Effects Of Background Tank Colour On The Growth And Survival Of Juvenile *Heterobrachus Bidorsalis* Fed Four Formulated Fish Feed.

Solomon, R.J. And Ezigbo, M. N

Department Of Biological Sciences, Faculty Of Science, University Of Abuja, Abuja, Nigeria.

Abstract: A 6-month semi-intensive mono-culture experiment was conducted to determine the effects of different tank colours /feed types on the production of *Heterobranchus bidorsalis* juveniles of average weight (0.68g±0.25g). Five culture tank with different colours made of plastic material, having the same surface area and volume were used. The fish were fed 45% protein of four different meals (coppens commercial floating pellets, *Cyperus esculentus* meal, *Tamarindus indica* meal and *Digitaria exilis* meal) at 10% body weight twice daily throughout the experimental period. Production parameters were used to determine growth (feed utilization) as well as survival rate with coppens feed producing the best overall results for growth. There was significant relationship ($P < 0.05$) in growth parameters of the fish in all the treatments. However, the best overall results were obtained in black tanks for all feed types compared to other tank colours as well as survival rate which has advantages for fish culture compared to other colours.

[Solomon, R.J. And Ezigbo, M. N. **Effects Of Background Tank Colour On The Growth And Survival Of Juvenile *Heterobrachus Bidorsalis* Fed Four Formulated Fish Feed..** *Academ Arena* 2018;10(3):34-58]. ISSN 1553-992X (print); ISSN 2158-771X (online). http://www.sciencepub.net/academia. 4. doi:10.7537/marsaaj100318.04.

Keywords: Effect; Background Tank; Colour; Growth; Survival Of Juvenile; *Heterobrachus Bidorsalis;* Fed Four Formulated; Fish Feed

Introduction

Aquaculture Systems.

Fish farming has become a worldwide practice and has been for years. This is the growing and cultivation of different species of fish including other aquatic animals for various purposes such as, feeding, decoration, ornamental and for advanced research. Fish farming also known as Aquaculture plays a major role in Agriculture in Africa and especially in Nigeria. This could be practiced in their natural habitat or artificial methods, most especially to boost fish productivity in Nigeria and the world as a whole. Artificial fish farming could be carried out with the use of ponds, tanks and aquariums, making available facilities which will enhance fish growth.

Intensively reared fish may often be subjected to several chronic and acute stressors of endogenous (e.g. social interactions) or exogenous (e.g. unfavourable water quality, high densities, grading, handling) origin that may have detrimental effects on fish welfare and growth especially when imposed together (Huntingford *et al*., 2006).

The African catfish is commonly used in homestead fish culture because it takes up oxygen from the air, has a high growth rate and is often disease resistant (Eyo, 1997). *Heterobranchus bidorsalis* species are very popular with fish farmers, and command a very good commercial price in Nigerian markets (Oladosu *et al*., 1993; and Ayinla *et al*., 1994). In the long run homestead fish pond will enable fish culturists and the entire country to be fish protein sufficient. Furthermore, excess production will be sold to non-producers and income so generated will be used to meet other domestic needs. Anetekhai *et al*. (2004) observed that additional income can be generated at homes through homestead aquaculture. However, Omitoyin, (2005) observed that some major problems militating against mass production of catfish in Nigeria are inadequate supply of fingerlings, lack of quality brood stock and disease outbreak among others. With the present government initiative in aquaculture development in Nigeria, more intensive and semi-intensive commercial fish farms and hatcheries are fast developing.

The future of aquaculture in Africa lies in increasing production efficiencies and intensities so as to produce more fish using less land, water and financial resources (Jamu and Ayinla, 2003). Hunger and poverty are among the challenges facing African society today. These arise from the ever increasing cost of food, especially dietary fish protein.

The declining production of fish from rivers and lakes as well as the subsistence level of aquacultural development are some of the reasons for these problems. Intense aquaculture of local species using simple, low-cost technology could provide a ready solution to overcome these challenges.

Clariidae catfishes (*Clarias spp* and *Heterobranchus spp.*), are the most widely cultured fish and are suited to low-technology farming systems in many other developing countries because of their fast growth rate, efficient use of natural aquatic foods propensity to consume a variety of supplementary feeds, omnivorous food habits, resistance to disease and handling, ease of reproduction in captivity and tolerance to wide ranges of environmental conditions. Catfish grows fast, commands high market value, hardy and can survive where most other cultivable species cannot. Fish supplies over 50% of the total animal protein consumed in developing countries and less so in developed countries (Ayoola and Fredrick, 2010).

Colour as a Rearing Condition.

Lighting is one of the rearing conditions that can be easily manipulated in aquaculture and most of the related research papers are focused on photoperiod and intensity (Boeuf and Le Bail, 1999). To our knowledge only a limited number of studies are related to coloured light effects on fish stress response either to chronic stressors such as daily disturbance (Head and Malison, 2000) and high density (Salm *et al*., 2004 a and b) or to acute stressors such as confinement (Volpato and Barreto, 2001) and chasing (Barcellos *et al*., 2006). Although mechanisms involved are not yet elucidated, the above-mentioned studies indicate that light spectrum can differentiate fish stress response (evaluated by plasma cortisol levels) and may be a useful means to alleviate adverse effects of stress. It has been previously reported that rearing of rainbow trout *Oncorhynchus mykiss* for 11 weeks under blue light (480 nm) had negatively affected growth and led to increased brain neurotransmitters indicating that blue light was perceived as stressful (Karakatsouli *et al*., 2007a). In that experiment light intensity was 300 lx and although red light seemed to improve fish performance it was not possible to distinguish significant differences compared to white light.

In nature, light intensity and background color can affect feed detection, feed conversion rate and feeding success of cultured fish. Therefore, all these factors can affect the fish growth and mortality (Henne and Watanabe, 2003). Under culture conditions, tank color and light intensity can cause stress to the fish (Rotllant *et al.,* 2003; Papoutsoglou *et al.,* 2005) resulting in behavioural changes such as swimming performance, activity level, and habitat utilization (Mesa and Schreck, 1989; Schreck *et al*., 1997). The common colors of the surrounding environment of fish are blue, green or near infrared (Levine and MacNichol, 1982). Very few studies have been conducted to understand the effects of background or light color on fish biology except for change in fright reaction, color attractiveness, survival, and growth rate (Tamazouzt *et al*., 2000). The effect of environmental color on animal physiology and behavior is a developing field. As in earlier studies, environmental color showed both improvement and disruption of fish condition factor. Therefore, these studies support initiation of investigations on this type of studies for better understanding of the factors affecting the fish health and condition factor. The environment surrounding the fish habitat comprises a wide range of colours which the fish can distinguish. A wide range of production systems have been exploited for culturing fish. These systems include: cages, raceways, tanks and ponds. Culture in earthen ponds remains the dominant production system in Nigeria.

With increased urbanization and the attendant increase in fish demand, large expanse of land required for intensive aquaculture in earthen ponds is becoming seemingly unavailable in many areas. Similarly, earthen pond system of production is characterized with low productivity. Therefore, for Nigeria to make significant contribution in aquaculture at a global level and meet her Millennium Development Goals (MDGs) of increasing fish production by over 250% by 2015, efforts need to be geared towards achieving higher production intensities. One way of achieving this is through encouraging urban aquaculture systems. This system of production makes use of varieties of water and culture facilities that provide needed environment for the growth of the fish. Many researchers have studied the effects of tank volumes in relation to growth performance of fish (Gonzalez *et al.,* 1997). However, effects of tank configurations on the performance of the fish have not been adequately investigated. The fact that a vessel holds water does not necessarily make it a good fish-rearing habitat.

In aquaculture ponds, growth rates of fish are related to a variety of factors, such as stocking density, nutrition, water quality, and health. In the case of indoor recirculating water systems, producers attempt to maximize productivity by optimizing the above parameters, as well as other aspects of the environment. Several studies now suggest that the color of indoor tanks should also be considered for improved animal health and performance in indoor systems. (Papoutsoglou, 2001). One of the environmental factors that may influence fish performance in culture is environmental color (Brännäs *et al*., 2001). In nature, light intensity and background color can affect feed detection, food conversion rate and feeding success of cultured fish, thus influencing fish growth and mortality (Henne and Watanabe, 2003). Furthermore, tank color and light intensity can contribute to fish stress (Rotllant *et al*., 2003; Papoutsoglou *et al*., 2005), which may affect their behavior by altering swimming performance, activity levels and habitat utilization (Mesa and Schreck, 1989; Schreck *et al*., 1997). Very few studies have been conducted to understand the effects of background or light color on fish biology, in some fish families, effects of environmental color have been described, such as changes in fright reaction, color attractiveness, survival and growth rate (Tamazouzt *et al*., 2000). The effect of environmental color on animal physiology and behavior is a developing field. As in earlier studies, environmental color showed both improvement and disruption of fish welfare. These findings are supporting the rising interest to investigate and get a better understanding of the effects of such related rearing conditions on fish performance. Thus, in fisheries, the environmental conditions should definitely be monitored to guarantee improved fish welfare.

Diet as a Rearing Condition.

The over-exploitation of fish resources and the ever increasing protein demand by the world population have posed problems to the fish supply from natural waters. The supply of protein foods in Africa is very expensive, a problem that needs to be tackled very seriously, considering the limited available resources (Gabriel *et al*., 2007). Faced with a supply constraint, attention has now been drawn to aquaculture as a means to combat protein malnutrition in the developing countries. Fish production is relatively inexpensive when compared with other sources of animal protein such as cattle, pig and poultry their productions are very expensive due to low level of technology and poor pasture lands (Ayoola, 2010). Among the prerequisites for successful fish farming is the availability of suitable artificial feeds formulated from locally available and cheap ingredients that contain all the nutritional requirements of the fish cultured (Lovell, 1989). However, fishmeal is very scarce and when available, it is usually very expensive (Eyo, 1985). The high cost and scarcity of fish meal in formulated feeds had led to the use of other, locally available plant and animal proteins such as freshwater mussel, periwinkle, snail, crab, lizard and frog (Falaye, 1992; Fagbenro *et al*., 1993; Akegbejo-Samsons, 1999).

One of the important problems in aquaculture is the development of practical diets for the rearing of larval and juvenile organisms in order to increase growth and survival rates. The development of better feeds and their more efficient use have resulted in the production of larger fish for which there is not only a higher demand but which also command a premium price (FAO, 2010). Fish feed is responsible for 60-80% of production cost in aquaculture industry (Eyo, 2001). The high cost of fish feed has led to food insecurity for most Nigerians due to low income. Since diets generally represent the largest single cost item of most fish farm operations, it follows that the selection of feed ingredients for use within diets will play a major role in dictating the ultimate nutritional and economic success for farmed fish. Fish meal which serves as the main protein source for fish feeds due to its high quality protein is very expensive and usually unavailable particularly in developing countries (Tacon and Barg, 1998).

The Fish *(Heterobranchus bidorsalis).*

Heterobranchus is a species of catfishes with remarkable fast growth rate (Madu and Olurebi, 1987; Ayinla *et al*., 1994). Genus *Heterobranchus* can be differentiated from other Clariid catfishes by the presence of a large adipose fin that follows its spineless dorsal fin.

Plate 1: Juvenile *Heterobranchus bidorsalis.*

The family Clariidae is present in African freshwaters and extends to Syria, Southern Turkey and South-East Asia (Teugels, 1996). Fourteen genera are recognized in the family; Teugels, (1986) listed it to contain 12 African genera with 74 species and 3 Asian genera with 18 species (Teugels, 1996). Genus *Heterobranchus* contains four important species namely, *Heterobranchus bidorsalis* , *Heterobranchus longifilis, Heterobranchus isopterus* , and *Heterobranchus boulengeri* (Reed *et al*., 1967; Teugels *et al*., 1990; Teugels, 1996). The latter species presence in the genus was reported to be of great concern due to some striking different features it possesses compared with its congeners (Agnèse and Teugels, 2001). Reed *et al*. (1967) regarded *Heterobranchus isopterus* to be the about the smallest fish species in the genus and very rare to be found in local waters. *Heterobranchus* and *Clarias* are the two most economic important genera in this family. The species for this study, *Heterobranchus bidorsalis* is a highly economic species that performs better than other species in the family Clariidae. It is identified from its congeners by the presence of longer dorsal fin compared to its adipose fin with absence of black spot at its tail end. *Heterobranchus longifilis* and *Heterobranchus isopterus* are characterized with equal lengths of dorsal fin to adipose fin and the two can be distinguished by the absence of black spot at the end of adipose fin of latter while it is present in the former (Reed *et al*., 1967). The larger size of *Heterobranchus bidorsalis* (length = 1.2 m; weight = 30 kg) and its congener species relative to members of the genus *Clarias* proves that the former has significant potential for aquaculture (Reed *et al*., 1967). It performs well in captivity by attaining maturity in 10–12 months of domestication but 2–3 years in the wild (Fagbenro *et al*., 1993; Adebayo and Fagbenro, 2004). Also, its meat is of high quality and palatability. However, its intensive aquaculture is limited due to constraints in getting its seed from natural waters that are uneconomical and unrealistic (Adebayo and Olanrewaju, 2000; Adebayo and Fagbenro, 2004). Moreover, there is generally dearth of knowledge on the biology of this species, *Heterobranchus bidorsalis* except fewer studies on its haematological characteristics, nutritional or feeding characteristics, salinity tolerance, digestive enzymes profile, parasite fauna and induced spawning (Fagbenro *et al*., 1991, 1993; Adebayo and Fagbenro, 2004). This is due to the species' limited availability, breeding constraints of longer timed sexual maturity and short breeding period which is at the peak of the rainy season. Though the species has not been listed as endangered but there is risk of extinction because of environmental problems or effect of the breeding sites (Honji *et al*., 2009, 2012); for example, the species does not breed in the ponds but the fingerlings are sourced at the bank of large rivers (Adebayo and Olanrewaju, 2000; Adebayo and Fagbenro, 2004). Further threats are anthropogenic activities like the construction of dams, riparian habitat destruction, water pollution and fishing (Honji *et al*., 2009 and Olaniyi, 2014). Limited studies have been conducted on this species for improvement on its breeding (Adebayo and Fagbenro, 2004; Agbebi *et al*., 2005) while few studies on hybridization and growth performance in comparison with other species are just developing (Nlewadim *et al*., 2004; Akinwande *et al*., 2009; Ekelemu, 2010) and this is attributed to its defined spawning season or non-spontaneous breeding system, reproductive dysfunction, poor technical/breeding knowledge, breeding and/or artificial propagation constraints and very few biological studies. Therefore, efforts need to be made to find alternatives to high cost feeds for the growth of *Heterobranchus sp* fingerlings under intensive culture system.

