PRODUCTION OF *Clarias gariepinus,* BURCHELL 1822, INNET CAGES UNDER VARYING STOCKING DENSITIES AND FEED FORMS

BY

(Matriculation No.: 17532)

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A Ph.D Thesis in theDepartment of Aquaculture and FisheriesManagement, Submitted to the Faculty of Renewable Natural Resources

In Partial Fulfilment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

of the

UNIVERSITY OF IBADAN,

JULY, 2019

ABSTRACT

Decline in fish production from capture fisheries has necessitated the development of intensive aquaculture practices such as Cage Culture (CC). However, the practice of CC is not well established in Nigeria. This is due to the fact that information on operational procedures like Stocking Density (SD) and feed forms (floating and sinking) for important culture fish species such as *Clarias gariepinus* are limited. Therefore, growth performance and nutrient utilisation of *C.gariepinus* in net cages under varying stocking densities and feed forms were investigated.

Eighteen (1.0m x 1.0m x1.5m)floatingnet cages were set on Owala Lake, Osun State, Nigeria. In each of the cages, *C gariepinus* (n=3,600; 70.00±0.03g) were randomly allotted to the cages at different stocking densities of 100 (SD_1), 200 (SD_2) and 300 (SD_3) fish per m^3 with 100 (SD_1) as control. The fish in each SD were fed diet containing 45% crude protein in form of either Extruded Floating Diet (EFD): (SD_1-EFD; SD_2-EFD; SD_3-EFD) or Pelleted Sinking Diet (PSD): (SD_1-PSD; SD_2-PSD; SD_3-PSD). The fish were fed twice daily at 3% body weight for 150 days. All the treatments were replicated three times using 2×3 factorial arrangement in a completely randomised design. Mean Weight Gain (MWG, g), Specific Growth Rate (SGR, %), Survival Rate (SR, %), Protein Efficiency Ratio (PER) and Feed Conversion Ratio (FCR) were measured. Blood (5 ml) was sampled to determine Packed Cell Volume (PCV, %), Heterophil (HET, 10^6/µl), Lymphocyte (LYM, 10^6/µl) and Heterophil: Lymphocyte ratio (H: L) using standard methods. Net Revenue (NR; ₦ /kg of fish) and Benefit Cost Ratio (BCR) were determined. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$.

The MWG varied from 669.35±1.92 and 902.97±11.52; SGR 1.6±0.02, 1.8±0.02; SR 98.0±0.6, 99.00±0.56 and PER 1.6±0.01, 1.7±0.05 in SD_3−PSD and SD_1−PSD, respectively. Least and highest MWG 735.3±5.49, 1108.3±3.19, SGR 1.6±0.02, 1.9±0.02, SR 98.0±0.6, 99.0±0.6 and PER 1.7±0.02, 1.8±0.01 were obtained in SD_3-EFD and SD_1-EFD, respectively. The FCR increased from 1.2±0.01 (SD_1−EFD), 1.3±0.01 (SD_2−EPD) to 1.3±0.1 (SD_2−EFD); 1.4±0.01 (SD_2−PSD). Significantly, least and highest PCV 19.0±6.1, 23.0±8.7 and LYM 4.5±2.3, 5.4±2.3 were obtained in SD_3-PSD and SD_1-EFD, respectively. The HET varied from 3.7±0.4 (SD_1-EFD) to 4.0±0.9 (SD_3-EFD) while HET was 4.2±0.6 and 4.3±1.2 in (SD_1-PSD) and (SD_3-PSD), respectively. Least and highest H: L were recorded in SD_1-EFD (0.7±0.2), SD_1-PS (0.70±0.09) and SD_3-EFD (1.0±1.2), SD_3-PSD (1.0±2.1). The NR significantly increased from ₦13,974.50±697.9 (SD_1−EFD) to ₦20,653.02±308.3

(SD_2−EFD). The NR was ₦17,512.93±216.5 and ₦29,848.1±190.3 in SD_1-PSD and SD_3-PSD, respectively. Least (1.1±0.02) and highest (1.3±0.03) BCR were recorded in SD_3-EFD and SD_1−EFD, respectively while BCR ranged from 1.34±0.02 SD_3-PSD to 1.43±0.02 SD_1-PSD.

Production of *Clarias gariepinus* could be enhanced in net cages at stocking density of 100 fish/m^3 when fed either floating or sinking pellet. However, benefit cost ratio was higher in *Clarias gariepinus* fed sinking diet at 100 fish/m^3.

Key words: Cage aquaculture, *Clarias gariepinus,* Stocking density, Fish feed forms, Feed Conversion Ratio.

Word count: 479

ACKNOWLEDGEMENT

I am greatly indebted to my Lord and Saviour Jesus Christ, who accepts me unconditionally, gives me meaning to life and by whom I can do all things. Now unto theking eternal, immortal, invisible, omnipresence, omnipotent, omniscience, be honour, glory and adoration forevermore (Amen).

My unreserved appreciation goes to my supervisor: Dr. Oyin. A. Olukunle for her valuable contributions, timely suggestion coupled with useful advice. I cannot but also reference your patience because it takes patience to supervise a senior citizen who has graduated from University forover three decadesago. May God in His infinite mercy, continue to bless you in Jesus name.

I am very thankful toall the academic and non-academic staff of the Department of Aquaculture and Fisheries Management: Professors E.A. Faturoti, A.E. Falaye, B.O. Omitoyin, E.K.,Ajani, T.B.Fregene, A.Jenyo-Oni, A. O. Akinwole and Drs. A.O. Oyelese, F.Olaifa, S.A.Omitoyin,O. O.Oyebola, K.K.,Kareem and F. E. Osho for their support, encouragement and inputs towards the success of this work.

I also want to appreciate Prof. Ben. Emikpe and Dr. Theophilus Jarikre of the Department of Veterinary Pathology, University of Ibadan for their kind assistance in the area of haematological analysis. You and my supervisorwere there for me, you followed me to the experimental site for blood samplingduring the study. Thank you and God bless you. I am immensely indebted to my darling wife Deaconess M.O. Adigun, a virtuous, loving, caringand supporting woman. You are always there in time of need. A million and one thanks are not sufficient to appreciate you for your prayers, encouragement and financial support throughout my study, but as far as Ican do, I say a big ‘THANK YOU’. I also appreciate our wonderful children, Ibukunoluwa, Iyinoluwa and Ifeloluwa. Thank you for your prayers and encouragement.

DEDICATION

Dedicated to Jesus Christ, my Lord and Saviour, the only one who madeall things beautiful for my life and in whom I can do all things. I also dedicate this work to my wonderful friend and companion, Holy Spirit, the custodian of wisdom, knowledge and understanding.

CERTIFICATION

1 certify that this work was carried out by Mr. N.O. Adigun in the Department ofAquaculture and Fisheries Management, University of Ibadan, Nigeria.

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ABBREVIATIONANDACRONYMS

AOAC	Association of Official Analytical Chemist
ATA	Agriculture Transformation Agenda
AU-IBAR	African Union- Inter African Bureau for Animal Resources
BCR	Benefit- Cost Ratio
CAFFAN	Catfish and Allied Fish Farmer Association of Nigeria
CIFA	Central Institute of Freshwater Aquaculture
Cm	Centimeter
CTA	Centre for Technology Assessment
DO	Dissolved Oxygen
Df	Degree of freedom
EFD	Extruded Floating Diet
FAO	Food and Agriculture Organiation
FAWC	Farn Animal Welfare Council
FGN	Federal Government of Nigeria
GAIN	Global Agriculture Information Network
GDP	Gross Domestic Product
GM	Gross Margin
Hb	Haemoglobin
HET	Heterophil
H:L	Heterophil: Lymphocyte Ratio
H_2O	Water
IA	Ionized Ammonia
IQP	Import Quota Policy
K	Condition Factor
Kg	Kilogramme
KOH	Potasium Hydroxide
LYM	Lymphocyte
Mg/l	Milligramme per litre
MLG	Mean Length Gain

MMT	Million Metric Tonnes
MS	Mean Square
MWG	Mean Weight Gain
₦	Naira (Nigeria currency)
NaCl	Sodium Cloride
NBS	National Bureau of Ststisticss
NSPFS	National Special Programme for Food Security
NH_3	Ammonia
NO_3	Nitrite
OATA	Ornamental Aquatic Trade Association
PER	Protein Efficiency Ratio
pH	*Pouvoir hydrogen* (Hydrogen ion concentration)
Ppm	Part per thousand
PI	Production Index
PRI	Protein Intake
PSD	Pelleted Sinking Diet
PVC	Poly-vinyl Chloride
RBC	Red Blood Cell
$	USA Dollar
SD	Stocking Density
SGR	Specific Growth Rate
SR	Survival Rate
SS	Sum of Square
SSA	Sub- Saharan Africa
SSC	South South Corporation
TAN	Total Ammonia Nitrogen
TR	Total Revenue
TVC	Total Variable Cost
UIA	Unionized Ammonia
UK	United Kingdom
UNDESA	United Nations Department of Economic and Social Affairs.

USA	United State of America		
USSR	Union of Soviet Socialist Republic		
RWS	Recirculating	Water	System

CHAPTER ONE

1.0 Introduction

1.1 Background of the study

Fish and fisheries products constitute an essential means of good quality protein and nutritional security for the majority of households all over the world (FAO, 2012). Fish stillconstitutes up toabout 17 % of the world people's consumption of protein, and this could increase to 70 % in many coastal and island countries(FAO,2014). Fisheries sector of agriculture is asource of health,providing essential nutrients, vitamin and omega-fatty acids, and also of wealth. It provides a means of revenue including livelihoods to multi-million of African populations, providing job to almost 12 million Africans, with women playing a preponderant role especially in post-harvest ventures like processing and marketing (Ozigbo *et al*. 2014;Tumusiime, 2014).

Fisheries participationin the agricultural sector of the Nigerian economy is very substantial.With regard to Gross Domestic Production (GDP), the fisheries exhibited the swiftest growth rate of agriculture contribution to the GDP. Fisheries sub-sector of agriculture input to GDP stood at 476,144.21 million naira ($2,391.17 million) while agriculture in general was 19,160,824.83 million naira ($96,224.63 million) in 2015 (NBS, 2016).

The consumption of fish traverse varied nationalities and cultures all over the world (FAO, 2012). In Africa, fish is an invaluable source of nutrient of the utmost importance for diversified and nourishing diet. Many populations in Africa rely on fish as part of their diet. This is evident by the fact that in some coastal and island countries, fish contribute to over 25 % of their animal protein intake. For most of thesecountries, fish is relatively cheap source of animal protein as compared toalternative protein sources (Tumusiime, 2014).

Fish is the main and inexpensive means of good protein of animal origin in the food of agreater population of Nigerians. Fish quality in terms of the nutritional value is veryimpressive because ofits rich display of amino acids (protein / body builder). Of greater importance isits relatively low price when compared with other sources of animal protein except for pork, and relative long shelflife when it is dried or smoked(Ayinla, 2010; Akinbode and Dipeolu, 2012;Odum, 2016). Fish alone account for 40 % on the average of animal protein intake in Nigeria (Adedeji and Okocha, 2011; Ozigbo*et al*., 2014). Nigeria's current annual per capital consumption of 11 kilogrammes (kg) is considered lower than the

global average of 21kg (Odum, 2016; Proshare, 2016 andDaferighe *et al*., 2017) and just less than the estimate of 13.5 kg for Cotê d'Ivore (Proshare, 2016).

The demand for fish in Nigeria exceedsthe local production (Ozigbo,2014). The total demand for fish in the country based on 2014 estimated population of 180million is 3.32 million tonnes. In 2014, the country's fish production from aquacultureand capture fisheries contributed 1.12 million tonnes leavinga shortfall of approximately2.2million tonnes(Odum, 2016; Premium Times, 2016 andProshare, 2016). This huge demand and supply deficit has compelledthe country to import about 1.9 million tonnes of fish worth over₦125billion($625million) per annum (Odum, 2016;Vanguard, 2018). The continuous importationof fish portendsan enormous drain of foreign exchange reserved and import of jobopportunity to the teeming unemployed people in the country. Also, the inceasing request for foreign exchange to import fish into the country is unsustainable taking into consideration the pressure on foreign reserves coupled with fluctuating revenues from crude oil.In view of the population growth rate of 3% annuallyin Nigeria, the deficiency betweendemand and supplyfor fish is anticipated to continuously escalate (Nigeria Fisheries Report, 2013).

Aquaculture is regarded as panacea for reducing the food fish demand and supply gap and moving Nigeria towards sufficiency in fish production especially African catfish farming (Ugwumba, 2005 and Nwipie, 2015). The steady increase in aquaculture production indicates that it is a panacea towards boosting fish outputto satisfy the immediate and future requirement. Thus, the intensification of fish cultureproduction would ensure food security in the country and bring about foreign exchange inflow.

Adesina (2014), revealed that the Federal Ministry of Agriculture and Rural Development (FMARD) has put in placea number of plans to boost fish production in the countryunder Agriculture value chain. Notable among these plans and targets set are: to increase fish fingerlings production by 1.25 billion; production of0.4 million metric tonnes of fish feed annuallyand to escalate table size fish output by extral250,000 metric tonnes to achieve above 67% sufficiency.

Import Quota Policy (IQP) of 2013 is another policy adopted to makeNigeria becoming self-sufficient in fish output through a 25 % fish import reductionover a period of four years from the commencement of the policy. This implies that only 0.5 million metrictonnes out of 0.7 million metric tonnes bench-mark originally setfor fish import in 2014 would be permitted for importation. However, catfish and tilapia speciescultured in Nigeria coupled with Croaker

(*Pseudotholithustypus* and *P.elongates)* from country's coastal waters are prohibited from importion (USAD, 2014 and Nairaland Forum, 2014). According to National Mirror (2014), Import Quota Policy has led to escalated domestic fish production and about 20 % reduction in prices of various species of fish in the markets across the country.

Just as fish supply from capture fisheries persist to dwindle and world people increases, intensive fish farming such as cage culture offers an effective and viable option of boosting domestic fish production in Nigeria.

Nigeria is naturally endowed with huge species of fishes with potential for culture. However, only a fewspecies are currently cultured commercially. Notable among these cultured species are the Clariidae (*Clarias gariepinus*,*Heterobranchus* species), Cichlidae(*Oreochromis niloticus, Sarotherodon* and *Tilapia* species), Osteoglossidse(*Heterotis niloticus*),Cyprinidae (*Cyprinus carpio*)(common carp, an exotic species) (Anetekhai, 2013; Osondu and Ijeoma, 2014). However,*Clarias gariepinus*is commonly cultured in the country. Among the characteristics that position*Clarias gariepinus* a number one "preference"aquaculture species and most enjoyed by consumers in Nigeria encompass the following: The fish is found in allecological zones, consumed by majority of the tribes, capability to withstand severe environ-
mental cicumstances, attracts premium price, very delicious and can be living for day*s* in the course of marketing (Anetekhai, 2013). Other desirable attributes of *Clarias gariepinus* include rapid growth, efficient conversion of feed to flesh, ability to resist pathogens andprolong dry spell(De Graaf and Janssen, 1996). Furthermore, *Clarias gariepinus* is a suitable species for high density culture such as cage culture (Hengsawat,1997). Owing to all these attributes, especially high environmental tolerance andits easily controllable breeding habits, *Clarias gariepinus* was selected by FAO as a favourable species for fish culture production (FAO, 2015a). Presently, live *Clarias gariepinus* commands high price in the countrywith high economic returns on investment varying from 40% to 60% in some very profitable enterprise.

The estimated production of *Clarias gariepinus* as at 2013 was over 253,898 MTs per year (Anetekhai, 2013) but recently the Catfish Association of Nigeria (CAFAN)reporteda production figure of 370,000 metric tonnes in 2016 (Akingbolagun, 2017). The current aquaculture production figures of 1.2 million metric tonnes (Premium Times, 2016) represents 33.63 per cent of total aquaculture production. Catfish production in 2016 also

contributed about 4.5 % to the nation's GDP and offers more than two million employments to Nigerians in the various section of economy (Akingbolagun, 2017). This species has been reported to be successfully culture in cages (Otubusin, 2009 and Collins, 2017). Thus, *Clarias gariepinus* was selected for this study.

The commonly used enclosure technology for fish rearing in Nigeria are earthen or dug-out ponds and fish tanks (Idowu, 2013). These are most expensive in terms of land procurement and construction. The earthen ponds are common in rural areas while concrete tanks and cement block wall tanks are very common in cities (Olukunle, 2004 and Omintoyin, 2007). The systems of production are extensive and semi-intensive with production figures that could not bridge the demand-supply gap for fish in the country. In order to achieve sufficiency in fish productionin Nigeria,there must be a paradigm shift from current production systems that could not meet the nation's demand to an intensive fish culture most especially cage culture (aquaphore or water based). Cage culture system attracts less investment than other intensive systems such as fish pens, raceways and recirculating water systems. This is because cage culture supplies energy savings,it doesn't require facilitieslike water pump for impoundment and draining or aerator for aeration of water. According to Guo and Li (2003), Cage culture is among the utmost effective fish culture systems commonly employ for intensive fish production.

The Federal Government of Nigeria (FGN) has identified the importance of cage aquaculture in bridging the demand-supply deficit. This made the FGN to incorporate this method into its field support activities under National Special Programme for Food Security (NSPFS), phase one of 2002-2006. Also, the expansion of cage aquaculture techniques is embodied in the new National Agricultural Fisheries Policy which listed it as a neglected but profitable system which must be urgently developed for fish production in the country (Ingawa, 2006). The current Nigeria's Agriculture Transformation Agenda (ATA), put cage culture under the fisheries addition value programme (Adesina, 2014b).

Cage culture is an established and profitable intensive aquaculture system in many countries. According to Beveridge (2013), cage culture has thrived in coastal water ofNorth and South America, Northern Europe, inland waters of Asia, especially China, Philippines, Indonesia, Vietman and more recently in Bangladesh. In Nigeria, cage culture can be best described to be at infancy when compared with sub-Saharan Africa countries like Ghana, Kenya, Malawi, Uganda, Zambia and Zimbabwe where cage aquaculture on commercial scale is currently

growing(Blow and Leonard, 2007). The productivity of cage culture is very high with up to 5000 MTs per hectare per year (Beveridge, 2013), and 10 to 20 times higher compared to production in ponds (Alam and Kumar, 2015).Cage culture is easy to adopt because itis practiced on existing public waters, costs lesstoconstruct, minimal in capital expenditure, guarantee protection from predators and high productivity with good returns on investment (Imelda *et al*., 2009).

Nigeria is endowed with huge potential for cage culture development, extensive coastline (853km), perennial swamp (1.0) million ha), freshwater (14 million ha), brackish water (741,509ha) and marine water (48,695 ha) (Anetekhai, 2013). Furthermore, Nigeria has about 263 medium and large man made lakes and reservoirs with an amalgamated water volume of about 33 billion cubic meters (Ukuedojor, 2013).

In view of the huge potential for cage culture development coupled with its high productivity, development of this type of intensive fish aquaculture would boost fish production to bridge the fish demand-supply gap in Nigeria.

However, the growth in the cage culture business in sub-Saharan Africa is affected by a number of constraints. These include inaccessiblity and astronomicalprice of quality fish seeds, high cost of good quality feed (extruded floating feed), lack of technical relevant production skill as wellas access to information (Blow and Leonard, 2007). All these bottlenecks are vital in the adoption and expansion of cage fish culture in Nigeria.

Stocking densityis a crucial variable in rearing of fish as thesurvival, growth, health, behaviours, feeding and water quality are directly influenced by this variable (Dibattista, *et al*., 2005). Understocking of fish ensues in failure to maximally utilize the available space in the culture enclosure while excessive stocking induces stress that perhaps culminate in stunted growth and poor feed utilization (Hengaswat, *et al.,* 1997), both understocking and excessive stocking influence farm business and economic returns. Discovering optimal density for individual fish species is consequently, a principalelement when planning an effective cage culture methodology for altmost production and economic returns (Rowland*, et al.,* 2006). The probable effects of understocking and overstocking elucidate the necessity for research to establish optimal densities for diverse species of fish (Beveridge, 2004).

Feed is also one of the operating costs mostly limiting the expansion of cultured species (Sørensen, 2012). Feed commonly accounts for 40% - 60% of the operating costs depending

on levels of intensification and fish species under culture (Limbus and Jumanne, 2014; Kannadhason *et al*., 2009). The rearing of *Clarias gariepinus* in many countries normally involves the purchase or production of on-farm pelleted sinking or extruded floating diets. Whether purchased or produced on-farms, extruded floating diets are usually more expensive than sinking diets because extrusion process which is the main activity that makes the diet to float adds extra cost (Kannadhason *et al*., 2009). Absolute reliance on extruded floating diets limits the production performance and profitability in aquaculture enterprise (Limbu, 2015). Thus, the use of less expensive pelleted sinking diets in cage aquaculture need to be considered and investigated as alternative to floating diets.

This study is therefore designed to evaluate the production of *Clarias gariepinus* under varying stocking density and feed forms (floating and pelletized sinking diets) in floating net cages.

1.2. Justification

It is evident that the demand for fish in Nigeria has outstripped the domestic production. The country's need for fish is 2.7 million MTs per annum while the domestic production is 0.8 million MTs, causing a demand-supply gap of 1.9 million MTs per annum (Nigeria Fisheries Report, 2013; Ozigbo *et al*., 2014 and Adesina, 2014). The available evidence has shown the decline of fish output in Nigeria from artisanal capture fisheries, the principal source. The decline in fish production isas a consequence of overexploitation, habitat degradation and pollution in the very rich artisanal fisheries area of Niger Delta due to the activities of oil prospecting companies (Adewumi and Olaleye, 2011;Adedeji and Okochaa, 2011 and Akinrotimi *et al*., 2011), problems of piracy and militant groups (Jamabo and Ibim, 2010; Nigeria Fisheries Report, 2013), and the global climate change (Mustapha, 2013).

Globally, the decline in fish production from capture has brought about the expansion of aquaculture, a more reliable and manageable fish production system (FAO, 2012). In Nigeria, the cognizance on the capability of fish culture to boost domestic fish production has continued to increase(Adewuyi*et al*., 2010). However, aquaculture production from earthen ponds can

not satisfy the request for fish in the country. This has necessitated the development of intensive aquaculture practices in other area of aquacultural production such as cage culture. In this case, the system of cage culture, an intensive aquaculture system,that is highly productive, profitable and reasonable with regards to capital investment, it has an important

role in correcting imbalance between the demand and supply of fish in Nigeria. The importance of cage aqua-culture in meeting global demand for fish was also reported by FAO, (2012).

Cage culture is an established and profitable intensive aquaculture system in many countriesaccording to Beveridge (2013). In Nigeria, the practice of cage culture can be best described to be at infant stage.

Nigeria endowed with huge potential for cage culture development, extensive coastline (853Km.), perennial swamp (1.0) million ha.), fresh water (14 million ha.), brackish water (741,509 ha) and marine water (48,695 ha) (Anetekhai, 2013) has not employed the practice of cage aquaculture.

Stocking density isincludedin the crucial parameters affecting survival, growth, behaviours, well-being, water quality, feeding and yieldin fish culture (Sanchez, 2010). Currently, small and medium cage culture fish farmers in Nigeria lack adequate technical knowledge with respect to optimal stocking densities. They employ various stocking density ranging from 50 - 150 fish (juvenile or advanced fingerlings) per cubic metres for the most farmed fish species *(Clarias gariepinus)* in the country. Therefore, extensive evaluations of various management strategies to select optimal culture procedure such as stocking densities among others, under certain socio-economic conditions require urgent attention in Nigeria.

Dependence on costly extruded floating diets has also been reported as limiting production performance and profitability in aquaculture by Limbu, (2015). The results of preliminary survey of fish farmers in Lagos, Ogun and Osun States ofNigeria in this present study revealed that all cage culture farmers only utilized extruded floating feed which is more expensive than pelleted sinking feed (FAO, 2015;Santo-Agro, 2017). Therefore, it is imperative to investigate the use of cheaper pelleted sinking diets in cage fish culture to reduce the operating cost with resultant increase in profitability.

1.3. Main objective

The main objective of this study is to compare the production performance and economic evaluation of *Clarias gariepinus* under varying stocking densities and feed forms in floating net cages.

1.4. Specific objectives

1. To evaluate the impact of varyingstocking densities and feed forms on growth and feed

utilization of fish in net cages

2. To assess the effect of stockingdensity on stress markers of fish in net cages.

3. To assess the impact ofstocking density and feed forms (floating and sinking) on economic returns offish rearedin net cages.

1.5. Hypotheses

1.H_o.Stocking density and feed forms do not significantly affect the growth performance and feed utilization of fishin floating net cages.

2. H_o. Stocking density and feed forms have no influence on the haematological profiles (stress

Markers) of fish in floating net cages.

3. H_o. There is no significant difference in the yield and economic profitability of fishunder varying stocking densities and feed forms in net cages.

CHAPTER TWO

LITERATURE REVIEW

2.1. Global overview of fisheries and aquaculture

Fish and its products are indispensable to food security, supplying global population ofapproximately 3 billion with nearly 20 %of their major supply of protein and over 4.3 billion with nearly 15 % of mean per capita animal protein consumption (FOA, 2014). Global per capital fish intake has grown from about 9.9 kg to 20kg between 1960s and 2014, a significant increase up from 67% in the 1960s to 87%in 2014 (FAO, 2016a).

Globally, fish output has grown consistently during the past 50 years with fish supply inceasing at the rate of 3.2 % annually, faster than global population increase of about 1.6 % (FAO, 2014). In 2014, worldfisheries outputattained 167.2 million metric tonnes, out of which93.4 and 73.8 million tonnes werefrom capture and aquaculture, respectively. In this same year, a record was created when, for the first time ever, fish consumed from culture fish outpaced that from capture fisheries. More than 146million metric tonnes of fish were directly consumed as food by the world's population (FAO, 2016a).

The worldwide fisheries and aquaculture supports the livelihood ofbetween 10 and12 % of globalpopulation (FAO, 2014; Living Blue Planet Report, 2015). About 60 million people are engaged in this sector in 2012 with Asia leading with 84 % followed by Africa 10 % (FAO, 2014). Nearly 90 % of the fisherfolks are artisanal out of which 15 % are women engaging in ancillary operationslike processing, marketing etc. (FAO, 2014).

The demand for fish as a mean of readily digestible protein of animal origin for human intake is very high and will continue to escalate in the coming decades due to ever-increasing population growth coupled with urbanization. The United Nations Department of Economic and Social Affair (UNDESA) projected that; the world population would attain 9.7 billion in 2050 from 7.3 billion in 2015. Greater than 50 % of the world's population growth would occur in Africa, while Nigeria is expected to be the second major contributor to the global population growth (UNDESA, 2015). The increased need for fish to satisfy the rising human population and animal feed production requires higher production level of healthy and safe fish and fish products.

The world consumption of fish food has been reported to havedoubledsince 1973, with undeveloped nations responsible for over 90 % of theincrease (Brummett and Williams, 2000;Bénéand Allison, 2007). The world intake of seafood is increasing, while capture fisheries is declining and aquaculture has increased in recent years and persists to be among the swiftest developing sector (FAO, 2014).

Predictions indicate that wild-caught fish will not satisfy the increasing globalrequirement for fish food in the future. The reason is thatnearly all the majorworld fishing sites have attained their optimal potential production(FAO, 2012). However, with the speed aquacul-ture is expanding, predictions have shown that it will providethe most dependable source of aquatic food in the future (Hixson, 2014). According to World Bank (2014), fish culture will contributealmost 66.67% of world fish intake by the year 2030 as production from wild-catch stabilize and requirement from a rising world middle-class greatlyincreasing.

2.2.Sub-Saharan Africa aquaculture

Fish and fishery products are of great importance to food and nutritional security. Many populations in Africa rely on fish as partof theirdaily foodand in some coastal countries fishes contribute over 25 % of their animal protein consumption (Tumisiine, 2014).

The contributionof sub-Saharan Africa (SSA) to world fish culture production is still insignificantbut increasing significantly (Satia, 2010). The world aquaculture production reached 106 million metric tonnes (MMT) in 2015, 76.6 MMT of aquatic animals and 29.4 MMT of aquatic plants with an annual growth of 6.6% since 1995. Out of this global aquacultureproduction figure, Africa contributed 1.772 MMTrepresenting 2.3% share in world total (FAO, 2017).

Aquaculture in sub-Saharan Africa is still at its infancy stage practicing at a very low level (Machena and Moehl, 2001). However, commercial aquaculture is experiencing a renaissance in a number of countries likeAngola, Congo, Ghana, Nigeria, Kenya, Madagascar, Malawi, Uganda and Zambia (Moehl *et al.,* 2006). Sub-Saharan Africa's contribution to global aquaculture production in 2014 was 0.75 % with Nigeria contributing 313,231 metric tonnes(56%) compared to 143,207 metric tonnes (60 %) in 2008, an indication of production growth in other countries (FAO, 2016a; Table 2.1). According to INFOFISH(2015), aquaculture provides aprogressively appealing key to supplying food fish demands in sub-Saharan Africa.

About 93% of aquaculture production in sub-Saharan Afica is from fresh water and mainly the culture of ubiquitous species of Tilapia and African catfishes (Satia, 2010).

2.3. Aquaculture in Nigeria

Fish culture in Nigeria commenced over five decades ago (Olagunju *et al.,* 2007), still the nation could not satisfy its production need for fish (Ozigbo *et al.*, 2014) because it is least exploited when compared to huge potential for its production and marketing (Ejiola and Yinka, 2011. Foood and Agricultural Organization of United Nations(FAO), (2005b, 2006b) indicated that Nigeria blessed with vast mangrove ecosystem and more than 14 million hectares of inland freshwater areafrom which 1.7 million hectares are exploitable and satisfactory for fish aquaculture, should notface any seriousproblem in attaining enough and renewable fish production to supply national requirement.

In Nigeria, fish contributes 40 % on the average animal protein consumption (Adedeji and Okocha, 2011; Tijani, 2011; Ozigbo *et al*. 2014). Therefore, the vital role of the aquaculture and capture enterprise to continuous supplyof animal protein cannot be over exaggerated. Unfortunately, the domestic production of fish could not meet ever-growing demand. This is because of persistent dewindling output from the nation's principal means of food fish (GAIN, 2007).

In recent times, aquaculture production seems to be expanding progressively in Nigeria. The country's fish output by aquaculture sector between 2010 and 2015 was 1,584,225 metric tonnes, represented 27.37 % of total production of 5,788,474 metric tonnes from all sectors. In 2015, the estimated aquaculture production in the country was 316,727 metric tonnes approximately 1.6 times higher than 2010 production figures of 200,535 metric tonnes (National Bureau of Statistics, 2017; Table 2.2).

The driving force for the growth of aquaculture in the country include hunger, poverty, unemployment, increase awareness of fish farming as business, population increase, declining capture fisheries and local demand (Nene *et al.,* 2014). Currently, the sector contributes 3 to4 % to the nation's Gross Domestic Product (GDP) (Kingsway Agro Service, 2012 and Blueprint, 2014). According to Ugwumba (2005), the best option of increasing fish production and make Nigeria toachieve sufficiency is by means of intensive aquaculture particularly African Catfish culture.

Table 2.1: Upmostseven aquaculture producingnations in sub-Saharan Africa from 2008 – 2014 in tonnes

Country	2008	2009	2010	2011	2012	2013	2014
Nigeria	143 207	152 796	200 535	221 128	253 898	278 706	313 231
Uganda	52 250	76 654	95 000	85 713	95 906	98 063	111 023
Ghana	5 594	7 154	10 200	19 092	27 450	32 513	38 545
Kenya	4 452	4 895	12 154	22 135	21 488	23 501	24 098
Zambia	5 640	8 505	10 290	10 530	12 988	20 271	19 281
Madagascar	10836	6 116	6 886	8 845	8 585	8 974	8 470
South Africa	3 587	3 433	3 133	3 572	3 999	4 010	4 160
Other	14 001	14 426	17 917	24 898	28 380	33 683	38 142
Total	239 567	273 979	356 115	395 913	452 697	499 721	556 950

Source: FAO, 2016a

Table 2.2: Fish production in Nigeria from different fisheries sub-sectors (2010-2015)

S/NO	Sectors	2010	2011	2012	2013	2014	2015
1.	Artisanal:						
	Coastal & Brackish Water	328,332	346,381	370,918	418,537	435,384	382,964
	Inland: Rivers & Lakes	288,649	292,105	297,836	326,393	324,444	311,903
	Sub-total	616,981	638,486	668,754	744,930	759,828	694,867
2.	Aquaculture (Fish farm):						
	Sub-Total	200,535	221,128	253,898	278,706	313,231	316,727
3.	Industrial (Commercial):						
	Fish (Inshore)	19,261	19,736	27,977	37,652	29,237	10,727
	Shrimp (Inshore)	12,249	13,749	17,654	22,219	20,715	4,737
	EE2	-	-	-	-	-	-
	Sub-Total	31,510	33,485	45,631	59,871	49,952	15,464
	Grand Total	849,026	893,099	968,283	1,083,507	1,123,011	1,027,058

Source: National Bureau of Statistics (NBS) 2017

2.4. Fish culture production systems and techniques in Nigeria.

There are different systems and techniques engaged in fish production in Nigeria. The three major systems based on feeding methods are; extensive, semi-intensive and intensive. In the extensive system, fish feedexclusively on natural food(phytoplanktons and zooplanktons) without supplementary feeds. The intensive system is the one in which the fish are fed with external food supply (nutritional complete formulated feed). Whereas, in the semi-intensive,the natural food supplyis supported with supplementary feed such as agricultural and industrial wastes.

In Nigeria, the systems of fish production are traditionally extensive or semi-intensive. However, in recent years aquaculture industry has moved from extensive or semi-intensive to intensive system (Akegbejo-Samson and Adeoye, 2012). In sub-Saharan Africa, Nigeria has been reported asone of the countries where commercial (intensive aquaculture) is experiencing renaissance (Moehl *et al.*, 2006).

Rearing of fish in Nigeria takes place in different enclosures or facilities like earthen ponds (commonly practiced), concrete ponds and tanks, fibre glass and plastic tanks, cages and intensivewater recirculating system (WRS) (Anetekhai, 2013; Nénée*t al*., 2014). The earliest record of WRS technology for intensive aquaculture in Nigeria was in 1978atNigerian Farms Ltd. Patani in Delta State by a group of businessmen from Germany. Subseqiently, Chi Farms Nigeria Ltd. Lagos, Zartech and Durante Farms in Ibadan, Oyo Stateadopted this technology in 1996 (Anyawu and Ezenwa, 2003). Presently, the use of concrete pond/tank is gaining prominence over earthen ponds.This type ofrearing facilities is rampant mostly in cities especially where land is unavailable or unsuitable for earthen pond establishment (Omitoyin, 2007). In southwest Nigeria for example, 55 % of fish farmers produce fish in concrete tanks, about 35 percent in earthen ponds and 10 % in other enclosures (Akegbejo-Samson and Adetoye, 2012). In Lagos State as reported by Adeogun*et al*. (2012), more than half (58.3 %) of fish farmers culture fish in concrete tanks, earthen pond (35 %) while other enclosures takes care of the remaining to make up 100%.

2.5. Culture fish species in Nigeria

The predominant species cultured in Nigeria include African catfish(*Clarias gariepinus*,*Heterobranchus*spp.*),* Tilapia (*Oreochromis*spp., *Sarotherodon*spp. and *Tilapia*spp.; Osteoglossidae (*Heterotis niloticus)*and exotic species like common carp (*Cyprinus carpio)* (Offem *et al*., 2010; Anetekhai, 2013; Osondu and Ijeoma, 2014).

However, the most commonly cultured species is *Clarias gariepinus* (Adewolu*et al*., 2008; Adewumi and Olaleye, 2010; Anetekhai, 2013; Nkamigbo*et al*., 2014 and Ozigbo*et al*., 2014).

