture Organization (FAO), 2010). In Asia, African catfish are cultured mainly in Thailand, The Philippines, China, Indonesia and Malaysia. In Europe, this fish species are being farm in countries like Netherland, Germany and Belgium whereas in South America, this fish species are mainly produced in Brazil (Marimuthu et al., 2010). According to the production statistics from FAO (Figure 2.3), the global aquaculture production of African catfish is increasing rapidly from 8,133 tons in 2001 to 213,862 tons in 2013 (Fisheries and Aquaculture Department, 2017). The production of African catfish is expected to be higher in the future as the human population increases in the future.