Tank Colour and Fish Behavior.

Different colors have different contrasts against background colour and influence the efficiency of detecting and catching the feeds by sight. A high contrast leads to higher visibility of feeds and better feed consumption (McLean *et al*., 2008). Despite colour having a profound impact on fish behavior and biological functioning, the compatibility of fish with tank colour has been largely neglected within the aquaculture industry. While it is possible to have tanks manufactured in any colour, in North America, the most popular colour of tank for fish aquaculture is light blue. The origin of this colour selection is unclear but likely took place without any considerations of fish preferences (McLean *et al*., 2008).

Justification of Research.

Duray *et al*. (1996) studied the effect of background color and rotifer density on rotifer intake, growth and survival of the grouper (*Epinephelus suillus*) larvae and Papoutsoglou *et al*. (2000) experimented on the effects of background color on growth performances and physiological responses of scaled carp (*Cyprinus carpio L.*) reared in a closed circulated system and but there are no previous works showing the relationship between background colours of tanks and feed types on the growth and survival of *Heterobranchus bidorsalis*.

Tank Colour in Relation to Stress and Growth.

A number of studies have demonstrated that various coloured tank lights impact fish stress responses and growth. An experiment conducted by Volpato and Barreto, (2001), for example, exposed groups of Nile tilapia (*Oreochromis niloticus*) to green, blue, and white coloured environments. In contrast, Karakatsouli and Batzina, (2012) failed to conclude whether 10 European sea bass (*Dicentrarchus labrax*) were more or less stressed in blue or white environmental light conditions. In another study by Karakatsouli (2010), the effect of white and blue lights on the growth of scaled and mirror common carp species (*Cyprinus carpio)* was compared. Results of this study showed that specific growth rate, weight gain, and feed efficiency were positively affected by red light and blue light at low and high stocking densities of scaled common carp, respectively. For mirror common carp, however, the coloured light sources did not induce many differences in growth performance. Conversely, red light, in comparison to blue, violet, green, and yellow light, limited weight gains for individually held Nile tilapia and increased weight heterogeneity for groups of Nile Tilapia (*Oreochromis niloticus)*; *(*Luchiari and Freire, 2009). Blue light was shown to have negative growth effects for rainbow trout (*Oncorhynchus mykiss*), especially after eight (8) weeks under experimental conditions, while blue light seemed to be favourable in gilthead sea bream (*Sparus aurata*) (Karakatsouli *et al*., 2007b).

Tank substrate colour has also been shown to influence fish growth. For example, the presence of blue and red-brown substrates, in comparison with green or no substrate, was shown to enhance growth in gilthead sea bream (*Sparus aurata* (Batzina and Karakatsouli, 2012). Tank wall colour has been shown to affect the stress response and growth of a number of fish. For example, Barcellos *et al*. (2006) revealed that Jundia (*Rhamdia quelen*), either in the blue or white tanks, presented similar amounts of whole-body cortisol (a glucocorticoid hormone released in response to stress) after exposure to an acute stressor (pursuit with a net for 60 seconds). However, when shelters that provided hiding places for the fish were added to the tanks, the fish kept in the blue tanks had the lowest cortisol concentrations compared to the fish kept in the white tanks after exposure to the acute stressor. Imanpoor and Abdollahi, (2011) saw a higher final body mass and a lower stress response for juvenile Caspian kutum (*Rutilus kutum)* reared in yellow tanks, as opposed to red, blue, white or black tanks. Fatollahi and Kasumyan, (2006) examined feed colour preference in the laboratory and reported a blue bias among 4-month old juvenile *Clarias gariepinus*, indicating colour vision. Light can have several life-affecting characteristics: quality (colour), quantity (intensity) and periodicity. McLean *et al*., (2008) studied the impacts of tank color on the performance of cultured fish; they examined the effect of black, green, red, dark, and light blue colored tanks on the short–term growth and feed efficiency of summer flounder and growth, feed efficiency, body composition of Nile tilapia. Cortisol response was also examined for both species. Tank color did not affect growth performance of flounder or tilapia although, fish maintained in red colored tanks returned better percent increases in weight. Differences ($P < 0.05$) in feed conversion efficiency were observed for summer flounder held in red tanks. Plasma cortisol levels in summer flounder ranged from 1.39–3.71 ng cortisol per ml, compared to 12.7–94.4 ng cortisol per ml plasma for tilapia. Lowest cortisol levels ($P < 0.05$) were detected in flounder and tilapia reared in red colored aquaria. Background color had no effects on tilapia fillet composition. Elnwishy *et al.* (2012) carried out a research on the effect of difference in environmental colors on Nile Tilapia (*Oreochromis niloticus*) production efficiency. The impacts of 37 and 45 days' exposure of fish to different colors (yellow, blue, green, red and darkness) on *Oreochromis niloticus* were evaluated. Fish showed highest growth under blue light color, followed by green while red color caused least growth in the fish. This study recommended the application of blue color lighting in aquaculture systems in order to enhance fish growth and productivity to enhance the economic efficiency of aquaculture production of tilapia in the region.

Tank Color and Environment.

The color of the environment surrounding aquatic animals raised indoors is a function of illumination (intensity, spectrum, and photoperiod) and the inside color of the tank (Papoutsoglou, 2001). Some fish species modify their skin color in response to background color and other factors. For example, a naturally dark-colored fish can quickly (within few days or even less) turn to a lighter color in a white tank. Color adaptation depends on specific neural and hormonal processes related, for example, to defense mechanisms, reproduction, inter-animal behavior, and others (Papoutsoglou, 2001). The color change is implemented through neuro-endocrine control of dispersion and aggregation of fish pigments, as well as hormonal control of the number of chromatophores and amount of pigments. Given the neural and hormonal responses elicited by background colors, it seems clear that tank color can affect fish behavior and physiology. An improper tank color might be considered a stressful condition to fish during culture. Fish stress can be classified as acute (sudden and short-term) or chronic (moderate and continuous) (Papoutsoglou, 2001). Growth suppression is mainly associated with chronic stress, while immune suppression can be associated with either acute or chronic stress (Papoutsoglou, 2001).

Reactions to Tank Color.

Studies have shown that reactions to tank color vary with the species and life stage. For example, grey to green-colored tanks have been reported to yield best results for smoltification, Batty *et al,* (1990). No clear consensus exists about the optimum color for larval-rearing tanks, despite several studies that monitored larval growth, survival, and swim bladder development. This may be due to confounding effects caused by use of different species, densities, feed types and densities, photoperiods, and light intensities.

Larvae of some species seem to prefer white or light gray. Others like black-colored tanks, while still others prefer a "green water" environment for locating food and/or maximizing swim bladder inflation.

Tank background color has been examined primarily for its effects on larval and juvenile survival, usually with respect to the feeding response (Batty, *et al.,* 1990; Pankhurst and Hilder, 1998). Different tank colors have been shown to elevate cortisol levels in red porgy (*Pagrus pagrus*) (Rottlant *et al*., 2003), and *Tilapia* (*Oreochromis niloticus*) (Merighe *et al*., 2004), and has been suggested as a stressor in white sea bream (*Diplodus sargus*) (Karakatsouli *et al*., 2007b). The particular 23 colors that elevate cortisol levels in fishes seem to be species specific however. In red porgy, white tanks produced the highest levels of cortisol (Rottlant *et al*., 2003), while carp and sea bream responded with elevated cortisol levels in black tanks (Merighe *et al*., 2004), (Karakatsouli *et al*., 2007b). *Tilapia* exhibited elevated cortisol levels in brown and blue tanks and lower levels in black, green and white tanks (Merighe *et al*., 2004). Appelbaum and Kamler, (2000) reported that *Clarias gariepinus* reared in the dark were larger than those reared in the light, while Almanzan-Rueda *et al*., (2005) showed that no light resulted in an increase growth of this species. Britz and Pienaar, (1992) also reported high rates of growth of *Clarias gariepinus* juveniles when reared under continuous darkness. The aim of the present study was to evaluate the effects of photoperiod on the growth and body coloration of juvenile *Clarias gariepinus*. This is with a view to simulating the best photoperiod for increasing production of the species from juvenile to table size in less time and with a simple, low-cost technique as well as achieving the most acceptable body coloration for the marketability and high price of the species.

Species Studied.

So far, all teleost species studied (*Anguilla anguilla*, *Salmo trutta*, *Pleuronectes americanus, Oncorhynchus mykiss, Sarotherodon mossambicus, and Zacco temmincki*) have shown skin darkening on a black background, which in most cases and under certain conditions has been associated with increased cortisol secretion. Conversely, white background color has been associated with skin lightening and diminished cortisol secretion. Also, some species (*Anguilla anguilla, Oncorhynchus mykiss*) maintained in black tanks showed increased plasma cortisol levels in response to an external stress or such as noise. These facts suggest that black tank color increases stress sensitivity, at least in those fish species studied so far. (Papoutsoglou, 2001).

Physico-chemical Parameters.

Water is the culture environment for fish and other aquatic organisms. It is the physical support in which they carry out their life functions such as feeding, swimming, breeding, digestion and excretion (Bronmark and Hansson, 2005). Based on this, access to adequate, regular and constant supply of good quality water is vital in any aquaculture project. According to Sikoki and Veen, (2004), any water body is a potential medium for the production of aquatic organisms. Water quality parameters can be divided into three main categories: physical (density, temperature); chemical (pH, conductivity, nutrients) and biological (bacteria, plankton and parasites) (Delince, 1992). All living organisms have tolerable limits of water quality parameters in which they perform optimally. A sharp drop or an increase within these limits has adverse effects on their body functions (Moody, 2004). Water quality is one of the most critical factors besides good feed/feeding in fish production. It is not constant; varies with the time of the day, season, weather conditions, water source, soil type, temperature, stocking density, and feeding rate and culture systems. For a successful aquaculture venture, the dynamics and management of water quality in culture media must be taken into consideration.

Experimental Feed Ingredients.

Tamarindus indica.

Tamarind or *Tamarindus indica* L. of the family Fabaceae, subfamily Caesalpinioideae, is an important food in the tropics. It is a multipurpose tree of which almost every part finds at least some use (Kumar and Bhattacharya, 2008), either nutritional or medicinal. Tamarind is indigenous to tropical Africa but it has been introduced and naturalized worldwide in over 50 countries. The major production areas are in the Asian countries India and Thailand, but also in Bangladesh, Sri Lanka and Indonesia. Minor producing countries in Africa are Senegal, Gambia, Kenya, Tanzania and Zambia (El-Siddig *et al*., 2006).

Food Uses.

Tamarind fruit pulp is used for seasoning, as a food component, to flavour confections, curries and sauces, and is a main component in juices and certain beverages. Tamarind fruit pulp is eaten fresh and often made into a juice, infusion or brine (El-Siddig *et al*., 1999; El-Siddig *et al*., 2006), and can also be processed into jam and sweets. The refreshing drinks are popular in many countries around the world, though there are many different recipes. In some African countries, the juice obtained from the fruit pulp is mixed with wood ash to neutralize the sour taste of the tartaric acid. However, the most common method is to add sugar to make a pleasantly acid drink. In Ghana, the pulp is mixed with sugar and honey to make a sweet drink. Most of the producing countries manufacture drinks commercially. Sometimes the pulp is fermented into an alcoholic beverage (FAO, 1998)

Nutritional composition of tamarind fruit varies considerably (El-Siddig *et al.*, 1999). However, a typical fruit contains 40% pulp (El-Siddig *et al.*, 1999). According to other authors, the fruit contains about 55% pulp, 34% seeds, and 11% shell (pod) and fibres (Kumar and Bhattacharya, 2008). However, the seeds become edible after soaking and boiling in water, which removes the seed coat (El- Siddig *et al.*, 2006). In the past, and even today, seeds have been wasted (El-Siddig *et al.*, 2006) even though they could be ground to make a palatable livestock feed (El-Siddig *et al.*, 2006). In view of the overall nutrient and chemical composition, tamarind seeds may be adopted as an inexpensive alternative protein source to alleviate protein malnutrition among traditional people living in developing countries (Siddhuraju *et al.*, 1995).