2.6. African catfish *(Clarias gariepinus)*

African catfish,*Clarias gariepinus* (Burchell, 1822) has been identified as one of the most stable species for fish culture in Africa.Also,adjudged to be the most important species of aquaculture (de Graaf and Jenssen, 1996).It is the major commercial species in Nigeria for its excellent culture and market attributes. Since the 1970s, *Clarias gariepinus* has held to the great promise for aquaculture in Africa. The attributes, which contribute to its great production successes include; fast growth rate, ability to withstand handling and stressful conditions(Hecht *et al*., 1996), and high acceptability by consumers.

2.6.1. Classification

African catfish,*Clarias gariepinus* belongs to the following taxonomic groups (Eschmeyer, 2014)

Phylum − Vertebrata

Class – Actinoptrygii

Subclass − Osteichthyes

Order – Siluriforms

Family – Clariidae

Genus −*Clarias*

Species – *gariepinus*

2.6.2. Distribution and habitat

Clarias gariepinus has an almost Pan-African distribution, as it is naturally found in all (West, South, North, and East) African countries. They are also reported to occur or introduce to other parts of the world including: Argentina; Bangladesh; Brazil; Cambodia. China; Czech Republic; Greece; India; Indonesia; Iraq; Israel; Jordan; Loa People's Democratic Republic; Myanmar; Netherland; Philippines; Singapore; Syria;Thailand; South of Turkey; and Vietnam.

Clarias gariepinus inhabit a variety of freshwater environments, such as lakes,streams, rivers, swamps, pools and flood plains (Eschmeyer, 2014 and Freyhof, 2014).It is highly adjustableto acute environmental situations and can survive in a pH range of 6.5- 8.0.*Clarias gariepinus* optimum temperature for growth vary from 28-30^0 C (Teugels, 1986).This fish species is a bottom dweller, obligate air breather and can tolerate very poorly oxgynated waters (Skelton,1993).

2.6.3. Physical description

Clarias gariepinus(Figure 2.1) is a scale-less fish with elongated cylindrical body containing dorsal, anal, pectoral and caudal fins. The caudal and anal fins are extremely long with61-80; and 45-65 soft rays, respectively. It also has round caudal fins containing soft rays, while the pectoral fins have strong spine (Teugels, 1986). The fish has large, flattened and highly ossified head with skull bone and two small eyes as well as four pairs of unbranched barbells. This species has a pair of accessory air-breathingorgan; springing up from gill arches, which are cauliflower-like structures and highly vascularized. The breathing organs allow the fish to remain alive outside water for many hours breathing atmospheric oxygen (de Graaf and Janssen, 1996; Pouomogne,2010) and also enhance high survival rates of the fish in low oxygenated culture environment. The colour of this fish can be gray and olive green with dark greenish-brown markings dorsally and creamy white ventrally. The male can be differentiated by the existence of a distinct, pointed or conical sexual papilla which is absent in the female.

Figure 2.1 African catfish, *Clarias gariepinus*

2.6.4 Feeding habit and nutritional requirement of *Clarias gariepinus*

Clarias gariepinus is an omnivorous predatory fish, feeding on a wide range of food stuffs; ranging from minutes zooplankton, to fish, up to 0.1 % of its physical body. Under culture system, it accepts formulated feeds. Table 2.3;shows nutritional requirement of African catfish, *Clarias gariepinus.*

2.6.5 African catfish culture

African catfish is a major fish that is reared in different parts of the world. According to FAO (2016b), the leading ten catfish producing countries in order of production quantity are Nigeria, followed by Netherlands, Brazil, Hungary, Kenya, Syrian Arab Republic, South Africa, Cameroon, and Mali. The combined production of African catfish in 2015 was 246,476 metric tonnes (FAO, 2017). In Asia, a number of aquaculture producing nations like China, Indonesia, Thailand, and Malaysia also contribute substantial quantities of African catfish to global production figures, but there are paucity of statistics on production figures by the FAO. Therefore, the total African catfish output could be grossly under-reported. For example, production figures from 2001 to 2012 reported for Nigeria by Federal Department of Fisheries were greater when compared with the official FAO statistics (Anetekhai, 2013). The disparity could be attributed to rearing of catfish hybrids which occur not only in Africa but also in many Asian coutries. Therefore, it is difficult to distinguish the data for pure-breed African catfish species from that of their hybrids and FAO production figures were recorded underneath the designation African catfish but were misconstrued and expressed as *Clarias* species (Dauda *et al*., 2017).

Table 2.3: Nutrient requirement of *C. gariepinus* as percentage or per unit kg (Dry diet)

Nutrients	Fry & fingerlings	Juveniles &growers	Broodstock
Crude protein (%)	40 – 55	35 – 40	45 – 50
Crude lipid (%)	14 – 15	12.14	10 – 12
Calcium (%)	1.5	2	1.5
Phosphorus (%)	1.2	0.9	1.0
Methionine + cystine (%P)	2.1	1.6	1.8
Lysine (%P)	3.08	2.78	2.78
Leucine (%P)	2.66	2.45	2.40
Vitamin A (IU)	3000 – 6000	2500 – 5000	3000 – 6000
Thiamine (mg/kg)	24	20	24
Niacine (mg/kg)	120	100	120

Source: Pillay and Kutty (2005)

P = Protein

2.6.6Catfish culture systems

The African catfish,*Clarias gariepinus*can be culturedemploying various culture systems like the earthen ponds; concrete tanks, raceways (flow-through system),water recirculating system includingcages.

2.6.7 Catfish culture in Nigeria

In Nigeria, African catfish is the most preferred fish and accountable for the greatest fish culture production of the country (FAO, 2017). Adewumi and Olaleye, (2010) submittedthat catfish especially *Clariasgariepinus* accorded the country a place in the worldwide fish culture output.Presently, Nigeria is the largestproducer ofcatfish in Africa and in the world (FAO,2017).

As reported by FAO, the share of African catfish culture to entireoutputs in Nigeria escalated from 7-8 % in 2001 to 53.2 % in 2013 (Figure 2.2). In 2015, FAOstatistics revealed that overal African catfish produced in the country was 160,295 metric tonnes included in global production of 316,727 metric tonnes, which constitutes 50.61 %. However,Anetekhai (2013), on the basis of the statistics acquired from Federal Department of Fisheries inthe country from 2001 to 2012, indicated that the contribution of African catfish to fish culture outputs in the countryvaried from 80 percent to 90 %. The disparity is likely due to FAO reporting only for pure *Clarias geripinus*whereas their hybrids as well as otherswhich couldn't be authenticated were communicated as *Clarias*species.

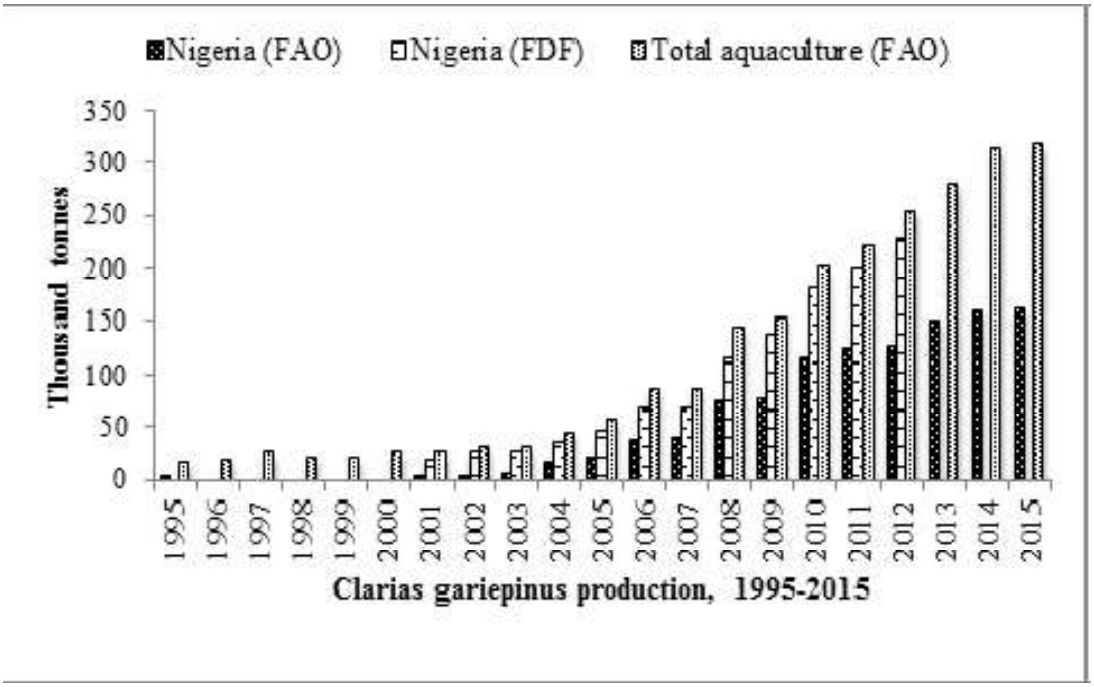

Figure 2.2*Clarias gariepinus*output in Nigeria in comparison with overall aquaculture outputfrom 1995 to 2015.

Source: Dauda *et al*, (2018)

2.7Cage culture

Cage culture is adevelopingmode of production whereby fishes are cultured from fingerlings to table size while confined in an enclosure that allows the unconstrainedmovement of water with the surrounding water body. All the sides of a cageis enclosed,including the bottom with synthetic net materials that can withstand decay for an extremely long period of time (Schmittou, 2006 and Vaishnav *et al.,* 2017). Cage culture has a great developmental potential as is presently among the rapidly expanding component of worldaquaculture production.Also, it plays a significant role in most leading aquaculture production countries with a production of approximately 3.5 million metric tonnes (Tacon and Halwart, 2007).Cage culture isoften employed all over the world in freshwater as well as marine environs which include: rivers, ponds, lakes, reservoirs, estuaries andopen ocean (Beveridge, 2004). It is widely perceived that cage culture has the potential to increase fish output on the scale that would be needed to meet Africa's fish demand and production deficit.

The concept of culturing fish in cages is not new. However, the on-going production of farmed aquaculture organism in cagesis a relatively newaquaculture technology. Though, the emergence of the employment of cages for keeping and conveying fish for short durations may be predated approximately two hundred years ago (Pillay and Kutty, 2005). It may have originated possibly before (late 1800s) (Gopakumar, 2009) as one of local methods of fisherfolks living on boats particularly in Kampuchea Southeast Asia along the River Mekongfor the rearing of fish predominantly Siluridae and of Clariidae in bamboo cages (Hickling, 1962, Huet,1970).This practice was introduced to other far East Asia, first to Thailand, (Ling,1968, Bardach*et.al.*,1972).Later, this technology spread to Java Islandas well as Indonesiain1940 as firsly reported by Vaas and Sachlan, 1956(cited in Hickling, 1962). Marine cage culture of fish traces its origin back to the 1950s in which aquaculture research at the Fisheries Laboratory of Kinki University in Japan brought about the commercial prodction of yellow tail, *Seriola quinqueradiata,* in floating net cages and later grew into a large-scale enterprise as early as 1960 (Gopakumar,2009). By 1970 the commercial production of fish through cage aquaculture in Japan reached 52,000 metric tonnes for more than 9000 cages covering nearly 100 hectares of water surface (Furukawa,1973).

Following the success of cage aquaculture, and coupledwith the development of nutritionally complete artificial diet prompting intensive fish culture, its geographical spread greatly accelerated in the 1960s. In 1994, cage culture was introduced to the United State of America

in Alabama(Trotter, 1970), Canada (Seguin, 1970),Chile (Arroyo,1973), United Kingdom (Milne,1972), and Russia,USSR (Gribanov*etal*. 1968). Other countries where cage culture was employed include Hungary, Ireland, Norway the Netherland, and Germany(Coche,1976).

The cage culture sector has grown very fast in the last two twenty years and is currenly experiencing speedytransformation in regards to pressure from global development resulting in escalating demand for fish and its products inundevelopedand advanced / industrial nations(Tacon and Halwark, 2007). Prediction has shown that fish intake in undeveloped nations likely to escalate from 62.7 million metrictonnes in 1997 to 98.6 million metric tonnes by the year 2020, an increase of 57 % (Delgado*et al*., 2003).

In 2005, principalproducers of fish in cages include China (29%), Norway (19%), Chile (17%), Japan (8%), United Kingdom (4%), Vietnam (4%) etc. (Tacon and Halwart, 2007; Figure 2.3).

Presently, nearly 80 fish species are reported cultured in cages. Whereas, 51% of overall cage aquaculture output are contributed by a single species, *Salmo solar* while 27 % were accounted for by these species namely: *Oncorhynchus mykiss, Seriola quinqueradiata, Pangasius* spp. and *Oncorhynchus kisutch* (Figure 2.4).

In 2005, cage culture production from 62 countries and provinces / regions engaging in cage fish culture stood at 3,403,722 tonnes (Tacon and Halwark, 2007), with China alone contributed about0.99 million tonnes from inland and coastal cages (Chen *et al.,* 2007). Out of total production in 2005, Norway contributed approximately 0.65 million tonnes, Chile (0.59 million metrictonnes), Japan (0.27 million metric tonnes), United Kingdom, (0.145 milliontonnes), Viet Nam (0.13 million tonnes), Canada (0.01million tonnes), Turkey (0.08 milliontonnes), Greece (0.08 milliontonnes), Indonesia (0.07 million tonnes), and the Philippines (0.07 milliontonnes).

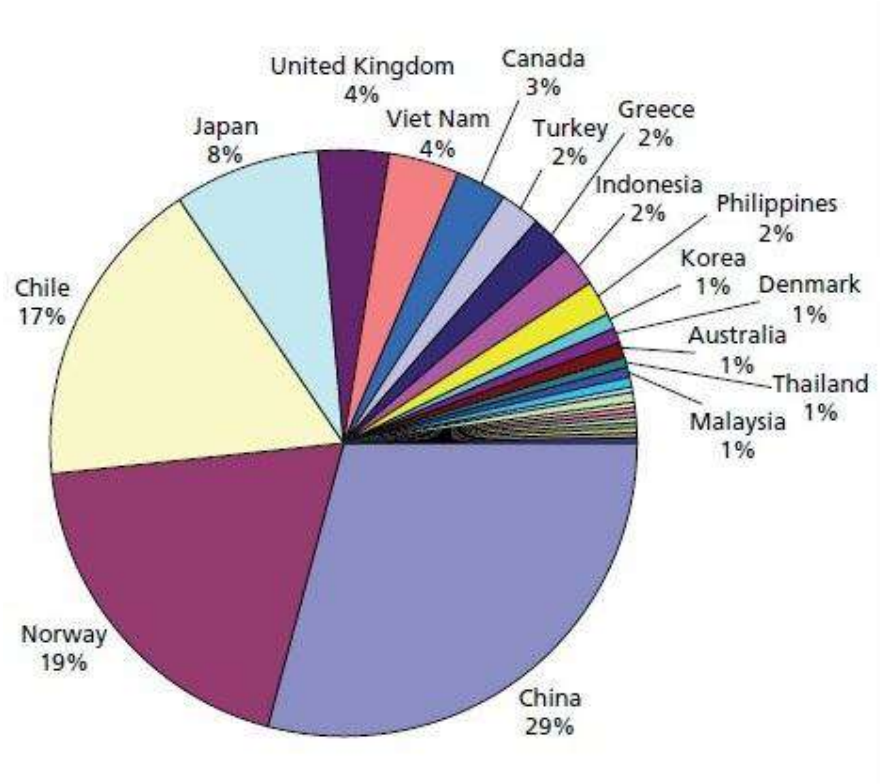

Figure 2.3: Major global cage cultureproducing nations

Source: Tacon and Halwart, (2007)

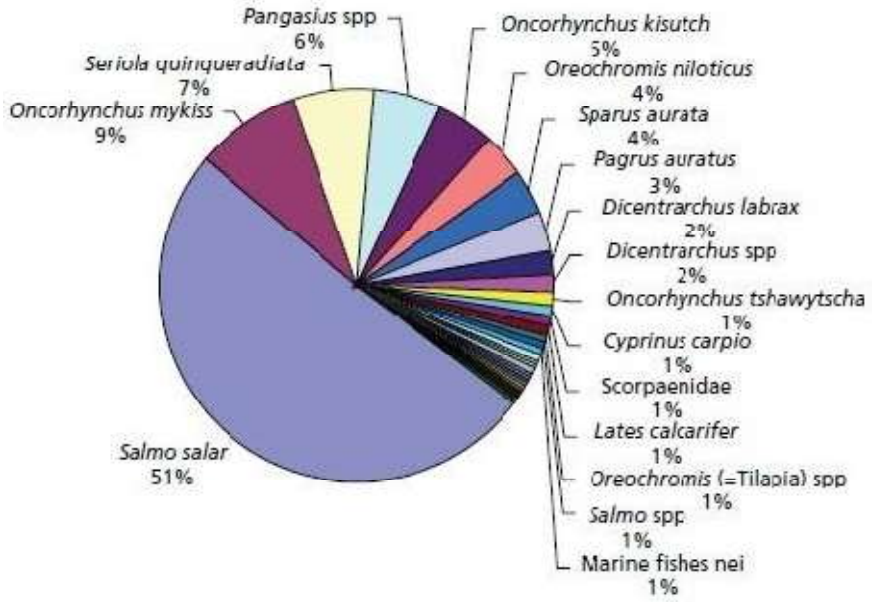

Figure 2.4: Global cage aquaculture productionby species

Source: Tacon and Halwart,(2007)

Cages are fabricated from diverse materials (strong, durable and non-toxic), and can be invarious shapes (round, square or rectangle) and sizesranging from one cubic meters to several hundred cubic meters (Sandfoss, 2003; Schmittou, 2006). Cage shape doesn't adversely influence production with mostfreshwater fish species (Masser, 1988). Also, it is easier to manage small cages than big cages. However, big cages normally accrue more profits per unit volume (Soltan, 2016).

Cage frame can be fabricated frombamboo orwood (coated with nontoxic and water resistance to prevent rotting), aluminium, fibre glass, polyvinylchloride (PCV) pipe, galvanized iron and steel.

The net bag can be constructed using, nylon, wire (wire coated welded or galvanized) and strong plastic mesh netting. Floatation can be supplied by utilizing Styrofoam, waterproof rubber, or plastic drums (close-fitted and srong).Also, the frame made with PVC pipe can satisfactorily providefloation (Sandfoss, 2003).

2.8 Types of cages

Four classifications of cages are utilized in cage aquaculture: fixed, floating, submersible and submerged (Beveridge, 2004; Das *et al.,* 2009).

Fixed cages: Fixed cages comprise of a net bag supported by poles (wood or bamboo) pegged into bed of rivers, rivulets, streams, lakes or reservoirs. These type of cages are comparatively cheap but their use is limited to protected water with little depth of about 1-3 metres.

Floating cages: Floating cages are made up of a net bag supported by a floatation collar or, a framework. These are the commonest employed method that can be designed in diversity of shapes and sizes. In terms of site specifications, floating net cages are less limited than any other designs.

Submersible cages: The net or rigid mesh bag of submersible cages have no collar, instead they are designed with rigid framework (steel frame) to maintain shape in water. The merit of this type of cages over other types is that they can be adjusted up and down the water surface and bottom to exploit the prevalent environmental situation. Typically, the cages are positioned at the surface when the water is calm and submerged in the course of harmful algal bloom.

Submerged cages: Submerged cages are the least common and are permanently kept under water. It is highly intensive with all operations mechaniced. When properly planned and managed, this type of cages can be environmentally and economically sustainable. Submerged cages are widely employed in cage mariculture.

2.9Merits and demerits of cage culture

2.9.1Merits of cage culture

Several benefits that can be derived from cage culture include:

Probability of optimally using the available existing water resources (Beveridge, 2004; Schmittou, 2006;Gopakumar, 2009; Abowei and Tawari, 2011);fabriation of cages is relatively easy, either artisanal or industrial types (Gopakumar, 2009; Soltan, 2016);initial investment is relatively minimal Swann *etal*., 1994; Cline, 2011; Soltan, 2016);fish stock is easily observed in cages. Also, feeding and routine management is easy (Gopakumar, 2009; Cline, 2011; Abowei and Tawari, 2011; Soltan, 2016);intensification of fish production (high density, optimum feeding, fast growth), (Coche, 1979). Other advantages include reduced length of rearing period (Coche, 1976); easy control of fish reproduction, especially in Tilapia species (Soltan, 2016); harvesting of stock is simple and easy. It is by lifting up the net bag to garther the fishand taking out the quantity neededwith hand or scoop net.(Gopakumar, 2009); reduced pressure on land hence land-ownership is not necessary. (Coche, 1976); high yield with good economic returns as cage culture can be practiced intensively; (Imelda *et al*., 2009). Furthermore, according to Das *et al.,* 2009 and Soltan, 2016, cage aquaculture eradicates loss of stock through predation;facilitates preventive measures against any occurence of disease; ensuring very high survival rates of fingerlings; cage culture makes productive utilization of manpower, as day to day maintenance routing and observation are pretty easy; Also, an advantage of cage farm technology is that the farm can be moved from one site to the other if conditions show to be unfavourable (Soltan, 2016).

2.9.2Demerits of cage culture

Various constraintsaffiliated with cage aquaculture are high stocking densities related(Beveridge, 2004).High stocking induces a stressful environment and stress consequently impairthe immune system of the fish (Masser, 2008; Gopakumar, 2009);abrasions coupled with build-up of wastefeeds usually bring about chance fordevelopment and rapid spread of diseases at high densities (Abowei and Tawari, 2011);

andincrease vulnerabiliy of fish to dissolved oxygen deficiency (Abowei and Tawari, 2011; Soltan, 2016). Furthermore,the confinement of stock in a small area engender easy poaching.(Coche, 1982; Gopakumar, 2009); cages attract predatorshence, predator or outer protectivenets nets must be provided (Coche, 1979; Gopakumar, 2009; Abowei and Tawari, 2011); net fouling which clogs the net diminishes mesh size canseriously decrease the rate of water flowing past the cages (Gopakumar, 2009); storms can damage cages and cause fish to escape (Gopakumar, 2009; Abowei and Tawari (2011); absolute dependence on nutritional complete artificial feeding, especially proteins, minirals and vitamins and feed wastes probable through the net cages(Abowei and Tawari, 2011; Soltan, 2016); feeding hierarchies, such as pecking order in poultry, are often noticed while densities are very low and result in deacreased feed intake and retarded growth in smaller animals (Schmittou, 2006) and accumulation of unused feed and excreta will lead to water pollution as well as eutrophication (Krishnapriya, 2016), caged fish are unable to access the natural food of their choice, whereas it is readily abundantly available to the free fish (Soltan,2016).

2.10Cage culture in Nigeria

The emergence of cageaquaculture in Nigeria can be predated to the 1960s. However, it is just presently getting increasedawareness with popularity amidst researchers and industrial fish culturists. Cage culture has been attempted in some areas of the nation for years (Adegboye, 2010).

In Nigeria, cage culture has been reported to be economically viable and recommended by (Otubusin, 1991; Adekoya and Miller, 2004; Xiangpin, 2006). The Federal Government of Nigeria identified the importance of cage culture in bridging the demand and supply deficit and thereby incorporated it into its field support activities of the National Programme for Food Security (NSPFS), first phase of 2002 to 2006 (Ingawa, 2006). The development of cage culture is also embodied in the new National Agricultural (fisheries) Policy which listed it as a neglected but profitable system (Ingawa, 2006).

Under NSPFS with the assistance of the Chinese South-South Corporation (SSC), cage culture was introduced in few commercial fish farm site as a pilot enterprise. These farms are the Niyya farms in Kaduna, Maizube farm in Minna, Nasko Farms in Kaduna, Orits farms in Lagos among others (Ingawa, 2006). The programme has been fully integrated into and supportedby Nigeria's Agriculture Transformation Agenda (ATA) and one of the highly successful technologies of SSC has been cage aquaculture.

Few successful adopters of cage culture under SSC programme include; Dalha Lawal and his cooperative members in Katsina State and Osin farms in Osun State. It was reported that Osin Farms in 2009 with the assistance of SSC experts established 18 cages of (2m x 2mx2m) each producing about one metric tonnes of tilapia fish, in a six mouth cycle (FAO, 2014).

Lagos State in 2007 introduced and made funds available for the take-off of fish cage culture in six river communities in Lagos namely: Ise, Badore, Epe, Badagry, Ojo-Otoawori, and Ijede Ikorodu. Presently cage culture is the most economical way of culturing catfish (*Clarias gariepinus)* and Tilapia species in Lagos State, Nigeria (Ganzallo, 2012). Recently, the cage culture of catfish establishedat Agbowa-Ikosi Beach by Lagos State Government to empower 60 unemployed youths yielded over 50 metric tonnes of fish from one culture cycle for sale in Ikosi-Ejinrin Local Government Development Area (Vanguard, 2017).Also from Lagos State, the Fish N Fish cage culture farm in Badagry produces 150tonnes of catfish on annual basis from 27 cages placed in a stream (Wijsman, 2015).Durante Fish Inc. cage culture farm established in 2012 in the Oyan Dam, Ogun State is presentltly the biggest in Nigeria with production of 300 tonnes of fish annually from 28 cages of 6m×6m×5m each.

Catfish (*Clarias gariepinus)* and Tilapia species were reported successfully cultured in cages in the country (Otubusin*et al*., 2001, 2007; Collins, 2017). Adekoya and Muller, (2004) also obtained encouraging result in cage culture which was replicated in a number of locations in Ogun State Nigeria. He recommended cage culture system to fisherfolks to enable them enter fish husbandry and diversify income sources.

2.11Stocking density in cage culture

Stocking density tells about the initial aggregation at whereon fish are stocked (Ruane*et al.,*2002) or any concentration of fish at any point in time (Ellis*et al.,*2002).

Stocking density is among thevital factors to be resolved during intensive fish culture (Sahoo *et al*., 2010). This factor directly effects growth,survival, behaviour, state of health, quality ofwater and feed intake of cultured fish (Hengaswal*et al*., 1997), and eventually the fish orfingerlings output in an intensive techniques of fish culture (Chakraborty and Banerjee, 2010; Sahoo *et al*., 2010).

Various stocking densities are employed in cage aquacultureand not much research has beencarried out to validateideal stocking densities for a lot of aquaculture species. According

to Beveridge (2004), high density-low volume cages are more prevalent in freshwater cages where stocking densities of 150-450 fish/m^3 are often employedwithdesired cropping weight of 1.0 kg or below. In North America, stocking densities utilize in cage aquaculture of freshwater species are very high, varying between 200-700 fish /m^3putting into considerationthe species coupled with targeted market size (Masser*et al*. 2007). Xiangping*etal*., (2006) recommended for African catfish of 50g and above stocking density of 300-400 fish per cubic meter while fish of 10g could be stocked at 500-600 fish per cubic meter but sorting must be ensured. For new cage culture farmers, minimum stocking density of 80 fish per cubic meter was recommended for carp (*Cyprinus carpio),* Tilapia and catfish species (Schimittou, 1991).The impacts ofextremely low or very high densities that bare very lowor very high present the necessity for research to establish optimum densities for various aquaculture fishspecies (Beveridge, 2004).

2.12Growth of fish in cages and stocking density

Stocking density is among the key elements influencing the growth of fish(Engle, and Valderrana, 2001; Rahman*et al.,* 2006). Recognition of optimal density for any fish is not just a crucial element in planning an effective rearingoperations(Leatherland and Cho, 1985), but besidesfor optimal rearing procedures.Many researchers have studied the influenceof density on yield, growth and survival on a number ofAfrican catfishes. Notable among them are: Osofero*et al.,* (2007); Edward,*et al.,*(2010); Dasuki *et al.,*(2013) and Abou-Zied, (2015). The stocking density that adversely influences the growth of fish is regarded as density dependent as reported for African catfish, *Clarias geriepinus* (Haylor,1991); Sahoo, *et al.,*2004*,* and Nile tilapia, *Oreocromis niloticus*(Asase, 2013) and Walleye, *Sitzostedion vitream* (Fox and Flower,1990). Several studies also reported for some cultured species a negative correlationbetween growth performance and stocking density (El-Sayeed and Abdel-Faith, 2002; Rowland *et al.*2006;Schram*et al.,*2006 and Osofero*et al.,*2009). The poor growth reported from these studies can be ascribed to social interactions through competition for space as well as food (Jiwyan,2011).

2.13Survival of fish and stocking density

Stocking density has a considerable consequence on survival of fish (Netti *et al.,* 2017;Jamabo and Keremah, 2009). The adverse influenceof stocking density on survival of cultured catfish has been extensively published by many reserchers (Dada *et. al.,* 2000; Sahoo *et al*., 2004). However, Hengsawat *et al.,*(1997) reported that survival of *Clarias*

*gariepinus*cultured in cages wasn't distinctly effected by stocking density. Furthermore, it was reported that correlation between survival and stocking density is not established to be persistent (El-Sayeed, 2002).

Islam*et al.,*(2006), reported that it is assumed that catfish, being able tobreatheatmospheric air, are probably to be resistant tohigh stocking densities, hence they can obviously survive under crowding condition. Overstocking densities can induce stress in cultured fish, which sequentially, has adverse inffluences on survival rates and growth. (Teodorowicz, 2013).

2.14Effect of stocking density on feed utilization

Stocking density induces possible waste of diet from the cage including easyaccess to dietby the fish (Schmittou 2006). Just as the density increases, beside the growth rate, water quality as well as access to food reduce and limit output via its impact on water quality and food access (Schmittou, 2006).

Food Conversion Ratio (FCR) for *Clarias gariepinus*was not effected by density as there was no significant difference among the varying stocking densities used (Dai *et al.*, 2011; Ofor and Afia, 2015).However, the bestFCRvalue was recorded at lowest density. This indicates that stocking density did not affect feed consumed as fish in the treatment groups were fed according to their body weight. Similar results were reported for *Clarias gariepinus* raised in cages (Dasuki *et al.,* 2013). The FCR for Asian river catfish, *Pangasius bocourti* was on the other hand reported to be higher at least density though not significant (Jiwyam, 2011). Furthermore, it was reported that FCR valueindicated no significant difference for other species such as in sex reversed male Nile tilapia, *Orechromis niloticus,*although value was higher in high density than lower density (Kapinga*et al.,* 2014); and also intetra hybrid red tilapia (Silva*et al.,* 2000).

2.15Influences of stocking density on yield and profitability of culture fish

The primary objective of fish culture is to boost production effectiveness. The expenses associated with cage fabrication and mooring differ significantly with the sizes utilized. Similar to numerous types of construction, the price per unit increases. Generally, cage farms are relativelyinexpensive to construct and manage in comparison to other systems (Beveridge, 2004).

Feed costs are commonly the greatest variable expenditures varying between50 and 60 % of the overall expenditures (Beveridge, 2004). For channel catfish, the cost of feed to the total

production cost was put at 44 to 50 % (Wurts, 2001; Engle and Stone, 2002). This indicates that the economic returns of cage fishculture is directly correlated to expenses on feed (Hoffman, *et al*., 1997). The next recurrent expenses to feed cost is usually fish seed(fingerlings/juveniles fish) and this can vary between 10 and 40 % of total variable costs (Beveridge, 2004).

Stocking density is an importantfactor in establishing the productiveness and economic benefit of fish farms business. Commercial fish aquaculturists are believed to utilize both intuitiveness and practical knowledge to choose the best ideal density as well as handbooks as guides (Ellis *et al*., 2002).

Hogendoorn and Koops (1983), report a direct relationship between density and production for *Clarias gariepinus* reared in ponds. Hengsawat, *et al*., (1997) also reported the same scenario for *Clarias gariepinus* cultured in cages. Rahman *et al.* (2006) documented higher yield, lesser output expenses and increaseeconomic return with Sutch catfishcultured at higher densities in cages; the indication is that the highest stocking density effects the highest production with the best economic benefit. The same observation was reported for other catfish species for example, channel catfish, *Ictalurus punctatus* (Engle and Valderrama, 2001). Comparable results were reported for other fish species including tilapia (Cruz and Ridha, 1989; Asase, 2013); Silver perch (Rowland *et al.,* 2006).

2.16. Effect of stocking density on fish welfare

Acording to Ellis *et al*., (2002),concern over the well-being of cultured animals has been increasing, also the well-being of fish in culture enclosures has become a vital matter.According to (FAWC, 1996), almost all welfare guidelines arecurrently establisbsedon the United Kingdom Farm Animal Welfare Councils “five freedom’’indicated as the freedom from:

(i) Hunger and thirst;

(ii)discomfort;

(iii) pain, injury or disease;

(iv) fear or distress and

(v) the freedom to express normal behaviours.

There areobvious problem using these welfare standards builton terrestrial animals to aquaculture species, and although fish well-being in large commercialised fish culture farms is oftentimes hard to evaluate.However, physical endpoints like growth, death, or disease are dependable measures of well-being (Huntingford,2006). The greatest threat to fish health are in declined water condition coupled with escalatedadverse interferense with other fish; these two conditions tightly connected to stocking density (North*et al*.,2006). In spite of the fact that deplorable fish welfare is probable at increased stocking densities, the welfare of fish does not at all predict or restraint by higher stocking density (Turnbull *et al*.,2005). High stocking density can adversely affect conventional swimming behaviour, increase aggressive coupled with competitive behaviouralattributes likefeed competition or reduced access to feed (Greaves and Tuene, 2001; The Fish Site, 2010) and territoriality and dominance (Ellis *et. al*., 2005). This eventuallyescalates the danger of tissue destruction as a result of abrasion from fish-to-fish contact (Hastein *et al*., 2005). Fish can experience declinesin feed consumption and feed conversion efficiency (Ellis *et. al*., 2005). Besides, overstocking cause in flow of water not to be sufficient, thereby generating deficientdissolved oxygen supply and waste products (uneaten feed and excrement)deposition (Ashley, 2006). Dissolved oxygen is vital for fish inspiration and concentration levels lower than essential levels can be stressful and can also lead to suffocation (Ellis *et al*., 2005). The influence of density induced stress, could be a crucial elementin promoting disease in fish (Conte, 2004).Consequently, the socioeconomic sustainment of an aquaculture enterprise is dependent on maintainance of satisfactory welfare condition for fish under culture. Optimum densities, feeds, and output schemes are required to enhance fish well-being as well as efficiency for advanced output systems.

Haematological studies are considered as one of the tools employed to assess the welfare or healthstatus index of different fish species because it provides a dependable evaluation via non-lethal means (Satheeshkumar, *et al*., (2012).

2.17 Importance of water quality in fish culture

Water quality is included in the main factor inffluencing fish well-being and performance in fish culture production systems (The Fish Site, 2015); especially in case of cage aquaculture system under controlled condition (Devi *et al.,* 2015).Fish lives are absolutely depending on the water they exist in for their entire requirements. Individual species has a distinct and particular range of water quality variableslike dissolved oxygen,temperature, pH, salinity,

hardness, ammonia, nitrate, nitrite*etc.* in which they can live, grow, and reproduce. Inside these tolerance limits, individual fish species has its unique optimum limitsin which it performs most. Above or below the optimal limits, fish will manifest unfavourable growth, unusualbehaviours, as well as disease indicators or parasite attacks. Under instance, or where the unfavourable conditions persist for a very long interval of time, fish mortality may take place (Fish Site, 2015). According to Mallya (2007), the successfulness of a commercial fish farming business hinges on ensuring the optimum water environs for fast growth at minimal value of resourses and funds.

2.17.1 Temperature

Temperature is among the major physical variables that affect the welfare of poikilothermic animals like fish. The entire biochemical activities in fish culture operations are effected by temperature. Fish regulate their body temperature and metabolic rate by relocating to either cooler water or warm water. Individual fish has an idealtemperature wherein it exhibits optimum growth, along with maximum and minmum fatal temperatures.Deviation from optimal temperature, fish growth is declined while mortality can happenat acute temperature (Imelda*et al.,* 2009). Over the optimal temperature food intake increases whereas food conversion decreases (Masser, 1997). As stated by Delince (1992),a temperature range of 10-30^{o}C is tolerable to fish. Britz, (1987), reports optimum temperature range of 25-33^{0}C for high growth rates of*Clarias gariepinus* with the highest growth found to be 30^{0}C, while The Fish Site, (2014) reports thatideal temperature for the growth of this same species is 26-32^{0}C. Surface water temperature in the tropics has been reported to vary between 21 and 32^{0}C (Ayodele and Ajani, 1999). This is suitable for the optimum production of tropical water species like catfish and tilapia. According to Akiyama, (1999), optimum production temperature for most tropical water fish is approximately 28^{0}C with a range between 25 and 30^{o}C.The rate ofbiological and chemical reactions was reported almost twice for every 10^{0}C rise in temperature (Helfrich *et al.,* 2009). Temperature highly influences dissolved oxygen concentrations in aquatic environment (Kajak, 2001), Teodorowicz, (2013). Temperature exhibits negative correlation with solubility of oxygen in water.

2.17.2 Dissolved oxygen

Dissolved oxygen (DO) is the greatest vital water quality parameter (Alabaster and Lloyd, 1982). It influences the growth, survival, distribution, behavior and physiology of shrimps and other aquatic creatures like fish(Solis, 1988). Obtaining sufficient oxygen in water and

solubility are influenced by a number of factors like rise in temperature and salinity, light atmospheric pressure, high atmospheric moisture, and eutrophication. Exhaustion of oxygen in aquatic environment causes low feed consumption, hunger, retarded growth and high mortalityof fish.(Bhatnagar and Garg, 2000). Dissolved oxygenranging between 3–5 mg/lis tolerated by fish (Banerjea, 1967). Dissolved oxygen levels of 3 mg/l can stress fish and if this level goes below 2 mg/l can increase fish mortality (Soltan, 2016). Excessive concentration (super saturation) of dissolved oxygenoccasionally becomes toxic to fish fry culturing in nursery ponds (Alikunhi *et al*., 1952). Swingle (1969) reported a range of 6-8 mg/l as desirable for fish culture as this enhances oxidation of poisonous compounds to useful materials, for example, NH_3 (ammonia) to NO_3 (nitrite). According to Bhatnagar and Singh (2010) and Bhatnegar *et al*., (2014), dissolved oxygen concentrations below 1.0mg/l causes death of fish whilethe levelsunder 5mg/lfish can remain alive but grow tardily and will be inactive, 5mg/l and higher is preferable. Catfish along with other species that can breatheatmospheric airhavecapability tolive in low oxygen levelof not less than 4mg/l (Santhoshand Singh, 2007). Minimum dissolved oxygen level of 1 mg/l is crucial to keep fish alive for a prolong duration of time and 5 mg/l is sufficient in fish ponds (Ekubo and Abowei, 2011).

2.17.3 Hydrogen ion concentration (pH)

The origin of the term pH isfrom French word, *pouvoir hydrogène*, meaning power of hydrogen (Joe, 2017).New Medical Dictionary defines pH as the negative logarithm of hydrogen ion concentration and also a degree of relative acidity or alkalinity in a given liquid.The pH value of pure fresh water is about 7.0, neutral value, at 25^0C.Values less and greater than 7.0 are acidicand alkaline, respectively (FAO, 2015). The pH of natural water is highly impacted by the level of carbon dioxide, an acid gas (Boyd, 1979). A mean blood pH of fish is about 7.4, and a slightest variation from this figure, between 7.0 and 8.5 is optimal and favourablefor fish existence. This range is also considered to be optimum for biological productive capacity. Hydrogen ion concentration varying between 4.0 - 6.6 and 9.0 - 11.0 induces stress inFish. The acid and alkaline death point ispH value of 4.0 and 11, respectively (Masser, 1997; Bhatnagar, *et al.* 2004;Ekubo and Abowei, 2011). The satisfactory pH value for fish farming variesbetween6.7 and 9.5, while the optimum pH ranges from 7.5 to 8.5, any value higher or less than this causes stress in fish under culture (Santhosh and Singh, 2007). Ideal pH of a fish culture pond should range from 6.5-9.0 (Bhatnagar *et al*., 2004). When pH

is higher than the optimum level, growth is retarded, reproduction declined, and vulnerability to disease outbreak escalated (Roy, 2014)

2.17.4 Ammonia

Ammonia is the primary derivation from proteometabolism defecatedby fish and bacterial breakdown of wasted feed,excreta, dead planktons etc (Robert*etal*., 1997; Masser, 1997; Bhatnager and Devi, 2013).Total ammomia(TAN)consist of toxic unionized ionised ammonia, UIA (NH_3) along with nontoxic ionized ammonia, IA (NH_4^+).

The level of UIA in aquatic enviroment rises as the temperature including hydrogen ion concentration rises (Wurts and Durborow, 1992;Brain, 2014). For each and every pH rise of a single unit, the toxicity of UIA escalates almost ten times (Wurts and Durborow *et al*., 1992).According to Robert*et al.,* (1997); Joel and Amajuoyi, (2010), hazardous short-live level of ammonium(UIA) which can kill the fish within a short number of days begin arround 0.6 mg/l.Continuous vulnerability to toxic UIA levels of about 0.06mg/l may result in gill and kidney destruction, retard growth rate, probable brain impairment coupled with decreased oxygen conveying potential of the fish. Bhatnagar and Devi, 2013, also reported that ammonia concentration ranging from 0.1-1.0 mg/leffect gill destruction, impair mucous producing membranes, diminish the growth rates, and kidney failure in fish. Fish affected by toxic UIA usually look inactive or frequentlyat the water surface struggling to breath atmospheric air with the mouth.

Excessive concentrations of ammonia has been reported as a reason for massive death in fishes by many authors (Joel and Amajuoyi, 2010;Farhangi and Rostami-Charati, 2012). For instance in 2013, several metric tonnes of fishes were reported conterminated and killed in Fuhe River in China owing to release of toxic ammonia into the river by a chemical plant (www. cnn.com, 2013).

2.17.5. Nitrite (NO_2)

Nitrite is an intermediary consequence of the aerobic nitrification bacterial process induced by the autotrophic *Nitrosomonas* bacteria combining oxygen and ammonia (Eddy and Williams, 1987). Nitrite gain access into an aquaculture system subsequent to digestion of

feed by fish and the surplus nitrogen transformed into total ammonia nitrogen (TAN), which is later discharged as waste into the aquatic environment. Afterwad, total ammonia nitrogen; NH_3 + NH_4^+ is changed to NO_2,whichunder natural or common conditions, is speedily changed to non-toxic $NO_3$by naturally existing bacteria species,*Nitrobacter*(Durborow*et al*., 1997); Uncomsumed diet and other organic materials also breakdown into total ammonia nitrogen, nitrite, and nitrate in a same way. Eddy and William 1987 observed that the concentration of nitrite in unpolluted waters is significantly very low but elevated concentrations are regularly found in hypoxic lakes and ponds and in oxygen minimum zones of the oceans. Pollutions with nitrogenous wastes, such as sewage, effluents and fertilizers can elevate nitrite in aquatic habitats.

According to Durborow *et al*., (1997), nitrite problems are usually most probable in crowded intensive aquaculture techniques as a result of deficient or defective filtration systems. High nitrate levels in ponds happen more often when temperatures are unstable, causing the breakdown of the nitrogen cycle as a result of reduced plankton activities in ponds because of decreased temperatures, nutrient reduction, cloudy weather, herbicide applications*etc,*can cause low ammonia absorbed by the algae, hence ascalating the load on the nitrifying bacteria. Whenever nitrite concentrations outstrips which inhabitant bacteria can quickly transform to NO_3, an accumulation of NO_2 happens, causing brown blood disease which is fatal to fish life. Brown blood disease is caused when nitrite oxidizes haemoglobin to methaemoglobin, therebychanging both the blood and gills from red to brown consequently hindering breathing. Furthermore, nitrite also inflicts damage to a number of vital organs such as; kidney, liver, nervous system and spleen of the fish (Bhatnagar and Devi, 2013).

The perfect and standardvalue of NO_2 is 0 mg/lin all water systems (Bhatnagar and Devi, (2013). Stone and Thomforde (2004), suggestthe desirable concentration of$\leq$ 1.0 mg/l NO_2 and adquate value of$<$4 mg/l NO_2. Bhatnagar *et al*., (2004), revealed that nitrite value of 0.02 mg/l is lethal to most of the aquaculture species, below 1.0 mg/l is fatal for numerous tropical water fish species while lower than 0.02 mg/l is suitable. According to Santhos and Singh (2007), nitrite level in water should not be more than 0.5 mg/l, while OATA (2008) recommends that NO_2 concentration should not be above 0.2mg/l in freshwater and 0.12mg/l in marinewater.

Susceptibility of fish to nitrite toxicity varies with species, for example, largemouth and small mouth bass, and bluegill and green sunfish, are invulnerable to excessive nitrite

accumulations. The centrarchids can adequately hinder nitrite from passing into the gills;numerous other tropical fishes accumulate nitrite in the blood. However, catfish and tilapia species are relatively susceptible to nitrite, and trout coupled with other temperate water species are verysusceptibleto exceedingly low levels of nitrite (Durborow *et al*., 1997).

High concentration of nitrite in fish culture environment can induce stress in aquatic animals, thereby reducing the survival rate and in due courseresulting in high production deficitin fish culture enterprise (Jiang *et al*., 2013). Many authors have also ascertain from their various studies in many fish species, that excessive nitrite level in water is among the vital factors inducing appreciablestress in fish (Ajani *et al*.,2007; Dolezalova *et al*., 2011and Zuskova *et al*., 2013).

Bhatnagar and Devi, (2013) recommended some preventive measures to decrease the level of nitrite in culture system, among these are optimal stocking densities, improvement of general husbandry techniques, maximum aeration, terminate or reduce feeding. Others include application of little quantity of specific chloride salts, frequentwaterchange out and application of bio-fertilizers to increase nitrification.

2.17.6 Carrying capacity and limit of cage numbers

According to Sugunan *et al.,* (2016), carrying capacity of water body to accomodate cages is the most crucial input for decision making in cage aquaculture of fish. However, due to paucity of data, it is difficult to arrive at precise carrying capacity level. Therefore, any policy on this issue has to be guided by a precautionary approach. Provision of FAO Code of Conduct for Responsible Fisheries clearly stated to employ the “precautionary approach” while handling data deficiency systems. Considering the likelihood of nutrient loading from cage aquaculture, these carrying capacities have been developed on a precautionary approach basis; Reservoir area more than 10,000 ha should be installed with 5000 cages either as maximum stand-alone (one unit cage) or in batteries (groups)of6,12, or 24 cage units,as desired. One cage unit is 6m×4m×4m.

‘

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Preliminary field study

Preliminary field survey of nineteen fish cage culturefarmers in Lagos,one in Ogun and ten in Osun States,Southwest Nigeriawas conducted to capture information on their socio-economic characteristics, current culture and management operationsuch as stocking density practiced, type of fish feed utilized, constraints and profitabilityof cage culture.

3.1.1. Area of study

The study was implemented in Lagos, Ogun, and Osun States of South-West Nigeria. Lagos, Ogun and Osun States are situated on the geographical coordinates of (6^{o}.35’N 3.45’E), (7^{o}00’N; 3.35’E), and (7^{o}.30’N; 4^{o}.30’E), respectively (Wikipedia). These states have a tropical wet and dry climate with two definite raining seasons; the more profound season happens within April and July, with moderate one betweeen October and early November. In August, there is a dry season (August drought) which may extend to early September and from December to March, ushered by Harmattan (dry and cold winds) emanating from Sahara desert, which are at their severest from late December to February. The annual rainfall in Lagos, Ogun and Osun States are 1,603.38mm,1,455.94mm and 1,379.38mm, respectively. The mean minimum and maximum temperatures in Lagos State are 23.44^{0}C and 31.86^{0}C, in Ogun State, 21.08^{0}C and 33.42^{0}C, and Osun State, 21.08^{0}C and 31.94^{0}C, respectively (Annual Abstract of Statistics, 2012).

3.1.2. Sampling technique

Purposive sampling method was utilised to choose Lagos, Ogun and Osun States out of all the six states inSouthwest Nigeria for this study. These three states were selected based on

the knowledge that they were the states engaged in net cage aquaculture as at the time of this study. All the actively engaged farmers in cage culture were selected as respondents. In Lagos State, ninteen(19) farmers were selected with the following distribution;Ebute Afuye (7), Oko- risan (3), coastal lagoon near Epe (5) in Epe Local Government Area and 4 from Badagry, Badagry Local Govement Area. One farmer was selected at Oyan Dam (Durante fish farm) in Ogun state, and 10 farmers in Osun State at Osin Farm (1) and Owala Dam (9).

3.1.3. Data collection

The data for the study were gathered employing a structured questionnaire (Appendix 3.1), and oral interviews with some respondents. Atotal of 30 questionnaires were dispensed and recovered.

3.1.4 Analytical technique

Observations from 12 respondents were used for the economic analysis based on incomplete and questionable responses from 18 respondents. Data was analysis by descriptive statistics inclusive of frequency, percentage and mean values.

The Gross Revenue, Net Revenue and Benefit Cost Ratio analysis were utilised to examine the cost and returns of net-cage culture in the study area.

Gross margin was calculated using the upcoming formula:

(i) Gross Margin (GM) = Total Revenue (TR) – Total Variable Cost (TVC).

(ii)Profitability ratios were determined using the formula underneath:

Benefit Cost Ratio (BCR) = Total Revenue (TR) / Total Variable Cost(TVC).

3.2.0. Experimental study

3.2.1. Description of study area

The experimental study was conducted at Owala Lake, in Osun State,Southwest Nigeria. The site is situated on geographical coordinates 07.8973^{o}N and 004.54601^{o}E (Figure 3.1). This Lake is one of the Osun State Water Corporation Lakes constructed in 1999 to supplyportable water to Osogbo, Ede and environs (Osun State Fisheries Statistics, 1994). The nearest city to the site is Osogbo, capital city of Osun State Nigeria. The lake catchment area is approximately 23,000 hectares (Osun State Fisheries Statistics, 1994). The main imputes into the lake are mainly from Ekonde lake created by building a dam across River Otin that

accounts for about 35% of the lakes discharge, River Erin, Owala and other rivers account for 65% of the total discharge into the lake (Osun State Fisheries Statistics, 1994). The site was well suited for cage culture due to its attributes of being sheltered and protected area with less exposure to strong current or waves which indicates reduced economisedmaintenance costs (Ross, *et al*., 2013; FAO, 2015), highflow rate of the water in cage (ranged from12-18 cm per second) and mean depth of 7.26 – 10.54 meters at the net cage sit.The large size of the lake also made it suitable for the reason that the water quality is usually very stable andrarely influenced by fish waste in comparison to small ponds.

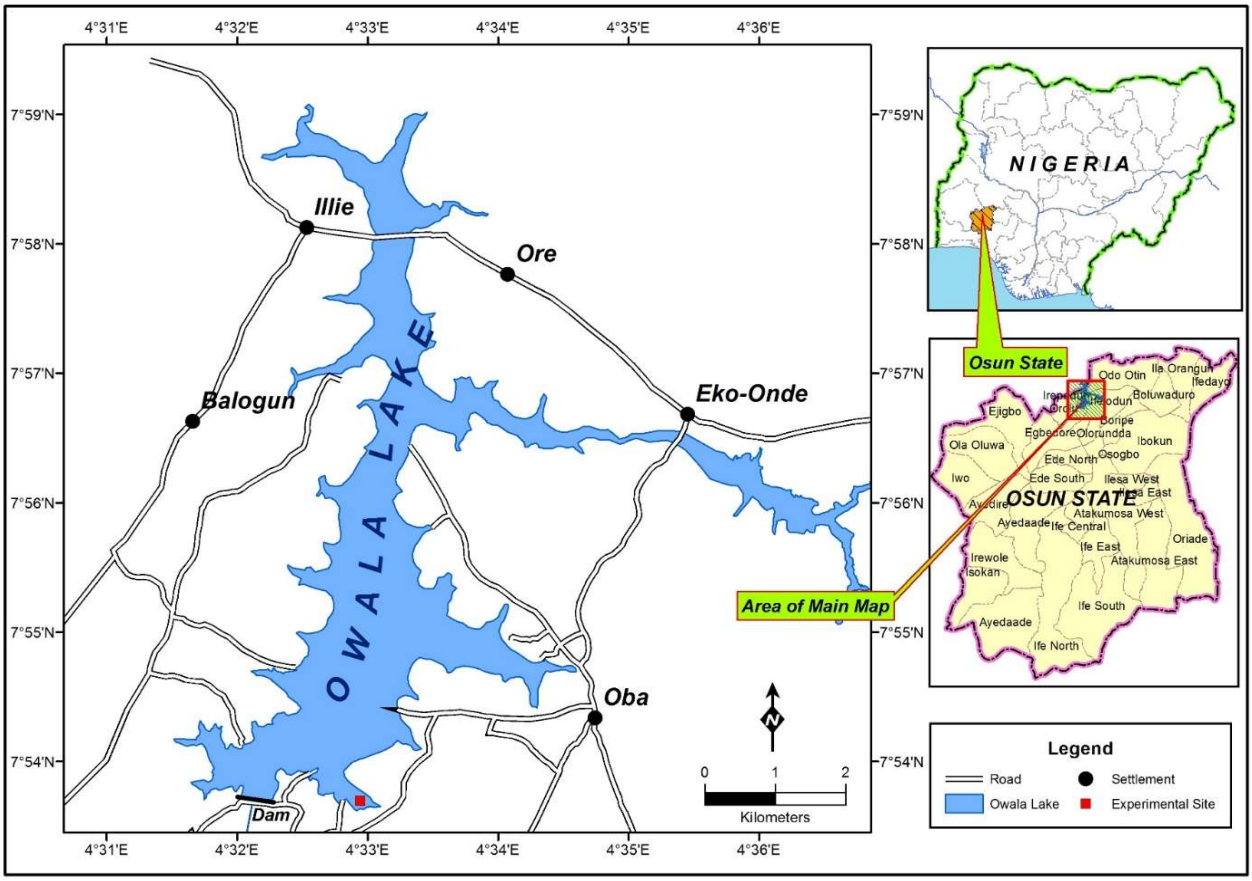

Figure 3.1: Map of Owala Lake showing Experimental site.

Source: Geography Department, University of Ibadan, Nigeria

3.2.2. Experimental design

The experiment was a 2×3 factorial arrangement ina completly Randomized design. There were two factors in this experiment: A diet at two levels[extruded floating diet (EFD) and pelleted sinking diets (PSD)] and a stocking density at three levels[100(SD_1),200 (SD_2), and300 (SD_3)fish/m^3)] with 100 (SD_1) as control. Thus, the total number of treatment groups were six (2×3): SD_1-EFD,SD_2-EFD, SD_3-EFD,SD_1-PSD, SD_2-PSD andSD_3-PSDreplicated thrice. The experiment lasted for 20 weeks (150 days) from 15 February to 14 July, 2015.

3.3.0. Construction and installation of experimental cage units

3.3.1. Construction of cages

i. Net cage

Eighteen experimental inner net cages and eighteen outer predator net cages were constructed for thisstudy. The experimental inner net cages were 1.5m^3 (1.0m x1.0m x1.5m) in volumemade of high density polyamide net with mesh sizeof 15mm. The submerged volume of experimental cages was 1.0m^3. The experimental cages were totally enclosed on all sides, the bottom including the top to avert predation by birds. The outer top sides of each experimentalcage was surrounded using nylon mosquito net (15 cm depth) from the surface of water to prevent loss ofextruded floating feed from the cage by current or storm and from fish struggling for feed. Also the entire bottom with vertical edge that extends 15cm above the cage bottom of experimental net for fish fed pelleted sinking diets was covered with fine meshed net to form feeding tray shape for preventing sinking feed to go down the lake bottom. The outer predatorpreventive net cages made of 20 mm polythene net were 1.2 x 1.2 x 1.75m (2.52m^3) in volume (Figures 3.2 and 3.3). To maintain the cage shape, the cages were weighted in the corners with a sinker (locally available stone of 1 to 1.5kg). All the cages were numbered for easy identification during feeding and sampling operation.

Figure 3.2 Experimental inner net Cage (1.0m x 1.0m x1.5m)

Figure 3.3: Predator net cage/ outer protective net cage (1.2m x 1.2m x 1.5m)

ii. Cage frame

The cage frame or raft was made from locally available bamboo (*Bambusa vulgaris*) tied together with nylon twine to form a frame. Two frames were used to make a battery of three cages and six were made to accommodate eighteen cages. The distance between the cages in a raft was 1.0m each and the raft was buoyed by six 200litre plastic drums sandwiched between the two frames. These drums were firmly tied to the frame with nylon twine(Figure 3.4).

Figure 3.4: Cage frame (4.2m x 2.5m).

iii. Anchor

The cages were anchored with circular concrete blocks of average weight of 50kg to hold the cages in place, preventing them from drifting by current or storm (Figure 3.5).One anchor was tied with 10mm nylon rope (mooring line) to every corner of the frame making four anchors for a battery of 3 cages. The mooring line was one-third longer than the minimum depth of the lake to prevent the cages from submerging by the flood.

Figure 3.5: Circular concrete anchor(50 kg weight each) for the net cage

3.3.2Installation of cage

The constructed frames were carried into the lake water, rolled to the culture site for installation, anchored at the site and the net cages were tied with nylon twine to the bamboo frames. The bamboo cages were arranged in a straight line perpendicular to the prevailing winds.A complete installed raft of three net cages and one unit net cage on the raft is shown in (Figure 3.6 and 3.7).

Figure 3.6: A raft of three installed net cages

Figure 3.7: A unit of net cage ($1.5m^3$)

3.4.Fish stocking

Prior to stocking, the experimental fish, *Clarias gariepinus* juveniles(mean weight 70±0.03 g; length21±0.07 cm) were quarantined in two concrete tank of 20m^2 each in a nearby reputable hatchery, about 4.0km from the study area (Owala lake) for two weeks and treated continually with sodium chloride salt, table salt (NaCl) at 5g/l to eliminate possible ectoparasite, to inhibit fungal disease and to minimize stress (Selosse and Rowland, 1990). Preceding all handling, sorting, transportation, stocking and bleeding and other actions, fish were anaesthetized utlizing 20mg/l benzocaine (Ethyl Aminobenzoate)(Rowland*et al*., 2007).

Prior to transportation of experimental fish to the study area (Owala Lake), the fish were starved for 24 hours. After starvation, they were anaesthetized and graded into sizes. A total of 3,600 juvenilesof the same spawners and age group were chosen for stocking and randomly assigned to treatments SD_1-EFD, SD_2-EFD, SD_3-EFD, SD_1-PSD,SD_2-PSD andSD_3-PSD in cages. Where, EFD and PSD are extruded floating diet and pelleted sinking diet, respectively and SD_1,SD_2 andSD_3 are stocking densities100 (control),200 and 300 (fish/m^3). The treatments were replicated thrice. Fish were transported very early in the morning at 6:00 hours GMT.

3.5. Feeding

The fish were fed with a commercial grow-out feed (Durante feed), comprising 45% crude protein at 3% body weight daily. The choice of the feed was based on its availability in both extruded floating and pelleted sinking forms. The feed was fed to the fish in each cage in two equal quantities at 7-8 and 16-17 GMT. The daily weight of diet deposited into every cage was recorded. At feeding time mortality was monitored and recorded.Table 3.2.1 and Table 3.2.2 present the proximate composition of the diets utilized. The technique of feeding with extruded floating diet and pelleted sinking diet vary. Extruded floating diet was poured at once into the water surface with a fine meshed net enclosure. Pelleted sinking diet was poured all at once down a 5 cm PVC pipe to a sinking feed enclosure (cage bottom screened with fine meshed mosquetoes nylon net) at the bottom of the cage to prevent feed loss through the bottom and bottom sides.

Table 3.2.1: Proximate composition of commercial extruded floating feed

Parameters	Manufacturer's proximate Composition (%)	Analysed composition (%)
Moisture	7.3	8.25 ± 0.04
Ash	8.0	7.74 ± 0.16
Crude protein	45.0	44.05 ± 0.03
Crude fat	11.0	10.49 ± 0.05
Crude fibre	2.6	3.05 ± 0.02
Nitrogen Free Extract	33.6	33.00
Vit. D_3	2000 iu/kg	1992.04±0.07 iu/kg
Vit. E	200 mg/kg	193.92±0.05 mg/kg
Vit.C	150 mg/kg	145.69±0.03 mg/kg

Table 3.2.2: Proximate composition of commercial pelleted sinking feed

Parameters	Manufacturer's proximate Composition (%)	Analysed composition (%)
Moisture	8.0	8.65 ± 0.06
Ash	9.0	9.20 ± 0.14
Crude protein	45.0	43.97 ± 0.03
Crude fat	10.0	11.40 ± 0.06
Crude fibre	3.0	2.83 ± 0.05
Nitrogen Free Extract	33.60	32.45±0.09
Vit. D_3	2000	196.08±1.4 iu/kg
Vit. E	Vit. 200 mg/kg	196.27±03 mg/kg
Vit. C	Vit. 150 mg/kg	147.08±06 mg/kg

3.6. Proximate composition analysis of experimental diets

The experimental diets were analyzed employing the standard procedures of the Association of Official Analytical Chemist (AOAC, 2005)

3.7. Fish sampling and final harvest

Bi-weekly, 20% of the fish in each of the experimental cages were sampled between 7:00 – 9:00 hours GMT to calculate an average weight, and diet supplies were regulated appropriately. At the conclusion of experiment, the whole of the fish in the experimental cages were cropped, enumerated and total weight, length and survival rates were recorded.

3.8. Fish growth performance analysis.

At the conclution of the experiment (after 150 days), the entire net-cages were transferred to the shore, fish were harvested and weighed for each cage and treatment for determination of total fish output. The growth performance and feed utilization such as mean weight gain (MWG), mean length (MLG) specific growth rate (SGR), survival rate (SR), protein intake*(*PRI),feed conversion ratio (FCR),protein efficiency ratio (PER), and condition factor (K) were calculated using the following formular

3.8.1. Mean Weight Gain (MWG)

MWG = Wf – Wi

Where

Wf = Final mean weight (g)

Wi = Initial mean weight (g)

3.8.2. Specific Growth Rate:

SGR = $\frac{\ln Wf - \ln Wi}{t} \times 100$ (Hepher,1988)

Where,

ln = natural log

Wf = Final mean weight (g)

Wi = Initial mean weight (g)

t =time of trial in days

3.8.3Feed Conversion Ratio:

FCR =Total dry weight of feed fed (g)(Castell and Tiews, 1980)

Total wet weight gain (g)

3.8.4. Protein Efficiency ratio:

PER =Wf – Wi(Wilson,1989)

PI

Where

Wf= Final weight (g)

Wi= Initial weight (g)

PI =Protein intake = (% Protein in feed x Total diet consumed)/100

3.8.5.Survival rates (%)

SR =Number of fish that survived×100

Total number of fish stocked

3.8.6Production Index:

PI = SR x W_2– W_1/ t(Mohanty, 2004)

Where

SR =Survival rate

W_2 = Final weight (g) W_1- Initial weight (g)

t = time of trial in days

3.8.7. Condition Factor

$K = W.100/SL^3$(Pauly, 1984)

Where:

W = weight of fish

SL = the total length

3.9 Evaluation of haematological profile

This was executed at Clinical Pathology laboratory of the Department of Veterinary Pathology University of Ibadan, Nigeria.

3.9.1. Sampling protocols

Five fish were carefully collected from each of net cages in treatment groups, SD_1-EFD, SD_2-EFD, SD_3-EFD, SD_1-PSD, SD_2-PSD and SD_3-PSD. Fish were deprived of foodfor one day previous to sampling.

The sampled fish were anaesthetizedusing 20ml/g benzocaine (EthylAmminobenzoate) immediately they were collected from the cages. Blood was sampled by vein puncture using 5ml heparinized plastic syringe attatched with a 21 gauge hypodermic needle.In order to eliminate stress during sampling, bleeding was accomplished in less than 2 minutes after which the fish were treated with salt (NaCl at 5gl/l) to prevent fungal and bacterial infection. The extracted blood was collected into heparinized eppendof tubes and immediately kept in a plastic container (Cooler) with crushed ice-block for transportation to laboratory where analysis was carried out.

The following haematological parameters weremeasured and these include packed cell volume (PCV), red blood cell count (RBC), haemoglobin concentration (Hb), heterophil (HET), lymphocyte (LYM), and heterophil : lymphocyte (H : L) ratio

3.9.2 Packed cell volume (PCV)

Packed cell volume (PCV) was determined following the microhaematocrit centrifugation method as described by Jain, (1986). Blood in a blood collection tube (vacutainer tube) was mixed by thoroughly by turning the tube upside down many times. A 75mm x 1.0mm micro-haematocrit capillary tube was filled up to about 2/3 of its entire length by means of surface capillary action as well as surface tention. One end of the capillary tube was blocked with platicine, placed into a microhaematocrit centrifuge spinned at 11000 rpm for a period of 5minutes.subsequently, the capillary tube was withdrawn from the centrifuge and put on haematocrit reader where the PCV was recorded

3.9.3 Haemoglobin concentration determination (Hb)

The haemoglobin (Hb) level of the blood sample was determined using cyanomethaemoglobin technique as described by (Jain, 1986). Twenty microliter (20 µL)of blood thoroughly mingled in a vacutainer tube was added to 5ml of Drabkin's solutioncomprising potassium in a test tube. In the Drabkin's solution, the erythrocytes were haemolysed and Hb was oxidized by the ferricyanide to methaemoglobin. After about ¼ hour, 1.0 ml of the mixture was pipetted into a burette was put in a spectrophotometer (Jenway, England, Model: Genova Mk 3) atadjusted wave length at 540nm. Cyanomethaemoglobin solution absorbance was read and recorded subsequent to adjusting the spectrometer to zero reading utilizing normal Drakin's solution. Calculation of Hb level of the blood was carried out by fractionating the absorbencevalue recordedby the slop derived from a graduated graph.In order to obtain the graduated graph, a blood sample of known Hb was mingled with Drabkin's solution in the following ratio: 5 to 0; 4 to 1; 3 to 2; 2 to 3 and 1 to 4. Every one of these solutionsvalue was read in the spectrophotometer subsequently zeroedutilizing Ho neutral Drabkin's Solution. A graph of absorbance for each and every one of the solutions was plotted against the correspondent Hb value, and the graph slope was determined.Afterward, Hb value of each and every one of the solutions was got by multiplying the ratio of standard Hb in that solution by the Hb value of the standard.

3.9.4 Red blood cell counts

Red blood cell counts were determined by the haemo-cytometric technique as described by Jain (1986).

3.9.5 Leucocyte differential cells analysis

Blood smears were made on slides and allowed to air dry. The slides were stained with Giemsa stain (Giemsa Laboratories Limited, Molbase, Shanghai) using differential stain. Slides were examine by using light microscope (Olympus, Olympus Corporation, USA) with 100× magnification. Each slide was moved in one Direction, while the number of heterophil and lymphocytes were counted by using blood cell differential counter (Durga, Miniscience, Inc, USA) until a sum of one hundred leucocytes were counted. The defferential cells were expressed in percentage (%). The ratio of heterophil and lymphocytes was also calculated.

3.10. Water quality monitoring

Physical and chemical analysis of water was measured every week throughout the study between 07:00-9:00 GMT. The variables such as water temperature, pH (hydrogen ion concentration), dissolved oxygen, ammonia, nitrite and transparency were measured on-site.

Dissolved oxygen, ammonia, nitrite and pH were measured on-site using a Hanna 83203 multi- probe meter. Temperature was measured with HANNA HI 991001 portable meter. Transparency was measured with secchi disc.

3.11Economic analysis

The economic analysis employed was that Gomes *et al.,* (2006) with little modification. These supositions were made for economic analysis: Net cage expensesencompass materials and construction, boat cost, and labour cost of one person capable of handing routine job of 18 cages of 1.0m×1.0m×1.5m, maintenance and repair cost of nets and wooden boat. Salary and wages were by negotiation. Depreciation per annum was calculated by straight-line methods, put into consideration the economic life of equipment. The investments on cage culture enterprise were grouped into capital costs (fixed costs) and operation costs (variable costs). Interest on variable and fixed costs was calculated multiplying the total cost variable and fixed costs by the annual interest rate (4%) on loan from Cooperative society. The gross margin analysis and profitability ratio were utizlised to investigate the cost and economic returns of the cage culture of experimental fish, *Clarias gariepinus.*

The economic and financial parameters such as Gross revenue (GR), Net revenue (NR), Benefit Cost Ratio (BCR) were calculated using the following formulae:

i. Gross Revenue (GR) = Total Revenue (TR) – Total Variable Costs (TVC)

ii. Net Revenue (NR) = Total Revenue (TR) – Total Cost (TC)

iii. Benefit Cost Ratio (BCR) = Total Revenue (TR) / Total Cost (TV)

3.12Data/statistical analysis

Data was analyzed with SPSS Version 22 IBM Corporation, 2013

Preliminary analyses

Preliminary analysis contained exploratory data analysis whereby line graphs were employed to present the trend in average weight throughout the duration of the experiment. Descriptive statistics were utilised to present the variables. Spearman rank correlation matrix was utilised to test for the correlation among pair of the paramaters as they change along time of experiment. Non-parametric correlation was employed because of the inconsistency in values of standard deviations among the study variables.

Repeated measures analysis of variance

Effect of the three factors: Stocking Density, Diet and Days of experiment on the weight and length gain of the fishes were tested using repeated measures analysis of variance. The fixed factors were crossed with each other. Individual fish were the 'subjects', treatments were the 'among-subject' factors, while the days of experiment are the repeated measures ('within-subject' factors). Where plausible, the result of analysis of variance was adjusted for sphericity where the assumption of sphericity was violated.

Data generated for growth and feed utilization parameters were subjected to descriptive (means and standard deviation) and inferential (two-way analysis of variance, Analysis of variance (ANOVA) and correlation) statisticat $\alpha = 0.05$. The mean values of the experimental variables were compared with Bonferroni or Tamhane T2 tests.

Spearman rank correlation was used to analyze the linearity of the physico-chemical properties over time. One-way analysis of variance was employed to test the significant difference among the variables, while One-way ANOVA was employed to test the significant difference among the physical and chemical parameters, while Bonferroni test was utilizsed to compare values of parameters where there is significant difference.

CHAPTER FOUR

RESULTS

4.1 Field survey of net-cage farms

4.1.1Demographics

As indicated in Table 4.1, all the 30 respondents sampled were male. Majority (53.33%) of the farmers were 31 to 40years, while the rest-16.67% were 21 to 30years, 23.33% were 41 to 50years and 6.67% were about 50 years. The marital status of the cage culture farmersrevealed that most of them (90%) were married, while 10% were single. Most of the Respondents household size were 1 to 4 persons (73.33%), while 20% of them had 5 to 8 persons and 6.67% had more than 8 persons. The average household was abour 6.02 persons.

In education, most of the respondents (50%) were University or other tertiary institution graduates, 30% and 20% were secondary school and primary school certificate holders respectively, and 3.33% were illiterates. The respondents had different experience in cage culture. Majority (80%) of them had 5 to 8 year-experience, 6.67% had 1 to 4 years and 13% had more than 8 years of experience.

The results further indicated that most of the respondents (46.67%) were civil servants, 13.33% engaged in trading/ business, 10% were crop farmers, 20% were artisanal fishermen and 10% engaged in vocational job. Dealing with funding of net-cage fish farming, majority (93.33%) of the respondents had personal or family funding, 6.67% from cooperatives and no farmer obtained bank loan. Concerning the membership of farmers' cooperative society, 73.33% claimed to be members and 26.67% were not members of any cooperative society or farmer's association.