Digitaria exilis.

Hungry man rice also called acha in hausa language or fonio which is the common name is probably the oldest African cereal. It is indigenous to West Africa where it is grown for its straw and edible grains. There are two main prominent species, the white acha (*Digitaria exilis*), most widely cultivated and the black acha (*Digitaria iburua*) which is a little bigger in terms of stature and even grain size (Okoh, 1998). West Africans have cultivated it across the Dry major food crop in this region of the world. Although, the crop has been neglected for quite some time and a few people know of it, acha remains important in areas scattered from Cape Verde to Lake Chad. Consequently, the crop is popular in parts of northern Nigeria where the soil is unable to support adequate growth of some of the more popular cereals like maize, sorghum and millet (Okoh, 1998). It is commonly grown in Plateau State. They are perhaps the world's fastest maturing cereal, producing grains 6-8 weeks after they are planted. However, some varieties are late maturing from 165-180 days.

The Hausa speaking tribe prepare cous cous which is a staple meal from acha. In Togo, a famous beer (tchapalo) is brewed from it and acha is prepared with beans in a dish that is reserved for special occasions. Some people have made side-by-side comparisons of dishes made with acha and common rice and have greatly preferred acha. The grains are efficiently digested by farm animals while the straw and chaff can also be fed to farm animals. It is one of the most nutritious of all grains. In gross nutritional composition, acha differs little from wheat. Temple and Bassa, (1991) stated the proximate regions of Mali, Burkina Faso, Guinea and Nigeria; acha is either a staple or a major part of the diet.

***Cyperus esculentus* L.**

Tiger nut (*Cyperus esculentus* L.) is an edible perennial grass-like plant native to the Old World, and is a lesser-known vegetable that produces sweet nut-like tubers known as "earth almonds" (Coskuner *and Karababa*., 2005). Tiger nut is also known by various other names as chufa (in Spanish), earth nut, yellow nut sedge, groundnut, rush nut, and edible galingale (Oderinde and Tairu, 1988). Tiger nut is widely used for animal (feed) and human consumption. It is rich in energy content (starch, fat, sugar, and protein), minerals (mainly phosphorus and potassium), and vitamins E and C (Belewu and Ojo-Alokomaro, 2007). Tiger nut has been demonstrated to be a rich source of good quality oil (Dubois *et al.,* 2007) and contains a moderate amount of protein (Oladele and Aina, 2007). It is also a source of some useful minerals such as potassium and calcium as well as vitamins E and C (Belewu and Ojo-Alokomaro, 2007).

Materials And Methods

Study Area.

This was carried out at the Biological Garden of Biological Sciences Department of University of Abuja main campus which is located at Km 23, along Gwagwalada-Airport Road covering about 11,824 hectares and at latitude and longitude of $8^0$57'15" and 7^0 4'28" respectively.

Experimental Design.

The experimental design used was the Factorial Design.

Fish and Rearing Conditions.

Hatchery bred fingerlings of *Heterobranchus bidorsalis* with an average weight of 0.68g±0.25g were transported in well aerated black (50 litre) containers from Christian Association of Nigeria (CAN) fish farms in Kubwa-FCT to the Biology Department of the University of Abuja, where they were kept for seven days in the Biology Garden and deprived of feed for 24 hours for acclimatization purposes before beginning experiments.

Sampling and Measurements.

Fingerlings were randomly distributed into 20 tanks in triplicates before trials and fish samples were taken and measured throughout until the end of the experiment. The samples for the white, blue, green, yellow and black colored tanks were designated as A1, B1, C1, D1 and E1. Morphometric assessments were taken of the fish and recorded on weekly basis. The duplicate tanks were also designated as A2, B2, C2, D2 and E2 and triplicate as A3, B3, C3, D3, E3. Fish survival was monitored after each trial along with fish weight, fish length and feed intake. All fish were randomly distributed into (60) rectangular shaped plastic tanks (60×30×50 cm). Duration of trial was six (6) months between August 2015-January 2016; three (3) months of rainy season and three (3) months of dry season.

Physico-chemical Parameters.

During the experiment, temperature of each treatment was measured daily with the aid of a mercury in glass thermometer. pH meter also measured weekly with the aid of pH meter paper, Dissolved oxygen was measured by titration with 0.1 NAOH and the Azide modification of the Winkler method (American Public Health Association, 1976), Ammonia-N (NH_3) was determined using a spectrophotometer, using the phenol hydrochlorite method (Stirling, 1985) weekly. Test for other parameters present in water samples such as Nitrites, Protein, Specific gravity, Ketones, Bilirubin, Glucose and Creatinine were carried out with Kroma 14A Test strips to determine the amount of dissolved solids, ions and nutrients produced on a weekly basis. The pH was maintained at 6.5–7.0.

Experimental Feed Stuff and Preparation.

To eliminate anti-nutritional factors and improve digestibility, the following processes were carried out on experimental feed stuff.

Digitaria exilis grains were subjected to artificial drying at 240^{o}C in an oven for a period of 15 minutes after which they were ground to powder. *Cyperus esculentus* was parboiled for a period of 15 minutes, oven dried for 24 hours and ground to powder. Seeds and pulp extracted from the fruits of *Tamarindus indica* were subjected to artificial drying at a temperature of 240^{o}C for 20 minutes in a locally made oven after which they were ground to powdered form. *Digitaria exilis*, *Cyperus esculentus* and *Tamarindus indica* were used in the experimental feed stuff used to formulate the diets for the feeding trial as seen in table 6. The feed ingredients were weighed using an electronic sensitive weighing balance (OHAUS-LS-2000) into a plastic bowl and small quantity of water was added. The moist ingredients were made into dough and pelleted with the improvised pelleting machine. The pellets were oven dried. The pellets were ground into particles about 0.8-1.5mm in size at the beginning of the experiment for easy uptake by the fish. The weight of the feed given daily was determined based on the 10 % of the total body weight of the fish.

Experimental Feed Formulation.

All experimental feeds were formulated in the same ratio as coppens with each having 45% crude protein.

Proximate Analysis.

All experimental feed and major feed stuff ingredients were subjected to proximate analysis. The percentage composition of experimental diets, proximate composition of experimental dietary ingredients, proximate composition of experimental dietary ingredients and proximate analysis of experimental feed types is seen in Tables 7 and 8 respectively.

Feeding and Measurement.

Fish were fed on floating diet pellets (0.8mm and 1.5mm) for starters for two (2) months and were increased subsequently to 2mm, 3mm and 4mm with three different experimental feeds as above while the commercial feed (coppens) served as control. They were fed (45% crude protein) twice daily; morning and evening at 10% of body weight (Eurell *et al.*, 1978). The wet weight of individuals were measured on an analytical balance and recorded weekly to the nearest 0.01 g. At the end of the experiment, all fish individual wet weight in each tank after 1-day food deprivation were measured.

During this procedure, all of the fish from each tank were counted to determine survival rates and losses caused by cannibalism. Underweight individuals were also noted on the final day of the experiment.

Food Utilization Parameters.

Specific growth rate (SGR): Specific growth rate (SGR) of fish was calculated by using the following formula: $SGR= 100 X (LnWt – LnW_1)/ \Delta t$.

Where Wt is the weight in grams at time t, W_1 is the initial weight, Ln stands for natural log, and Δt is the duration of exposure of fish to light color in day according to the method of Brown, (1957).

Weight gain: Weight gain was calculated using $W_2 – W_1$, where W_2 is final weight and W_1 is initial weight over a sampling period. (Olvera-Novoa *et al.,* 1990).

Percentage Weight Gain: Percentage weight gain was determined as the difference between the final weight and initial weight of the experimental fish using the formula:

% Weight gain = (Final weight – initial weight) x 100/ Initial weight

Feed conversion ratio: Feed conversion ratio (FCR) was calculated according to Jhingran, (1991) using formula:

FCR = FI/ Wt

Where FI is feed intake in grams and Wt is gain in weight. The values of fish growth and efficiency parameters were subjected to statistical analysis by comparing their mean values. This was done with the help of SPSS software (Mohamad and Mehdi, 2011) and (Elnwishy *et al.*, 2012).

Survival Rate (%): This was determined at the end of the culture period using the formula: (Initial

Number of Fish Stocked – Mortality X 100%) (Akinwole and Akinnuoye, 2012).

Statistical Analysis.

Results were analyzed via SPSS statistical package and Microsoft Excel data analysis. ANOVA and Duncan's mean separation were used to determine the level of interactions between background tank colours and feed types on the growth and survival of *Heterobranchus bidorsalis.*

Also, test for relationship between opercular respiratory rates with time and physico-chemical parameters with time as factors were done using correlation analysis.

Results

Production (Growth) Parameters.

The results of growth performance of the juvenile *Heterobranchus bidorsalis* among the treatments are presented in (Figure 1).

The best overall specific growth rate was observed to be from *Cyperus esculentus* treatment closely followed by the coppens commercial feed treatment while and *Tamarindus indica* treatments did not perform well.

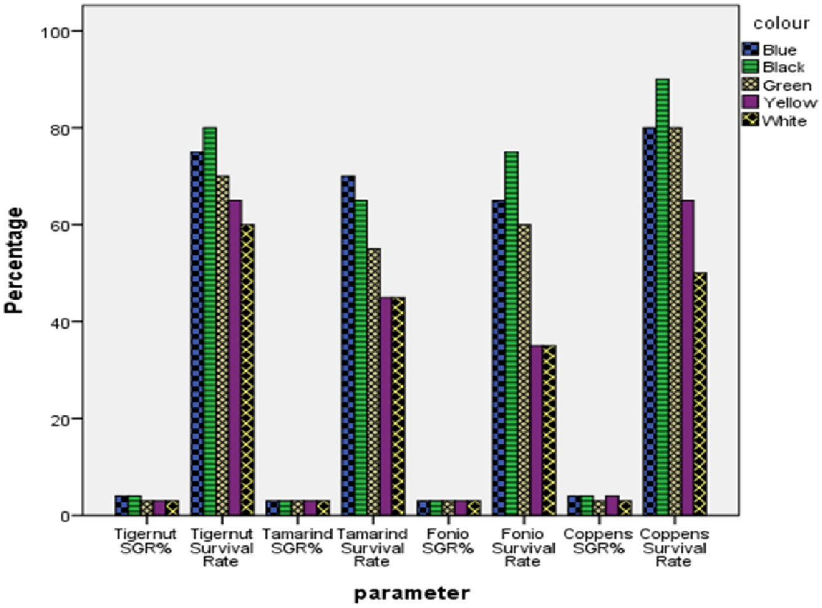


Figure 1: Summary of Production Parameters derived after experimental period.

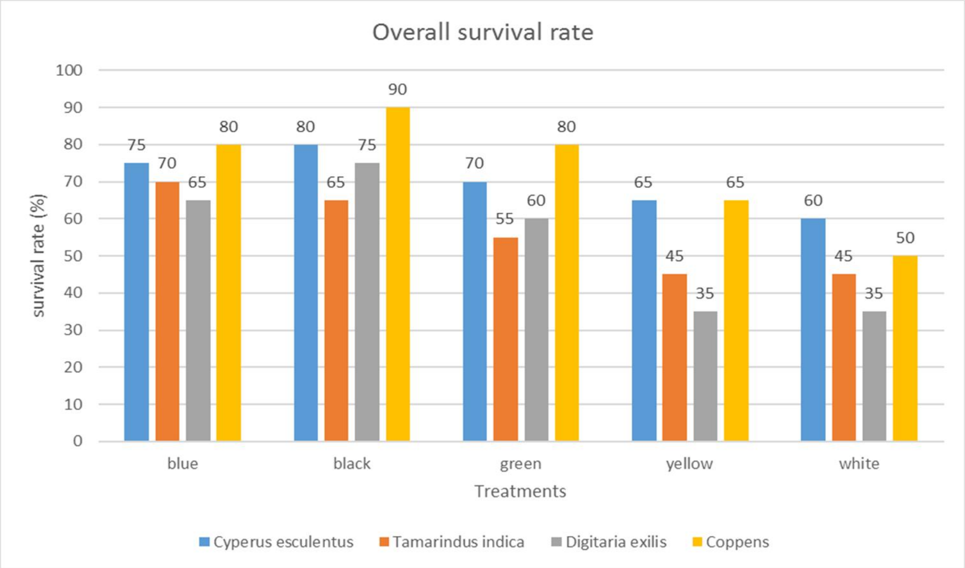


Figure 2: Overall Survival Rate of *Heterobranchus bidorsalis* derived in all Treatments during the Experimental Period.

Survival Rate.