Table 4.1.1: Socio economic characteristics of cage culture farmers in Lagos, Ogun and Osun States, Nigeria

Variable	Frequency	Percentage	Mean
Age (Years):			
21-30	5	16.67	
31-40	16	53.33	
41-50	7	23.33	
>50	2	6.67	43.7
Total	30	100	
Male	30	100	
Female	0	0	
Total	30	100	
Marital Status:			
Married	26	86.67	
Single	4	13.33	
Total	30	100	
Household size:			
1-4	22	73.33	
5-8	6	20.00	
>8	2	6.67	6.02
Total	30	100	
Educational Achievement:			
Non-formal	0	0	
Primary school certificate	6	20.00	
Secondary school certificate	9	30.00	
Tertiary / university degree	15	50.00	
Total	30	100	

Table 4.1.1 continued

Variable	Frequency	Percentage	Mean
Cage culture experience:			
1-4	2	6.67	
5-8	24	80.00	
>8	2	13.33	
Total	30	100	
Occupation:			
Trading	4	13.33	
Farming (crop)	3	10.00	
Fishing (artisan)	6	20.00	
Civil service	14	46.67	
Vocational job	3	10.00	
Total	30	100	
Source of capital:			
Personal/family savings	28	93.33	
Cooperative society	2	6.67	
Bank loan	0	0	
Total	30	100	
Membership of farmers cooperatives:			
Member	22	73.33	
Non-member	8	26.67	
Total	30	100	

Source: Field Survey 2013

4.1.2 Cage culture operation

Table 4.2.2 to 4.2.3 present the cage culture operation in the study area

4.1.3Farm size

Majority (63.33%) of the farms had 1-2 cages, 23.33% had 3-4 cages, 6.67% had 5-6 cages, and 6.67% had above 10 cages.

4.1.4Cage size

Majority (76.67%) of the net-cage farmers in the study area used 4m x 2m x 2m cages, 20.00% used 2m x 2m x 2m cages and 3.33% cultured their fish in 6m x 6m x 6m cages

Table4.1.2: Distribution of cage culture by farm size

Farm Size	Frequency	Percentage
1 to 2	19	63.33
3 to 4	7	23.33
5 to 6	2	6.67
6 to 10	0	0
Above 10	2	6.67
Total	30	100

Source: Field Survey 2013

Table 4.1.3: Distribution of cage culture by cage size

Cage Size	Frequency	Percentage
2m by 2m by 2m	6	20.00
4m by 2m by 2m	23	76.67
6m by 6m by 6m	1	3.33
Total	30	99.99

Source: Field Survey 2013

4.1.5 Size of fish stocked by species

Clarias gariepinus:

As presented in Table 4, majority (63.33%) of the fish stocked are between the size bracket of 21 – 25g, 13.33% were below 15g, 6.67% (21 – 25g), 26 – 30g (10%) and above 30g (6.67%).

Tilapia species:

The stocking size for Tilapia species, *Oreochromis niloticus* and Red Tilapia ranged from 5 – 10g in all the farms sampled.

4.1.6Stocking density

As shown in Table 4.5, the stocking density practiced for *Clarias gariepinus* were mostly 100fish/m^3 (43.33%). Some farmed used 101 – 150fish/m^3 ((33.33%), 50 – 80fish/m^3 (6.67%), less than 50fish/m^3 (3.33%).

For Tilapia species, the stocking density used were mostly ranged from 50 – 100fish/m^3 (75%) and less than 50fish/m^3 (25%).

4.1.7Source of fingerlings/juveniles and procurement

As shown in Table 4.6, most (93.33%) of the farmers procured their fingerlings or juvenile fish, *Clarias gariepinus* and Tilapia species from reputable hatchery close to their farms, while 6.67% breed or raised fingerlings/juveniles fish in their hatchery. No farmer sourced fingerlings or juvenile fish from the wild.

Table 4.1.4: Size of fish stocked in farms practicing cage culture

Fish species size (g)	Frequency	Percentage
Clarias gariepinus		
< 15	4	13.33
15 to 20	2	6
21 to 25	1	63.33
26 to 30	3	10
> 30	2	6.67
Total	30	100.00
Tilapia species		
5 to 10	2	50.00
11 to 15	2	50.00
Total	4	100.00

Source: Field Survey 2013

Table 4.1.5:Stockingdensity employed by farmers

Stocking density	Frequency	Percentage
Clarias gariepinus		
< 50	4	13.33
50 to 80	2	6.67
81 to 100	13	46.67
101 to 150	10	33.33
> 150	1	3.33
Total	30	100
Tilapia species		
< 50	1	25.00
50 to 100	3	75.00
Total	4	100

Source: Field Survey 2013

Table 4.1.6: Source of fingerlings / juvenilesfish

Source	Frequency	Percentages
Private Hatchery	28	93.33
Farm Hatchery	2	6.67
From the wild	0	0
Total	30	100

Source; Field survey 2013

4.1.8Types of commercial fish feed used by net-cage farmers

As indicated in Table 4.7, all the farmers utilised extruded floating feeds in feeding the fish

4.1.9Distribution of net cage culture by constraints

Table4.8presents the constraints of cage cultue in the study areas. The major constraints are, high cost of quality feed (100%), high cost of overall operation (100%), lack of fingerlings/ juveniles (90%). Others are lack of skilled manpower (60%), bio-fiouling (60%) and lack of knowledge (50%).

Table 4.1.7: Type of commercial fish feed used by cage farmers

Type	Frequency	Percentage
Floating	30	100
Sinking	0	0
Total	30	100

Source: Field Survey 2013

Table 4.1.8: Distribution of net cage culture by constraints

Constraint	Frequency	Percentage	Rank
Lack of skilled manpower	18	60	3
lack of knowledge	15	50	4
Loss/damage of cage equipment	6	20	5
Poaching of fish	15	50	4
Lack of fingerlings/ juveniles	27	90	2
High cost of overall operation	30	100	1
Low survival rate	0	0	6
Bio-fouling	18	60	3
High cost of quality feed	30	100	1

Source: Field Survey 2013

4.1.10 Cost and returns of floating net cage culture farmers in the study areas

Table 4.9 presents cost and benefit of 12 farmers with 28 cages in the study areas. All the respondents operated 2 culture cycles of 4-5 months per cycle per annum. The annual gross and net revenues were ₦15,768,681.06 (₦563,167.18 per cage per annum) and ₦14,928,681.18 (₦533,167.1per cage per annum).The benefit cost ratio was 1.21.

Table 4.1.9: Cost and returns of floating net cage farmers in Lagos, Ogun and Osun States

	Unit cost (₦)	Total Amount (₦)	% of total cost (₦)
Total harvest (kg)		156,891.29	
Total Revenue (TR)	550.00	86,290,209.50	
Capital Investment			
Wooden boat (No: 12)	35,000.00	420,000.00	
Cage (No: 28)	270,000	7,560,000. 0	
Total capital investment		7,980,000.00	
Variable cost (VC)			
Clarias gariepinus (post juvenile)	40	4,885,640.00	6.85
Feed	333.33	62,755,888.44	87.94
Labour *(*month)	12,000	2,880,000.00	4.04
Total variable cost (TVC)		70,521,528.44	98.82
Fixed cost (FC) depreciation (year)			
Cage		756,000.00	
Boat		84,000.00	
Total Fixed Cost (TFC)		840,000.00	1.18
Total Cost (TC = TVC +FC)		71,361,528.44	
Gross Revenue (TR – VC)		15,768,681.06	
Net Revenue (NR) = (TR – TC)		14,928,681.06	
Benefit Cost Ratio (BCR) = TR/TC		1.21	

Source: Field Survey, 2013

4.2 Experimental trial: Growth performance and feed utilizationof *Clarias gariepinus* under varying stocking densities and feed formsin net cages

4.2.1 Preliminary data exploration for fortnightly mean weight increase (g)of *Clarias gariepinus* in floating net cages

The model assumed for the change in weight is

Weight (g) = *Intercept + Days + Diet + Density + Diet* Density + Diet* Days + Days* Density + Diet* Days* Density.*

The assumption of sphericity was not violated in the results (*Density:* X^2 *=1.22, P=0.54; Diet* Density:* X^2 *= 0.34, P=0.85*). Hence there was no need for adjustment of the F-ratio and the results of test of sphericity have not been presented here.

4.2.2 TheANOVA Test of within – subject effect

Appendix 4.2.1 shows results of ANOVA test of within- subject effects. The results shows that all the terms in the model are significant i.e. both main effects, two-way interactive effects and three-way interactive effect are significant in the model. Specifically there is a main effect of diet (floating and sinking diets) F= 861.087, $p<0.05$. Similarly, there is main effect due to stocking density (100, 200 and 300 fish/m^3 densities) F=8048.960, $p<0.05$.

4.2.3 Meancomparison offortnightly weightincrease of *Clariasgariepinus*under varying stocking densities and feed forms in net cages

The initial weight at Day 0 and day 15ranged from 69.98±0.01g (SD_3-PSD) to 70.00±0.05g (SD_2-PSD) and 100.00±1.73g (SD_3-PSD) to 117.83±2.31g (SD_1-EFD), respectivelywith no significant difference ($p<0.015$. From Day 30 to the end of the experiment (Day 150), the results showedthat weight increase was significantly different among the treatments. The least (739.33±2.03g) and the highest (1178±3.18 g) final mean weight were obtained from SD_3-PSD(fish stocked at density of 300 fish/ m^3 andfed sinking diet) andSD_1-EFD those stocked at density of 100 fish/m^3 and fed extruded floating diet),respectively, $p<0.01$ (Appendix 4.2.2; Figure 4.2.1).

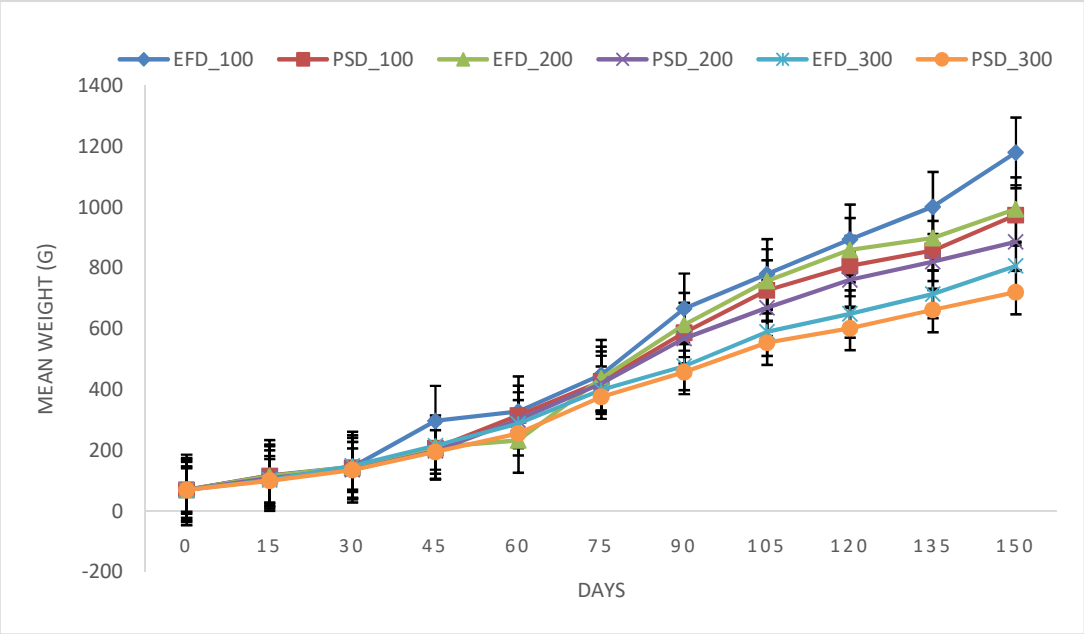

Figure 4.1:Mean fortnightly weight increase of *Clarias gariepinus*among treatments groups.

4.2.4 Preliminary data exploration on effect of diet types and stocking density on length increase of *Clarias gariepinus* in floating cages

The model assumed for the change in length is:

Length(cm) = *Intercept + Days + Diet + Density + Diet* Density + Diet* Days + Days* Density+ Diet* Days* Density.*

The assumption of sphericity was not violated in the results. Hence, there was no need for adjustment of the F-ratio and the results of test of sphericity are not presented.

4.2.4.1 The ANOVA test of within – subject effect

Appendix 4.2.3 shows thesummary of ANOVA result of test within subject effect. The results revealed that all terms in the model are significant, that is, both main effects, two-way interactive effects and three-way interactive. Specifically, there is a main effect of diet, F= 25.775, P<0.001. Hence, if we hold other variables constant, there is a significant difference in the lengths of fish fed with floating diets as well as those fed sinking diet. Similarly, there is main effect due to stocking density, F=103.960, P<0.01, which implies that if we hold other variables constant, there is a significant difference in length of fish stocked at SD_1, SD_2, and SD_3(100, 200 and 300 fish/m^3),respectively.

4.2.4.2Comparison of mean total length increase of fish among the treatment groups for the period of experiment:

Table 4.2.1presentscomparison mean total length of fish amongthe treatment groups for the period of experiment since the interaction is significant in the model. At the commencement of the experiment, Day 0 and Day 15, all the treatment groups had the same average mean length of about 21.12±0.0 cm; 21±0.0 cm for fish fed EFDand PSD, respectively. And no significant difference among the treatments (Appendix 4.2.3). However, from Day 30 to Day 150there are significant different among the treatments. The least (43.67$\pm$0.09cm), and highest (45.70±0.26cm) final mean total length were obtained from fish fed pelleted sinking diet at density at stocking density of 300 fish/m^3(SD_3 –PSD)and fish fed extruded floating diet at density of 100 fish/m^3(SD_1 –EFD) respectively,p<0.05. The final average mean length for fish feed EFD and those fed PSD were 45.03±0.55m and 44.49±0.52 cm, respectively. The main effects of stocking density and feed forms were significant were significant on mean Length Gain

Table 4.2.1: Mean forthnight Length (cm) increase of *Clarias gariepinus* under varying stocking densities and feed forms in flo net cages

Day	SD_1-EFD	SD2-EFD	SD_3-EFDMSE	SD_1-PSD	SD_2 _ PSD	SD_3-PSD MSE
0	21.17±0.03[a]	21.10±0.06[a]	21.10±0.21[a] 21.12±0.03	21.00±0.00[a]	21.00±0.06[a]	21.00±0.00[a]21.00±0.0
15	24.20±0.46[a]	23.97±0.20[ab]	23.00±0.0[ab] 23.72±0.45	23.73±0.07[ab]	23.50±0.12[ab]	22.87±0.03[ab]23.37±0.31
30	27.93±0.84[a]	27.33±0.1[a]	26.13±0.12[b]27.60±0.65	27.60±0.17[a]	26.80±0.49[ab]	25.13±0.54[c]26.57±0.87
45	31.17±0.78[a]	30.90±0.06[ab]	29.20±0.23[b]30.42±0.76	30.70±0.12[ab]	30.50±0.06[ab]	28.93±0.38[c]30.04±0.67[ab]
60	35.20±0.44[a]	34.30±0.17[b]	33.20±0.12[c]34.23±0.71	34.93±0.09[b]	33.97±0.09[c]	31.10±0.06[d]33.33±1.41
75	38.27±0.23[a]	37.00±0.06[b]	36.30±0.06[c] 37.19±0.71	37.83±0.22[b]	36.63±0.09[c]	33.30±0.15[d]35.92±1.66
90	40.07±0.17[a]	39.13±0.18[b]	38.20±0.12[c] 39.13±0.66	39.70±0.15[b]	38.37±0.27[c]	37.23±0.09[d]38.43±0.87
105	42.30±0.21[a]	41.47±0.20[b]	39.63±0.35[d]41.13±0.97	41.40±0.06[b]	40.17±0.10[c]	39.43±0.23[d]40.33±0.70
120	43.07±0.15[a]	42.85±0.25[b]	42.00±0.00[c]42.64±0.40	42.77±0.12[b]	41.70±0.12[c]	41.17±0.34[c]41.88±0.58
135	44.00±0.06[a]	43.93±0.09[ab]	43.99±0.06[ab]43.97±0.04	43.81±0.03[ab]	43.30±0.17[b]	43.33±0.20[b]43.48±0.20
150	45.70±0.26[a]	45.23±0.23[a]	44.17±0.12[b]45.03±0.55	45.10±0.06[a]	44.70±0.12[b]	43.67±0.09[c]44.49±52

Mean ±Std. Error values with the same superscript are not significantly different along the row at $p<0.05$.

MSE = Group Mean Standard Error.

SD_1-EFD = Stocking density of 100 fish/m^3 with extruded floating diet, SD_2-EFD = Stocking density of 200 fish/m^3 with extruded floating diet, SD_3-EFD = Stocking density of 300 fish/m^3 with extruded floating diet, SD_1-EFD = Stocking density of 100 fish/m^3 with pelleted sinking diet, SD_2-EFD = Stocking density of 200 fish/m^3 with pelleted sinking diet, SD_3-EFD = Stocking density of 300 fish/m^3 with pelleted sinking diet.

4.3: Effect of diet and stocking density on growth and feed utilization parameters of *Clariasgariepinus* under varying stocking densities and feed forms in net cages

The growth and feed utilization parameters considered were weight gain, length gain, specific growth rate, survival rate, production index, condition factors, feed intake, protein intake, protein efficiency ratio and feed conversion ratio.

Table 4.2.2 and 4.2.3show descriptive statistics and the summary of ANOVA results of effect of the diet and stocking density on the calculated mean growth and feed utilization parameters, respectively.

4.3.1Weight Gain of *Clarias gariepinus* reared in net cages

Mean Weight Gain (MWG) for fish fed Extruded Floating Diet (EFD) ranged from 735.33±9.52g (SD_3-EFD)to 1108.33±5.53g(SD_1-EFD)with average MWG (922.00±161.64g), while those fed pelleted sinking diet (PSD) varied from 649.45±3.33g(SD_3-EFD)to 902.97±19.95g (SD_1-EFD)with average MWG 789.25±112.01g). Least735.33±9.52g; 649.45±3.33g MWGfor fish fed EFD and those fed PSD were obtained in SD_3-EFD and SD_3-PSD, respectively, while highest1108.33±5.53g; 902.97±19.95g MWG for fish fed EFD and those fed PSDwere obtained in SD_1-EFD and SD_1-PSD, respectively.The least average MWG789.25±112.01g) and highestaverage(922.00±161.64g) were obtained from fish fed PSD and EFD,respectively (Table4.2.1). The MWG among all the treatment groups varied from 649.45±3.33g (SD_3-PDS) to1108.33±5.539g (SD_1-EFD).The MWG 1108.33±5.53g (SD_1-EFD) was significantly different from all other treatments, whileSD_2-EFD (922.33±5.98g)as well asSD_1.PSD(902.97±19.95g) were not significantly different but significantly different from SD_2-PSD (815.33±6.52g),SD_3-EFD (735.33±9.52g) and SD_3-PSD (649.45±3.33g) (Table 4.2.3). MWG was strongly and positively correlated ($p<0.01$)with Length Gain ($r=0.895$), Specific Growth Rate ($r=0.997$),Production Index ($r=0.1$), Condition Factor ($r=0.932$), Feed Intake ($r=0.952$), Protein Intake ($r=0.952$), Protein Efficiency Ratio ($r=0.664$). However, MWG was negatively related with Food Conversion Raio ($r=-0.999$) and weak correlation ($p<0.05$) with Survival Rate ($r=0.189$) (Appendix 4.2.5).

4.3.2 Length Gain of *Clarias gariepinus* reared in net cages

Mean Length Gain (MLG) for fish fed extruded floating diet (EFD) ranged from 23.07±0.12cm (SD_3-EFD)to 24.53±0.23cm (SD_1-EFD); with anaverage of 23.91±0.74cm,

while Mean Length Gain for fish fed pelleted(PSD) varied from 22.67±0.09cmSD_3-PSD to 24.10±0.06cmSD_1-PSD; with an average of23.49cm±0.66cm. Least(23.07±0.0.12cm; 22.67±0.09cm) MLG for fish fed EFD and PSDwere obtained in SD_3-EFD and SD_3-PSD, respectively.While the highest(24.53±0.23cm; 24.10±0.06cm) MLG for fish fedwere obtained in SD_1-EFD as well asSD_1-PSD, respectively. The least average MLG (23.49±0.66cm) and highest(23.91±0.74cm) were obtained from fish fed PSD and EFD, respectively (Table 4.2.6). The least and highest MLG among all the treatment groups were 22.67±0.09 cm (SD_3-PDS) and24.53±0.23cm (SD_1-EFD, respectively. The MLG forSD_1-EFD (24.53±0.23cm) was not significantly different from that ofSD_2-EFD (24.13±0.29cm) as well asSD_1-PSD (24.10±0.06cm) but significantly different from SD_3-EFD (23.07±0.12cm), SD_2-PSD (23.7±0.15cm) and SD_3-PSD (22.67±0.09cm) (4.2.3).)). MLG was strongly and positively correlated ($p<0.01$) with mean Weight Gain ($r = 0.895$), Specific Growth Gate ($r = 0.910$), Production Index ($r = 0.896$), Condition Factor ($r= 0.678$), Feed Intake ($r = 0.836$), Protein Intake ($r = 0.836$), Protin Efficiency Ratio ($r = 0.651$). However, MLG was negatively related with Food Conversion Ratio ($r = -0.630$) and weak correlation ($p<0.05$) with Survival Rate ($r = 0.210$) (Appendix 4.2.5).

4.3.3 Specific Growth Rate of *Clarias gariepinus* reared in net cages

Mean Specific Growth Rate(SGR) for fish fed extruded floating diet (EFD) varied from 1.57±0.00% SD_3-EFD to 1.86±0.00%SD_1-EFD ; average (1.73±0.0 %); while mean SGR for fish fed Pelleted sinking diet (PSD) ranged from 1..63±0.00% SD_3-PSD to 1.70±0.00%SD_1-PSD; average (1.67±0.0%). Least SGR (1.57%) and 1.57±0.09% were obtained from SD_3-EFD as well asSD_3-PSD, respectively. While the highest (1.86±0.00% and 1.70±0.00%) were obtained from SD_1-EFD and SD_1-PSD, respectively. The least average mean SGR (1.49±0.00 %) and highest (1.91±0.00%) were obtained from fish fed PSD as well as those fed EFD, respectively (Table 4.2.2). The SGR among all the treatment groups varied from 1.63±0.00% (SD_3-PDS) to 1.86% ±0.00 (SD_1-EFD). The mean SGR 1.86±0cm% (SD_1-EFD) was not significantly different from 1.77±0.00% (SD_2-EFD) but significantly different from 1.57±0.00 % (SD_3-EFD), 1.70±0.00% (SD_1-PSD), 1.65±0.00% (SD_2-PSD) and 1.63% (SD_3-PSD) (Table 4.2.3).SGR was strongly and positively correlated with mean weight gain ($r = 0.997$), mean length gain ($r = 0.910$), production index ($r = 0.996$), condition factor ($r= 0.921$), feed intake ($r = 0.954$), protein intake ($r = 0.954$), protin efficiency ratio ($r = 0.658$). However, SGR was negatively related with food conversion ratio ($r = -0.626$) and weak correlation with survival rate ($r = 0.186$) (Appendix 4.2.5).

4.3.4 Survival Rateof *Clarias gariepinus* reared in net cages

Mean Survival Rate (SR) for fish fed extruded floating diet (EFD) varied from 98.00±0.58% (SD_3 -EFD)to 99.0±0.56% (SD_1–EFD); average (98.73±0.57); while mean SR for fish fed Pelleted sinking diet (PSD) ranged from 98.00±0.58% (SD_3-PSD) to 99.00±0.56 % (SD_1–PSD); average(98.89±0.11%). (Table 4.2.3). The mean SR in all thetreatments were not significantly different. (Table 4.2.3).Survival Rate has weak and positive correlation with mean Weight G (r = 0.189), Length Gain (r = 0.), Specific Growth Rate (r = 0.997), Production Index (r = 0.1), Condition Factor (r= 0.932), Feed Intake (r = 0.228), Potein Intake (r = 0.228), Protein Efficiency Ratio (r = 0.007). However, SR was negatively related with Food Conversion Ratio (r = -0.012). (Appendix 4.2.5).

4.3.5 Production Index of *Clarias gariepinus* reared in net cages

Mean Production Index (PRI) for fish fed extruded floating diet (EFD) ranged from 4.86±0.06 (SD_3 EFD) to 7.34±0.03 (SD_1 _EFD) average (6.10±1.08); while those fish fed with pelleted diet (PSD) ranged from 4.30±0.03(SD_3-PSD)to 6.00±0.09(SD_1-PSD); average (5.23±0.75). The least average mean (5.23±0.75) and highest (6.10±1.08) were obtained from fish fed pelleted sinking diet and those fed extruded floating diet, respectively (Table 4.2.3). The PRI among all the treatment groups varied from 4.30±0.03 (SD_3-EFD) to 7.34±0.03 (SD_1-EFD). The PRI values were significantly different among all other treatments. (Table 4.2.3).

4.3.6 Condition Factor (K) of *Clarias gariepinus* reared in net cages

Mean Condition Factor (K) for fish fed extruded floating diet (EFD) ranged from 0.93±0.02 (SD_3 –EFD) to 1.23±0.02 (SD_1-EFD) with average of 1.08±0.09, while values for fish fed pelleted sinking diet (PSD) ranged from 0.86±0.02 (SD_3-PSD) to 1.06±0.02 (SD_1-PSD) with average of 0.97±0.06. Least K for fish fed extruded floating diet (0.93±0.0.02) and those fed pelleted sinking diet (0.86±0.02) were obtained in SD_3-EFD and SD_3-PSD, respectively. While the highest K value for fish fed EFD (1.23±0.03) and those fed PSD (1.06±0.05) were obtained from in SD_1-EFD as well asSD_1-EFD. The least average mean K value (0.97±0.06) and highest (1.08±0.09) were obtained from fish fed PSD and those fed EFD, respectively (Table 4.2.2). The mean K among the treatments varied from 0.86±0.02 (SD_3-PDS) to 1.23±0.02 (SD_1-EFD). The K 1.23±0.02 (SD_1-(EFD) was not significantly different from1.07±0.02 (SD_2 – EFD) and 1.06±0.02 (SD_1-PSD), but significantly different from other

treatments (4.2.3). Condition factor was strongly and positively correlated ($p<0.01$) with weight gain ($r = 0.932$), Length Gain ($r = 0.678$), Specific Growth Rate ($r = 0.921$), Production Index ($r = 0.931$), Feed Intake ($r = 0.908$), Protein Intake ($r = 0.908$), Protein Efficiency Ratio ($r = 0.564$). However, Condition Factor was negatively related with Food Conversion Ratio ($r = -0.526$ and weak correlation ($p<0.05$) with Survival Rate ($r = 0.137$) (Appendix 4.2.5).

4.3.7 Feed Intake of *Clarias gariepinus* reared in net cages

Mean Feed Intake (FI) for fish fed extruded floating diet (EFD) ranged from 954.73±5.0g (SD_3-EFD) to 1343.17±5.78 g (SD_1-EFD); average 1169.29±178.93g, while values for fish fed pelleted sinking diet (PSD) ranged from 895.56±3.30g (SD_3-PSD) to 1176.37±24.56g (SD_1-PSD); average 1040.42±123.72g. Least FI (954.73±5.0g; 895.56±3.30g) were obtained from SD_3-EFD and SD_3-PSD, respectively. The highest values (1343.17±5.78g; 1176.37±24.56g) were obtained from SD_1-EFD and SD_1-PSD. The least average(1040.42±123.72g) and highest average (1169.29±178.93g) were obtained from fish fed pelleted sinking diet and those fed extruded floating diet, respectively. (Table 4.2.2). The FI among all the treatment groups varied from 895.56±3.30g (SD_3-PSD) to 1343.17±5.78g (SD_1-EFD). The FI values are significantly different (Table 4.2.3). Feed intake was strongly and positively correlated ($p<0.01$) with Mean Weight Gain ($r = 0.952$), Length Gain ($r = 0.836$), Specific Growth Rate ($r = 0.954$), Production Index ($r = 0.953$), Condition Factor ($r = 0.908$), Protein Intake ($r = 1.00$), Protein Efficiency Ratio ($r = 0.406$). However, FI was negatively related with Feed Conversion Ratio ($r = -0.367$) and weak correlation ($p<0.05$) with Survival Rate ($r = 0.228$) (Appendix 4.2.5).

4.3.8 Protein Intake of *Clarias gariepinus* reared in net cages

Mean Protein Intake (PRI) for fish fed extruded floating diet (EFD) ranged from 429.63±2.29 (SD_3 -EFD) to 604.43 ±2.60 (SD_1-EFD); average (526.18±80.52), while values for fish fed pelleted sinking diet (PSD) ranged from 403.00±0.19 (SD_3-PSD) to 529.37±11.05 (SD_1-EFD); average 468.19±55.67. Least PRI in fish fed extruded floating diet and those fed pelleted sinking diet 429.63±2.29; 403.00±0.01 were obtained in SD_3-EFD and SD_3-PSD, respectively. While the highest PRI values 604.43 ±2.60; 529.37±11.05 were obtained fromSD_1-EFD and SD_1-PSD, respectively (Table 4.2.2). These values were significantly ($p<0.05$) different among the treatments. (Table 4.2.3). Protein intake was strongly and

positively correlated ($p<0.01$) with Mean Weight Gain ($r = 0.952$), Length Gain ($r = 0.836$), Specific Growth Rate ($r = 0.954$), Production Index ($r = 0.953$), Condition Factor ($r= 0.908$), Feed Intake ($r = 1.00$), Protein Efficiency Ratio ($r = 0.406$). However, PRI was negatively related with Feed Conversion Ratio ($r = 0.367$) and weak correlation ($p<0.05$) with Survival Rate ($r = 0.228$) (Appendix 4.2.5).

4.3.9 Protein Efficiency Ratioof *Clarias gariepinus* reared in net cages

Mean Protein Efficiency Ratio (PER) for fish fed extruded floating diet ranged from 1.71±0.02 (SD_3–EFD) to 1.83±0.01 (SD_1–EFD); average to 1.75±0.10, while values for fish fed pelleted sinking diet (PSD) ranged from 1.61±0.01 (SD_3–PSD) to 1.75±0.05 (SD_1–PSD); with average of 1.68±0.07. Least PER values for fish fed extruded floating diet 1.71±0.02 (SD_3–EFD) and those fed pelleted sinking diet 1.68±0.01 (SD_3–PSD) were obtained from the highest stocking density. While the highest PRI 1.71±0.02 (SD_1–EFD); and PSD 1.61±0.01 (SD_1–PSD); were obtained from lowest stocking density. The least average (1.61±0.07) and highest (1.75±0.01) were obtained from fish fed pelleted sinking diet and those fed extruded floating diet, respectively (Table 4.2.3). The PER among all the treatment groups were not significantly different (Appendix 4.2.5). Protein Efficiency Ratio was strongly and positively correlated ($p<0.01$) with Mean Weight Gain ($r = 0.664$) with Length Gain ($r = 0.895$), Specific Growth Rate ($r = 0.997$), Production Index ($r = 0.1$), Condition Factor ($r =0.932$), Feed Intake ($r = 0.406$) and Protein Intake ($r = 0.406$), However, PERwas negatively related with Food Conversion Ratio ($r = -0.999$) and weak correlation ($p<0.05$) with Survival Rate ($r = -0.007$) (Appendix 4.2.5).

4.3.10 Feed Conversion Ratioof *Clarias gariepinus* reared in net cages

Mean Feed Conversion Ratio (FCR) for fish fed extruded floating diet ranged from 1.21±01 (SD_1–EFD); to 1.31±0.07 (SD_2–EFD); average 1.27±0.0, while values for fish fed pelleted sinking diet ranged from 1.29±0.01 (SD_1–PSD); to 1.38±0.07 (SD_3–PSD); average 1.32±0.06. Least FCR in fish fed extruded floating diet and those fed pelleted sinking diet were 1.21±0.03 (SD_1–EFD) and 1.29±0.01 (SD_2–PSD), respectively. While the highest FCR values 1.31±0.07; 1.38±0.07 were obtained in SD_2–EFD and SD_3–PSD, respectively. The least average (1.21±03) and highest (1.29±0.01) FCR were obtained in fish fed EFD and PSD, respectively. Treatment with lower stocking density presents the best FCR. (Table 4.2.2). The FCR among all the treatment groups varied from 1.21±03 (EFD100) to (1.38±0.07) and were not significantly different among all the treatments (Table 4.2.3). Feed

Conversion Ratio was strongly and negatively correlated ($p<0.01$) with Mean Weight Gain ($r = -0.631$), Mean Length Gain ($r = -0.630$), Specific Growth Rate ($r = -0.626$), Production Index ($r = - 0.627$), Protein Efficiency Ratio ($r = -0.999$) Condition Factor ($r= 0.526$); weak negative Feed Intake ($r = -0.367$) andProtein Intake ($r =- 0.367$. The FCR also has weak correlation ($p<0.5$) with Survival Rate ($r = 0.012$) (Appendix 4.2.5).

Table 4.2.2: Descriptive statistics of growth performance and feed utilization variablesof *Clarias gariepinus* under varying stocking densities and feed forms in net cages

		SD_1-EFD	SD_2-EFD	SD_3-EFD	Mean	SD_1-PSD	SD_2-PSD	SD_3-PSD	Mean
Initial weight (g)	Mean	70.01	70.00	70.00	70.00	70.02	70.00	69.98	70.00
	SE	0.03	0.04	0.04	0.03	0.03	0.05	0.07	0.01
Final weight (g)	Mean	1178	992.63	805.33	992.63	973.00	855.76	739.33	865.89
	SE	3.18	3.48	5.46	I31.88	11.55	68.15	2.03	68.15
Weight Gain (g)	Mean	1108.33	992.33	735.33	922.00	902.97	815.76	649.45	789.25
	SE	5.53	5.98	9.52	161.64	19.95	6.52	3.33	112.01
Initial length (cm)	Mean	21.17	21.10	21.10	21.12	21.20	21.09	21.00	21.03
	SE	0.04	0.06	0.21	0.02	0.04	0.06	0.03	0.00
Final length (cm)	Mean	45.70	45.23	44.17	45.03	45.10	44.70	43.67	44.49
	SE	0.26	0.23	0.12	0.45	0.06	0.12	0.09	0.52
Length Gain (cm)	Mean	24.53	4.13	23.07	23.91	24.10	23.70	22..67	23.49
	SE	0.40	0.50	0.21	0.74	0.10	0.26	0.15	0.66
Specific Growth Rate (%)	Mean	1.88	1.77	1.63	1.76	1.75	1.69	1.55	1.66
	SE	0.03	0.02	0.02	0.07	0.05	0.02	0.04	0.06

Appendix 4.2.2 (Continued)

Survival Rate (%)	Mean	99.00	98.67	98.67	98.73	99.00	99.00	98.33	98.89
	SE	0.00	0.11	0.11	0.11	0.00	0.00	0.11	0.11
Production Index	Mean	7.34	6.10	4.86	1.10	6.00	5.38	4.30	5.38
	SE	0.3	0.01	0.03	0.05	0.16	0.01	0.03	0.61
Condition Factor	Mean	1.23	1.07	0.93	1.08	1.06	0.99	0.86	0.97
	SE	0.02	0.02	0.02	0.09	0.02	0.02	0.02	0.06
Feed Intake (g)	Mean	1343.17	1209.98	954.73	1169.29	1176.37	1049.35	895.56	1040.42
	SE	10.01	104.85	8.80	178.93	4254.75	7.85	5.71	123.72
Protein Intake	Mean	604.43	544.49	429.63	562.18	529.37	472.21	403.00	468.19
	SE	4.50	47.18	3.96	80.52	19.15	3.53	2.57	55.67
Protein Efficiency Ratio	Mean	1.83	1.70	1.71	1.75	1.71	1.73	1.61	1.68
	SE	0.01	0.15	0.02	0.10	0.09	0.02	0.02	0.70
Food Conversion Ratio	Mean	1.21	1.31	1.30	1.27	1.30	1.29	1.38	1.32
	SE	0.01	0.12	0.03	0.08	0.07	0.02	0.02	0.06

Table 4.2.3: Pair comparison of growth performance and feed utilization parameters of *Clariasgariepinus* under varying stocking densities and feed formsamong the treatments

S/N	Variable	SD_1 – EFD	SD_2 -EFD	SD_3 –EFD	SD_1 – PSD	SD_2 – PSD	SD_3 – PSD
1	.Weight Gain (g)	1108.33 ± 5.53^{a}	922.33 ± 5.98^{b}	735.33 ± 9.52^{d}	902.98 ± 19.95^{b}	815.33 ± 6.52^{c}	649.45 ± 3.33^{e}
2.	Length Gain (cm)	24.53±0.40a	24.13 ± 0.50^{a}	23.07 ± 0.21^{bc}	24.10 ± 0.10^{a}	23.70 ± 0.26^{ab}	22.67 ± 0.15^{c}
	Specific Growth Rate ($^{c}/_{o}$)	1.88 ± 0.02^{a}	1.77 ± 0.02^{ab}	1.63 ± 0.02^{c}	1.75±0.02	1.69 ± 0.02^{c}	1.55 ± 0.02^{e}
4.	Survival Rate ($^{0}/_{0}$)	99.00 ± 0.56^{a}	98.00 ± 0.58^{a}	98.00 ± 0.58^{a}	99.00 ± 0.56^{a}	99.00 ± 0.56^{a}	98.00 ± 0.58^{a}
5.	Production Index	7.34 ± 0.05^{a}	6.10 ± 0.02^{ab}	4.86 ± 0.06^{d}	6.00 ± 0.16^{b}	5.38 ± 0.02^{c}	4.30 ± 0.03^{e}
6.	K-factor	1.23 ± 0.02^{a}	1.07 ± 0.02^{a}	0.93 ± 0.02^{b}	1.06 ± 0.02^{a}	0.99 ± 0.02^{b}	0.86 ± 0.02^{c}
7.	Feed Intake (g)	1343.17 ± 5.78^{a}	1209.98 ± 60.54^{abcd}	954.73 ± 5.08^{c}	1176.37 ± 24.56^{abcd}	1049.35 ± 4.53^{b}	895.56 ± 3.30^{d}
8.	Protein Intake	604.43 ± 2.60^{a}	544.49 ± 27.24^{abcd}	429.63 ± 2.29^{c}	529.37 ± 11.05^{abcd}	472.21 ± 2.04^{b}	403.00 ± 1.48^{d}
9.	Protein Efficiency Ratio	1.83 ± 0.01^{a}	1.7 ± 0.09^{ab}	1.71 ± 0.02^{ab}	1.71 ± 0.05^{ab}	1.73 ± 0.01^{ab}	1.61 ± 0.01^{b}
10.	Food Conversion Ratio	1.21 ± 0.01^{a}	1.31 ± 0.12^{ab}	1.30 ± 0.03^{ab}	1.3 ± 0.07^{ab}	1.29 ± 0.01^{a}	1.38 ± 0.01^{b}

Mean values ± Standard error with same superscript are not significantly different at 0.05 level.

SD_1-EFD = Stocking density of 100 fish/m^3 with extruded floating diet, SD_2-EFD = Stocking density of 200 fish/m^3 with extruded floating diet, SD3-EFD = Stocking density of 300 fish/m^3 with extruded floating diet, SD_1-PSD = Stocking density of 100 fish/m^3 with pelleted sinking diet, SD_2- PSD = Stocking density of 200 fish/m^3 with pelleted sinking diet, SD_3–PSD = Stocking density of 300 fish with pelleted sinking diet

4.3.11 Haematological Indices of *Clariasgariepinus* under varying stocking densities and feed forms in net cages

The haematological profiles of *Clarias gariepinus* cultured in net cages under varying stocking densities and feed forms: Pack Cell Volume, haemoglobin, red blood cell count, lymphocyte, heterophils, and heterophils: lymphocytes ratio values are presented in Tables 4.2.4.

4.3.11.1 Packed Cell Volume (PCV)

The comparison of Packed Cell Volume statistical results among different treatments revealed significant ($p<0.05$). Pack Cell Volume (PCV) at the conclusion of the study in fish fed extruded floating diet varied from 20.56±5.03% (SD_3-EFD) to 23.00±8.66 (SD_1 -EFD), while the values in fish fed pelleted sinking diet ranged from 19.00±6.08 (SD_3-PSD) to 23.00±8.66 (SD_1-EFD). The range among all the treatment groups varied from 19.00±6.08 (SD_3-PSD) to 23.00±8.66 (SD_1-EFD). The PVC in fish fed Extruded Floating Diet (EFD) and Pelleted Sinking Diet (PSD) decreased as the stocking density increased.

4.3.11.2 Haemoglobin (Hb)

Haemoglobin values in fish fed extruded floating diet varied from 6.33±2.00 gd/l (SD_3-EFD) to 9.50±2.89 gd/l (SD_1-EFD). The final concentration of Hb in fish fed pelleted floating diet ranged from 5.67±1.86gd/l (SD_3-PSD) to 9.00±1.60 gd/l(SD_1-PSD). The range among all treatment groups was 5.67±1.86 gd/l (SD_3-PSD) to 9.50±2.89 ((SD_1-EFD). Significant differences ($p<0.05$) were found in mean values among the treatments.Haemoglobinconcentration decreased as the stocking density increase in fish fed EFD as well as in those fed PSD.

4.3.11.3 Red Blood Cell (RBC) of *Clarias gariepinus* reared in net cages

There were significant variation ($p<0.05$) in mean values of Red Blood Cell counts (RBC) among the treatments. The final mean RBC ranged in the fish fed extruded floating diet from 1.87±0.77 10^6µ/l (SD_3-EFD) 2.40±1.20 10^6µ/l (SD_3-EFD) while those fed pelleted sinking diet ranged from 1.30±0.15 10^6µ/l (SD_3-PSD) PSD to 2.40±1.20 10^6µ/l (SD_1-PSD). The final RBC values among all treatment groups varied from 1.30±0.15 10^6µ/l (SD_3-PSD) to 2.40±1.20 10^6µ/l (SD_1-EFD). The RBC showed a decreasing trend as the stocking density increasedin both fish fed EFD and PSD.

Table 4.2.4: Haematological parameters of *Clarias gariepinus*reared in net cages under varying stocking densities and feed forms

Parameter	Day	SD1-EFD	SD2- EFD	SD3-EFD	SD1-PSD	SD2-PSD	SD3-PSD	Standard value (Akinrotimi *et al.*, 2012)
PCV (%)	0	30.67±0.92^{a}	30.0±1.73^{a}	30.00±1.73^{a}	31.33±0.88 ^{a}	31.33±0.88^{a}	31.33±0.68^{a}	32.64-45.74
	15	26.36±3.28^{b}	26.33±3.50^{b}	25.67±1.33^{b}	26.50±3.50^{b}	28.33±4.18^{a}	29.00±1.53^{a}	
	60	19.63±3.32^{ab}	18.00±2.50^{c}	11.83±1.25^{c}	19.00±3.51^{b}	19.50±8.01^{ab}	20.88±3.52^{a}	
	105	22.33±3.28^{b}	22.60±4.41^{b}	22.67±4.33^{b}	22.23±3.33^{b}	24.00±2.03^{a}	20.69±2.03^{c}	
	150	23.00±8.66^{a}	22.33±0.33^{b}	20.56±5.03^{d}	22.77±4.10^{b}	21.50±8.01^{c}	19.00±6.08^{d}	
Hb (g/dl)	0	9.50±0.22^{ab}	9.90±0.44^{ab}	9.90±0.44^{ab}	10.27±0.35^{a}	10.16±0.25^{a}	10.27±0.15^{a}	10.02-16.70
	15	9.33±0.88^{a}	8.00±0.58^{b}	8.00±0.58^{b}	7.67±1.53^{ab}	8.33±0.33^{b}	8.00±1.23^{b}	
	60	5.33±1.20^{d}	7.00±0.00^{a}	6.67±1.33^{b}	6.00±1.20	6.50±0.65^{b}	6.67±0.88^{a}	
	105	5.75±1.10^{c}	7.00±0.90^{a}	6.88±0.40^{ab}	5.33±1.20^{c}	7.67±1.33^{a}	6.00±0.58^{b}	
	150	9.50±2.89^{a}	6.40±1.69^{b}	6.33±2.00^{b}	9.00±1.60^{a}	6.00±4.00^{b}	5.67±1.86^{d}	
RBC ($x10^{6}$/µl)	0	3.47±0.31^{a}	3.44±0.04^{a}	3.34±0.14^{a}	3.42±0.03 ^{a}	3.32±0.03^{a}	3.33±0.05^{a}	3.05-8.64
	15	2.32±0.12^{ab}	2.90±0.30^{ab}	2.78±0.04^{ab}	2.60±0.52^{ab}	3.03±0.67^{a}	3.23±0.42^{a}	
	60	1.47±0.33^{a}	1.53±0.88^{a}	1.67±0.63^{a}	1.17±0.33^{a}	1.23±0.63^{a}	1.43±0.12^{a}	
	105	2.78±0.32^{a}	2.59±0.68^{a}	1.95±0.57^{b}	1.97±0.67^{b}	2.73±0.43^{a}	1.63±0.29^{b}	
	150	2.40±1.20^{a}	187±0.77^{b}	1.63±0.75^{c}	2.25±1.15^{a}	2.12±0.59 ^{a}	1.30±0.15^{d}	
LYM ($x10^{3}$/µl)	0	7.58±1.22^{ab}	8.43±0.62^{a}	8.43±0.62^{a}	7.98±1.50 ^{ab}	7.98±1.50^{ab}	7.98±1.5^{ab}	51.14-70.16
	15	6.07±0.75^{b}	5.16±1.27^{c}	6.53±0.63^{ab}	7.13±1.15 ^{a}	5.69±0.57^{c}	6.90±0.88^{ab}	
	60	1.99±0.12^{ab}	1.78±0.10^{ab}	1.57±0.08^{c}	1.49±0.03^{c}	4.19±2.47^{a}	2.69±2.29^{b}	
	105	4.48±2.76^{b}	1.58±0.37^{d}	1.15±0.01^{d}	5.83±2.41^{a}	1.28±0.14^{d}	3.35±2.23^{c}	
	150	5.44±2.34^{a}	5.41±3.18^{a}	4.50±2.34^{ab}	5.38±4.06^{a}	5.11±1.40^{a}	4.85±4.36^{ab}	
HET ($x10^{3}$/µl)	0	2.99±0.19^{ab}	3.16±0.30^{a}	3.80±0.30^{a}	3.18±0.02^{a}	3.20±0.02^{a}	3.17±0.02^{a}	27.64-40.14
	15	3.55±0.66^{ab}	4.19±0.98^{a}	3.60±0.25^{ab}	3.47±0.59^{ab}	3.44±0.30^{ab}	4.20±0.54^{a}	
	60	4.24±0.12^{c}	4.98±0.98^{c}	5.71±1.06^{b}	6.28±0.79^{a}	4.93±0.66^{c}	6.22±1.31^{a}	
	105	3.12±1.48^{c}	3.24±0.46^{c}	4.88±36.01^{b}	5.78±1.16^{a}	4.39±0.85^{c}	5.83±0.66^{a}	
	150	3.68±0.44^{b}	3.95±0.92^{b}	4.28±0.75^{a}	3.74±0.84^{b}	4.22±0.61^{a}	4.89±1.17^{a}	
HL ratio	0	0.45±0.20^{a}	0.33±0.15^{ab}	0.33±0.43^{ab}	0.40±0.25^{a}	0.40±0.10^{a}	0.40±0.45^{a}	
	15	0.62±0.19^{b}	0.81±0.20^{b}	1.27±0.22^{a}	0.49±0.27^{b}	0.43±0.10^{b}	1.45±0.83^{aa}	
	60	1.23±0.16^{a}	0.26±0.16^{b}	1.27±0.51^{a}	1.21±0.53^{a}	1.18±0.87^{a}	0.93±1.19^{b}	
	105	1.59±0.02^{d}	0.85±1.01^{b}	1.27±0.36^{e}	2.11±1.42^{a}	1.80±0.82^{b}	1.74±1.69^{b}	
	150	0.68±0.18^{d}	0.73±0.31^{c}	0.95±1.20^{a}	0.70±0.09^{c}	0.83±0.99^{b}	0.99±2.09^{a}	

Mean values ± Standard error with same superscript are not significantly different at 0.05 level

SD_1-EFD = Stocking density of 100 fish/m^3 with extruded floating diet, SD_2-EFD = Stocking density 200 fish/m^3 with extruded floating diet, SD_3-EFD = Stocking density of 300 fish/m^3 with extruded floating diet, SD_1-PSD = Stocking density of 100 fish/m^3 with pelleted sinking diet, SD_2 -PSD = Stocking density of 200 fish/m^3 with pelleted sinking diet, SD_3-PSD = Stocking density.

Day-0 (initial / normal value); Day-150 (final value).

Table 4.2.5: ANOVA of haematological parameters of *Clarias gariepinus* reared in netcages under varyingstocking densities and feed forms

		SS	Df	MS	F	Sig.
PCV	Between Groups	2677.122	24	111.547	2.039	.011*
	Within Groups	3829.783	70	54.711		
	Total	6506.905	94			
HB	Between Groups	349.714	24	14.571	2.297	.004*
	Within Groups	444.033	70	6.343		
	Total	793.747	94			
RBC	Between G10oups	49.616	24	2.067	2.935	.000*
	Within Groups	49.310	70	.704		
	Total	98.926	94			
LYM	Between Groups	3262925.492	24	135955.229	1.596	.068
	Within Groups	5963279.139	70	85189.702		
	Total	9226204.632	94			
HET	Between Groups	3060497.708	24	127520.738	4.910	.000*
	Within Groups	1818005.724	70	25971.510		
	Total	4878503.432	94			
HL	Between Groups	53.700	24	2.238	2.503	.002*
	Within Groups	62.565	70	.894		
	Total	116.266	94			

* Significant at 5% level (P<0.05)

4.3.11.4 Lymphocytes (LYM) of *Clarias gariepinus* reared in net cages

There were no significant variation ($p>0.05$) in mean values of lymphocytes (LYM) among the treatments. The values at the end of this study in fish fed Extruded Floating Dietand Pelleted Sinking diet ranged from 4.50±2.3410^{3}µ/l (SD_3-EFD) to 5.44±2.34 10^{3}µ/l (SD_1-EFD) and 4.85±4.36 (SD_3-PSD) to 5.38±4.06 (SD_1-PSD), respectively.Thevalues among all treatments varied from 4.50±2.34 10^{3}µ/l (SD_3-EFD) to 5.44±2.34103µ/l (SD_1-EFD). The LYM values decreased with increased in stocking density.

4.3.11.5 Heterophils (HET) of *Clarias gariepinus* reared in net cages

The statistical results of heterophils (HET) among the treatments revealed significant differences ($p<0.05$). The final HET values ranged in the fish fed extruded floating diet from 3.68±0.44 10^{3}µ/l (SD_1-EFD) to 4.28±2.75 10^{3}µ/l (SD_3-EFD) while values in fish fed pelleted sinking diet ranged from 3.74±0.8410^{3}µ/l(SD_1-PSD) to 4.89±1.17 10^{3}µ/l(SD_1-PSD). The values among all treatments varied from 3.68±0.44 10^{3}µ/l (SD_1-EFD) to 4.89±1.17 10^{6}µ/l (SD_1-PsD). The HET values revealed an increasing trend as the stocking density increased.

4.3.11.6 Heterophils: Lymphocytes ratio (H: L) of *Clarias gariepinus* reared in net cages

The heterophils: lymphpcytes (H: L) ratio statistical results among the treatments showed significant differences 9P<0.05). The H: L in the fish fed extruded floating diet ranged from 0.68.±0.18 (SD_1-EFD) to 0.95±1.20 (SD_3-EFD). The values in fish fed pelleted sinking diet ranged from 0.70±0.09 (SD_1-PSD) to 0.99±2.09 (SD_3-PSD). The values among all treatment groups varied from 0.68±0.18 (SD_1-EFD) to 0.99±2.09 (SD_3-PSD). The H: L ratio increased as the stocking density increased in both fish fed EFD and those fed

4.4.Water quality parameters of Owala Lakeduring the experimental period.

4.4.1 Dissolved oxgen (DO_2) of Owala Lake

Dissolved oxygen concentration showed no significant difference ($p>0.05$) among the sites, middle (cage site) and two non-cage/reference sites at the upper and lower parts of the cagesduring the study period.The highest mean DO value of 7.03±0.74 mg/lwas obtained in upper non-cage site, while the lowest mean value of 6.93±o.73 mg/l was recorded in middle cage site and lower non-cage site. Dissolved oxygen value ranged between 5.98 and 7.54 mg/l throughout the study period (Table 4.2.6).

4.4.2 Water temperature of Owala Lake

Water temperature ranged between 26.47 ^{o}C and 31.10 ^{O}C throughout the study period with the highest mean temperature value (28.32±1.65 ^{o}C) recorded in cage site, while the lowest value (28.22±1.55 ^{o}C) in lower non-cage site. No significant variation ($p>0.05$) was noticed among the sites during the study period.

4.4.3 Hydrogen ion concentration (pH) of Owala Lake

Hydrogen ion concentration ranged between 6.95 and 7.06 throuhgout the studu period. The highest mean pH value of 7.68±0.64 was observed in lower non-cage site, while the mean lowest value of 7.43±0.68 was recorded in lower non- cage site.

4.4.4 Secchi disc transparency

Secchi disc Transparency varied between 1.10 m to 1.32 m throughout the study period with the maximum mean transparency value of 1.22±0.22 m obtained in lower reference site and minimum mean value of 1.20±0.05 m was recorded in upper non-cage site.No significant variation was seen among the sites the study period.

4.4.5 Nitrite (NO_2) concentration of Owala Lake

Nitrite concentration among the sites revealed no significant difference ($p>0.05$).The highest mean NO_2value (0.24±0.04 mg/l was recorded in cage site, while the lowest value (0.20±0.04 mg/l was obtained in lower non-cage site.Nitrite concentration ranged between 0.19 and0.25 mg/l during the study period.

4.4.6 Ammonia (NH_3) concentration of Owala Lak e

Ammonia concentration ranged between 0.22 to 0.25 mg/l throughout the study period. The mean maximum NH_3 concentration value of 0.24±0.14 mg/l was obtained in cage site and lower non-cage site. No significant variation ($p>0.05$) was noticed among the sites during the study period.

Table 4.2.6:Physico-chemical parameters of Owala Lake at Three monitored Zones during the experimental period

Parameters	Upper point (non- cage site)	Middle (cage site)	Lower point (non- cage site)	Mean ±SE	RangeOptimum level (Boyd, 1998)	
Dissolvedoxygen (mg/l)	7.03 ± 0.74^{a}	6.93 ± 0.73^{a}	6.93 ± 0.73^{a}	6.97 ± 0.59	5.98−7.54	5 -10
Temperature (^{O}C)	28.24 $\pm 1.57^{a}$	28.32 ± 1.65^{a}	28.22 ± 1.55^{a}	28.29 ± 1.59	26.47−31.10	25-32
Ph	7.43 ± 0.63^{a}	7.48 ± 0.63^{a}	7.68 ± 0.64^{a}	7.53 ± 0.63	5.95−7.06	6.5-8.5
Transparency (m)	1.20 ± 0.56^{a}	1.21 ± 0.56^{a}	1.22 ± 0.22^{a}	1.21 ± 0.56	1.10−1.32	0.3-0.4
Nitrite (mg/l)	0.20 ± 0.05^{a}	0.24 ± 0.04^{a}	0.22 ± 0.05^{a}	0.22 ± 0.05	0.19−0.25	0-0.5
Ammonia (mg/l)	0.21 ± 0.03^{a}	0.24 ± 0.04^{a}	0.24 ± 0.04^{a}	0.23 ± 0.04	0.22−0.25	0-1.0

Mean values with same superscript are not significantly different at 5% level ($p>0.05$)

4.5 Economic analysis of *Clarias gariepinus* under varying stocking densities and feed forms in net cages

Table 4.2.7 and 4.2.8 present the composition of the fixed costs and cost and return of *Clarias gariepinus* cultured in net-cages for 150 days at varying stocking densities and two feed forms.

The principal constituents of variable costs were feed and *Clarias gariepinus* juveniles. Highest and least feed costs as percentage variable cost ranged from82.52±0.08%(SD_1-EFD) to 84.17±0.01% (SD_2-EFD) in fish fed extruded floating (EFD)and stocked at density 100 fish/m^3 (SD_1) and 200 fish/m^3 (SD_2), respectively. While in fish fed pelleted sinking diet (PSD) varied from 76.77±0.12% (SD_1-PSD)to 78.1±0.05% (SD_3-PSD)in those stocked at density 300 fish/m^3 fed pelleted sinking diets (PSD). Highest total costs of feed were ₦94,532.39±436.04; ₦66,472.50±212.13 recordedin SD_3-EFD and SD3-PSD and least ₦29,052.5o±228.04; ₦44,4o2.89±367.69 were recorded in SD_1.EFD and SD_1- PSD, respectively. *Clarias gariepinus* juveniles, the second major component of the variable cost as percentage variable costranged from 7.43±0.07%SD_1-EFD to 10.50±0.04%SD_3-EFDand 10.57±0.07% SD_1-PSD to 14.10±0.04% SD_3-PSD for fish fed with EFD and PSD, respectively.

The total cost of production for fish fed extruded floating diet ranged from ₦56,249.48±144.90 (SD_1-EFD) to ₦116,704.16±983.91 SD_3-EFD, while those fed pelleted sinking diet ranged from ₦40,285.07±1279.08 (SD_1-PSD)to ₦87,521.28±1070.63(SD_3-PSD). Comparatively among the treatments, the least (₦40,285.07±1279.08and highest (₦116,704.16±983.91) were recorded inSD_1-PSDand SD_3-EFD,respectively.

The production cost per kilogramme of fish ranged from₦480.60±6.89 (SD_1-EFD), to₦494.70±8.03(SD_2-EFD) in fish fed EFD and ₦390±4.21 (SD_2-PSD), to ₦418.23±7.66 (SD_1-PSD), in those fed PSD. Comparatively among the treatments, the highest (₦494.70±8.03)and least (₦390. 05±4.21) production cost per kilogramme of fishwere obtainedin SD_2-EFD and SD_2-PSD, respectively.

The NR increased significantly from ₦13,974.50±697.86 (SD_1−EFD) to ₦20,653.02±308.30 (SD_2−EFD) in fish fed extruded floating diet, while in fish fed sinking pelleted diet NR varied from ₦17,512.93±216.47 to ₦29,848.10±190.28 in SD_1-PSD and SD_3-PSD, respectively. Significantly least 1.13±0.02 and highest 1.25±0.03 BCR were recorded in fish cultured under

SD_3-EFD and SD_1−EFD while the BCR rose significantly from 1.34±0.02 to 1.43±0.02 in fish cultured under SD3-PSD and SD_1−PSD, respectively.

The net income per kilogramme in fish fed EFD ranged from ₦ 61.53±1.77 (SD_3-EFD) to ₦ 119.40±2.58 (SD_1-EFD), respectively, while those fed PSD ranged from ₦ 139.87±1.96 (SD_3-PSD)to ₦181.77±5.11(SD_1-PSD), respectively. Comparatively, the highest net income per kilogramme of fish(₦181.77±5.11) among the treatmentswas recorded in SD_1-PSD,100 fish/m^3 and fed pelleted sinking diet and the least ₦61.53±1.77 was obtained in fish stocked at 100 fish/m^3 and fed extruded floating diet (SD_1-EFD).

The Benefit Cost Ratio (BCR) in fish fed extruded floating diet ranged from 1.13±0.00 (SD_3 – EFD) to 1.25±0.01 (SD_1 –EFD). While those fed with pelleted sinking diet ranged from1.34 (SD_3 –PSD) to1.43±0.00 (SD_1 –PSD).The highestBCR (1.43±0.01) was recorded in SD_1 –PSD, while the least1.13 was obtained in (SD_3 −EFD).

Table 4.2.7: Composition and depreciation valuesof fixed cost of net cage culture of *Clarias gariepinus* under varying stocking densities and feed forms

Item	Total cost (18 cages)	Quantity per cage	Unit cost per cage	Use life (year)	Depreciation
	(₦)		(₦)	(Year)	(₦)
Wooden boat	30000,00	1.00	1.666.07	5	333.33
Cage:					
Plastic drum	43200.00	2.00	1200.00	10	240.00
Net (polyamide)	90000.00	0.056 bundle	5000.00	5	1000.00
Nylon mosquito net	2400.00	0.08 bundle	133.33	1	133.33
Bamboo	5760.00	4 pieces	80.00	1	320.00
Nylon rope (10mm)	7873.92	16m	27.34	2	218.72
Nylon twine	3750.00	0.167 bundle	208.32	3	69.44
Anchor	9600.00	4 per battery of 3 cages	400.00	15	35.00
Interest on fixed cost (4%)					133.99
Total fixed cost					2443.81

*Interest rate on loan from cooperatives attracts 4%

Table 4.2.8: Cost and return analysis of *C. gariepinus* reared at three stocking densities and two feed forms in net cage for150days

Parameters	Unit cost (₦)	SD_1- EFD	SD_2-EFD	SD_3-EFD	SD1-PSD	SD_2-PSD	SD_3-PSD
Total harvest per cage (kg)		117.04±1.18^{e}	196.14 ± 1.05^{c}	238.92 ± 1.14^{a}	96.33 ± 1.96^{f}	175.30 ±1.20^{d}	213.40 ± 1.66^{ab}
Price per kg of fish	600/550	600.00	600.00	550.00	600.00	550.00	550.00
Revenue per cage		70,224.00±710.64^{d}	117,684.00± 632.15^{b}	131,406.00± 511.24^{a}	57,798.00± 1175.21^{e}	96,415 ± 539.82^{c}	117,370.00±746.23^{b}
Variable cost							
Juvenile fish	40	4,000.00^{c}	8,000.00^{b}	12,000.000^{a}	4,000.00^{c}	8,000.00^{b}	12,000.00^{a}
Feedcost/kg :Floating	333.33	44,402.89± 367.69^{e}	79,615.87± 83.80^{b}	94,532.39 ± 436.04^{a}	29,052.50 ± 228.04^{f}	52,062.50 ± 291.68^{d}	66,472.50 ± 212.13^{c}
Sinking	250						
Labour (month)	₦12,000	3,333.33	3,333.33	3,333.33	3,333.33	3,333.33	3,333.33
Interest on operational capital (4%)		2,069.45 ±217.13^{e}	3,637.97 ± 3.35^{b}	4,394.63 ± 17.44^{a}	1,455.43 ± 9.12^{f}	2,535.83 ± 237.16^{d}	3,272.26 ± 8.45^{c}
Total variable cost		53,805.67± 312.23^{e}	94,587.17± 87.15^{b}	114,260.35 ± 453.49^{a}	37,841.26± 237.16^{f}	65,931.66 ± 303.47^{d}	85,078.09 ± 220.58^{c}
Feed as % Total Cost		78.94 ± 0.08^{b}	82.05 ± 0.01^{a}	81.00 ± 0.05^{a}	72.12 ± 0.12^{d}	76.14 ± 0.08^{c}	75.95 ± 0.05^{c}

Juvenile fish as % Total Cost		7.11 ± 0.07^{f}	8.24 ± 0.01^{e}	10.28 ± 0.04^{c}	9.93 ± 0.07^{d}	11.70 ± 0.41^{b}	13.71 ± 0.04^{a}
Parameters	**Unit cost (₦)**	**SD_1- EFD**	**SD_2-EFD**	**SD_3-EFD**	**SD1-PSD**	**SD_2-PSD**	**SD_3-PSD**
Fixed cost (Depreciation/year)							
Wooden boat and cage		2,349.82	2,349.82	2,344.82	2,344.82	2,344.82	2,344.82
Interest on fixed cost (4%)		93.99	93.99	93.99	93.99	93.99	93.99
TotalFixed cost		2,443.81	2,443.81	2,443.81	2,443.81	2,443.81	2,443.81
Total cost (TC)		$56,249.48 \pm 144.90^{e}$	$97,030.98 \pm 559.90^{b}$	$116,704.16 \pm 983.91^{a}$	$40,285.07 \pm 1279.08^{f}$	$68,375.47 \pm 623.29^{d}$	$87,521.28 \pm 1070.63^{c}$
Gross Revenue		$16,418.33 \pm 689.29^{f}$	$23,096.83 \pm 715.95^{d}$	$117,883.51 \pm 453.49^{a}$	$19,956.74 \pm 230.94^{e}$	$30,483.34 \pm 671.83^{c}$	$32,291.94 \pm 693.35^{b}$
Net revenue		$13,974.52 \pm 697.86^{f}$	$20,653.02 \pm 308.30^{c}$	$14,701.84 \pm 229.00^{e}$	$17,512.93 \pm 216.47^{d}$	$28,039.53 \pm 48.06^{b}$	$29,848.10 \pm 190.28^{a}$
Production cost/kg of fish		480.60 ± 6.89^{c}	494.70 ± 8.03^{a}	488.47 ± 5.32^{b}	418.23 ± 7.66^{d}	390.05 ± 4.21^{f}	410.13 ± 8.29^{e}
Net revenue/kg of fish		119.40 ± 2.58^{d}	105.30 ± 5.87^{e}	61.53 ± 1.77^{f}	181.77 ± 5.11^{a}	159.95 ± 2.21^{b}	139.87 ± 1.96^{c}
Benefit cost ratio (BCR)		1.25 ± 0.03^{d}	1.21 ± 0.01^{e}	1.13 ± 0.02^{f}	1.43 ± 0.02^{a}	1.41 ± 0.02^{b}	1.34 ± 0.02^{c}

Table 4.2.8 Continued

Note:$ = ₦361 (2015 exchange rate).

Mean values with same superscript are not significantly different at 5% level ($p>0.05$)

SD_1-EFD = Stocking density of 100 fish/m^3 with extruded floating diet, SD_2-EFD = Stocking density of 200 fish/m^3 with extruded floating diet, SD_3-EFD = Stocking density of 300 fish/m^3 with extruded floating diet, SD_1-PSD = Stocking density of 100 fish/m^3 with pelleted sinking diet, SD_2 -PSD = Stocking density of 200 fish/m^3 with pelleted sinking diet, SD_3-PSD = Stocking density of 300 fish

CHAPTER FIVE

Discussion

5.1Preliminary field survey

The present survey has provided knowledge on socio-economic characteristics of net cage aquaculturists, the current management and cultural operations particularly stocking density and feed types employed, and constraints of floating net cage in southwest Nigeria specifically Lagos, Ogun and Osun States.

Age is avital factor in an agricultural enterprise. It establishes farmer productive capability and accordingly his production (Makinde *et al.,*2015). From this present study, socio-economic characteristic of floating net-cage farmers revealed that majority of fish farmers (53.33%) were 31-40years with mean age of 43.75 years. This indicates that majority of the cage culture farmers were comparatively young and in their active and productive age. This was in agreement with Ande, (2008)who ranked persons between this age group as the working population of a nation. Furthermore, the young farmers were dynamic, innovative and very courageous to have investments (Syandri *et al*., 2015). This postulation was also in consonant with Silviyanun, (2013) in hisstudy on net cage aquaculture in Lake Laut Air Tawar, Indonesia where it was reported that the age bracket of 35-41 years was the most productive for farmers. In Nigeria, Aihonsu and Olatingiri (2012) and Fregene *et al.,* (2011) also asserted that fish farmers in such age bracket were in their supreme age and thus, economically enterprising.

In theperspective of gender, all the farmers were males. This result concur with Vidzro, (2014) who reported that cage culture farmers in Lake Volta, Ghana were males. Syandri, *et al.,* (2015)also reported that most (89.0%) of the cage culture farmers in Indonesia were males. According to the postulation of Brummett *et al*, (2010), fisheries ventures are exclusivelydonminated by males. This is also in conformity with the reports of Fregene *et al.*, (2011), Omitoyin and Fregene, (2012), Adebayo and Daramola, (2013), Thompson and Mafimisebi (2014), Tunde *et al.,* (2015) and Olaoye *et al.,* (2016), who observed similar trends from their studies in the same part of the country. According to Tumusiime, (2014), and Makinde *et al.,* (2015), the dominance of males in cage fish farming could further be supported due to the fact that women in the study locality as well as in other African nations usually play a preponderant role in fisheries sub-sector of agriculture particularly in post-harvest handlings,

processing, marketing and distribution.However,in Asia, especially in giant aquaculture nations like Cambodia, China, Thailand, Vietnam *etc*., women usually carry the unique responsibility of fish culture production (Silver, 2011, and Satapornvanit *et al.*, 2015). With regards to marital status, almost all (86.67%) of the net-cage fish farmers were married. This is in consonant with Olaleye *et al.,* (2016) who reported that 93.33% (84 out of 90 farmers) engaging in aquaculture in Lagos were married. This is also in accordance with the findings of Baruwa *et al.*, (2012) and Tunde *et al.*, (2015) who revealed 94.7% and 76% fish farmers to be married in Lagos State and in Saki Local Government Area of Oyo states respectively. It implies that majority of the cage culture farmers have advantage of cheap labour supply by involving their wives in the enterprise especially in feeding and marketing.

In educational attainment, majority(50.00%) of the cage culture farmers in the study areaswere University or other tertiary graduates. This implied that majority of the cage culture fish farmers in the study localities were educated who can undoubtedly embrace new techniques such as cage aquaculture. This in agreement with the findings of Syandri *et al.,* (2015), who analysed socio status of net cages aquaculurists in Lake Maninjau, Indonesia and Pontoh, (2012) in his analysis of cage culture enterprise in Tandengan village Minahasa Regency, North Sulawesi.Contrarily, Gupta and Haque, (2012) reported that only 1.3% of the house hold heads engaging in cage culture fingerlings production in Adivasi, north-east and north-west of Bangladesh had tertiary education.

Experience plays a prominent role in fish farming *(*Abiona *et al.,* 2011 and Makinde *et al.,* 2015). The number of years in cage culture operation often determine how the farmer will organize his resources so as to achieve a good level of production. Williams *et al.,* (2012) submitted that capacity to operate fish pond effectively relies on years of experience and this is directly correlated to the total production of the farm. The cage culture farmers had different years of experience in cage culture farming. However, majority of them (80.00%) had experience of 5-8 years in the practice ofnetcage culture. Thus, most of the farmers were discovered to be very young in cage culture enterprise. This implied that the enterprise is relatively new in the study locality.

The results of the study indicated that majority (46.67%) of the respondents were civil servants. Based on this result, it was revealed that all the respondents were engaged in other occupation

aside from cage culture enterprise. This implied that respondents had varied income sources and consequently, were facilitated to handle the hazard associated with fish cage culture business. Furthermore, the reason may be because the civil service rules and regulations in Nigeria encourage the participation of civil servants in farming business, after the close of work (Nairaland Forum, (2016). The dominance of civil servants in cage culture business may also be attributed to preparation for retirement engagement that would make them to be financially secured.

The result of working capital showed that personal and family savings was represented by 86.67%, cooperatives (13.33%) and no farmer obtained bank loan. This result was in agreement with Akarue and Aregbor, (2015) findings in their study on socio-economic analysis of catfish farming in Delta State, Nigeria. This might be due to high interest rates,excessive bureaucracy, payback period coupled with late release of fund from the institutional source thereby making loan very difficult to access (Adegbite and Adeleye, 2011; Ugbajah, 2014; Fili*et al.,*2015).

With regards to membership of fish farmers' association and cooperative society, 73.33% of the respondents were involved in cooperative society to execute their production activities like improvement of cage culture operations, purchase of inputs like fingerlings or juvenile fish, feeds and other basic needs. Further more, cooperative enables the farmers to access more fund with very low interest rate for fish production on commercial scale (Dzadze *et al.,* 2012).

Cage culture management require less manpower because daily routine and monitoring relatively minimal and simple (Das *et al*.,2009). The results of this survey revealed that less manpower, a manager or caretaker and 1-2 hired workers wereoften involved in cage culture operation.
Majority (93.33%)of the farmersoperating small scale size floating net cage farms (1−6 cages) of 4×2metres on the sides and 2meters deep while (6.67%). This is contrary to what operates in Rwanda tilapia net cage farms where farmers were reported to operate medium and large scale size net cage farms ranging between 10−50 cages of 2m×2metres on the sides and 2metres deep, for a volume of ($8.0m^3$) (Kampayana *et al*., 2016).