The best overall survival rate was observed in the control treatment (coppens commercial feed) with best results from the black coloured tanks. The treatments had the best survival rate from the black tanks with the exception of *Tamarindus indica* which has the least survival rate compared to other black tanks. The second best result was observed to be the *Cyperus esculentus* treatment with higher survival rates than *Digitatria exilis* and *Tamarindus indica treatments* with the exception of the white coloured tank which showed higher survival rate than coppens commercial feed treatment.

In (figure 2), the overall survival rates from all the coloured tanks are almost the same until week six where a steady decline was observed with the white coloured tanks having the poorest results from week six to week twenty-four followed by the yellow coloured tank.

Relative Weight Gain.

The best relative weight gain was recorded in the *Digitaria exilis* treatments and *Tamarindus indica* treatments which performed as well as coppens commercial feed (control treatment) in (figures 3) with *Cyperus esculentus* treatments performing below the rest.

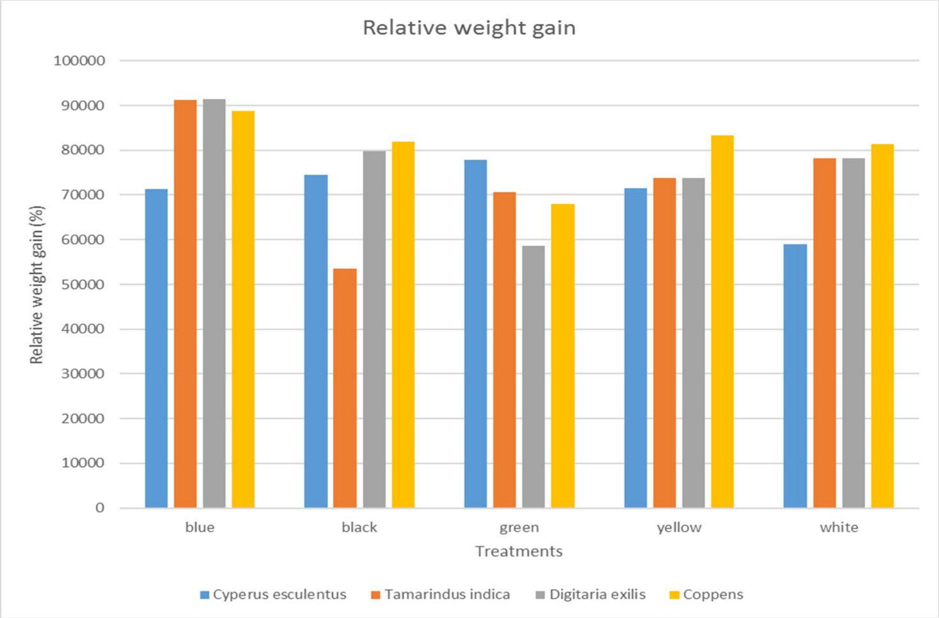


Figure 3: Relative Weight Gain of *Heterobranchus bidorsalis* in different Treatments

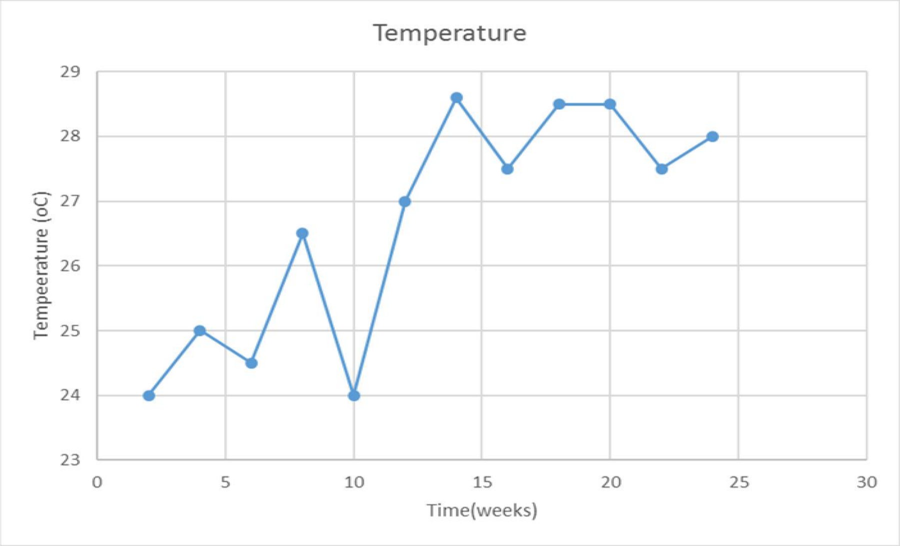


Figure 4: Average Temperatures Measured in all Treatments

Physico-chemical Parameters.

Temperature.

The mean physico-chemical parameters in the different tank sections of the experimental tanks are presented in Figure 4. The average temperature ranges between 24°C and 28.5°C in all the experimental tanks throughout the experimental period of 24 weeks.

Ammonia.

Ammonia values in all treatments were within tolerable ranges of between 0.3mg/l and 2.3 mg/l as seen in (Figure 5) for African catfish culture. At the end of the experimental period, ammonia was recorded in high concentrations; this was due to increase in biomass. These although were at a tolerable range.

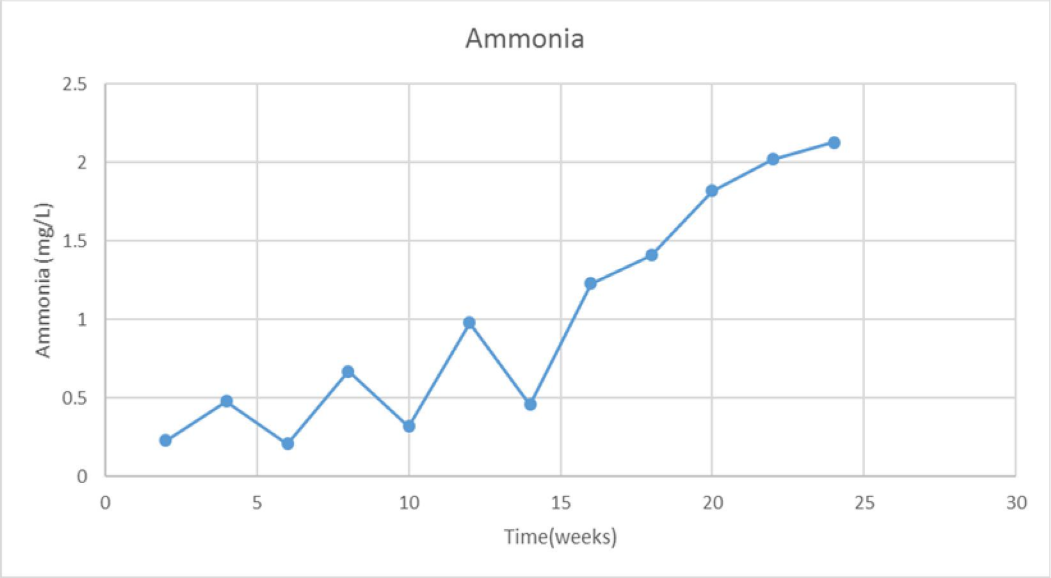


Figure 5: Average Ammonia Measured in all Treatments

Dissolved Oxygen.

The dissolved oxygen (DO) in all the experimental tanks ranged from 3.1mg/l–5.10mg/l, respectively. The least range was recorded in the white tank treatment as seen in (Figure 6), while the black tank had the highest value.

High and low points on the graph were as a result of changing water fortnightly.

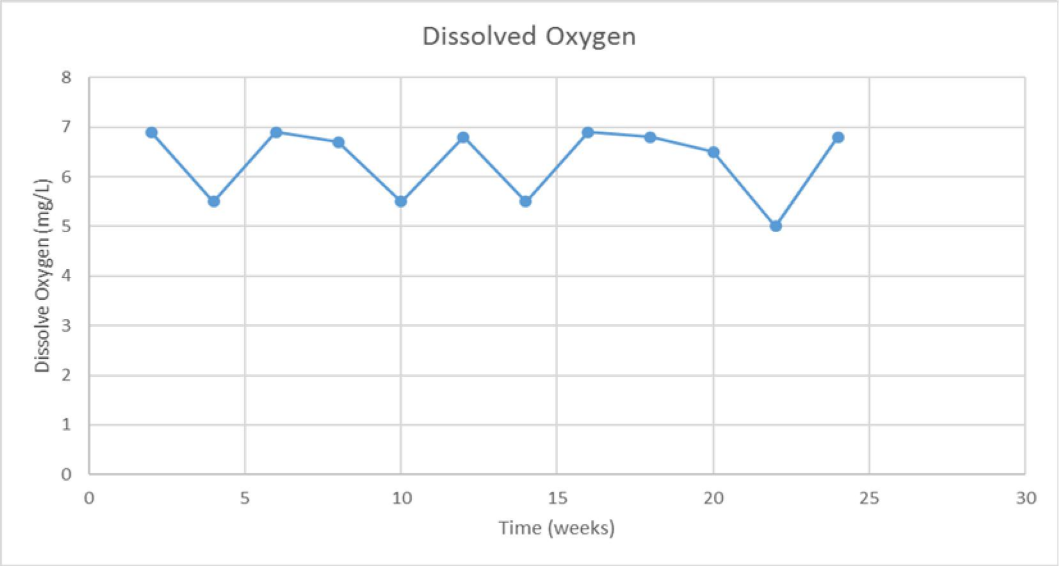


Figure 6: Average Dissolved Oxygen Measured in all Treatments

pH.

The pH ranged from 6.5-7.5 in all the tanks as observed in (Figure 7), with all black tank treatments recording the highest pH values and the white tank having the lowest values.

The low levels on the graph show a steep decrease in pH values.

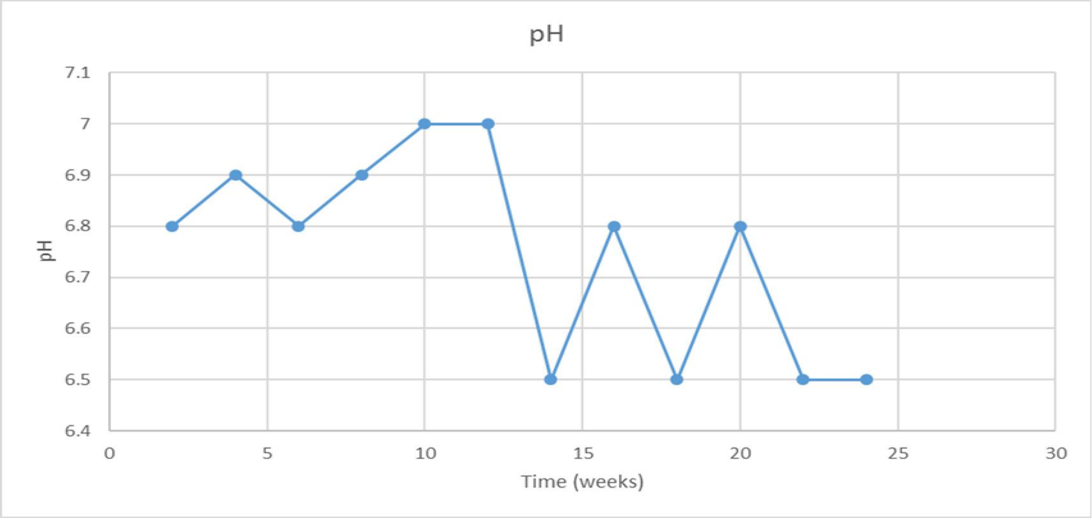


Figure 7: Average pH Measured in all Treatments

Nitrites.

Nitrite levels in the treatments ranged from as low as 0.0mg/L to about 0.06 mg/L as shown in the linear graph in Figure (8).

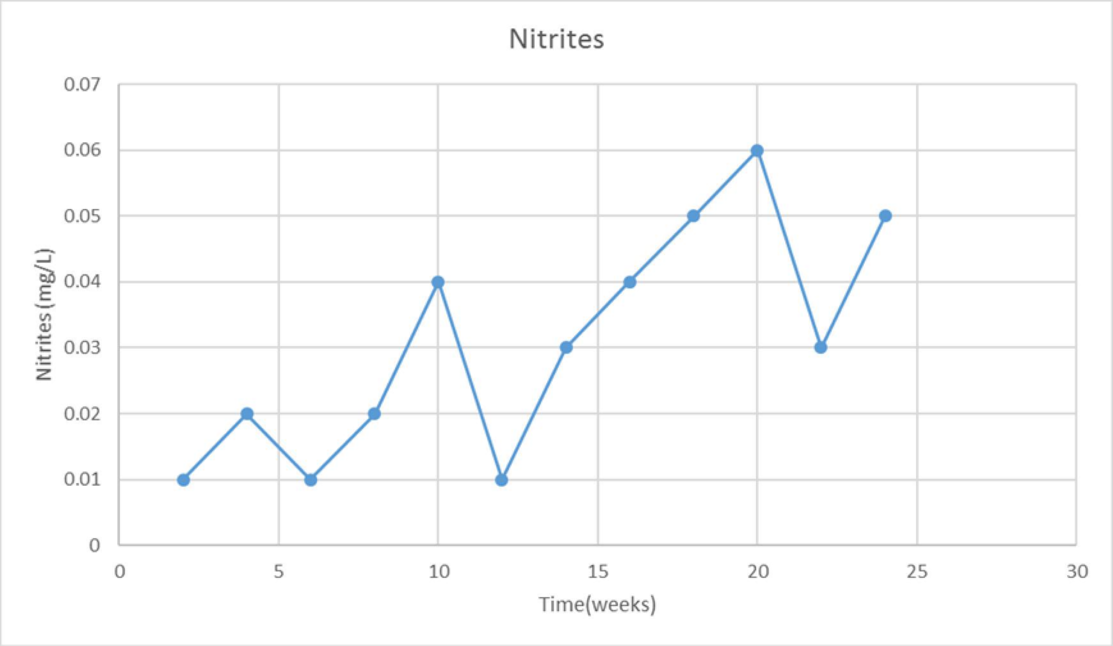


Figure 8: Average Nitrites Measured in all Treatments

Nitrates.