It was also shown from this study that, the small-scale cage operator stock *Clarias gariepinus* juvenile ranged from 25-35g weight in their cages. For a successful cage culture, fish weighing at least 15g is the recommended weight for farmers to maximize their growing season, and increase returns (Beveridge, 2004).

The study also indicated that majority of the cage culture operators stocked their cages at densities ranging from 100−150 fish /$m^{3.}$

Lack of good quality aquafeed at affordable prices was identified as one of the important bottlenecks confronting fish culture development and outputin the survey localities inNigeria. This result is in agreement with Blow and Leonards, (2007), Asase, (2013), FAO, (2015) and Karikari, 2016. The utilisation of aquafeeds will persistent to perform a crucial part in fish culture development and production (The Fish Site, 2007). Without high quality feed at affordable cost there will be poor growth and low economic returns.

All the respondents purchased the juvenile *C. gariepinus* from reputable hatchery close to their farms. The majority of them claimed to encounter difficulty with the availability of juvenile fish for stocking their cages. This result is in agreement with Halwart and Moehl, (2006) who recognizes inadequate supply of fingerlings as a major constraint for cage culture in Africa. This result also corroborates Atanda, (2007) that in Nigeria, the desired number and quality fish seeds (fingerlings/ juveniles) have not always been obtainable.

Although all the respondents had formal education ranging from primary to university or tertiary level, yet majority of them lacked the knowledge and skills of cage culture operations. These problems were also identified to be facing cage aquaculturistsin Ghana (Rurangwa *et al.,* 2015 and Karikari, *et al.,* 2016), Malaysia (Islam *et al.,* 2016) and Rwanda (Kampayana *et al.,* (2016).The level of knowledge and skills possessed by the net cage fish farmers would determine the level of their productivity. Hormiga *et al*., (2011)discovered in their studies that the probability of anenterprise to prosper is determined by the entrepreneur's degree of technical proficiency. Also according to Anaglo *et al.,* (2014), higher technical know-how of entrpreneurs results in good customer satisfaction, higher profits and ultimately high growth.The reasons for these problems could be attributed to lack or inadequate information dissemination via extension, trainings and worhshops to cage culture farmers including their managers (Islam *et al*., 2016).

Fish poaching was reported to be one of the challenges that net cage operators faced in the study area. Similar constraint was reported by a number of authors. Notable among them are:Halwart and Moehl, and Kampanaya, (2016). However, the employment of security persons could remedy this challenge. This suggestion is in agreement with Beverage (2004) who opined that

security is afactor that each and every cage culture farmers must contemplate and plan for. Cages must also be sited where access can be controlled and risks minimized.

The results of economic analysis of cage culture in the study areas revealed that the mean total cost of producing a kilogram of fish was ₦424.00, while the mean total revenue per kilogram of fish cultured was ₦76.00. This gives a gross margin of ₦81.28 per kilogram of fish. The result implied that variable cost is very high (98.75%) while fixed cost is very low (7.29%) hence the gross margin is also low. The Benefit Cost Ratio (BCR) value of 1.20 obtained from this survey study fuether indicate that cage culture is a viable and profitable enterprise. According to Olagunju et al. (2007), as a general guidline, project with BCR Higher than one, precisely one or below one portend financial gain, break-even or economic loss, respectively. Owing to the fact that the ratio in the results is greater than one, it implies that cage culture enterpriseis viable and profitable.

5.2 Effect of stocking density and diet on growth performance, feed utilization and survival of *Clarias gariepinus* reared in net cages under varying stocking densities and feed forms

Growth performance parameters like mean weight gain, mean length gain, specific growth rate and survival rate arevital concerns for a successful cage culture since they influence the output and economic returns of the system.

5.2.1 Mean weight gain, length gain and specific growth rate of *Clarias gariepinus* reared in net cages

The findings from this study clearly showed that the main effects of stocking density and diet, as well as their interaction are significant on the growth performance like weighr gain, length gain, and of specific growth rate of *Clarias gariepinus* reared in floating cages.

These growth parameters have very strong and significant positive bivariate correlation. This resultalso depicts anegative relationship between stocking density and growth variables likemean weight gain, mean length gain and specific growth rate in fish fed extruded floating and pelleted sinking diets. This is similar to the results ofRahman *et al.,* (2017) for Stinging catfish, *Heteropneustes fossilis* in net cages. Dasuki*et al*., (2013); Hengswat and Jaruratjamorn, (1997), for *C. gariepinus*reared in net cages.Similar findings were also reported by Abou- Zeid, (2015)and Toko *et al.,* (2007) for *Clarias gariepinus* culturedin earthen ponds. Many authors

also reported same findings for other fish species. Notably, Asase, (2013);Chakraborty and Banerjee, (2010), for Chichlidae, *Oreochromis niloticus* reared in net cages in floating net cages. Contrarily, non impacts of excessive stocking densities on the growth rate were published by Mckenzie *et al.,*(*2012*) for Rainbow trout, *Oncorhyncus mykiss*;Jiwyam, (2011) for Asian river catfish, *Pangasius bocourti* reared in net cages;Björnrros and Ôlafsdótti, (2006) for juvenile cod,*Ghadu morhua*.The poor growth of African catfish,*Clarias gariepinus* recorded at higher densities in this study can be attributed to over-crowding conditions resulting in restricted living spaces, deficient surface area for feeding which may induce severe competition forfood and nutritional shortfalls, increased energy consumption, escalated stress as well as retarded growth performanceas published by (Chakraborty and Banerjee, 2010; Rowland *et al.,* (2006)and Ellis *et al*., 2002.

The present findings are alsoin consonant with Ofonime and David (2017) andEkanem *et al*., (2012) who revealed fron their reports that *C. gariepinus* fed floating pellets had higher growth performance than those fed sinking pellets. However, the results disagree withAjani*et al.,*(2011);Olanipekun (2014) andLimbus, (2015) who observed greater growth performancefor *Clarias gariepinus* fed pelletedsinking diets than those fed extrudedfloating diets.

The better growth performance of *C. gariepinus* recorded in this study with extruded floating diet can be ascribed to the character or form of feeds. Extruded floating pellet has very strong aqua stability that can make itfloat and not disintegrated for very long time thereby making it available for fish to consume for growth and health. Hence the need for the method of feeding used in this study, whereby the floating diet was administered at once into the surface of the floating cage equipped with fine meshed nylon net enclosure to prevent drifting out of feedby water current or fish struggling for feed. Sinking diet was poured at once down a 4 inch (10.16mm) PVC pipe to the net bottom screened with fine meshed nylon tray-like enclosure. This is novel to reduce feed wastage.

5.2.2 Survival rateof *Clarias gariepinus* reared in net cages

The survival rate of *C. gariepinus* in this present study was generally very high (98.83 – 99.33%) with no significant difference between the diets and densities.It has the weakest correlationwith other growth and feed utilization parameters considered in this study with correlation coefficients ranging from $r=0.007(p>0.05)$ with protein efficiency ratio and $r=0.228(p>0.05)$ with feed intake

and protein intake.Survival rate does not have a significant correlation with any of the other parameters. This implies that survival rate of fish in this study is not diet or density dependent. High survival rate recorded in this study is in agreement withthose of Jiwyam, (2011) and Dasuki, *et al.,* (2013) forcatfish reared in floating net cages. Theresultsare also in consonant with Toko *et al.* (2007)for earthen ponds but disagree with Yi, *et al.,* (1996) and Rahman, (2006). Futhermore, the present result corroborates Limbu, (2015) andAfia *et al.,* (2017) on the effect of floating and sinking diets on survival rates of*C. gariepinus* reared inponds and tarpaulin tanks, respectively.

The probable reason for high survival rates recorded in this study could be ascribled to stocking advanced juvenile fish (70.00±0.03g) According to Huguenin, (1997), stocking larger and old fingerlings reduce fish mortality rates.

5.2.3 Production index (PI)of *Clarias gariepinus* reared in net cages

The production index values in this study were significant among the treatments. The values decreased with increasing stocking density. The highest value of PI was recorded in the lowest density and the least value recorded in the highest density. The results concur with Ajani *et al*., (2015) and Nwipie, *et al.,*(2015) who reported PI values ranged from 1.42±0.15 to 2.80±1.13 and 0.330±0.01 to 0.717±0.06, respectively.

5.2.4 Condition factor (K) of *Clarias gariepinus* reared in net cages

Main effect of the treatments are significant on the mean condition factor (K) of *C. gariepinus* in this study, while the interaction between stocking density and diet was not significant.The resultsof K greater than 1.0 or very close to one and inversely related to increase in densityare in consonant withresults of Datta,(2013)who reportedK values ranged from 1.344 to 1.595 for catfish*Pangasius pangasius,* in net cages. Nwipie *et al.,* (2015) alsoreported similar findings in *C. gariepinus* reared inrectangular plastic tanks.The K values obtained in this study indicate that the fish under culture were in normal or good condition. According to Jorgensen, (2017), condition factor of 1.0 indicates a normal fish condition and that condition factor in a robust or fat fish will be higher like 1.2 or 1.5 and above for a cannon ball, while a stunted or skinny fish will be below 1.0. As the condition factor in this present study is normal for good health of fish showed that the experimental diets, commercial extruded floating and sinking diets were nutritionally complete and digested well for good growth and sound health.

5.2.5Feed intakeof *Clarias gariepinus* reared in net cages

The results of feed intake (FI)inthis study revealed that feed intake of*Clarias gariepinus*isinfluenced by diets. The FI intake valuesincreaseas the stocking density increases for floating and sinkingdiets. The impactof stocking density and diet are significant on the mean feed intake of fish while the interaction between diet and density were not significant. This indicates that there was a contrast in the mean FIbetween the two tested diets for each stocking density. However, FI values were obtained in fish fed floating diet than those fed sinking diet.The present results are in conformity with Abou-Zied, (2015), who published similar findings in his studies on *C. gariepinus* reared in ponds. Feed intake has very strong and significant positive correlation with other growth and feed utilization parameters considered in this study.Accessibility of space and minimized competition for food perhaps inffluencedbetter feed intake with lower stocking density than with higher densities recorded in this present study. According to Craig and Helfrich, (2002),feed intake is also influenced by feed types and sizes. Extruded floating feed is buoyant and does not easily crumble on water thereby making it easily accessible to fish for consumption. In contrast, pelleted sinking feed is rarely buoyant and easily crumle, as a consequence it is not easily accessible to fish for consumption (Eriegha *et al*., 2017; Ajani *et al*., 2011).

5.2.6 Protein intakeof *Clarias gariepinus* reared in net cages

The results of protein intake in this study showed that protein intake of experimental fish is densityand diet dependent. Protein intake decreased as the stocking density increased. However, higher protein intake was obtained for fish fed floatingthan those fed sinking diet. The results are in agreement with Ajani *et al.,* (2015);Oguguah *et al.,* (2011) and Narejo *et al.,* (2005) who reported that floating pellets had better protein intake than sinking pellets in their studies.The probable reasons for higher protein intake in fish stocked at lower stocking density than those stocked at higher densityemanating from this current study could beattributed to adequate space for movement, enoughwater surface area for feeding resulting in less competition for food coupled with reduce density induced stress.

5.2.7 Protein efficiency ratioof *Clarias gariepinus* reared in net cages

The results of protein efficiency ratio (PER)in this study were not significant; that is, main effect of diet and stocking density as well as interaction between stocking density and diet types were not significant. This parameter also has very strong and positive significant correlation coefficients with growth variables like weight gain and specific growth rate; and feed utilization parameters such as protein intake, feed intake and feed conversion ratio considered in this study.Hence, PER is not density or diet dependent. The value for fish fed extruded floating diet ranged from 1.70±0.09-1.83±0.01 and those fed with sinking diet ranged from 1.61±0.01-1.73±0.02. Lower but better values were recorded in lower densities 100 fish/m^3(SD_1) and 200fish/m^3(SD_2) in fishfed extruded floating(EFD) and pelleted sinking diets (PSD), respectively.The results of this study are consistent with some density trials of *Anguilla marmorata* (Tan *et al.,* 2018) and*Oreochromis niloticus* (Osofero *et al*.,2009).

5.2.8 Feed conversion ratioof *Clarias gariepinus* reared in net cages

This result shows that excessive stocking density reduce efficiency to convert given feed to flesh when compared with the fishstocked with low density(Akinwole *etal.,* 2014 and Abou *et al*., 2007). Thisresultagrees with some density trials of *Clarias gariepinus*(Abou-Zied, 2015 and Nwipie *et al*., 2015).Similar results for other species includeTan *et al*., (2018) in *Anguilla marmorata* in a Recirculating Aquaculture System, Vaishnar *et al*., (2017) in *Pangasius* speciescultured in floating net cages, Costa *et al.,* (2017) in Nile tilapia cultured in cages and Oliveira *etal.,* (2013) in juvenile of Pirarulu, *Arapaima gigas* in cages. However, the result of this study is lower and better than that of Sulieman and Solomon, (2017) with FCR values ranged from 2.57±0.23 to 4.68±0.13 and Dasuki, (2013) with values varied from 3.43 to 4.99 for*Clarias gariepinus* reared in cages at varying densities.

The FCR from this present study could be considered good. According to Craig and Helfrich, (2009), a good FCR of 1.5 to 2.0 are considered good for most fish species in grow-out operations.The adducible reasons for low and better FCR values of less than 2.0 but greater than 1.0 recorded in this present study may perhaps ascribed to good quality and quantity of commercial floating and sinking pellets (45% crude protein) of the same manufacturer (Durante) utilized to feed the fish at 3% body weight twice daily at two equal portion.Regular and consistent feeding pattern throughout the period of study also affected the fish positively with better FCR. Furthermore, the suitable water quality produced outstanding FCR in this study.

According to Eniola, (2016),water quality has significant influence on feed compassion performance of catfish and satisfactory water quality enhances excellent feed conversion efficience in intensive catfish aquaculture

5.3.Haematologiacal profilesof *Clarias gariepinus* reared in net cages under varying stocking densities and feed forms

Haematological assessments of fish is aquick tools for diagnosing welfare or health status index of various fish species as it provides a reliable evaluation via non-lither means (Satheshkumar *etal.* (2012) and Fazio *et al.* (2016).

In this study, the level of some haematological parameters of*Clarias gariepinus* were effected by densitiesand feed forms. The haemocrit (PVC), haemoglobin (Hb) and red blood cell (RBC) levels significantly varied between the treatments. The initial values for RBC and Hb fell within the standard or reference values reported by Akinrotimi *et al*. (2012) while PCV and Hb values obtained were the same or very close to the standard values. The values for these parameters reduced with increasing stocking density in fish fed extruded floating diet as well as those fed with pelleted sinking diet. This is in accordance with the results of Ayoade*et al.,* (2014) and Dai *et al*., (2017) in their related studies for *Clarias gariepinus*. Docan *et al*., (2011); Charoo *et al.,* (2014) and Naderi *et al*., (2017)reported similar findingsin their various studies on influence of density on haematological profiles of salmon (*Salmogardneri*)*, Oncorhycus mykiss* andgreat sturgeon (*Huso huso*) juveniles, respectively.In contrast, a number of authors reported increased values of haematological parameters of fish as the stress factors increased (Monterio *et al*., (1999)andAjani *et al*. (2015)in their similar studies employing fish such as, gilthead seabream (*Sparus aurata*) and juvenile *Clarias gariepinus.*

The reduction in PCV, Hb and RBCas the stocking density increased in this study may be attributed to increased breakdown of Red Blood Cells (haemolysis) caused by haemodilution as the stocking density increased resulting in anemia (Ayoade, *et al*., 2014). Furthermore, reduction

in PCV with increased stocking density indicated poor transportation of oxygenand absorbed nutrients which consequently have resulted in in a reduced status of fish condition. In this present study, PCV ranged from 19.00±6.08% (SD_3-PSD) in fish stocked at 300 fish/m^3fed with pelleted sinking dietto 23.00±8-66% (SD_1-EFD) in fish stocked at 100 fish/m^3fed with extruded floating diet.These values fell within an accepted range of 20 % to 45 % in fish species without an established ideal PCV (Hrubec, *et al*., 2000). Hence, it implied that fish in each of the treatment groups in this study were in good health (Tonya*et al*., 2008).

Physiological stress induced by stocking densityis also reflected in the haematological parameters such as leucocytes differential such as lymphocytes, heterophils and heterophil and lymphocyte ratio (H:L). In this study, fish stocked at lower density presented a significant higher level of lymphocyte values than those held at higher stocking density while heterophils increased as the density increased. The H:L ratio presented the same trend as heterophil increased in values as stocking density increased.Increase in H: L ratos are observed in response to stressors as reported by Davis *et al*. (2008). The increase in H:L ratio might be due to the release of cortisol that produce an immunosuppressive effect in fish (Palikova *et al*., 2010 and Roques *et al.,* 2012) thereby reducing circulating lymphocytes and increasing circulating heterophils (Pickering, 1984). The implications of H:L increase with increase in density stress are reduction in welfare coupled with high vulnerability of fish to disease (Houghton and Matthews, 1990; Ballarin et al., 2004).

5.4 Water quality parameters of Owala lake Southwest Nigeria

The results of water quality variables in this study indicated that physical and chemical variables likedissolved oxygen (5.98-7.54 mg/l), temperature (26.47-31.10 ^oC), pH (6.95-7.06),ammonia (0.22-0.25 mg/l), transparency (1.10-1.32 m),and nitrites (0.19-0.25 mg/l)across the three monitored sites, experimental cage site, and the two non-cage or reference siteswere within satisfactory ranges for catfish aquaculture (Adakole, 2000; Boyd, 1998).Body, (1998), recommended for fish culture optimum temperature range of 25-32 ^oC, dissolved oxygen (5-10 mg/l), pH (6.6-8.5), ammonia (0-1.0 mg/l), nitrite (0-0.5 mg/l) and transparenct (0.3-0.4 m). These water parameters were also within the suitable ranges for most of otheraquaculturefish species as reported by many authors (Boyd; 1990; Beveridge, 1996; Boyd and Turker, 1998; Bhatnargar and Devi, 2013). These results also indicate that there is no significant difference in

the physico-chemical parameters valuesbetween the sites monitored during the study period. This implies that cage aquaculture has no recognizable effect on water quality of its environment. Several authors have also recently concluded from their various studies that, there is no recognizable impact of cage fish culture on physico-chemical parameters of the water environment(Karikari, 2016in Volta Lake in Ghana; Nabirye *et al*.,2016 in Napoleon gulf, northern Lake Victoria, Uganda and Devi *et al*., 2015 in Poondi reservoir, Tamil Nadu;Kashindye*et al*., (2013) inShiroti Bay-sota, Lake Victoria, Tanzania.

The low or unrecognizing impact of cage fish farms on the physical as well as chemical variables of water within their vicinity and environment may be attributed tothe highly dynamic physical environment of the farms (Gowen *et al*., 1983), nutrient losses through outflow from the dam(Karikari. 2013), dispersion and dilution of organic waste from fish cage by water current. Rapid passing of waste nutrientsthrough the food chain, from phytoplankton to higher levels (Mwebaza-Ndawula *et al.,* (2013), consumption of waste by large school of wild fishes around the fish cages (Machias *et al*., 2005) and low biomass of fish in cages compared with great volume of waterin the lake are other possible reasons for insignificant effect of cage culture at cage site and reference sites.

5.5 Economic returns of cage culture of *Clarias gariepinus* under varying stocking densities and diet forms

Themain purposeof any aquaculture enterprise is toobtain maximum production at minimum cost and maximize profit (Sarker *et al*., 2005 and). However, for net cage aquaculture to be viable and profitable, it is crucial for stocking density optimal for high production and the feeds must also be efficient and economical.

In this study, results on economic analysis indicated that feed cost was the highest component of variable costs in the treatment groups. Furthermore, these results were proportional to stocking density (SD)with fish fed extruded floating diet (EFD) recorded higher variable costs than those fed with pelleted sinking diet (PSD). The feed cost as a percentage variable cost varied from 82.52±0.08(SD_1-EFD) to 84.17±0.01% (SD_3-EFD);76.77±0.12 (SD_1-PSD) to 78.96±0.08%(SD_3-PSD) in fish stocked at SD_1 (100 fish/m^3) and SD_3(300 fish/m^3) and fed with either floating or pelleted diets, respectively. Similar findings were deriveded by Asase, 2013 in cage culture of tilapia (*Oreochromis niloticus*). These results corroborated the assertions of Chambel *et al.,*

(2015) and Soltan, (2016) that feed may compromise 60% and above in recirculating and cage aquaculture systems. However, results on cost and return analysis from similar studies with other fish species in cage culture indicated that juveniles cost was the highest variable cost, contrasting to the feed cost of *Clarias gariepinus* in this present study (Oliveira *et al.,* 2012 and Lago *et al.,* 2014).

In this experiment, the gross production cost, and gross revenue were positively related with stocking density. Comparatively, lowest stocking density (SD_1) showed the least total production cost and gross revenue, while the highest (SD_3) had the highest values in both fish fed extruded floating diet and those fed pelleted sinking diet. However, fish fed with pelleted sinking diet showed higher gross revenue and lower total production cost, while those fed extruded sinking diet had higher production cost and lower gross revenue. The present results corroborate those reported by (Sarker *et al.,* 2014 and Limbu, 2015). The reason for these results could be attributed to higher cost of extruded floating diet (₦333.33/kg) when compared with the cost of pelleted sinking diet (₦250.00/kg).

The net revenue (NR) values in this present study were positive but not directly or proportionallyrelated to stocking density in fish fed extruded floating diet (EFD). The lowest stocking density (SD_1)recorded the least NR (₦13,974.52±697.86) followed by the highest (SD_3) with net NR (₦14,701.84±229.00) and the highest NR (₦20,653.02±308.30) was obtained from SD_2. These results agree with Hassan *et al.,*2010 and Oliveira *et al.*2012 in their similar studies with other fish species. However, the net revenue values in fish fed with pelleted sinking diet (PSD) were positive and proportionally related to stocking density. Least NR (₦17,512.93±216.47) and highest (₦29,848.10±190.28) were obtained from (SD_1) and (SD_3), respectively which implies that net revenue increased with increase in stocking density. Similar findings were published byHengsawat *et al.,* 1997; Islam *et al.,* 2006 andJiwyam, *et al.,* 2011in their studies with African catfish (*Clarias gariepinus*), sutchi catfish (*Pangasius sutchi*) and river catfish (*Pangasius bocourti*) reared in cages, respectively. Net revenue values that were positive and proportionally related to density were also recorded for catfish reared in earthen ponds by Shoko *et al.,* (2009). The positive net revenue recorded in this study implied that all the treatment groups were profitable and that much more profits could be obtained by increasing stocking density until optimum density is exceeded.

Furthermore, the net revenue values in this study showed that fish fed with pelleted sinking diet had comparatively higher net economic returns in all the densities tested than those fish fed extruded stocking.Limbu, 2015 andin his studies also reported similar results.

The result of benefit cost ratios in this studyindicated an inverse relationship with the stocking density in fish fed with extruded floating diet as well as those fed with pelleted sinking diet. However, BCR had comparatively higher values in pelleted sinking diet treatment groups than in extruded floating diet treatment groups. This is becausesinking diet is inexpensive compared to very expensive extruded floating diet.The BCR values acrossthe treatment groups were greaterthan one (>1), ranging from 1.13±0.02 (SD_1–EFD) to 1.25±0.03 (SD_1–EFD) and 1.34±0.02 (SD_3–PSD) to 1.43±0.02 (SD_1–PSD) in fish fed with extruded floating and pelleted sinking diets, respectively. This implied that all the treatment groups were viable and profitable. However, sinking diet treatment groups showed higher profitability than extruded floating diet treatment groups. According toOlagunju, (2007) and Chung, (2017), BCR greater than one (>1) indicates that the project is viable and profitable.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

This study focused on production of *Clarias gariepinus* in net cages under varying stocking densities 100 fish/m^3, 200 fish/m^3 and 300 fish/$m^3$and feed forms (Extruded Floating and Pelleted Sinking Diets).

The preliminary field survey of 30 cage culture farms in Lagos, Ogun and Osun States of Southwest Nigeria was carried out to capture information on their socio-economic parameters, current culture management operations like stocking density employed, type of feed used, constraints and profitability of cage culture.

Cage culture in the study areas was all male enterprise with women playing ancillary role in post-harvest handlings, processing, marketing and distribution.Majority (53.33 %) of cage culture farmers were within 31-40 years. This implied that they were in their active and productive year. In the perspective of experience in cage culture, majority of them were new in the enterprise with 5-8 years experience.In educational attainment, majority of them were educated with 50% of the cage culture farmers being University or tertiary institution graduates who can easily adopt new technologies such as cage culture. About 80 % of cage culture farmershad 5-8 years experience in the practice of cage culture. Therefore, the enterprise was relatively new in the study areas.

The practice of cage culture in the study areas was on a small-scale, 1-6 cages except Fish and Fish farm in Badagry with 27 cages, Durante fish farming Inc. at Oyan Dam in Ogun State (28cages) and Osin farm in Osun State (18 cages). The stocking density employed by the farmers ranged between 100 and 150 fish/m^3. All the farmers in the study areas utilized very expensive floating feeds to feed their fish which is not cost-effective.

The high cost of feeds and over all operations account are the principal constraints confronting cage culture in the study areas. Poaching is another serious problem but employment of security persons could remedythis challenge.

The Beneft Cost Ratio analysis result was higher than one recorded for cage culture farms in the study areas showed that cage culture business of fish production is viable and profitable

The main impacts of stocking density and diet, as well as their interaction are significant on the growth performance like Weight Gain, Length Gain, and Specific Growth Rate of *Clarias gariepinus*reared in net cages. These growth variables have very strong and significant positive bivariate correlation and negative relationship between stocking densities in this study.

The impactsof stocking desity on Production Index and Condition Factor are significant. However, Production Index decreased with increasing stocking density, while Condition Factor is inversely related to stocking density. The interaction between stocking density and diet was significanton Production Index and not significant on Condition factor. This implied that there is a differencein Production Indexbetween fish fed floating and sinking diets and no contrast in the Condition Factor between fish fed floating and sinking diets.

The main effects of stocking density and diet, as well as their interaction were significant on the feed utilization like Protein Intake, Protein Efficiency Ratio, and Feed Conversion Ratio. In Protein Intake, the effects were significant; decreased as stocking density increased. Higher Protein Intake was obtained in fish fed floating diet than those fed pelleted sinking diet. The effects of stocking density and diet, as well as their interaction were not significant on Feed Conversion Ratio and Protein Efficiency Ratio. Also, no contrast was observed between fish fed floating diet and those fed sinking diet.

Water variables of Owala Lake during the study were within the standard values for fish culture and no significant variation between the cage site and other two monitored reference sites.

Haematological parameters such as Packed Cell Volume. Haemoglobin, Red Blood Cell of *Clarias gariepinus* reared in net cages were affected by stocking densities and feed forms werewithin the standard values as reported by Akinrotimi *et al.* (2012).

The Benefit Cost Ratio of more than one was obtained from survey of cage fish culture in Lagos, Ogun and Osun States and from experimental study.

Production of *Clarias gariepinus* in net cages was enhaced at 100 fish/m^3 when fed extruded floating and pelleted diets.

6.2 Conclusion

- Socio-economic study of cage culture farmers in the study areas revealed that cage culture is predominantly a male business.

- Cage culture is relatively new as majority of the farmers were young in cage culture operations and all the farms operated on a small scale with 1-4 cages expect Durante fish Inc. at Oyan Lake in Ogun state with 28 cages, Osin farm in Osun state with 18 cages and Fish N Fish farm in Badagry, Lagos state with 27 cages operated on commercial scales.

- It was established that cage culture farmers incurred higher variable cost (98.75%) with the majority of this cost attributed to feed and juvenile fish.

- The socio-economic study established that cage culture is a viable profitable enterprise playing acrucial role to boost fish output and revenue of farmers.

- This study demonstrated that the growth performance and diet utilization showed better results in fish fed with pelleted extruded floating diet than fish fed with pelleted sinking diet. Also, the lowest stocking density of 100 fish per cubic metre produced better results in terms of production performance while the highest stocking density recorded the lowest results.

- In accordance with the results of this study, it could be inferred that the lowest density of 100 fish/m^3permited the output of bigsize individual fish.

- The study concluded that *Clarias gariepinus* can be adapted to high stocking density as well as pelleted sinking diet in cages devoid of any consequential adverse influence on the welfare condition or reaction of fish if the right management strategies are embraced.

- Furthermore, this study revealed that cost effective pelleted sinking diet can be successively used in net cage culture to enhance economic returns.

- This study proved that survival of *Clarias gariepinus*innet cages was neither density nor diet dependent.

- The physicochemical variables of Owala Lake during the course of this study weresatisfactory for net cage culture of most species, especially for *Clarias gariepinus* culture in freshwater.Furthermore, it could be concluded from the results

of water quality parameters monitored at cage culture trial site and two non-cage sites (reference sites), thatcage cultureeffected none recognizable negative influence on the water

quality of its environment.

- The results of Benefit Cost Ratio (BCR) indicated that cage culture enterprise of catfish is viable and economically rewarding.

- Also,this study demonstrated that cage fish culturists can realize high production and economic returnsby employing high stockingdensity of 200 fish/m^3 and 300 fish/m^3 in fish fed floating diet and pelleted sinking diet.

6.3 Recommendations

- The present study recommends that *C. gariepinus* cage culture farmers can reduce the feeding cost by using pelleted floating diet with no unfavourable influence on growth performance, nutrient utilization, survival, health as well as theoutput of their fish.

- Stocking density of 100 fish/m^3 is recommended as the optimum stocking density for farmers in the study areas for good economic returns.

- The government through the Fisheries Extension Agents should ensure requisiteworkshops,trainings and seminars on regular basis to update the farmers' proficiency on cage culture farming so as to enable them have access to advancedmethodologies of fish cage culture.

- There must also be regular capacity building and training/workshops for Fisheries Extension Agents at the three tiers of government in the country to enhancetheir extension delivery packages to fish farmers especially cage culture fish farmers.

- As a consequence of the high price of feed and juvenile fish, it is imperative that the government institute policies that encourage private individuals and commercial farms to venture into production of good quality feeds and fingerling / juvenile fish to reduce the observed high variable fish and feed costs. This will in turn escalate fish production and farmers' incomes.

- Government through its agencies should empower the farmers with soft loan to expand or start cage culture farms and the loan must attract single digit interest without any strict lending policies.

- As exemplified by Lagos State government through the Ministry of Agriculture and Cooperatives, cage culture should be promoted and developed by government at all levels by supporting farmers with financial assistance and extension services.

- Investment in cage culture should be encouraged like any other venture to prove its profitability.

- Considering the recent establishment of commercial cage aquaculture in Nigeria especially in the southwest, it is crucial for the Federal Government of Nigeria to prepare an environmental guidline and operational protocol for the sustainability of cage fish culture development in Nigeria.

- This study recommends further investigation using larger net cages to further evaluate cage aquaculture profitability since larger net cages will reduce production cost and increase production per unit volume of water.

- It also recommends further study on how to combine the use of floating and sinking diets to optimize financial benefit in catfish cage aquaculture, using costly floating diet as a starter to raise juveniles for the initial two or three months of culture periodfollowed by the use of pelleted sinking diet for the remaining culture period.

REFERENCES

Abiona, B.G., Fakoya, E.O., Alegbeleye, W. O.,Fapojuwo,E. O., Adeogun, S. O., Idowu, A. A. and Aromolaran, A. K., 2011. Constraints of integrated and non-integrated fish farming activity in Ogun State, Nigeria. *Journal of Agricultural Science,3(*4): 233-240.

Retrieved Oct. 15, 2015, fromwww.ccsenet.org/jas.

Abou-Zied, R.M. 2015. Effect of stocking density and diet's type onproductive performance and economic efficiency of African catfish, *Clarias gariepinus* under semi-intensive systems.*Egyptian Journal of Animal Production*52(3):163-172.Retrieved Dec. 18, 2015,from www. fayoun.edu.eg/Agriculture/Animal/Production/pdf/Catfishfinal_ar.pdf.

Abowei, J.F.N. and Tawari, C.C. 2011. The classification, facilities and practices of culture fisheries in Nigeria. *Research Journal of Applied Sciences, Engineering and Technology,*3(10):1096-1107.Retrirved Oct.15, 2015, from www.maxwellsci.com/print /rjast/v3-1096-1107.pdf.

Adakole, J.A. 2000. The effects of diuretic, agricultural and industrialeffluents on the water quality biota of Bindare Stream, Zaria, Nigeria. Ph.D Thesis. Ahmadu Bello University, Zaria, Nigeria. 256pp.

Adebayo, O.O. and Daramola, O.A.2013. Economic analysis of catfish (*Clarias gariepinus*) production in Ibadan metropolis. *Discourse Journal of Agriculture and Food Sciences*. ISSN: 2346-7002. Retrieved Oct. 15, 2013 fromwww.resjournals.org/JAFS July 2013, vol. 1 (9):128-138.

Adedeji, O.B. and Okocha, R.C. 2011. Constraint to aquaculture development in Nigeria and way forward. *Journal of Applied* Sciences *Research,*7(7):1133-1140.ISSN 1819-544X.Retrieved Oct.22, 2014fromwww.aensiweb.com/old/jasr/jasr/2011/1133-1140.pdf.

Adegbite, D.A and Adeleye, O.A., 2011. Determinants of farmers' access to micro-credit in Oyo State, Nigeria. *Journal of Agricultural Research and Development,*10(1).Available fromhttp://www.ajao.info/index.php/jard/article/view/74029.

Adegboye, K. 2010. Floating fish cage farming a money spinning. Vanguard August. 2010 Retrieved Jan. 15, 2013, fromwww.vanguardngr.com/2010/floating-fish-cage-farming-a-money-spinning-business.

Adekoya, B.B. and Miller, J.W., (2004). Fish cage culture potential in Nigeria: An overview of national cultures,*Agric. Focus,* 1:10-16.

Adeniyi,O. R., Omitoyin. S. A., and Ojo, O. O.,(2012). Socio-economic determinants of consumption pattern of fish among households in Ibadan North Local Government Area of State, Nigeria. *African Journal of Food Agriculture, Nutrition and Development,* vol. 2 No.5: 6537-6552, August 2012. ISSN 1684-5374.

Adeogun, O.A., Alimi, T, and Adeyemo, R. (2012). Status, cost and profitability of aquaculture enterprises in Nigeria: Implicationsfor Food Security. *International Journal of Agricultural Sciences,*2(1): 059-066.

Adesina, A.2014a. Nigeria spends about N125bn on fish importation annually. *Naija 247News*. Retrieved Feb. 20, 2015, from naija news.com/2014/02/Nigeria-spends-n125bn-fish-importation-annually-adesina.

Adesina, A. 2014b. FG's Fisheries and aquaculture Transformation agendaAdesina, A FG's Fisheries and aquaculture Transformation agenda. Retrived February 20,2015 from leadership.ng/business/383650/ffgs-fisheries –aquaculture-transformation-agenda.

Adesiyan, I.O. and Ezekiel, A.A. 2007. Economic viability of catfish production in Oyo State, Nigeria. *Journal of Human Ecology,* 21(2): 121-124.

Adewolu, M. A., Ogunsanmi, A.O. and Yunusa, A. 2008. Study on growth performance and feed utilization of two Clariid and their hybrid reared under different culture system. . *Eropean Journal of Science and Research,* 23: 252-260

Adewumi, A. A. and Olaoye, V. F. 2011. Catfish culture in Nigeria: Progress, Prospects and Problems. *Journal of Agricultural Research,* 6(6): 1281-1285. Retrived May 12, 2015 from http://www.academijournals.org/AJAR

Adewuyi, S.A., Phillip, B.B., Ayinde, I.A and Akerele, D. (2010). Analysis of profitability of fish farming in Ogun State Nigeria.*J. Hum. Ecol.* 31(3):179-184.