Nitrates concentrations fell between 0.001 mg/l and 0.005 mg/l throught the duration of the experiment as seen in (Figure 9).

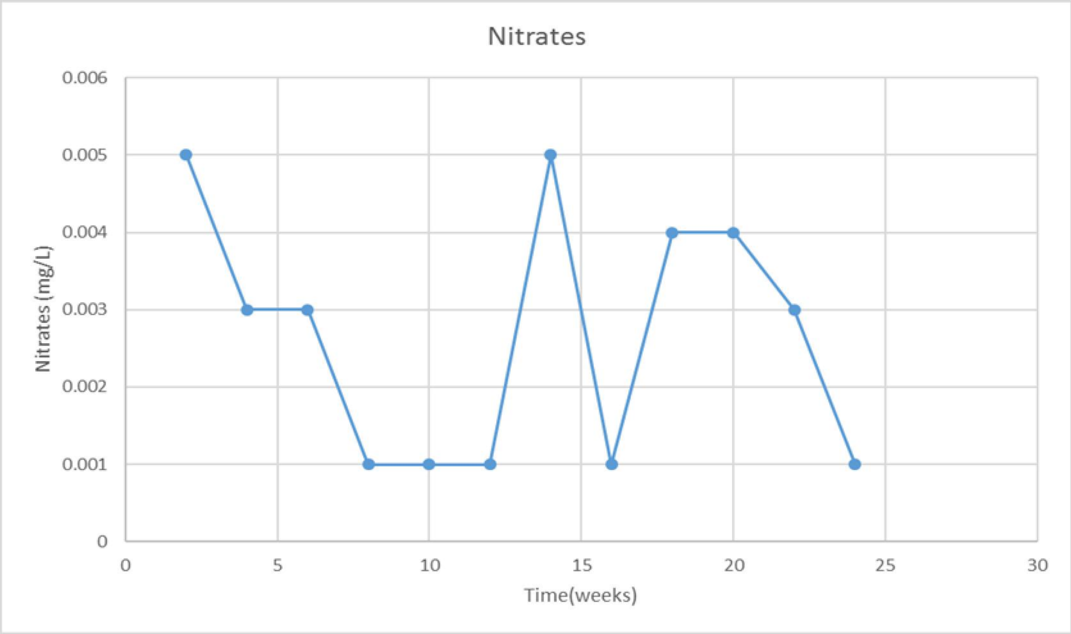


Figure 9: Average Nitrates Measured in all Treatments

Mean Opercular Respiratory Rate.

The mean opercular respiratory rate of *Heterobranchus bidorsalis* juveniles taken fortnightly in the different culture tank sections is shown in (figure 10). The yellow tank treatments ranged between 45.10-69.00 beats/min, the green tank treatments were between 47.00-69.00 beats/min, the blue tank treatments ranged between 55.00-76.00 beats/min, the black tank treatments were between 54.50-78.50 beats/min and the white tank treatments ranged between 45.00 – 79.00 beats/min. It was observed that the green coloured tank treatments showed peaked values around the sixteenth week. The same was also noted with the blue and black coloured tank.

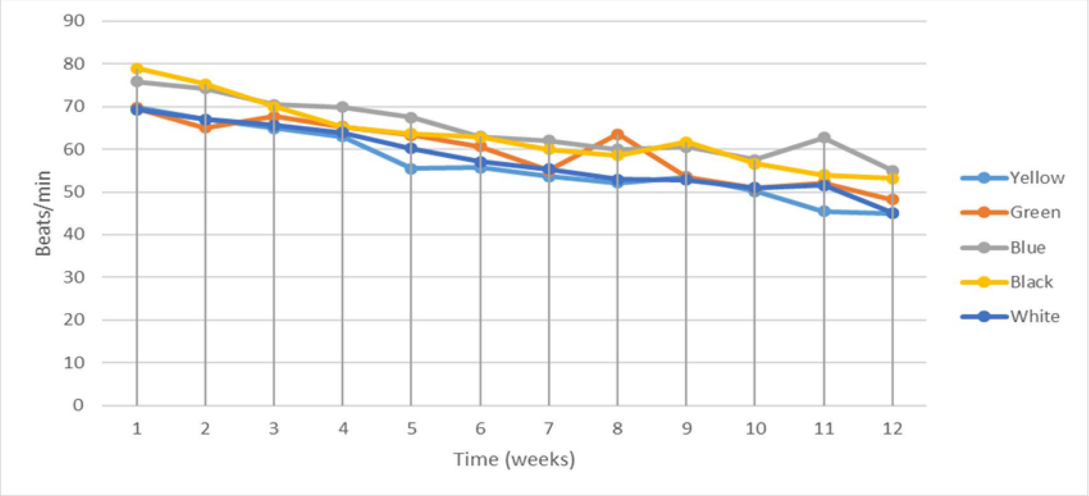


Figure 10: Mean Opercular Respiratory Rate (beats/min) in all Treatments measured fortnightly.

Discussion, Conclusion And Recommendation.

Discussion.

Two-way analysis of variance shows that there is significant relationship ($p<0.05$) at least between one background tank colour and feed utilization on the growth and survival of juvenile *Heterobranchus bidorsalis* in an intensive mono-culture system based on individual feed. Based on the growth parameters measured, there is significant difference ($p<0.05$) between the relative weight gain, specific growth rate, feed conversion ratio, survival rate and total fish production of fish fed with all the diets respectively.

Duncan's mean separation was used to compare differences among individual means of tank colour and feed utilization. The Duncan's mean separation revealed that two groups of significant differences exist in *Cyperus esculentus* tank colour. The first four colours are not statistically different from each other but the next colour (white) is different from all others. Also, in *Tamarindus indica*, the first two groups are not statistically different from each other but the second level is different from all others. The third group, although not significantly different from each other, are also significantly different from all other levels. In *Digitaria exilis*, the first level occupies a significantly different level of preference, while the next two groups are not statistically different but vary from first level. The third group although, not significantly different from each other, are also significantly different from all other levels. Finally, Coppens first two groups are not statistically different from each other but the second groups are different from the first. The third level, although not significantly different, is also significantly different from all other levels.

In a study by Papoutsoglou *et al*. (2000) on common carp fingerlings weighing between (100g and 160g), it was reported that tanks with white, green and black colors did not reflect any effect on growth performance which is not in agreement with those found in this study. The result from this study is similar to the result obtained by Almazan-Rueda *et al*. (2005). Britz and Piennar (1992), Appelbaum and Kamler (2000), and Adewolu *et al*. (2008) reported growth increase in *Clarias gariepinus* under total darkness and suggested reasons like high feeding activity in the dark for the high growth rate. The high specific growth rate under total darkness was a result of the complete feeding and utilization of the feed in the dark, more so because these fishes are nocturnal feeders. The absence of light was responsible for the very dark coloration observed in the fish reared under total darkness. This could be due to the physiological response of the fish in the dark in increasing the stimulation and production of melatonin (Hisar *et al*., 2005). Fish reared under continuous darkness or light have become adapted to these photoperiods, thus, they live with them.

In this study combined effects of tank color and feed type could be an explanation for relatively better growth performance of *Heterobranchus bidorsalis* juveniles kept in dark colored tanks because they are bottom feeders.

The average temperature showed a strong positive correlation for ranges between 24°C and 28.5°C in all the experimental tank sections fell within the range recommended by Akinyemi (1988) and Solomon and Ezigbo (2010) who recorded temperatures between 22°C and 35°C for catfish culture.

A strong positive correlation was observed as Ammonia values in all treatments were within tolerable ranges of between 0.3 mg/l and 2.3 mg/l and nitrites fell between 0.01 mg/l and 0.06 mg/l while Nitrates fell between 0.001 mg/l and 0.005 mg/l which are in agreement with (Solomon and Ezigbo, 2010) for African catfish culture.

Dissolved Oxygen range of 3-8 mg/l is generally considered suitable for fresh water fish culture. The range obtained in this study was slightly low but within the standard range of FAO (2006) and a weak negative correlation was noted. This may be attributed to inadequate artificial aeration and changing of water in all the experimental tanks.

pH values of 6.5-8.0 is recommended for catfish culture. The values obtained in this study were within the range recommended by Ivoke *et al*. (2007) and the results obtained gave a moderately negative correlation.

Nitrates values showed a weak correlation while nitrites showed a strong positive correlation.

The stress response marker used in this experiment which is the opercular respiratory rate showed a strong negative correlation to time. After testing the strength and direction of the two factors which are opercular respiratory rate and time, a strong downhill (negative) relationship was recorded on all treatments. This showed that as time increases, stress response decreases in *Heterobranchus bidorsalis*. This is in agreement with Fafioye (2001) who recorded opercular respiratory rate of 53.00 beats/ min for *Clarias gariepinus* adult fish not exposed to toxicants which is similar to results from this study. However, the result obtained in this study was a bit higher. This could be attributed to size of the fish since fish activity depends on the size. Ross *et al*. (1981) submitted that there is physiologic correlation between fish activity and opercular respiratory rate. Findings in this study buttressed the statement and indicate that opercular respiratory rate decreases with increase in growth.

Conclusion.

This study rejects the null hypothesis and demonstrates Ha hypothesis which states that there is significant relationship ($p<0.05$) between the background tank colours/feed types on the growth and survival of juvenile *Heterobranchus bidorsalis* in an intensive mono-culture system. Therefore, black coloured tanks gave the best growth performance and survival rate irrespective of feed type followed closely by both the blue and green coloured tanks for *Heterobranchus bidorsalis* juveniles.

Recommendations.

Use of black background coloured rearing tanks as artificial means of cultivating juvenile *Heterobranchus bidorsalis* should be encouraged in Nigeria as this encourages optimal feed utilization with the best survival rates.

The use of locally sourced feeds such as *Tamarindus indica* meal and *Cyperus esculentus* should be encouraged as these also brought about optimal production parameters similar to that of coppens.

Further work needs to be carried out on background tank colours on *Heterobranchus bidorsalis* with respect to determining physiological and biological stress responses.

References

1. Adebayo, O. T. and Olanrewaju, J. O. (2000). Reproductive Performance of African Catfish, *Heterobranchus bidorsalis* under different Feeding Regimes. In: Flos R, Cesswell L, editors. *Proceedings of the Sixth International Symposium on Reproductive Physiology of Fish*. Norway: Institute of Marine Research and University of Bergen, p.444.
2. Adebayo, O. T. and Fagbenro, O. A. (2004). Induced Ovulation and Spawning of Pond raised African Giant Catfish, *Heterobranchus bidorsalis* by Exogenous Hormones. *Aquaculture,* 242:229–236.
3. Adewolu, M. A., Adeniji, C. A. and Ademola, B. A. (2008). Feed Utilization, Growth and Survival of *Clarias gariepinus* (Burchell, 1822) Cultured under Different Photoperiods. *Aquaculture*, 283:64-67.
4. Agbebi, O. T., Otubusin, S. O. and Olufeagba, S. O. (2005). Embryogenetic Chronology of *Heterobranchus bidorsalis* (Geoffroy St. Hillaire, 1809). 5(1):73–80.
5. Agnese, J. F. and Teugels, G. G. (2001). Genetic Evidence for Monophyly of the Genus *Heterobranchus* and Paraphyly of the Genus *Clarias siluriformes*, Clariidae, Vol. 2:548-552. Comptes Rendus de l'Academie des sciences serie.
6. Akegbejo-Samsons, Y. (1999). The Use of Cassava Flour as a Substitute for Yellow Maize in Diets for *Clarias gariepinus* Fingerlings. *Journal of Tropical. Aquaculture*, 14 (3): 247-253.
7. Akinwande, A. A., Moody, F. O. and Umar, S. O. (2009). Growth Performance and Survival of *Heterobranchus longifilis*, *Heterobranchus bidorsalis* and their reciprocal hybrids. *African Journal of Science*, 10(1):15–18.
8. Akinwole, A. O. and Akinnuoye, F. C. (2012). Influence of Culture Tank Shapes on Haematology and Proximate Composition of *Clarias gariepinus* Juveniles. *Aquafield: Journal of Field Aquatic Studies*, Vol.8: 9-17.
9. Akinyemi, O. (1988). Water Quality and Pond. In: A.M. Ajani (ed). *Proceedings of the Nationwide Fish Farmers Workshop Management*, pp:101-106.
10. Almazan-Rueda, P., Van Helmond, A. T. M., Verreth, J. A. J. and Schrama, J. W. (2005). Photoperiod Affects Growth, Behavior and Stress Variables in *Clarias gariepinus*. *Journal of Fish Biology*, 67:1029-1039.
11. American Public Health Association, American Water Works Association, and Water Pollution Control Federation. (1976). Standard Methods for the Examination of Water and Waste Water. *American Public Health Association*, 14th Edition, 1193 p.
12. Anetekhai, M. A., Akin-Oriola, G. A., Aderinola, O. J. and Akintola, S. L. (2004). Steps Ahead for Aquaculture Development in Sub-Saharan Africa—The Case of Nigeria. *Aquaculture,* 239:237-248.
13. Appelbaum, S. and Kamler, E. (2000). Survival, Growth, Metabolism and Behavior of *Clarias gariepinus* (Burchell) Early Stages under Different Light Conditions. *Aquaculture Engineering*, 22:269-287.
14. Ayinla, O. A., Kayode, T. I. L., Idoniboye, O. A., Oresegun A. I. and Adindu. (1994). Use of Tadpole Meal as a Substitute for Fish Meal in Diet of *Heterobranchus Bidorsalis Journal Aquaculture Tropical*, 9(1): 25-23.
15. Ayoola, O. T. (2010). Yield Performance of Crops and Soil Chemical Changes under Fertilizer Treatments in a Mixed Cropping System. *African Journal of Biotechnology,* 9:4018-4021.
16. Ayoola, O. A. and Fredrick, C. A. (2010). Effects of the Shape of Culture Tanks on Production of The African Catfish *Clarias gariepinus* Juveniles. *Journal of Agriculture and Social Research,* 12(1):11-18.
17. Barcellos, L. J. G., Kreutz, L. C. and Quevedo, R. M. (2006). Previous Chronic Stress does not Alter the Cortisol Response to an Additional Acute Stressor in Jundiá (Rhamdiaquelen, Quoy and Gaimard) Fingerlings. *Aquaculture,* 253: 317-321.
18. Batty, R. S., Blaxter, J. H. S. and Richard, J. M. (1990). Light Intensity and the Feeding Behaviour of Herring, *Clupea harengus*. *Marine Biology*, 101, 107:383-388.
19. Batzina, A. and Karakatsouli, N. (2012). The presence of Substrate as a Means of Environmental Enrichment in Intensively Reared Gilthead Sea Bream (*Sparus aurata*): Growth and Behavioral Effects. *Aquaculture*, 370-371:54-60.
20. Belewu, M. A. and Ojo-Alokomaro, K. O. (2007). Haematological Indices of West African Dwarf Goat Fed Leaf Meal Based Diets. *Bulgarian Journal of Agricultural Science*, 13: 601-606.
21. Boeuf, G. and Le Bail, P. Y. (1999). Does Light have an Influence on Fish Growth? *Aquaculture,* 177: 129-152.

22. Brännäs, E., Alanärä, A. and Magnhagen, C. (2001). The Social Behavior of Fish. In: Keeling, L. J. and H. W. Gonyou (eds.), *Social Behaviour in Farm Animals*, pp: 275-304.
23. Britz, P. J. and Pienaar, A. G. (1992). Laboratory Experiments on the Effect of Light and Cover on the Behaviour and Growth of African Catfish, *Clarias gariepinus* (Pisces: Clariidae). *Journal of Zoology*, 227 (1): 43-62.
24. Brönmark, C. and Hansson, L. (2005). *Biology of Lakes and Ponds. Second edition.* Oxford, UK: Oxford University Press.
25. Brown, M. E., (1957). Experimental Studies on Growth in the Physiology of Fishes, edited by M.E. Brown, New York, *Academic Press*, Vol.1:361–400.
26. Coskuner, Y. and Karababa, E. (2005). Studies on the Quality of Turkish Flat Breads based on Blends of Triticale and Wheat Flour. *International Journal of Food Science and Technology*, 40:469- 479.
27. Delince, G. (1992). The Ecology of the Fish Pond Ecosystem with Special Reference to Africa. *Kluwer Academic Publishers*, London, 230pp.
28. Dubois, B., Feldman, H. H., Jacova, C., Dekosky, S. T., Barberger-Gateau P., Cummings, J., Delacourte, A., Galasko, D., Gauthier, S., Jicha, G., Meguro, K., O'brien, J., Pasquier, F., Robert, P, Rossor, M., Salloway, S., Stern, Y., Visser, P. J., Scheltens, P. (2007). *Lancet Neurol,* 6(8):734-46.
29. Duray, M. N., Estudillo, C. B. and Alpasan, L. G. (1996). The Effect of Background Colour and Rotifer Density on Rotifer Intake, Growth and Survival of the Grouper (*Epinephelus suillus*) Larvae. *Aquaculture*, 146, 217–224.
30. Ekelemu, J. K. (2010). Differential Growth Patterns of *Clarias gariepinus*, *Heterobranchus bidorsalis* and Hybrid Heteroclarias FedCommercially Prepared Diets. *Agric. Biol. J. N. Am,* 1(4):658–661.
31. Elnwishy, N., Sabri, D. and Nwonwu, F. (2012). The Effect of Difference in Environmental Colours on Nile Tilapia (*Oreochromis niloticus*) Production Efficiency. *International Journal of Agriculture Biology*, 14: 516-520.
32. El-Siddig, K., Ebert, G. and Lüdders, P. (1999). Tamarind (*Tamarindus indica* L.): a Review on a Multipurpose Tree with Promising Future in the Sudan. *Journal of Applied Botany – Angewandte Botanik*, 73: 202-205.
33. El-Siddig, K., Gunasena, H. P. M., Prasa, B. A., Pushpakumara, D. K. N. G., Ramana, K.V. R., Vijayanand, P.and Williams, J.T. (2006). Tamarind – *Tamarindus indica* L. *Fruits for the Future 1.* Southampton Centre for Underutilized Crops, Southampton, UK, 188p.
34. Eurell, T., Leuis, S. and Grumbles, L. (1978). Comparison of Selected Diagnostic Tests for Detection of *Aeromonas sepiticemia* in fish. *American Journal of Veterinary Res*, 39:1384–6.
35. Eyo, A. A. (2001). Fish Processing Technology in the Tropics. 1- 20 pp. Mendez, E,Gonzalez, R. M, Inocente, G., Giudice, H., Grompone, M.A. (1996). Lipid Content and Fatty Acid Composition of Fillets of six Fishes from the Rio de la Plata. *Journal of Food Composition and Analysis*, 9(2): 163-170.
36. Eyo, J. E. (1997). Morphometric and Cytogenetic Variations among Clarias Species (Clariidae) in Anambra River, Nigeria. *Ph.D. thesis. University of Nigeria, Nsukka*, p267.
37. Eyo, A. A. (1985). Studies on Dietary Protein Requirement of *Heterobranchus bidorsalis* Fingerlings. *NIFFR Annual Report*, pp:51-55.
38. Fafioye, O. O. (2001). Lethal and Sub-Lethal Effects of Extracts of *Parkia biglobosa* and *Raphia vinifera* on some Fresh Water Fauna. *A Ph.D. Thesis. Department of Zoology, University of Ibadan*, pp. 216.
39. Fagbenro, O. A., Olaniran, T. S. and Esan, A. O. (1991). Some Aspects of the Biology of the Catfish, *Heterobranchus bidorsalis* Geoffrey Saint-Hillarie, 1809 (Clariidae) in River Ogbese, Nigeria. *Journal of African Zoology*, 105:363-372.
40. Fagbenro, D., Balogun, B., Ibironke, N. and Fasina, F., (1993). Nutritional Value of some Amphibian Meals in Diets for *Clarias gariepinus*. (Burchell 1822). *Journal of Tropical Aquaculture,* 8(1):95-101.
41. Falaye, A. E. (1992). Utilization of Agro-industrial Waste as Feed Stuff in Nigeria, *Proceedings of the 10th Annual Conference of the Fisheries Society of Nigeria (FISON)*, pp:11-14.
42. FAO. (1998). Soil, Terrain and Crop Production Zones Database for Northeastern Africa. *FAO Land and Water Digital Media Series 2.* FAO, Rome.
43. FAO. (2006). Aquaculture Production in Tanzania, FAO Fishery Statistics, *Aquaculture Production*.
44. FAO. (2010). The State of World Fisheries and Aquaculture. FAO, Fisheries and Aquaculture Department. *Food and Agriculture Organization of the United Nations*, Rome.
45. Fatollahi, M. and Kasumyan, A.O. (2006). The Sensory Bases of the Feeding Behavior of the African Catfish *Clarias gariepinus* (Clariidae, Siluriformes). *Journal of Ichthyolology*, 46: S161–S172.
46. Gabriel, U. U., Akinrotimi, O. A., Bekibele, D. O., Onunkwo, D. N. and Anyanwu, P. E. (2007). Locally Produced Fish Feed, Potentials for Aquaculture Development in Sub-Saharan African. *Journal of Agricultural Research*, Vol. 297, pp:287-295.
47. González, A., Valero, M., Topham, N., and Parcerisa, J. M. (1997). Eliminating Cache Conflict Misses through XOR-Based Placement Functions. In *Proc. of the ACM Int. Conf. on Supercomputing*, pp 76-83.

48. Head, A. B. and Malison, J. A. (2000). Effects of Lighting Spectrum and Disturbance Level on the Growth and Stress Responses of Yellow Perch (*Perca flavescens)*. *Journal of World Aquaculture Society*, 31:73-80.
49. Henne, J. P. and Watanabe, W. O. (2003). Effect of Light Intensity, Salinity on Growth, Survival and Whole Body Osmolarity of Larval Southern Flounder *Paralichtys letostigma*. *Journal world Aquaculture Sacrifice,* 34: 450-465.
50. Hisar, S. A., Kirim, B., Bektas, S., Altinkaynak, K., Hisar, O. and Yanik, T. (2005). Effects of Photoperiod on Plasma Thyroxin Hormone Level of Mirror Carp (*Cyprino carpio*) Raised at Low Water Temperature in a Controlled Environment. *Israel Journal of Aquaculture Bamidgeh*, 57:19-24.58.
51. Honji, R. M., Caneppele, D., Hilsdorf, A. W. S. and Moreira, R. G. (2009). Threatened Fishes of the World: *Steindachneridion parahybae* (Steindachner, 1877) (Siluriformes: Pimelodidae). *Environ Biol Fish,* 85:207-208.
52. Honji, R. M., Tolussi, C. E., Mello, P. H., Caneppele, D. and Moreira, R. G. (2012). Embryonic Development and Larval Stages of *Steindachneridion parahybae* (Siluriformes: Pimelodidae) - Implications for the Conservation and Rearing of this Endangered Neotropical Species. *Neotrop Ichthyol*,10(2):313-327.
53. Huntingford, F. A., Adams, C., Braithwaite, V. A., Kadri, S., Pottinger, T. G., Sandoe, P. and Turnbull, J. F. (2006). Current Issues in Fish WWelfare. *Journal of Fish Biology*, 68:332-372.
54. Imanpoor, M. R. and Abdollahi, M. (2011). Effects of Tank Colour on Growth, Stress Response and Skin Colour of Juvenile *Caspian kutum*, *Rtilusfrisii kutum*. *Global Veterinaria,* 6:118-125.
55. Ivoke, N., Mgbenka, B.O. and Okeke, O. (2007). Effect of pH on the Growth Performance of *Heterobranchus bidorsalis* (♂) X *Clarias gariepinus* (♀) Hybrid Juveniles. *Animal Research International*, 4(1):639-642.
56. Jamu, D. M. and Ayinla, O. A. (2003). Potential for the Development of Aquaculture in Africa. *Naga*, *World fish Center Quarterly*, 26(3), pp. 9-13.
57. Jhingran, V. G., (1991). Fish and Fisheries of India, 3rd ed. *Hindustan Publishing Corporation,* Delhi, India, pp.727. Karakatsouli, N., Papoutsoglou, S. E., Pizzonia, G., Tsatsos, G., Tsopelakos, A., Chadio, S., Kalogiannis, D., Dalla, C., Polissidis, A., Papadopoulou-Daifoti, Z. (2007a).
58. Karakatsouli, N., Papoutsoglou, S. E. and Manolessos, G. (2007b). Combined Effects of Rearing Density and Tank Colour on the Growth and Welfare of Juvenile White Sea Bream (*Diplodus sargus* L.) in a Re-Circulating Water System. *Aquaculture Research*, (38):1152-1160.
59. Karakatsouli, N., (2010). Is the Extended Use of Fatty Acid Percentage in Fish Studies Adequate and Justified? *EAAP 61th Annual Meeting of the European Association for Animal Production*, Heraklion, Crete Island (Greece), August 23-27, 2006. *Book of Abstracts,* No. 16 p.186.
60. Karakatsouli, N. and Batzina, A. (2012). A Substrate Preference Test for Gilthead Sea bream (*Sparus aurata)* of Two Age Classes Tested Individually or in Groups. *AQUA 2012*: *Global Aquaculture*, 528-529pp.
61. Kumar, C. S. and Bhattacharya, S. (2008). Tamarind Seed: Properties, Processing and Utilization. *Critical Reviews in Food Science and Nutrition,* (48):1-20.
62. Levine, J. S. and MacNichol, E. G. (1982). Colour Vision in Fishes. *Scientific American,* 246:140-149.
63. Lovell, T. R. (1989). Growing Popularity of Tilapia Culture Increase. *The importance of Nutrition. Aqua Magazine*, 13: l.
64. Luchiari, A. C. and Freire, F. A. M. (2009). Effects of Environmental Colour on Growth of Nile Tilapia, *Oreochromis niloticus* maintained individually or in groups. *Journal of Applied Ichthyol*,25:162-167.
65. Madu, C. T. and Olurebi S. O. (1987). Effect of Varying Dietary Protein Levels on Growth and Food Utilization of Fish (*Clarias gariepinus*) Fingerlings. *NIFFR Annual Report*, pp.46-49.
66. Martin de Graaf, G.J., Born, B., Uddin, K.A. and Marttin, F. (2001). Floods Fish and Fishermen. Eight years of Experience with Flood Plain Fisheries, Fish Migration, Fisheries Modelling and Fish Biodiversity in the Compartmentalization Pilot Project, Bangladesh. The University Press Limited, Dhaka, 108 pp.
67. McLean, E., Cotter, P., Thain, C. and King, N. (2008). Tank Color Impacts Performance of Cultured Fish. *Ribarstvo*, 66(2):43-54.
68. Merighe, G. K. F., Pereira-da-Silva, E. M., Negrao, J. A. and Ribeiro, S. (2004). Effect of Background Colour on the Social Stress of Nile Tilapia (*Oreochromis niloticus*). *Reviews of Brazilian Zootechnology,* 33: 828-837.
69. Mesa, M. G. and Schreck, C. B. (1989). Electro-Fishing Mark-Recapture and Depletion Methodologies Evoke Behavioural and Physiological Changes in Cut-Throat Trout. *Transactions of the American Fisheries Society*. 118, 644-658.
70. Mohamad, R. I. and Mehdi, A. (2011). Effects of Tank Color on Growth, Stress Response and Skin Color of Juvenile *Caspian kutum, Rtilusfrisii Kutum. Global Veterinaria*, 6(2):118-125, *University of Agricultural Sciences and Natural Resources, Fisheries Department*, Golestan Province, Gorgan City, Iran.
71. Moody, F.O. (2004). An Assessment of Water Quality in Integrated Poultry-cum-fish Reservoir, NIFFRI New Bussa. In: P.A. Araoye (ed), *Conference Proceeding of Fisheries Society of Nigeria* (FISON), Ilorin, Nigeria.