Afia, O.E. and David, G.S. 2017. Haematological prolile and growth response of African sharptooth catfish (*Clarias gariepinus,* Burchell, 1822) fingerlings to locally formulated and commercial pelleted diets in tarpaulin tanks. *Tropical Freshwater Biology,* 26: 39-52. Available from http://www.ajaol.info/index.php/tfb.

African Union – Inter African Bureau for Animal Resources (AU-IBAR), 2012. Afrian catfish, *Clarias gariepinus.*Retrieved June 10, 2013 fromwww.au.ibar.org/2012-10-01-13-08-42/ series/know-your-animals-series/African-catfish-clarias-gariepinus

Aihonsu, J. O. Y, and Olaningiri, O. A. 2012. Analysis of socio-economic characteristics for Policy Enactment: The case study of Artisanal Fisherfolks in Ibeji-Lekki Local Govement Area of Lagos State, Nigeria. *In Referred Conference Proceeedings of the Nigerian Association of Agricultural Economics (NAAC).* 107-112 pp.

Ajani, F., 2008. Hormonal and haematological responses of *Clarias gariepinus* (Burchell)toammonia toxicity. *AfricanJournal of Biotechnology,* 7(19):3466-3471.

Ajani, F., Dawodu, M., and Olusoji, O. 2011. Effect of feed forms and feeding frequency on growth performance and nutrient utilization of *Clarias gariepinus* juveniles. *African Journal of Agricultural Resources,*6(2): 318-322.

Ajani, E.K., Orisasona, O. and Jenyo Oni A. 2015.Growth and economic performance of *Clarias gariepinus* fry reared at various stocking densities. *Journal Fisheries and Livestock Production,*3(2): 1-3.

Ajani, E.K., Setufe, S.B., and Oyebola, O.O., 2015. Effect of stocking density on Haematological function of juvenile African catfish (*Clarias gariepinus)* fed varyingcrude protein,levels*, African Journal of Food Science,* vol.(2):65-69.

Akarue, O. B., and Aregbor, O. E.,(2015).Socio- economic analysis of catfish farming in Uvwie Local Govement Area of Delta State, Nigeria. *International Journal of Innovative Agriculture and Biology Research.*3(3): 33-43, July –September 2015. www.seahipaj.org. ISSN: 2354-2934.

Aksungur, N.,Aksungur, M., Akbulut, B. and Kutlu, I. 2007. Effect of stocking density on Growth performance, survival and food conversion ratio of turbot (*Psetta maxima)* in the net cages on the southern coast of black sea. *Turkish Journal of Fisheries and Aquatic Science,* 7(2):147-152.

Akegbejo-Samson, T. and Adeoye D. 2012. Measuring profitability in small-scale aquaculture enterprises in southwest Nigeria. In:*Proceedingsof the sixteenth Biennial Conference of the International Institute of Fisheries Economics and Trade,* July 16-20, Dar es Salaam, Tanzania. Edited by Ann L. Shiver. International Institute of Fisheries Economics and Trade (IIFET), Corvallis, 2012.

Akinnifesi, F. K. and Setshwaelo, L.L. (2014).South-South cooperation in agriculture is empowering Nigerian farmers. *Daily Trust*, September 04, 2014. Retrieved February 04, 2015 from http://www.dailytrust.com.ng/daily/agriculture/33480-south-south-cooperation-in-agric-is-empowering-nigerian-farmers.

Akinrotimi, O. A. and Gabriel.U. U. 2012. Haematological profiles of *Clarias gariepinus* brood fish raised in waterrecirculating aquaculture system. *Advances in Agriculture, Sciences andEngineering Research.* Vol.2(2): 97-103. Available from http:www.ejournal.sedinst.com.

Akiyama, D.M., 1999. Feeding and Management of warm water fish in high density culture. *ASA Technical Bulletin* Vol. AQ 46; 1999.

Ande, C. E., (2008*). Essential Economics for Senior SecondarySchools.2nd edition Ogun State, Nigeria. TONAD publishers limited.* 157pp

Anetekhai, M. A. 2013. Catfish aquaculture industry assessment in Nigeria. African Union-Interafrica Bureau for Animal Resources, 84pp. Retrieved July 27, 2015 from www.au-ibar.org/component/...../1950_Catfish_aquaculture_idustry_assessment_in_nigeria.

Annual Abstract of Statistics, 2012. FederalBureau of Statistics Federal Republic of Nigeria: Climate, pp.7-9. Available from: annual_abstract_2012.pdf

Akinbode, S.O. and Dipeolu, A.O. 2012. Double-hurdle model of fresh fish consumption among urban household in South-West Nigeria. *Current Research Journal of Socio-Science,* 4(6):25-30.

Akingbolagun, T., 2017. Nigeria produce 370,000 metric tonnes of catfish in 2016- CAFAN. Retrieved Jan.10, 2018, from www.rockcity fmradio.com/ Nigeria-produce-370,000-metric-tonnes-catfish-2016-cafan.

Akinwole, A.O. and Faturoti, E.O. 2006. Biological performance of African catfish (*Clarias gariepinus*) cultured in Recirculating System in Ibadan. *Aquacultural Engineering, 36:*18-23).

Akinwole, O., Bankole, F., Dauda, B. and Saliu, E. 2014. Growth and survival of *Clarias gariepinus* (Burchell, 1822) fingerlings cultured in Igboora, Oyo State, Nigeria. *Journal of Agriculture and Biodiversity,* 4(3):58-60.

Akiyama, D. M., 1999. Feeding and managementof warm water fish in density culture.*asa Technical Bulletin,* vol.AQ46;1999.

Alabaster, J.S. and Lloyd, R. 1982. *Waterquality criteria for freshwater fish.* 2nd edition.ButterworthScientific, London. 361 pp.

Alikunhi, K.H., Ramachandra. V. and Chaudhuri, H. 1952. Mortality of carp fry under supersaturation of dissolved oxygen in water.*In*:*Proceedings of the national institute of sciences of India,* 17(4): 261-264.

America Heart Association, 2008. ISH and Omiga-3 fatty acids (Internet). Available at: *http://*www.americanheartorgan/presenter.jhtm?identifies=Ar32.

Ande, C.E. 2008. *EssentialEconomics for Senior Secondary Schools* (2nd edition) Ogun State Nigeria TONAD Publishers Limited, pp.157.

Anaglo, J.N., Freeman, C.K., Kumah, W.K., Boateng, S.D., and Manteaw, S.A. 2014. Influence of entrepreneur and enterprise characteristics of successof cage fish farming in the Asuogyaman and South Dayi Districts, Ghana. *Journal of Management and Sustainability.* 3(8): 517-529.

Anyanwu, P.E. Ezenwa, B. 2003. Water Recirculating System Technology as a major way for increased fish production by private fish farmers. *Proceedings of the 18th Annual FISSON* Conference, pp. 23-30.

AOAC, 2005. Official Methods of Analysis of Associationof Analytical Chemist (18th Ed.) Artlington, VA, USA.

AOTA, 2008. Water quality criteria. Ornamental fish, vol. 2: 6. Available from https://www. ornamentalfish.org/Water-Quality-Criteria.pdf.

Arroyo, I.S. 1973. Chile develops the cultivation of trout in cages. *Fish Farming International*, 1(1):99-104.

Asase, M. 2013. Effects of stocking density on the production of Nile tilapia (*Oreochromis niloticus*) in floating net cages on the Volta Lake. M.Phil. Thesis, University of Ghana, Legon, 2013. Pp. 111. http://ugspace.ug.edu.gh.

Ashley, P.J., 2006. Fish welfare. Current Issues in aquaculture. *Applied Animal Behavioural Science,*104 (3-4): 199-235.Doi 10. 1016/j.applanim.2006. 09.001.

Atanda, A. N., 2007. Analysis of freshwater fish seed resources in Nigeria: *In 21st Annual Conference of the Fisheries Society of Nigeria (FISON), 13-17 Nov 2006, Calabar, Nigeria, pp.21-27.*

Ayinla, O.A. 2010. The role of research in the conservation and development of fishery sector in Nigeria. *Invited paper delivered at the Fauna conservation week of the Fauna Conservation Society university of Ibadanchapter*. August 5,2010.

Ayodele, I.A. and Ajani E.K. 1999. *Essentials of Fish Farming (Aquaculture*). Oduduwa Press, Ibadan, pp.46.

Ayoade, O.A., Olatimehin, I.O and Oyelese, O.A. 2014. Hematological growth and blood metabolite responses in the monoculture of juvenile *Clarias gariepinus* to increasing stocking density. *GlobalJournal of Agricultural Reaserch*. Vol. 2 (1): 22-31.

Banerjea, S.M. 1967. Water quality and soil condition of fish ponds in some states of India in relation to fish production. *Indian Journal of Fisheries,* 14: 115-144.

Ballarin, L., Dall'Oro, M., Bertotto, D., Libertini, A., Francescon, A. and Barbaro, A. 2004.Haematological parameters on *Umbrina arrosa* (Teleiostei, Sciaenidae): a comparison between diploid specimens. *Comparative Biochemistry and Physiology,*138(1):45-51.

Bardach E., Ryther, H. and McLarney, O. 1972. *Aquaculture: The Farming and Husbandry of Freshwater and Marine organism.* John Wiley and Sons Inc., New York, 819pp.

Baruwa, O. I., Tijani, A. A. and Adejobi, A. O. 2012. Profitability and constraints to fishery enterprises: A case study of artisanal and aquaculture fishers in Lagos State, Nigeria. Nigeria *of Agriculture, Food and Environment.* 8(1):52-58.

Béné, C. Macfadyen, G., and Allison, C.H. 2007. Increasing the Contribution of small scale fisheries to poverty alleviation and food security. *FAO Fisheries Technical Paper*, No. 481, FAO Rome 125pp.

Beverige, M., 1996. Cage Aquaculture. Fishing News Book. Carlton, 346pp.

Beveridge, M. 2004. *Cage aquaculture.*3rd (eds.)Wiley – Blackwell publishing Oxford, U.K. 380pp.

Beveridge, M. 2013. *Report on an ASARECA Workshop on cage aquaculture and the Environment. Jinga, Uganda.March 14, 2013.* Retrived fromwww.worldfish centre.org.

Bhatnagar, A. and Singh, G., 2010. Culture Fisheries in village ponds: a multi-location study in Haryana, India.*Agriculture and Biology Journal of North America,* 1(5): 961-968.

Bhatnagar, A., and Devi P., 2013. Water quality guidelines for the management of pond fish culture. *International Journal of Environmental Sciences*, 3(6): 1980-2009.

Bhatnagar, A., Jana, S.N., Garg, S.K., Patra, B.C., Singh, G and Barman, U.K. 2004.*Water quality management in aquaculture technology in fresh and saline waters.CSS* Haryana Agricultural, Hisa (India), pp.203-210.

Bhatnagar, A. and Garg, S.K. 2000. Causative factor of fish mortality in still water fish ponds under sub-tropical conditions, *Aquaculture*, 1(2): 91-96.

Björnssen, B and ólafsdóttir, S.R. 2006. Effects of water quality and stocking density on growth performance of juvenile Cod (*Gadus morhus* L.) ICES *Journal of Marine Science,* 63:326-334.

Blow, P. and Leonard, S. 2007. A review of cage aquaculture: sub-Saharan Africa. In HalwartM, Soto D, and Arthur J.R. (eds) – *Cage Aquaculture REgioal reviews and global overview,pp.188-207. FAO TechnicalPaper No. 498. Rome, FAO.241pp.* Retrived from a129e08.pdf.

Blueprint News, 2014. What hope for the Nigeria fisheries sector?. *Blueprint News,* March 03, 2014.Retrieved from www.blueprint.ng//2014/03/03/What-hope-for-the-Nigeria-fishery -sector?

Boyd, C.E., 1979. *Water Quality in Warmwater Fish Ponds.* Auburn University, Agriculture Station, Auburn, Alabama, pp 359.

Body, C.E. 1990. *Water Quality in Ponds Aquaculture*. Auburn University, Agriculture Station, Alabama.

Boyd, C.E., and Tucker, C.S. 1998. *Pond aquaculture water quality management*. Kluwer Academic Publishers, USA.

Brain, O., 2014. Water Research Centre – Ammonia in Groudwater, Runoff, Surfacewater, Lakes, and

Sreams. Available online from:https://www.water-research.net/index.php/ammon-in-groundwater-runoff-surfacewater-lakes-and-streams.

Britz, P.J. 1987. Temperature preferences and optimum temperature for growth of African sharptooth catfish (*Clarias gariepinus*) larvae and post larvae. *Aquaculture,* 63(1-4):205-214.

Brummett, R.E. and Williams, M.J. 2000. The evolution of aquaculture in Africa rural and economic development. *Ecological Economics,* Vol. 33, pp. 193-203.

Brummett, R. E., Youaleu, J.I.N, Tiani,A.M. and Kenmegne, 2010. Women's traditional fishery and alternative aquaculture resource livelihood strategies in Southern Cameroon Rainforest. *Fisheries Management and Ecology,* vol. 17: 221-230.

Buttner, J.K., Soderberg, R.W. and Terlizzi, D.E., 1993. An introduction to water chemistry in freshwater Oxford University Press, Oxford, pp. 285.

Castell, J.D. and Tiews K.; *1980. Report of the EFAC, JUNS and ICES working group on the standardization of methodology in fish nutrition research*. Humberg, Federal Republic of Germany, 21-23 March, 1979. EIFAC Tech. paper 36, 24.

Chakraborty, S.B. and Banerjee, S., 2010. Effect of stocking density on monosex Nile tilapia growth during pond culture in India. *WorldAcademy of Science and Engineering Technology,* 44: 1521-1534.

Chambel, J., Severino, V., Baptista, T., Mendes, S. and Pedrosa, R. 2015. Effect of stocking density and different diets on growth of Perala Clownfish, *Amphiprion percula* (Lacepede, 1802). *SpringPlus, 4:183.*

Charoo, S.Q. 2014. Effect of stocking density stress on the haematological profiles of *Oncorhychus mykiss* in Kashmir Tfout Racrways. *Journal of Science and Technology,* vol.6No.1, 2014. ISSN: 2229-8460. E-ISSN: 2600-7924. Retrieved May 26, 2016, from penerbit.uthhm.edu.my/ojs/index.php/JST/article/viewfile/726/615/7Q.

Chen, J., Guang, C., Xu, H., Chen, Z., Xu, P., Yang, X., Wrang, Y. and Liu. J. 2007. *A* Review of Cage and Pen Aquaculture in China. In: M. Halwart, D. Soto and J.R. Arthur Ed. Cage aquaculture: Regional Reviews and Global Review, pp.156-187. *FAOFisheries Technical Paper*. No.498. Rome, FAO, 2007 pp.241.

Chung, W. 2017. Project benefit analysis concepts for the PMP exam (Part 2).Available from: hptts://Edward-designer.com/web/pmp-benefit-analtsis-concepts-2/.

CIFA, 2006.Genetic management of aquaculture stock in sub-Saharan Africa. *Report of of a Producers' Workshop in Accra Ghana, 27 February-3 March, 2006.*

Cline, D. 2011. Growing fish in cages. *Cage culture extension publication*, June 03, 2011 Edited by Vanessa Weldon, Extension Associate, University of Akansas at PineBluff. Retrieved Oct. 13,2016 fromwww.extension.org/pages/58698/cage-culture.

CNN, 2013. Tonnes of poisoned fish clog river in China's Hubei province. Cable News network September 05, 2013. Available from https://www.cnn.com/2013/09/05/world/ Asia/china-river-dead-fish/index.html.

Coche, A.G. 1976. A general review of cage culture and its application in Africa. *A paper presented at Technical Conference on Aquaculture.*Koyoto, Japan 25 May – 2 June 1976.FAO, FRI.AQ/CONF/76/E.72.

Coche, A.G., 1979. *A review of cage fish culture and its application in Africa. In Advances in aquaculture,*edited by T.V.R. Pillay and W.A. Dill. Farham, Surrey, Fishing News Book Ltd., for FAO, pp 428-441.

Coche, A.G. 1982. Cage culture of tilapias. *In Biology and culture of the tilapias*, edited by R.S.W. Paulline and R.H. Lowe-McConnell. ICLARM Conf. Proc., (7): 205 – 246.

Collins, R.A. 2017. Cage culture of catfish in reservoir and lakes.In: Proceedings of the Annual Conference of S.E. Association of Game and Fish Consummers, pp.489-496.

Conte, F.S. 2004. Stress and the welfare of cultured fish. *Appl. Anim. Behav, Sci.*86(3-4): 205-223.

Craig, S. and Helfrich, L.A. 2009. *Understanding Fish Nutrition, Feed and Feeding*: *Virginia Cooperative Extension Publication, 420-456 pp.*

Crusoe, O. 2012. Aquaculture as part of thriving agriculture. Retrieved Dec. 10, 2014, from www.thisday.com/articles/aquaculture-as-path-to-thrving-agriculture/124614/.

Cruz, E.M., and Ridha, M.T. 1989. Preliminary study on the production of tilapia, *Oreochromis spirulus* (Gunther) cultured in sea water cages. *Aquaculture Fisheries management,* 20:381-388.

C.T.A. 2013. Fish Farming: the new driver of the blue economy programme-CTA. Retrieved Nov. 27, 2014 fromwww.cta.int/images/docmab-files/BR32-Fish-Farming-the-new-driver-of-the-blue-economy-programme.pdf.

Dada, A.A., Fagbenro, O.A., Fasakin, E.A. 2000. Effect of varying stocking density on growth, and survival of an African catfish (*Heterobranchus bidorsalis*) fryon outdoor thanks. *J. Fish. Tech. 2(1):107-116.*

Dada, A.A. and Wonah, C.2003. Production of exotic*Clarias gariepinus* fingerlings at varying stocking densities in outdoor concrete ponds. *Journal of Aquatic Sciences,*18(1):21-24.

Daferighe, E.E., Offiong, P.E. and Emah, J.A. 2017. Application of Environmental Accounting Principles in Boosting Fish Production in Nigeria.*InternationalJournal of Natural Resource Ecology and Management*, 2(2): 24-31 Re.trieved June 9, 2017 from www.Sciencepublishinggroup.com/j/injnrem20172020.12p.

Dai, W., Wang, X., Guo, Y., Wang, Q. AND Ma, J. 2017. Growth performerance, haematological and biochemical responses of African catfish (*Clarisa gariepinus)* reared at different stocking densities. *African Journal of Agricultural Research,* vol.6(28):6117-6182. Available online at: http://www.academicjournals.org/AJAR.

Das, A.K., Vass, K.K., Shrivastava, N.P and Katiha, P.K.2009. *Cage culture in reservoirs in India (A Handbook) pp.24.*Retrived Oct. 20, 2015 from aquaticcommons./org/2864/1/ WF_2496.pdf.

Dasuki, A., Auta, J., and Oniye, S.J., 2013. Effect of stocking density on production of *Clarias gariepinus* (Tuegels) in floating bamboo cages at Kubanni Reservior, Zaria, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 6(1): 112-117.

Datta, S.N., Kaur, V. I., Dhawan, A. and Jassal, G. 2013. Estimation of length-weight relation-ship and conditionfactor of spotted snake-head, *Channa punctata* (Bloch)under
different feeding regimes. *Springerplus.* 2:436.Retrieved March 28, 2016, from:https://www.ncbi.nlm.nih.gov/pmc37770221.

Dauda, A.K., Natrah, I., Karim, M., Kamarudin, M.S and Bichi, A.H. 2018. African catfish aquaculture in Malaysia and Nigeria: Status, trends and prospects. *Fisheries and Aquaculture Journal,* 9:232. Doi: 10.4172/2150-3508.1000237.

Davis, A. K., Maney, D. L., and Maerz, J., 2008. The use of leuckocyte profils ito measure stress in vertibrates: a review for ecologist. Available from https://bedjournals.onlinelib
rary.wiley.com/doi/full/10.1111/j.1365.2008.01467x.

De Graaf, G. J. and Janssen, J. A. L. 1996. Artificial reproduction and pond rearing of African catfish, *Clarias gariepinus* in sub-Saharan Africa.*FAO Fisheries Technical Paper.* No.362. Rome:FAO.

De Silver, D. D. M. (2011). Faces of women in global fishery value chains: female involvement, impact and importance in the fisheryimpact and importance in thefishery of developed and developing countries, 44 pp.

Delgado, C.L., Wada, N., Rosegrant, M.W., Meijer, S. and Ahamed, M. 2003. Supply demand in changing global markets. International Food Policy Research Institute(IFPRI), Washington and World Fish Centre Penang, Malaysia.

Delince, G., 1992. *The ecology of the fish pond ecosystem*, Kluwer Academic Publishers London pp. 230.

Devi, P.A., Padmavathy, P., Srinivasan, A. and Jawahor, P. 2015. Environmental impact of cage culture on Poondi Reservoir, Tamil Nadu. *Curr. World Environ. 2015.*10(3): 1048-1054.Retrieved Feb. 10, 2016from: https://www.cwejournal.org/?p=12671

Dibattista, J., Levesque, H., Moon,T., Gilmourk. 2005. An investigation on factors thatcontribute to the growth of surbordinate Rainbow Trout (*Oncorrhynchus mykiss*). *In:Proceedings of the 4th Annual Meetingof the Canadian Societyof Zoology*2005.

Dickson, M., Nasr-Allah, A., Kenawy, D., and Kruijssen, F. 2016. Incresing fish farm profitability through aquaculture best management practice training.in Egypt. *Aquaculture.* Vol. 465: 172-178.

Docan, A., Cristea, V., Dediu, L., Moanu, M and Grecu, I., 2011. The impact of level of the stocking density on the haematological parameters of Rainbow trout (*Oncorhynchus mykiss*) reared in recirculating aquaculture systems. *Aquaculture,Conservation and Legistlation International Journalof the Boflux Society,* vol.4(4): 536-541. Available from: http://www.bioflux.com.so/aacl.

Dolezalova, P., Macova, S., Pistekova, V., Svobodova, Z., Bedanova, I and Voslarova, E., 2011. Nitrite toxicity assessment in *Danio rerio* and *Poecilia reticulata. ACTA VET Brno,* 80:309-312.

Durborow, R.M., Crosby, D.M., and Brunson, M.W., 1992. Ammonia in Fish Ponds.*Southern Regional Aquaculture Centre (SRAC*) *Publication* No. 463

Durborow, R.M., Crosby, D.M., and Brunson, M.W. 1997. Nitrite in fish ponds. *Southern regional Aquaculture Centre* (*SRAC)publicatio*n No. 462.

Dzadze, P., Osei Mensah, J., Aidoo, R. and Nurah, G.K., 2012. Factors determining access to formal credit in Ghana: A case study of smallholder farmers in the Abura-Asebu

Kwamankese district of central region of Ghana. *Journal of Development and Agricultural Ecomnomics.* 4(14):416-4230.

Eddy, F.B., and Williams, E.M., 1987. Nitrite and freshwater fish:*Chemistry in Ecology,* 3:1-38. Available from https://www.tandfonline.com/doi/abs/10.10801/0275754870832.

Edward, A.,Ladu, B.M.B. and Elihu, A. 2010. Growth, survival and production of *Clarias gariepinus* fingerlings at different stocking densities in concrete tanks. *African Journal of General Agriculture,* 6(2):59-66.

Ejiola, M.T. and Yinka, O.F. 2011. Comparative cost structure and yield performance analysis of upland and mangrove fish farms in Southwest, Nigeria. *International Journal of Agricultural Management and Development,* 2(3): 187-198.

Ekanem, A. P., Eyo, V. O., Obiekezie, A. I., Enin, U. I. and Udo, P. I. 2012. Acomparative study of the growth performance and food utilization of the African catfish (*Clarias gariepinus* Burchell, 1822*)* fed Unical aqua feed and Coppens commercial feed. *Journal of Marine Biology and Oceanography,* 1(2): 1-6.

Ekubo, A.A., and Abowei, J.F.N., 2011. Review of some water quality management principles in culture fisheries. *Research Journal of Applied Sciences, Engineering and Technology,* 3(2): 1342 – 1357..

Ellis, T., North, B., Scott, A.P., Bromage, N.R., Porter, M., Gadd, D. 2002. The relationships between stocking density and welfare in farmed rainbow trout. *J. Fish Biol.* 61:493 - 531. Retrived Oct, 25, 2016 from:https://onlinelibrary.wiley.com/doi/10.1111/j.1095-8649.2002.

Engle, C.R., and Valderram, D. 2001. Effect of stocking density on production characteristics, costs and risk of producing fingerlings channel catfish. *North American Journal of Aquaculture,* 63:201-207.

Eniola, A. 2016. Feed Conversion Ratio: Understandng this one facts can help catfish farmers maximize profit. Retrieved Jan. 2, 2017, from www.profitablefishfarming.com/feed-conversion-ratio-understanding-one-factor-can -help-catfish-farmers-maximize-profit/

El-Sayeed, A.F.M., (2002). Effect of stocking density and feeding levels on growth and feedingefficiency of Nile tilapia, *Oreochromis niloticus*, L. fry. *Aquaculture*

Research, 33; 621-626

Eriegha, O.J., and Ekokotu, P. A. 2017.Factors affecting feed intake in cultured fish species: *A Review. Animal Research International*,14(2):2697-2709.

Eschmeyer, W.N. 2014. Catalog of Fishes. Updated 10 March, 2014. Available from http:// research.ca.lacademy.org/research/ichthyology/catalogfishstatmain.asp.

FAWC, 1996. *Report on the Welfare of Farmed Fish.Surbiton, Surrey*.

FAO, 2007. *Cage aquaculture regional review. Technical paper* 498, pp.6.

FAO, 2005. *Small Scale Aquaculture in sub-Saharan Africa. Revisiting the Aquacultue Target Group Paradigm. Rome: FAO Fisheries.*

FAO, 2006. *Fisheries management in the Federal Republic of Nigeria.* Retrived fromwww.fao.ng/fi/fep/en/NGA/body.

FAO, 2008. *The State of World Fisheries and Aquaculture (Sofia)* 2008. PART 1: World review of fisheries and aquaculture; Fish consumption, pp. 58-65.

FAO, 2012. *The State of World Fisheries and Aquaculture 2012.* Rome, pp 200. Retrieved Jan. 15, 2015 from: http:www.fao.org/3a-i2727e.pdf.

FAO, 2014a. *State of the World Fisheries and Aquaculture Highlights Growing Fisheries Production and Consumption*. Retrived Nov. 06, 2015 from http://sdg.iisd.org/news/fao-state-of-the-World-fisheries-and-aquaculture-highlightsgrowing-fish-production-and-consumption.

.FAO, 2014b. *The State of World Fisheries and Aquaculture; Oportunities and Challenges, FAO, Rome*, 2014, pp. 96. Available from:www.fao.org/3/a-i3720e.pdf.

FAO, 2014c. *Transforming rural livelihoods: How South-South-Cooperation with China is improving lives in Nigeria, pp.30.* Available online at: www.fao.org/3i3785e.pdf..

FAO, 2015a. *African catfish (Clarias gariepinus* Burchell,1822*) production with special reference to temperate zones: a manual.* Andras Peteri, Thomas Moth-Poulsen, EvaKovacs, Imre Toth and Andras Woynarovich. Rome Italy.

FAO, 2015b.*Aquaculture seed and feed production and management in Bangladesh – status, issues and constraints, by Hassan, M.R and Arthur, J.R, FAO*. Available online fromwww.fao.org/3/a-i4945e.pdf.

FAO, 2016a.*The State of World Fisheries and aquaculture: Contributing to food security and nutrition for all.* Available from reliefweb.int/report/world/state-of-world-fisheries-and- aquaculture-2016.

FAO,2016b. *Cultured Aquatic Species Information Programme: Clarias gariepinus. Fisheries and AquacultureDepartment, Food and Agricultural Organization of United Nations, Rome.*

FAO, 2017. *Fishery and Aquaculture Statistics. Global Aquaculture Production 1950-2015 (Fishstat). In FAO Fisheries and Aquaculture Department. Rome*. Retrived May 02, 2017 from a-i717e.pdf.

Fili, F.B., Onu, J.I., Adebayo, E.F. and Tizhe, I., 2015. Factors influencing credit accessamong small scale fish farmers in Osun State, Nigeria. *Journal of Agricultural Economics. Environmen and Socio-Sciences.* 1(1): 46-55. Also available online at: http://www.unimaid.edu.ng/jaeess. ISSN: 2476-8423. .

Folayan, J.A., 2017. Economic and profitability analysis of catfish production in Akure North Local Government of Ondo State, Nigeria. *Current Journal of Applied Science and Technology,* 23(6): 1-8. Article No, CJAST.14483. Availabe online from: www.journalrepository.org/media/journals/CJAST_67/2017/Oct./Folayan2362014CJAST14483.pdf.

Fox, M.G., and Flowers, D.D. 1990. Effect of fish density on growth, survival and food consumption by juvenile walleyes in rearing ponds. *Transactions of the American Fisheries Society*119:112-121.

Fregene, T., Inyang, I. and Awolumote, S. 2011. Operational Attribute of urban Aquaculture Syatem in Ibadan Municipal, Oyo State, Nigeria. R. Adeyemo (ed.), Urban Cities and Climate Change, pp.173-17. Cuviller Verlag, Gottingen.

Freyhof, J. 2014. The IUCN Red list of threatened species. The African catfish, *Clarias gariepinus and Clarias angullaris.*Retrieved May 18, 2015, from: www.iucnredlist/det Ail16602310.

Furukawa A. 1973. *Present status of Japanese marine aquaculture in the Indo- Pacific region,* edited by T .V. R. Pillay. West By-fleet, Surrey, Fishing News (Books) Ltd., pp.29-47.

GAIN REPORT 2014. Nigeria begins import quota policy for fish: *Gain report,* April 17, 2014.

Ganzallo, T. 2012. Cage and Pen Fish Culture in Nigeria. Cage culture in LagosState.Retrived Dec, 23, 2015 from ganzallotaiwo.blogspot.com.ng./2012/07/cage-culture-in-lagos-state.

GAIN,2007. Nigeria fishery products, Nigeria's fish market, 2007, pp 5-11. *GAIN report* no. N17026. Lagos Nigeria.

Gomes, L.C., Chagas, E.C., Martins-Junior, H., Roubach, Ono, E.A. and Lourenco, J.N.P. 2006.Cage culture of tambaqui (*Colossoma macropomum*) in a Central Amazon floodplain lake. *Aquaculture*,256; 521-528

Gopakumar, G. 2009. History of Cage culture, cage culture operations, advantages and disadvantages of cages and current global status of cage farming. *National Training on 'Cage Culture of Seabass' held at* (CMFRI), Kochi, pp.14-23.

Gowen, R.J., Tett, P. and Jones, K.J.1983. The hydrography and phytoplankton ecology of Lock Ardhair: a small sea lock on the west coast of Scotland. *Journal of Experimental. Marine Biology and Ecology,* 71:1-16.

Greaves, K., and Tuene, S. 2001. The form and context of aggressive behaviour in farmed Atlantic halibut (*Hippoglossus hyppoglosus* L.). *Aquaculture* 193, (1-2): 139-147.

Gribanov, L.V., Koneev,A,N., Koneev, L.A. 1968. Use of thermal waters for commercial production of carps in floats in U.S.S.R., *FAO Fish Rep*,44(5):218-266.

Guo, L, and Li, Z 2003. Effects of nitrogen and phosphorous from cage culture on the communities of a shallow lake in middle Yangtze River basin of China. *Aquaculture,*266: 201-212.

Gupta, N, Haque,M.M., and Khan, M. 2012. Growth performance of tilapia fingerlings in cage in pond managed by Adivasi households: An assessment through length-weight relationship.*Journal of Bangladesh Agricultural University*, 10 (1): 149-155.

Halwat, M. and Moahl, J. 2006. *Food and Agriculture Organisation Regional Expert Workshop on Cage Culture in Africa, Enthebbe, Uganda,* Oct. 20-23, 2004. *FisheriesProceedings,*No.6 Rome. 113p.

Hargreaves, J.A. and Tucker, C.S. 2014. Managing ammonia in fish ponds. *Southern Regional*

Aquaculture Centre (SRAC) Publication No. 4603.

Hassan, M.R. 2001. Nutrition and feeding for sustainable aquaculture development in the third millennium. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery and J.R. Arthus, eds. Aquaculture in the third millenium. *Technical Proceedings of the Conferrence on Aquaculture in the third Millennium. Bankok, Thailand, 20-25 February, 2000.* 193-219 pp. NACA, Bankok and FAO, Rome.

Hastein, T., Scarfe, A.D., Lund, V.L. 2005. Science-based assessment of welfare: aquatic animals*. Rev. Sci. Tech. off Int Epizool,*24: 529-547.

Hayashi, M. 2004. Temperature electrical conductivity relation of water for environmental monitoring and geographical data inversion. *Environ. Mont. Assess.* 96:121-130.

Haylor, G.S. 1991. Controlled hatchery production of *Clarias gariepinus* (Burchell, 1822): Growth and survival of fry at high stocking density. *Aquacul. Fish.Manag.*22:405-422.

Hecht, T., Oellermaan, L. and Verheust, L. 2006. Perspectives on clariid catfish culture in Africa. *Aquatic Living Resources,* 9: 197- 206.

Helfrich, L.A., Parkhurst, J., and Neves, R. 2009.Guide to Understanding and Managing Lake Part 1 (Physical Measurement). *Virginia Cooperative Extension, VCE Publication*/420/420-538. Available fromhttps://pubs.ext.vt.edu/420/420-538.html.

Hengaswat, K., Ward, F. J. and Jaruratjamorn, P. 1997. The effect of stocking density on yield, growth and mortality of African catfish (*Clarias gariepinus* Burchell 1822) cultured in cage. *Aquaculture.* 152, 67-79

Hepher, B. 1988. *Nutrition of of pond fishes.* CambridgeUniversity Press,Cambridge. 388pp.

Hickling, C.F. 1962. *Fish culture*, London,Faber and Faber, 295p.

Hixson, S.M. 2014. Fish nutrition and Current Issues in Aquaculture: The balance in providing safe and nutritious seafood in an environmentally sustainable manner. *Journal of Aquaculture Research Development,* 2014, 5:3. Also available at: www.Sciencedirect.
com/science/article/pii/004 484683902077.

Hoffman, L.C., Prinsloo, J.F. and Rukan, G., 1997. Partial replacement of fish meal with either soybean meal, brewers yeast or tomato meal in the diets of African sharp tooth catfish, (*Clarias gariepinus).Water SA*, 23(2): 181-186.

Hogendoorn, H., and Koops, W.J. 1983. Growth and production of the African catfish, *Claria lazera* (cxv), 1. Effects of stocking density, pond size and mixed culture with tilapia (*Sarotherodon niloticus*) under extensive field conditions. *Aquacutlure,*34(3/4): pp.253-263.

Hormiga, E., Batista-Canino, R.M. and Sanchez-Medina, A. 2011. The role of intellectual capital in the success of new ventures. *International Entreperneurship Management Journal.* 7: 71-92.

Houghton, G. and Matthews. 1990. Immunosuppression in juvenile carp, *Cyprinus carpio* L.: The effects of the corticosteroid trimcinolene acetone and hydrocortisone 21-hemiscuccinate (cortisol) on acquired immunity and humoralantibody response to *Ichthyophthirius multifilis*Fouquet. *Journal of Fish Disease,* 13: 269-280.

Huet, M. 1970. *Traite de piscultuer*. Ppuexelles, ch, de Wyngaert, *Journal of Applied Icthyology,* 20:302-305.

Huguenin, j., 1997. The design, operations and economics of cage culture system: *Aquacultual*
Engineering, 16:167-205.

Hrubec, T.C and Smith, S.A., 2000. *Hematology of Fish. In: Feldman, B.F., Zinkl, J.G., Jain, N.C, editions. Schalm's Veterinary Hematology. 5th edition. Philadephia: Lippincott Williams and Wilkins;* pp.1120-1125.

Huntingford,F.A., Adams, C., Braithwaite, V.A., Kadril, S., Pottinger, T.G., Sandøe, P.and Turnbull, J.F. 2006. Current Issue in Fish Welfare, *J. Fish Biol.* 68:332-372.

IBM Corporation Release.2013. IBM SPSS Statistics for Windows, Version 22 Armonk, NY: IBM Corp.