72. Nlewadim, A. A., Onuoha, G. C. and Aluko, P.O. (2004). Studies on the Growth and Survival of Fry and Fingerlings of Clariid Catfish Species: *Clarias gariepinus* (Burchell, 1822), *Heterobranchus bidorsalis* (Geoffroy, 1809) and *Heterobranchus longifilis* (Valenciennes, 1840). *Journal Aquaculture Tropics,* 19(1):1-14. Oderinde, R. A. and Tairu, O. A. (1988). Evaluation of the Properties of Yellow Nutsedge (*Cyperus esculentus*) Tuber Oil. *Food Chemistry*, 28: 233-237.
73. Okoh, P. N. (1998). Cereal Grains in Nutritional Quality of Plant Foods. *Post Harvest Publication*: Benin, pp 32-52.
74. Oladele, A. K. and Aina, J. O. (2007). Chemical Composition and Functional Properties of Flour Produced from Two Varieties of Tiger nut (*Cyperus esculentus*). *African Journal of Biotechnology*, 6 (21):2473-2476.
75. Oladosu, G. A., Ayinla O. A., Adeyemo A. A., Yakubu A. F. and Ajani, A. A. (1993). A Comparative Study of the Reproductive Capacity of the African Catfish Species *Heterobranchus bidorsalis* (Geoffroy), *Clarias gariepinus*, (Burchell) and their Hybrid "*Heteroclarias*". *African Regional Aquaculture Centre Technical Paper*, 92:1-5.
76. Olaniyi, W. A. (2014). Climate Change and Biotechnology: Toolkit for Food Fish Security. In: Behnassi M, Shelat K, Hayashi K, (ed). *Vulnerability of Fisheries, Agriculture, and Water to Climate Change: Toward Sustainable Adaptation Strategies*. Netherlands: Springer, pp:243-258.
77. Olvera-Novoa, M. E., Campros, G. S., Sabido, G. M. and Martinez-Palacious, C. A.
78. (1990). The Use of Alfalfa Leaf Protein Concentrates as a Protein Source in Diets of Tilapia (*Oreochromis mossambicus*). *Aquaculture*, 83:45-58.
79. Omitoyin, B. O. (2005). Problems and Prospects of Fish Feed Production in Nigeria. *Invited Technical Paper Presented at the USAID Aquaculture Marketing Stakeholder Forum held at University of Ibadan Conference Center*, p3.
80. Pankhurst, P. M. and Hilder, P. I. (1998). Effect of Light Intensity on Feeding of Striped Trumpeter (*Latris lineate)* Larvae. *Marine and Freshwater Research*, 49:363-368.
81. Papoutsoglou, S. E., Mylonakis, G., Miliou, H., Karakatsouli, N. P. and Chadio, S. (2000). Effects of Background Colour on Growth Performances and Physiological Responses of Scaled Carp (*Cyprinus carpio* L.) Reared in a Closed Circulated System. *Aquacult. Eng*, 22:309-318.
82. Papoutsoglou, S. E. (2001). Colour of Indoor Tanks Can Affect Stress and Performance. *The Advocate*, 4(1):39-40.
83. Papoutsoglou, S. E., Karakatsouli, N. and Chiras, G. (2005). Dietary (L tryptophan) and Tank Colour Effects on Growth Performance of Rainbow Trout (*Onchorhynchus mykiss*) juveniles Reared in a Re-Circulating Water System. *Aquaculture Engineering*, 32:277-284.
84. Reed, W., Barchard, J., Hopson, A. J., Jennes, J. and Yaro, I. (1967). Fish and Fisheries of Northern Nigeria. *Ministry of Agriculture*, *Zaria, Northern Nigeria,* 226pp.
85. Ross, L. G., Watts, W. and Young, A. H. (1981). An Ultra-sonic Bioletemery System for the Continuous Monitoring of Tall Beat Rate from Free Swimming Fish. *Journal of Fisheries Biology,* 18(4):479-490.
86. Rotllant, J., Tort, L., Montero, D., Pavlidis, M., Martinez, M., WendelaarBonga, S. E. and Balm, P. H. M. (2003). Background Colour Influence on the Stress Response in Cultured Red Porgy (*Pagrus pagrus)*. *Aquaculture,* 223:129-139.
87. Salm, A. L., van der Pavlidis, M., Flik, G. and WendelaarBonga, S. E. (2004a).
88. Differential Release of Melanophore Stimulating Hormone Isoforms by the Pituitary Gland of Red Porgy, (*Pagrus pagrus)*. *General Comprehensive Endocrinology,* 135:126-133.
89. Salm, A.L., van der Martínez, M., Flik, G. and WendelaarBonga, S.E. (2004b). Effects of Husbandry Conditions on the Skin Colour and Stress Response of Red Porgy, *Pagrus pagrus*. *Aquaculture,* 241: 371-386.
90. Schreck, C. B., Olla, B. L. and Davis, M. W. (1997). Behavioral Responses to Stress. In: Iwama, G. K., Pickering, A. D., Sumpter, J.P., Schreck, C. B. (Eds.), *Fish Stress and Health in Aquaculture. Cambridge University Press, Cambridge,* pp. 145-170.
91. Siddhuraju, P., Vijayakumari, K. and Janardhanan, K. (1995). Studies on the Under Exploited Legumes, *Indigo feralinifolia* and *Sesbania bispinosa*: Nutrient Composition and Anti-Nutritional Factors. *International Journal of Food Sciences and Nutrition*, p1.
92. Sikoki, F. D. and Veen, J. V. (2004). Aspects of Water Quality and Potential for Fish Production of Shiroro Reservior, Nigeria. *Livestock System for Sustainable Development*, 2:1-7.
93. Solomon, J. R. and Ezigbo, M. N. (2010). Polyculture of Heteroclarias /Tilapia Under Different Feeding Regimes. *New York Science Journal*, 3(10):42-57.
94. Stirling, H. P. (1985). Chemical and Biological Methods of Water Analysis for Aquaculturists. Stirling, UK: *Institute of Aquaculture, University of Stirling*. Stirling, Scotland. p 261.
95. Tacon, A. G. J. and Barg, U. C. (1998). Major Challenges to Feed Development for Marine and Diadromous Fin fish and Crustacean Species. In: S. S. De Silva, editor. *Tropical Mariculture. New York: Academic Press*, pp. 171-207.

96. Tamazouzt, L., Chatain, B. and Fontaine, P. (2000). Tank Wall Colour and Light Level Affect Growth and Survival of Eurasian Perch larvae (*Perca fluviatilis* L.). *Aquaculture*, 182:85-90.
97. Temple, V. J. and Bassa, J. D. (1991). Proximate Chemical Composition of Acha (*Digitaria exilis*) Grain. *Journal of Science Food and Agriculture*, 56:561- 563.
98. Teugels, G. G. (1996). Taxonomy, Phylogeny and Biogeography of Catfishes (Ostariophysi, Siluroidei): An Overview. *Aquaculture Living Resources,* 9:9-34.
99. Volpato, G. L. and Barreto, R. E. (2001). Environmental Blue Light Prevents Stress in Nile Tilapia. *Brazilian Journal of Medical and Biological Research*, 34 (8):1041-1045.
100. Teugels, G.G. (1986). Checklist of the fresh water fishes of Africa. 2, pp: 66-101.
101. Teugels, G. G., Denayer, B. and Legendre, M. (1990). A systematic Revision of the African Catfish genus *Heterobranchus* (Pisces, Clariidae). *Zoological Journal of Linnean Society*, 98:237-257.

Appendices

Appendix 1: Showing the Factorial Experimental Design used for this Experiment.

Tank colours Experimental feeds	**A1 (white) control**	**B1 (blue)**	**C1 (green)**	**D1 (yellow)**	**E1 (black)**
Commercial feed (coppens) control	20	20	20	20	20
Cyperus esculentus	20	20	20	20	20
Digitaria exilis	20	20	20	20	20
Tamarindus indica	20	20	20	20	20

Appendix 2: Showing the Percentage Composition of the Three Experimental Diets.

Feed type Ingredients (% composition)	***(Digitaria exilis)***	**(*Tamarindus indica*)**	**(*Cyperus esculentus*)**
Fish meal	28	28	28
Yellow corn	35	35	35
Soya bean	15	15	15
Fonio/ Tiger nut/ Tamarind	15	15	15
Vegetable oil	2	2	2
Vitamin premix	2	2	2
Starch	1	1	1
Bone meal	1.5	1.5	1.5
Salt	0.5	0.5	0.5

*Vit/mineral premix (Agricare-Mix, Pfizer production Plc, Lagos, Nigeria) contained per 1000g: Vitamin A 12,000,000 IU; Vitamin D3 2,000,000 IU; Vitamin E 7,000 IU; Vitamin B2 4000mg; Nicotinic acid 15,000 mg; Calcium d-pentothenate 8,000 mg; Biotin 40 mg; Vitamin B12 10 mg; Mn 20,000mg; Fe 50,000 mg; Zn 100,000 mg; Cu 10,000 mg; Iodine 750 mg; Co 3,000 mg.

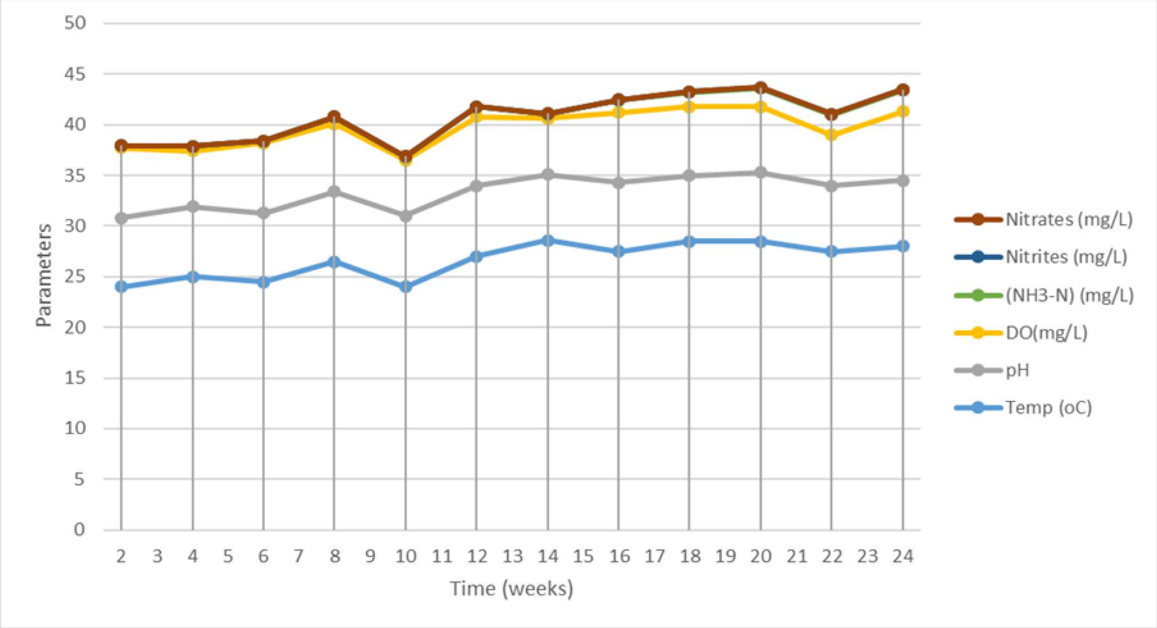
Appendix 3: Showing the Proximate Analysis of all Three Experimental Feed Types.

Feed type Nutrients	**Fonio meal *(Digitaria exilis)***	**Tamarind meal (*Tamarindus indica*)**	**Tiger nut meal (*Cyperus esculentus*)**	**Coppens (commercial feed)**
Moisture content (%)	7.33	8.56	9.04	8.10
Crude protein (%)	40.05	41.43	40.12	43.75
Crude lipid (%)	14.32	15.77	20.97	11.93
Crude fibre (%)	7.06	5.52	11.83	7.42
Total Ash value (%)	6.42	8.13	6.40	9.44
Acid Insoluble Ash (%)	2.33	4.51	2.63	4.04
Digestible energy (Calculated), Kcal/kg	2110.55	1020.33	1151.00	1372.11

Appendix 4: Showing the Percentage Composition of each Experimental Diet.

	Crude protein	**Crude carbohydrate**	**Lipid**	**Crude fibre**	**Ash**	**Moisture**	**Dry matter**
Fish meal	71.42	-	7.92	1.17	20.13	8.76	90.22
Yellow corn	10.81	73.9	4.56	3.53	1.91	12.26	90.42
Soya bean	44	43.12	20.45	6.5	5.0	8.5	93.69
Fonio	8.29	75.12	2.62	1.78	2.01	10.33	95.22
Tiger-nut	9.70	43.30	24.49	8.91	1.70	26.00	92.56
Tamarind pulp	3.1	70.8	0.44	3.03	2.10	20.6	-
Tamarind seed	26.93	50.05	10.91	7.4	2.01	10.10	-

Appendix 5: Showing the Mean Physico-Chemical Parameters in all Treatments which were measured fortnightly.



Appendix 6: Showing Parameter * Colour Cross-Tabulation Statistical Data

			Colour					Total
			Blue	Black	Green	Yellow	White	
parameter	Tigernut SGR%	Count	4	4	3	3	3	17
		% within parameter	23.5%	23.5%	17.6%	17.6%	17.6%	100.0%
	Tigernut Survival Rate	Count	75	80	70	65	60	350
		% within parameter	21.4%	22.9%	20.0%	18.6%	17.1%	100.0%
	Tamarind SGR%	Count	3	3	3	3	3	15
		% within parameter	20.0%	20.0%	20.0%	20.0%	20.0%	100.0%
	Tamarind Survival Rate	Count	70	65	55	45	45	280
		% within parameter	25.0%	23.2%	19.6%	16.1%	16.1%	100.0%
	Fonio SGR%	Count	3	3	3	3	3	15
		% within parameter	20.0%	20.0%	20.0%	20.0%	20.0%	100.0%
	Fonio Survival Rate	Count	65	75	60	35	35	270
		% within parameter	24.1%	27.8%	22.2%	13.0%	13.0%	100.0%
	Coppens SGR%	Count	4	4	3	4	3	18
		% within parameter	22.2%	22.2%	16.7%	22.2%	16.7%	100.0%
	Coppens Survival Rate	Count	80	90	80	65	50	365
		% within parameter	21.9%	24.7%	21.9%	17.8%	13.7%	100.0%
Total		Count	304	324	277	223	202	1330
		% within parameter	22.9%	24.4%	20.8%	16.8%	15.2%	100.0%

Appendix 7: Summary of Statistical Analysis of the Growth Parameters for *Heterobranchus bidorsalis* fed *Cyperus esculentus* meal in all Colour for twenty-four weeks.

Treatment

Parameters	Blue	Black	Green	Yellow	White
Relative weight gain (%)	71341.56a	74471.26a	77914.7a	71520.27a	58938.67b
Feed conversion ratio	81.92a	69.46a	84.93a	85.03a	101.8b
Specific growth rate (%/day)	3.5a	3.6a	3.48a	3.48a	3.38b
Survival rate (%)	75a	80a	70a	65a	60b
Total fish production kg/m3	41.26a	51.9a	37.14a	34.45a	26.57b

Values with the same subscripts across the rows are not significantly different (P<0.05)

Appendix 8: Summary of Statistical Analysis of the Growth Parameters for *Heterobranchus bidorsalis* fed *Tamarindus indica* meal in all Colour for twenty-four weeks.

Treatment

Parameters	Blue	Black	Green	Yellow	White
Relative weight gain (%)	91182.76a	53580.72b	70631.71c	73795.89c	78132.73b
Feed conversion ratio	85.09a	101.19b	77.7c	83.53c	104.72b
Specific growth rate (%/day)	3.48a	3.39b	3.42c	3.49c	3.37b
Survival rate (%)	70a	65b	55c	45c	45b
Total fish production kg/m3	37.06a	28.96b	31.9c	24.27c	19.36b

Values with the same subscripts across the rows are not significantly different (P<0.05)

Appendix 9: Summary of Statistical Analysis of the Growth Parameters for *Heterobranchus bidorsalis* fed *Digitaria exilis* meal in all Colour for twenty-four weeks.

Treatment

Parameters	Blue	Black	Green	Yellow	White
Relative weight gain (%)	91368.97a	79764.91b	58571.95a	73795.89c	78132.73b
Feed conversion ratio	84.93a	98.98b	93.69a	83.53c	104.72b
Specific growth rate (%/day)	3.48a	3.4b	3.43a	3.49c	3.37b
Survival rate (%)	65a	75b	60a	35c	35b
Total fish production kg/m3	34.48a	34.14b	28.87a	18.88c	15.06b

Values with the same subscripts across the rows are not significantly different (P<0.05)

Appendix 10: Summary of Statistical Analysis of the Growth Parameters for *Heterobranchus bidorsalis* fed Coppens Commercial Feed in all Colour for twenty-four weeks.

Treatment

Parameters	Blue	Black	Green	Yellow	White
Relative weight gain (%)	88788.89b	81844.05b	68047.83c	83333.33a	81438.46a
Feed conversion ratio	80.4b	65.46b	95.84c	81.82a	85a
Specific growth rate (%/day)	3.51b	3.63b	3.42c	3.51a	3.48a
Survival rate (%)	80b	90b	80c	65a	50a
Total fish production kg/m3	44.8b	61.95b	37.62c	35.79a	26.5a

Values with the same subscripts across the rows are not significantly different (P<0.05)

Appendix 11: Descriptives of Growth Parameters for *Heterobranchus bidorsalis* fed *Cyperus esculentus* meal in different tank colours for twenty-four weeks

Anova

TIGERNUT

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	10633.501	4	2658.375	6.154	.000
Within Groups	421590.804	976	431.958		
Total	432224.305	980			

Duncan

Column	N	Subset for alpha = 0.05	
		1	2
Tigernut Yellow	187	67.3229	
Tigernut Black	204	67.9706	
Tigernut Green	195	69.0595	
Tigernut Blue	201	69.6674	
Tigernut White	191		76.5613
Sig.		.315	1.000

Descriptives
Tigernut

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Tigernut Blue	202	69.6674	17.72525	1.24813	67.2063	72.1286	3.50	81.92
Tigernut Black	205	67.9706	14.01317	.97882	66.0407	69.9005	3.60	80.00
Tigernut Green	196	69.0595	19.53719	1.39712	66.3041	71.8150	3.48	84.93
Tigernut Yellow	188	67.3229	20.48082	1.49388	64.3759	70.2699	3.48	85.03
Tigernut White	192	76.5613	29.48273	2.12912	72.3617	80.7609	3.38	101.80
Total	982	70.0896	20.99144	.66990	68.7750	71.4042	3.38	101.80

Appendix 12: Descriptives of Growth Parameters for *Heterobranchus bidorsalis* fed *Tamarindus indica* meal in different tank colours for twenty-four weeks.

Anova
Tamarind

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	47944.534	4	11986.133	17.747	.000
Within Groups	597722.489	885	675.393		
Total	645667.023	889			

Duncan

Column	N	Subset for alpha = 0.05		
		1	2	3
Tamarind Green	168	60.0619		
Tamarind Yellow	156	61.4465		
Tamarind Blue	195		69.1400	
Tamarind Black	198			77.1360
Tamarind White	172			77.5729
Sig.		.617	1.000	.874

Descriptives
Tamarind

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Tamarind Blue	196	69.1400	19.60948	1.40200	66.3750	71.9051	3.48	85.09
Tamarind Black	199	77.1360	27.90043	1.98010	73.2312	81.0409	3.39	101.19
Tamarind Green	168	60.0619	19.24419	1.48463	57.1308	62.9929	3.42	77.70
Tamarind Yellow	156	61.4465	25.14355	2.01123	57.4736	65.4194	3.49	83.53
Tamarind White	172	77.5729	34.92117	2.65924	72.3238	82.8220	3.37	104.72
Total	891	69.4925	26.93558	.90241	67.7214	71.2636	3.37	104.72

Appendix 13: Descriptives of Growth Parameters for *Heterobranchus bidorsalis Digitaria exilis* meal in different tank colours for twenty-four weeks.

Anova

Fonio

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	37628.700	4	9407.175	12.563	.000
Within Groups	658190.284	879	748.794		
Total	695818.985	883			

Duncan

Column	N	Subset for alpha = 0.05		
		1	2	3
Fonio Yellow	140	60.8296		
Fonio Blue	187		67.2685	
Fonio Green	185		71.0955	
Fonio Black	211			78.4755
Fonio White	158			78.5927
Sig.		1.000	.193	.968

Descriptives

Fonio

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Fonio Blue	188	67.2685	20.43661	1.49093	64.3273	70.2098	3.48	84.93
Fonio Black	212	78.4755	24.73409	1.70067	75.1230	81.8280	3.40	98.98
Fonio Green	186	71.0955	25.72229	1.88610	67.3745	74.8166	3.43	93.69
Fonio Yellow	141	60.8296	28.17965	2.37400	56.1361	65.5232	3.49	83.53
Fonio White	158	78.5927	37.23280	2.96068	72.7449	84.4406	3.37	104.72
Total	884	71.7526	28.06449	.94367	69.9005	73.6047	3.37	104.72

Appendix 14: Descriptives of Growth Parameters for *Heterobranchus bidorsalis* fed Coppens (commercial) meal in different tank colours for twenty-four weeks.

Anova

Coppens

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	28591.710	4	7147.928	18.166	.000
Within Groups	390339.777	992	393.488		
Total	418931.487	996			

Duncan

Column	N	Subset for alpha = 0.05		
		1	2	3
Coppens White	164	63.2765		
Coppens Yellow	186	65.6176		
Coppens Blue	208		71.3334	
Coppens Black	221		73.4527	
Coppens Green	216			78.4409
Sig.		.242	.289	1.000

Descriptives
Coppens

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Coppens Blue	209	71.3334	17.04789	1.17990	69.0073	73.6595	3.51	80.45
Coppens Black	221	73.4527	15.76947	1.06067	71.3623	75.5431	3.63	90.00
Coppens Green	217	78.4409	22.69013	1.54073	75.4041	81.4777	3.42	95.84
Coppens Yellow	186	65.6176	19.00808	1.39329	62.8689	68.3664	3.51	81.82
Coppens White	165	63.2765	24.34786	1.89559	59.5336	67.0194	3.48	85.00
Total	998	70.9494	20.50085	.64901	69.6759	72.2230	3.42	95.84

Appendix 15: Correlation Analysis Descriptives for Mean Opercular Respiratory Rates

	Time	White
Time	1	
White	- 0.98343	1

	Time	Black
Time	1	
Black	- 0.94935	1

	Time	Green
Time	1	
Green	-0.927751737	1

	Time	Yellow
Time	1	
Yellow	-0.97232	1

	Time	Blue
Time	1	
Blue	- 0.94015	1

Appendix 16: Correlation Analysis Descriptives for Physico-chemical parameters

	Nitrites (mg/L)	Time
Nitrites (mg/L)	1	
Time	0.765215	1

	Nitrates (mg/L)	Time
Nitrates (mg/L)	1	
Time	-0.14057	1

	Temp (^{o}C)	Time
Temp (^{o}C)	1	
Time	0.818866	1

	(NH3-N) (mg/L)	Time
(NH3-N) (mg/L)	1	
Time	0.92091	1

	DO (mg/L)	Time
DO (mg/L)	1	
Time	-0.08806	1

	pH	Time
pH	1	
Time	-0.63763	1

3/22/2018