Idowu, A.N. 2013. Cultivable fish species culture system and medium management. *A paper presented at a training workshop sustainable fish farming for a secured future in Nigeria organized by Agriculture Media Resources and ExtensionCentre*, Federal University Agriculture, Abeokuta pp5.

Imelda, J. 2009. Important Management measures in cage culture. *National Training on cage culture of seabass held from 14-23 Dec., 2009 at*CMFRI, Kochi, India.

INFOFISH 2015. Tilapia markets in sub-saharan Africa. *INFOFISH 4th International Trade and Technical Conference and Exposition on Tilapia, Kuala Lumpus, April 2015.* Available from http://www.tilapia-farming.com.

Ingawa, S.A. 2006. A welcome address at National Programme for Food Security (NPFS) fish cage culture training workshop organized by the Federal Department of Fisheriea (FDF) in collaboration with South South Coporation (SSC) Chinese Fisheries experts, held at Maizube farms, Mina, Niger state, Nigeria, October 10-13, 2006.

Ishikawa, M.M., Pádua, S.B., Satake, F., Hisano, H., JerÔnimo, G.T., Matins, M.L. 2010. Heparin and NaEDTA as anticoagulants for hybrids sunbimcatfish *(Pseudoplatystomareticulatum* × *p. corruscants*): efficiency and hematological changes. *Gência Rur.* 40:1557-1561.

Islam, M.S., Rahman, M.M. and Tanaka, M. 2006. Stocking density positively influences the yield and farm profitability in cage aquaculture of Sutchi catfish, *Pangasius sutchi. J. Appl.Ichth.*22:441-445.

Islam, G.M.N., Tai, S.Y.and Kasairi, M.M. 2016. A stochastic frontier analysis of technical efficiency of fish cage culture in Penisular Malaysia. Available from https;//preview-springerplus-springeeropen.com/track/pdf/10.1186/s40064-016.

Jain, N.C. 1986.*Schalm Veterinary Haemotology*. Fourth Edition, Lea and Febriger Philadephia, USA.

Jamabo, N.A. and Keremah, R.I. 2009. Effects of stocking densities on the growth and survival of the fingerlings of *Clarias gariepinus* (Burchell, 1822).*Journal of Fisheries International* vol. 4(4):55-57. Retrived November 18, 2015 from medwelljournals.com /fulltext/?doi=jfish.2009.55-57.

Jiwyam, W. 2011. The effect of stocking density on yield, growth and survival of Asian catfish, (*Pangasius bocourti*Sauvage,1880) cultured in cages. *Aquaculture International,*19: 987-997.

Joe, J., 2017. Quora: What does pH stand for? Available fromhttps://www.quora.com/what-does -pH-stand-for.

Joel, O.F and Amajuoyi, C.A., 2010. Determination of the concentration of ammonia that could have lethal effect in fish pond. *Journal of Engineering and Applied Sciences;* Volume. 5(2):1-5 www.arpnjournals.com/jeas/research_papers_rp_2010_294.pdf.

Joergensen, M. 2017. A simple tool to calculate trout condition factor, length or weight from the two other number. Available online from*globaflyfisher.com/fish-better/fultons-condition-factor-calculator.*

Kampayana,F., Nguyen,S.T and Le, M.H.,2016. Tilapia cage culture in Rwanda: Current status and prospects for future development. *Int. J. Fish. Aquat. Stud.*4(3): 428-435.

Kannadhason, S., Muthukumarappan, K. and Rosentrater, K. A. 2009. Effect of ingridents and extrution parameters on aquafeeds containing DDGSand topica starch.*Journal of Aquacult. Feed Sci. Nutr.* 1(1):6-21.

Kapinga, I., Mlaponi, E., Kasozi, N. 2014. Effect of stocking density on the growth performance of sex reversed male Nile tilapia (oreochromis niloticus) under pond conditions in Tazania. *World Journal of Fish and marine Science*, 6(2):156-161.

Kaja, K.Z. 2001. Hydrobiology-Limnology, Inland aquatic ecosystem – Wyd, PWN, warcawa, 360p. (In Polish).

Karikari, A.Y. 2016. Assessment of environmental impacts of cage aquaculture on Lake Volta of Ghana. A Ph.D. Thesis of Kwame Nkruma University of Science and Technology, Faculty of Renewable Natural Resources, Department of Fisheries and Watershed
Management, Kumasi, Ghana, 225pp. Available from ir.khust.edu.gh/bitstream/12345 6789/9976/1/FINAL%20THESIS.pdf.

Kashindye, B. B., Nsinda, P., Kayanda. R., Ngupula, G. W. and Mashafi, C. A. 2013. Environ-
mental impacts of cage culture in Lake Victiria: The case of Shirati Bay-Sota, Tanzania. Springerplus, 4: 475. Available from: http://springer.com/content/pdf/10.1186%2Fs40064-015-1241-y.pdf.

Kingsway Agro Service in Agriculture, 2012. Aquaculture Development in Africa. Retrived April 05, 2015 from blogspot.com.n/2012/04/aquaculture-development-in-africa.

Kori-Siakpere, O., Ake, J.E.G. and Idoge, E. 2005.Haematological characteristics of the African snakehead, *Parachanna obscura. Afr. J. Biotechnol.* 4(4):527-530.

Krishnarpriya, T.R. 2016. Accumulation of unused feed and excreta will lead to water pollution as well as eutrophication.

La Rosa, M., Mirto,S., Favaloro, E., Savona, B., Danovaro, R. and Mazzola, A. 2002. Impacton the water colmn biogeochemistry of a Mediterranean mussel and fish farm. *Water Research,* 36:713-721.

Labarrère,C.R., Faria, P.M.C.,Teixeira, E.A. and Melo, M.M. 2012. Erytogram of hybrids surubin (*Pseudopltystoma corruscans* × *P. reticulatum*) kept at different stocking densities. *Arg. Bras. Vet. Zootac*. 64:510-514.

Lago, A.A., De Freitas, R.T. F., Pimenta, M.E.S.G., De Mattos, B.O., Neto, R.V.R and Costa, A.C. 2014. Stocking densities of juvenile *Brycon orthotaenia*: production parameters and economic benfits in net cages. *Acta scientiarum. Animal Science.*
*Maringa, volume 36(3): 253-258.*Availablle fromhttps://www.scielo.br/pdf.asas/v36

N3a03.pdf. ISSN printed: 1806-2636.

Leatherland, J.F. and Cho, C.Y., 2005. Effect of rearing density on thyroid and interrenal gland activity and plasma hepatic metabolic levels in rainbow trout,*Salmo gairdneri,* Richadson*. J. Fish. Biol.27:583-592.*

Limbu, S. M. and Jumanne, K. 2014. Effect of restricted and re-feeding regime on feeding cost, growth performance, feed utilization and survival rate of Nile tilapia (*Oreochromis niloticus*) cultured in tanks*. Int. J. Fish.Aquact Stud.* 2(1):118-123.

Limbu, S.M. 2015. The effect of floating and sinking diets on growth performance, feed conversion efficiency, yield and cost effectiveness of African catfish (*Clarias gariepinus*) reared in earthen ponds. *International Journal of Fisheries and Aquatic Studies*. 2(5):253-259.

Ling,S.W. 1967. Feed and feeding of warm water fishes in ponds in Asia and Far East. *FAO Fish Rep:* 44 vol.3:291-309.

Living Blue Planet Report (2015). Species, habitats and human well-being, pp.2. Living_blue_ planet_report_2015_final_LR (3).paf_Adobe Reader.

Lupatsch, I., Santos, G.A., Schrama,J.W., Verreth, J.A.J. 2006. Effect of stocking density and feeding level on energy expenditure and stress responsiveness in European sea bass, *Dicentrarchus labrax. Aquaculture,* 2010, 298 (3-4): 25-250. Doi: 10.1016/j.aquacultu
2009.11.007.

Machena, C. and Moehl, J. 2001. African Aquaculture: *A Regional Summary with emphasis on sub-Saharan Africa-African Aquaculture.*Retrived May 15, 2015 from: http://www.
fao.org/3/AB412E/ab412e21.htm.

Machias, A., Karakassi, I., Somarakis, S., Giannoulaki, M., Papadopoulou, K.N. and Smith, C. 2005. The response of demersal fish communities to the presence of fish farms. *Marine Ecology Progress Series*. 288:241-250.

Makinde,Y.O., Afodu, O.J., Balogun, O.I., Awoyinka, I.R. and Bello, T.A. 2015. Budgetary analysis and factor influencing profit level of culture fish enterprises by gender in

EPE Local Government Area of Lagos State, Nigeria. *International Journal of Agriculture Inovations and Research*. 3(6): 1671-1678.

Mallya, Y.J. 2007. The effect of dissolved oxygen on fishgrowthin aquaculture. The United Nations University Fisheries Training Programme, 1-30pp. Rerived Dec. 20, 2015 from www.unuftp.is/static/fellows/document/yovita07prf.pdf.

Mckenzie, D. J., Höglund,E., Dupont-Prinet, A., Larsen, B.K.,Skov, P.V., Pederssen, P.B. 2012. Effects of stocking density and sustained aerobic exercise on growth, energetics and welfare of rainbow trout.*Aquaculture,*338-341:216-222. Doi: 10.1016/j.aquacultre. 2012.01/020.

Masser, M.P. 1997. Cage culture: Handling and feeding caged fish. *SRACPublication*, No 164.

Masser, M.P. 2008. What is cage culture*? SRAC Publication,*No. 160, July 2008.

Masser, M.P. and Bridger, C.J. 2007. A review of cage aquaculture. North America. In:Halwart, M., Soto, D. and Arthus (Eds). *Cage aquaculture- Regional reviews and global overview* pp. 102-125. *FAO Fisheries Technical Paper,*No. 498, Rome, FAO, 2007.

Masser M.P. and Woods, P. 2008. Cage culture problems. *SAR Publication,*No. 165.

Miline, P.H. 1972. *Fish and shellfish farming in coastal waters*. London. News (Books} Limited. 208p.

Moehl, J., Brummett, R. and Porizoni, R. 2006. Genetic Management of Aquaculture stocks in sub-Saharan Africa.*CIFA ocational Paper* No, 27 pp.65. Report of a producers' workshop, Accra, Ghana, 27 February – 3 March, 2006.

Mohanty, R.K. 2004. Density- dependent growth performance of India major carps in rain water reservoirs. *Journal of Appied Ichthyology,* 20:123-127

Monterio, D., Izquierdo, M.S., Tort, L., Robáina, L and Vergara, J.M. 1999. High stocking density produces crowding stress altering some physiological and biochemical parametersin gilthead seabream, *Sparus aurata*, juveniles. *Fish Physiology andBiochemistry*. 20:53-60, 1999 Kluwer Academic Publishers. Printed in Netherlands.

Mustapha, M.K. 2013. Potential impacts of Climatic change on artisanal fisheries of Nigeria. *Journal of Earth Sciences and climatechange* 2013, 4.1. Available fromhttp://dx.doi. Org/…

Musa, S.M., Aura, C.M., Ngugi, C.C. and Kundu, R. 2012. The effect ofthree different feed types on growth performance and survival of African catfish fry (*Clarias gariepinus*) reared in hatchery. *ISRN Zoology*, 2012, 1-6.

Nabirye, H., Nwebaza-Ndawula, L., Bugenyi, F.W.B. and Myodi, F. J. 2016. The evaluation of cage fish farming effects on water quality using selected bentic macro-invertebrate community parameters in the Napoleon gulf, northern Lake Victoria. *Int. J. Fish. Aquat. Stud,* 4(1): 42-50.

Naderi, M, Jafaryan, H. and Jafaryan, S. 2017. Effects of different stocking densities on hemayological parameters and growth performance of great sturgeon (*Huso huso* Linnaeus, 1758) juveniles. *ItalianJournal of Aquatic Animal Health,* 3(2):1-10.

Nairaland, 2014. Import quota for fish: In Review: Top 10 Government Policies in Nigeria in 2014. www.nairaland.com/2069 347/2014-review-top-10-government-polices.

Nairaland September 26, 2016. Can civil servant be a billonnaire while in service? Available from*www.nairaland.com/3050550/civil-servant-billonnaire-while-service.*

Narejo,N.T., Salam, M.A., Sabur, M.A. and Rahmatullah, S.M. 2005. Effect of stocking densityon growth and survival of indigenous catfish, *Heteroneustes fossilis* (Bloch) reared in cemented cisternfed on formulated feed.*PakistanJournal of Zoology,* 37(1): 49-52.

National Bureau of Statistics 2016. *Overview of GDP in quarter three*, 2015. Retrieved January 08, 2017 from *nigerianstat.gov.ng*-.

National Bureau of Statistics 2017. *Nigeria'sFish Production (2011-2015) Report*, February 2017,20pp.

National Mirror, 2014. Fishimport review a palliative measure for local production.Retrived March 10, 2015 from nationalmirroronline.net/news/fish-import-quota-review-a-pallat ive-measurre-for-local-production/.

Nene A. Jamabo and Aduabobo I. H. 2014. Overview of fish farming in Nigeria: Prospect and challenges, the River State experience *World AquacultureConference Adelaide*, June, 11, 2014.

Nettena, J.J.C., Heide, T. and Smolders, A.J.P. 2013. Interactive effects of pH, temperature and light during ammonia toxicity events in *Elodea Canadensis. Chemistry and Ecology,* 29(5): 448-4582013. http://dx,doi.org/ 10.1080/02755740.2013.769971.

Netti, A., Ainul, M., Azrita and Hafrijah, S. 2017. Efficiency and carcass composition of bonylipbarb (*Osteochilus vittatus Cyprinidae*) fingerlings.*PakistanJournal ofBiological Sciences,* 20(10):489-497. Available from: docsdrive.com/pdfs/ansinet/pjbs/2017/489-489-497.pdf.

Nigeria Fisheries Report 2013. Fisheries in Nigeria: Nigeria Fisheries Report to the Nigerian Government, November 12, 2013.

Nkamigbo, D. C., Ovuomarie, O. S., Maduka, J. U. and Isibor, A. C. 2014. Economic efficiencu and profitability of catfish (*Clarias gariepinus*) production in Isoko Area of Delta State, Nigeria.*Journal of Agriculture anVeterinary Science,* 6 (2): 32- 40.

Nordvarg, L. and Johasson, T. (2002). The effects of fish farm affluents on water quality in the Aland archipelago, Baltic Sea. *Aquaculture Engineering. 25: 253-279.*

North, B.P., Turnbull, J.F, Ellis, T., Porter, M.J., Migaud, h., Bron,J., and Bronege, N.R. 2006, The impact of stocking density on the welfare of rainbow trout (*Oncorhrynchus mykiss*). *Aquaculture*, 255:446-479.

Nwabazza-Ndawula, L., Kiggundu, V., Magezi, G., Naluwayiro,J., Gandhi-PABIRE, W. and Ocaya, H. 2013.Effect of cage fish culture on water quality and selected biological communities in northern Lake Victoria. *Uganda J. Agricul. Sci.* 14(2): 61-75.

Nwabeze, G.O. and Erie, A.P. 2013. Artisanal fisheries use of sustainable fisheries management practices in the Jebba Lake Basin, Nigeria. *J. Agric. Ext.,* 17:123-134.

Nwipie, G.N., Erondu, E. S. and Zabbey, N. 2015. Influence of stocking density on growth and survival of post fry of African mud catfish, *Clarias gariepinus. Fish. J. Aquacul.*6:116.

Odum, F. 2016. Fish supply deficit; Bridging gap; Boosting protein access. *TheGurdaian*

Nigeria News, January 03, 2016.Available from: https://guardian.ng/features/agro-care/fish-supply-deficit-bridging-gap-boosting-protein-access.

Offem, B.O., Ikpi, G.U. and Ada, F. 2010. Fish culture technologies in South- eastern Nigeria. *African Journal of Agricultural Research.*Vol. 5(18):2521-2528.

Ofonime, E. A. and David, G. S., 2017. Haematological Profile and growth of African catfish *Clarias gariepinus,* Burchell, 1822) fingerlings to locally formulated and pelleted diets in tarpauling tanks.*American Journal of Innovative Research and Applied Sciences.* 5 (6):213-222.

Ofor, C. O. and Afia, O.E. 2015. Effect of stocking densities on growth, and feed utilization of hybrid Catfish (*Clarias gariepinus* × *Heterobranchus longifilis*) fed 1% body weight. *American Journal of Biology and Life Sciences,* 3(6): 211-217. Available from http://www.openscienceonline.com/journal/ajbl

Oguguah, N.M., Nwadukkwe, F., Atama, C. and Eyo, J.E. 2011. Growth performance of hybrid catfish (*Heterobranchus bidorsalis*×*Clarias gariepinus*) at various stocking densities in varied cultured tanks. *Animal Research International,* 8:1419-1430.

Olagunju, F.I., Adesiyan, I.O. and Ezekiel, A.A. 2007. Economic viability of catfish production in Oyo State, Nigeria. *Journal of Human Ecology,* 21(2):121-124

Olanipekun, O.E., 20014. Growth performance of juvenile Catfish, (*Clarias gariepinus*) fed with floating (imported) and formulated (sinking) pelleted feed in floating cages. MSc. Thesis, University of Abeokuta, Nigeria. Retrieved May 20, 2016 from http://journa Lunab.edu.ng/index.php/thesis/view/5226.

Olaoye, O.J., Ezeri, G.N.O.,Akegbejo-Samson, T., Awotunde, J.M. and Ojebiyi, W.G. 2016. Dynamics of adoption of improved aquaculture technologies among fish farmers in Lagos State, Nigeria. *Croatian Journal of fisheries,* 2016,vol.74: 56-70.

Oliveira, E., Pinheiro, A.B., Oliveira, V.Q, Silva junior, A.R.M., de Moraes, M.G., Rocha, I.R.C.B., de Sousa., R.R. and Costa, F.H.F. 2012. Effect of stocking density on the

Performance of juvenile Pirarucu *(Arapaima gigas*) in cages. *Aquaculture, 370-*371 (2012) 96-101. Available from: www.elsevier.com/locate/aqua.online.

Olukunle, O. A. 2004. *Homestead pond management.* Optimistic Printing press, Mokola, Ibadan. 94 pp.

Omitoyin, B.O. (2007).*Introduction to fish farmingin Nigeria*. Ibadan University press, University of Ibadan. 35- 40 pp.

Omitoyin, S.A. and Fregene, T.B. 2012.Potential impact of climate change onlivelihood and food security of artisan fisher folks in Lagos State, Nigeria. *Journal of Agricultural Science.* 4(9): 20-30).

Ornamental Aquatic Trade Association (OATA), *2008. Water Quality Criteria- ornamental fish.* Available from https;//www.ornamentalfish.org/wp-contents/uploads/2012/08/ Water- Quality'Criteria.pdf.

Osofero, S.A., Otubusin, S.O. and Daramola, J.A. 2009. Effect of stocking density on tilapia *(Oreochromis niloticus*) Linnaeus 1757) growth and survival in bamboo-net cages trial. *African Journalof Biotechnology*, 8:1322 – 1325.

Osondu, C.K. and Ijoma, J.C. 2014. Analysis of Profitability and production determinants of farming in Umuahia Capital Territory of Abia State, Nigeria. *World Journal of Agricultural Sciences 2(7):168-176.* Available from http://wsrjournals.org/journal/wjas.

Osun State Fisheries Statistic 1994. Fisheries Statistics. Osun State Ministry of Agriculture and Natural Resources, Fisheries Department, 1994. 34 pp.

Otubusin, S.O., Ayanda, J.O., Opeloye, G.O. and Asekome, I.G. 1991. Economic feasibility of cage fish farming. *In: Proceding of the 4th Annual Seminar of the committee of Directors of Research Institutes held at the NIOMR, Lagos on December 10,1991.*71-84pp.

Otubusin, S.O., and Osofero, S.A., Olaofe, O.O., Agbebi, O. T. 2007. High yields and growth of catfish (*Clarias gariepinus)* in floating bamboo net-cages system trials in South Western Nigeria. *European Journal of Scientific Research.* Vol. 16 No.2: 238-244.

Ozigbo E., Anyadike C, Adegbite, O. and Kolwawole P., (2014). Review of aquacultureproduction and management in Nigeria. *American Journal of Experimental Agriclture* 4(10):1137-1151. Retrived Oct.18, 2015 from: http://eprints.convenantuniversity.edu.ng/ 3561/1/AJEA.

Palíková. M., Kopp, R., Mareš, J., Navarátil, S., Kubíček, Z., Chmelăr, L., Baudouchová, H and Pikula, J. 2000. Selected haematological and biochemical indices of Nile tilapia (*Oreochromis niloticus*) reared in the environment with Cyanobacterial water bloom. *Acta Vet Brno,* 79: 563-571.

Pauly, 1984. Fish Population Dynamics in Tropical Waters: *A manual for use with Programmable Calculators.ICLARM Studies and revision,*8: 325 pp.

Pearson, M.P. and Steven, E.D. 1991. Size and hematological impact of the splenic erythrocyte reservoir in rainbow trout, *Oncorhynchus mykiss. Fish Physiology and* . *Biochemistry*, 9:39-50.

Pickering, A.D., 1984. Cortisol- induced lymphocytopaenia in Brown trout, *Salmotritta* L. *General and Comparative Endocrinology,*53:252-259.

Pillay, T.V.R. and Kutty, M.N. 2005. Nutrition and feeds: In Aquaculture Principles and Practices, 2nd edition, Blackwell Publishing Limited, pp.105-173.

Pontoh, O. 2012. Analysis of fisheries business on floating net cages in Tandengan village Minahasa Regency, North Sulawesi. *Pacific Journal of Fisheries,* 2: 1424-1428.

Pouomogne, V. 2010. Culture Aquatic Species information Programme. *Clarias gariepinus.* Rome. FAOFisheries and Aquaculture Department.

Premium Times, 2016. Nigerians consume 3.2 million tonnes of fish annually. *Premium TimesNigeria*Aug.17, 2016.Available fromhttps://.premiumtimesng.com/news/more/news/ more-news/208762-nigerian-consume-3.million-tonnes-fish-annually.

Proshare, 2016. Boosting domestic fish production in Nigeria.*Proshare,* June o6, 2016. 2016.Available fromdomestic-fish-production-in-Nigera/31289.

Rahman, M.M., Islam, M.S., Halder, G.C. and Tanaka, M. 2006. Cage Culture of Sutchi catfish. *Pangasius sutchi* (Fowler, 1937). Effect of stocking density on growth, survival, yield and farm profitability. *Aquaculture Research*, 37:33-39.

Rahman, M.A., Habib, K.A., Oasiqul, S.M. and Rayhan, M.Z. 2017.Impacts of stocking density and economic returns on the cage culture of stinging catfish, *Heteropneutes fossilis. International Journal of Fisheries and Aquaculture Studies,* 5(4): 198-201.

Ricker, W.E., 1975. Computation and Interpretation of Biological Statistics of Fish Population.

Fisheries Research Board of Canada, Bulletin, 191 pp.

Robert, M.D., David, M.C. and Martin, W.B. 1997. *Ammonia in Fish Ponds. South Regional Aquaculture Centre (SRAC). Publication,*No.46

Roques, J.A., Abbink, W., Chereau, G., Fourneyron, A., Spanings,T., Burggraaf, D., Bos., R V, H. and Flix, G. 2012. Physiological and behavioral responses to an electrical stimulus in Mozambique tilapia (*Oreochromis mossambicus*). *Fish Physiol. Biochem.,* 38(4): 1019 -1028.

Ross, L.G., Telfer, T.C. Falconer, L; Soto, D. and Aguilar – Manjarrez, J.eds. 2013. Site selection and carrying capacity for inland & coastal aquaculture. FAO institute of Aquaculture, University of Stirling, Expert Workshop, 6-8 December 2010. Stirling, the United Kingdom of Great Britain and Northern Ireland. *FAO, fisheries and Aquaculture proceedings* No. 21, Rome, 46 pp. Retrieved Jan. 30, 2015 from www.fao.org/decrep.0.17/i3099e00.htm.

Rowland, S.J., Mifsud, C., Nixon, M. and Boyd, P. 2006. Effect of stocking density on the performance of the Australian freshwater silver perch (Bidyanus bidyanus) in cages. *Aquaculture,*253:301-308.

Rowland, S.J. Lando, M., Callinan, R.B., Allan, G.L.; Read, P., Mifsud, C, Nixon, M., Boyd, P. Tully P., 2007.Development of a health management strategy for the silver perch aquaculture industry. *Final Fisheries Report to Fisheries Research and Development Corporation on Projects 200/267 and 2004/089. NSW Department of Primary Industries*. No. 93 NSW Department of Primary Industries, Cronulla, NSW, Australia.

Roy, P.S., 2014. Prospects of cage culture of *Puntitus sarana, Mystus vittatus and Macrobranchium rosenbergii in lentic aquaculture environment.* A M.Sc. Thesis of Bengal Univ. Anim.Fish.Sci. Chakgania, Panchasayer, Kolkata, pp.81.

Ruane, N.M.,Carballo,E.C. and Komen,J.2002. Increased stocking density influences the acute physiological stress response of common carp (Cyprinus carpio L.).*Aquaculture Research,* 33:777-784.

Rurangwa, E., Agyikwah, S. K. and Boon, B. C. 2015. Development of Aquaculture in Ghana: Analysis of the fish value chain and potential business cases. IMARES report C021/15. 58 pp.

Rusell, S., 2009. Fish Pond Water quality: As Simple Chemistry 101: Available online from http:www.noble.org/news.and-views/2009/…

Sahoo, S.K., Giri, S.S. and Shahu, A.K. 2004. Effect of stocking density on growth and survival of *Claries bratrachus* (Linn.) larvae and fry during hatchery rearing. *J. appl Icth.*.20:302-305.

Sahoo, S.K., Giri, S.S., Chandra, S., Sahu, A.K. 2010 stocking density-dependent growth and survival of Asian sun fish, *Horabagrus brahcysoma* (Gunther 1861) larvae. *J. Appl.ichthyol*. 26:609-611.

Sanchez, P., ambrosia, P.P., and Floss, R. 2010. Stocking density and sex influence individual growth kof Senegalese sole (*Solea senegalensis. Aquaculture,* 300: 93-101.

Sandfoss, M. 2003. Cage construction. Northern Carolina Cooperative extension, Northern Carolina State University and NCA & T State University. Available online fromhttps://mcdowell.us.ncsu.edu/cage.construction.

Santhosh, B. and Singh, N.P. 2007. *Guidelines for water quality management for fish culture in Tripura, ICAR Research Complex for NEH Region, Tripura Center.* Publication No. 29.

Santo-Agro, 2017. Floating fish pellets feed Vs Sinking fish pellets feed. Available online from
www.santo-agro.com/newsshow-2-39.html.

Sarker, M.R.U., Khan, S and Haque, M.M., 2005.Production and economic return in

Pangasiid catfish (*Pangasius hypophthalmus*). *Bangladesh J. Res.,* 9 (2): 111-120. Available from aquatic commons.org/17976/1/EJFR9.2_111pdf.

Sarker, M.A.M., Arshad, F.M., Alam, M.F., Mohamed, Z.A and Khan, M.A., 2014. Economics of Thai Koi (Climbing perch, *Anabas testudineus*) farming in pond in Bangladesh. *Trends in Agricultural Economics*, vol. 7(1): 26-40. Retrieved October 16, 2015 from https://scialert.net/abstract/?doi=tae.2014.26.40.

Satapornvanit, A.N., Villacorta, G., Sermwatanakul, A., Nakksung, K., Sochivi, K., Minh, T.H., Gopal, N. and Virapat, C. 2015. Women's involvement in selected aquaculture value chains in Cambodia, Thailand, and Vietinam. Reader. Retrieved Dec. 15, 2015 from Sataponvanit_453_71.pdf-Adobe.

Satheeshkumar, P. Ananthan, G. Kumar, D.K and Jagadeesan, L. 2012. Haematological parameters of different feeding behavior of teleost fishes from Valley estuary, India. *Comp. Clinic. Pathol*.21(6):1187-1191.

Satia, B. 2010. Aquaculture development in Africa: Current Status and Future Prospects. Global Conference on Aquaculture. Retrieved June 14, 2015 fromwww.enacaorg/?d=170.

Schmittou, H.R., (1969). The culture of channel catfish, Ictalurus punctatus (Rafinesque), in cages suspended in ponds. *In proceedings of 23rd Annual Conference of Southeastern Association of Game and Fish Commissioners, 1969.*

Schmittou, H.R. 1991. Guidelines for raising principally omnivorous carps, catfishes and tilapias in cages suspended in Freshwater Ponds, Lakes and Reserviors. *In proceedings of the People's Republic of China Aquaculture and Feed Workshop.*Akiyyama, D. Editor, 1989. America Soybean Association, Singapore, 24-42 pp.

Schmittou, H.R., 2006. *Cage culture. In C.E Lim and C.D. Webster (Eds.), Tilapia Biology, Culture and Nutrition,* pp. 181-210.

Schram, E. Vander Heul, J.W. Kamstra, A. and Verdegem, M.C.J. 2006. Stocking density dependent growth of Dover, (*Solea solea*).*Aquaculture* 252: 239 – 247.

Seguin, L.R. 1970. Rearing trout in a floating cages. *Am.Fish Farmer,* 1(4): 19.

Selosse, P.M., and Rowland, S.J. 1990 Use of common salt to treat ichthyophthiriasis in Australian warmwater fishes. *The Progressive Fish-Culturist*, 52, 124-127.

Silva, P.C., Souza, V.L., Padua, D.M.C., Dalacorte, P.C., and Gonclaves, D.C. 2000. Effect of stocking density on growth and fillet composition of tetra hybrid Red tilapia, Israeli Strain. *In: Tilapia Aquaculture in the 21st Century*: *Proceedings from 5th International Symposium on Tilapia Aquaculture,*(ed. by Fitzsimmons, K. and J.C. Filho), pp. 341-345.

Silviyanun, 2013. Analysis of floating net cage fish farming in LautTawarr Lake Aceh Province, Indonesia. Thesis, Department of Geography Education, Faculty of Social Science, State University of Medan.

Skelton, P. H. 1993. Acomplete Guide to the Freshwater Fishes of South Africa 1st edition (January, 1993) 390 p.

Solis, N.B. 1988. The Biology and Culture of Penaeus monodon. Department papers. SEAFDEC Aquaculture Department, Tigbouan, Boilo, Philippines, pp 3-36. Cited by Bhatnagar and Devi (2013).

Soltan, M. 2016.Cage culture of freshwater fish. Retrieved January 23, 2017, from www.researchgate.net/publication/cage_culture_of_freshwater_fish.

Sørensen, M.A. 2012. A review of the effects of ingrident composition and processing conditions on the physical qualities of extruded high-energy fish feed as measured by prevailing methods. *Aquacult. Nutr.* 18(3):233-248.

Soto, D. and Norambuena, F. 2004. Evaluaton of salmon farming effects on marine system in the inner sea of southern Chile: a large-scale mensurative experiment. *Journal of Applied Ichtyology,*20:493-501.

Stone, N.M. and Thomforde, H.K. 2004. Understanding your fish pond water analysis report. Cooperative extension programme University of Arkansa at Pine Bluff Aquaculture/ Fisheries.

Sugunan, V.V., and Katiha, P. 2004. Impact of stocking density on yield in small reservoirs in Andra-Pradesh, India. *Fisheries Management and Ecology,* 11:193-202.

Sugunan, V. V., Tripathi, S.D and Cruz, J.D. 2016. *Guildlines for Cage Culture in Open Water Bodies of India. National Fisheries Development Board, Govt. of India.*

Suleiman, M. A. and Solomon, R. J. 2017. Effect of stocking density on the growth and survival of *Clarias gariepinus* grown in plastic tanks. Direct Journal of Vetrinary Medicine and Animal Science. 2(3): 82-92. Available fromhttp://directresearchpublisher.org/journal /drjvmas.

Swann, L., Morris, J.E., Selock, D., Riepe, J. 1994. Cage culture of fish in the Northern Central Region. *Technical Bulletin Series No.110, U.S. Department of Agriculture* 3850 – 4319, December, 1994.

Swingle, H. S., 1969. Methods of Analysis for water, organic matter and pond bottom soils usad in Fisheries Research.Auburn University, Auburn, Alabama, 199p.

Syandri, H., Elfiondri, Junaidi, Azrita. 2015. Social Status of the fish- farmers of floating net-cages in Lake Maninjau, Indonesia. *J. Aquac.Res. Development,* 6:391.

Tacon, A.G., de Silva, S.S. 1997. Feed preparation and feed management strategies within semi-intensive fish farming systems in the tropics. *Aquaculture;* 15(1):318-322).

Tacon, G.J. and Halwart, M. 2007. Cage aquaculture: a global overview. In Halwart, M., Soto, D., Ahrtur,J.R. (Eds.), cage aquaculture- Regional Reviews and global Overview. *FAO Fisheries TechnicalPaper,* No. 498, Rome, pp.4-20.

Tan, C., Sun,D., Tan, H., Liu, W., Luo, G and Wei, X. 2018.Effects of stocking density on growth,bodycomposition, digestive enzymes levels and blood biochemical parameters of *Anguilla marmorata* in a Recirculating Aquaculture System. *Turkish Journal of Fisheries andAquatic sciences,* 18:9-16. Retrieved May, 26, 2016, from https://pdfs.semanticssolar.org/35ec/ed2cl/afa2cl3e9486002al961eefb09a.pdf/.

Teodorowicz, M. 2013. Surface water quality and intensive fish culture. *Arch. Pol. Fish*, 21: 65-111.

Teugels, G. G. 1996. A systematic revision of the African species of the genus *Clarias* (Pisces); Clariidae. *Annales Musée Royale de l'Afrique Centrale Sciences Zoologiques,* 247.

The Fish Site, 2007. Medium-term challenges and constraints for aquaculture. *The fish Site*. April 23, 2007. Available from: https//thefishsite.com/articles/mediumterm-challenges-
and-constraints-of-aquaculture.

The Fish Site, 2010. Stocking Density: does it Matter?*The Fish Site,* October10, 2010. Retrieved onlineNovember 15, 2015. Retrieved January 20, 2015 from https://www. thefishsite.com/articles/stocking-density-does-it-matter?

The Fish Site, 2014. Water quality monitoring and management for catfish ponds. *The Fish Site*, June 23, 20014.Retrieved December. 20, 2015 fromhttps://thefishsite.com/ Articles/water-quality-monitring-and-management-for-catfish-ponds.

The Fish Site, 2015. *How to achieve good water quality management in aquaculture*. *The Fish Site,* June 26, 2015. Retrieved December 20, 2015 from https//the fishsite.com/article/
how- to-achieve-good-watr-management-in-aquaculture-.

Thompson,A.O. and Mafimisebi, T.E.2014. Profitability of selected ventures in catfish aquaculture in Ondo State,Nigreia. *Nigeria Fisheries and Aquaculture Journal,* 2014, 5:2-7.

Tijani, B. 2011. Federal Ministry of Agriculture and Rural Development action plantowards the attainment of a sustainable Agricultural Transformation Agenda in Nigeria. *Being a Lead Paper Delivered at the World Food Day Seminar, Agricultural Show Ground Koffi Road, Abuja Nigeria,*pp. 1 - 10.

Toko, I., Fioghe, E.D, Koukpoda, B., Kestemont,P. 2007. Rearing of African catfish (*Clarias gariepinus)* andVundus catfish *(Heterobranchus longifils)* in traditional ponds(whedos).Effect of stocking density on growth, production and body composition. *Aquaculture,* 262(1): 65-72.

Tonya, M.C., Alistair, D.M.D and Jill, E.A. 2008. Hematologic Disorder of Fish. *Veterinary Clinics Exotic Animal* 11(3): 445-462.

Trotter, C.W. 1970. Why cage Culture? *Farm Pond Harvest,*4(1)8-11.

Tumusiime, R. P. 2014. Introductory remarks of DREA, commissioner SA delivered at the Roundtable of African Ministers of Fisheries and Aquaculture on April 30, 2014 at Addis Ababa, Ethopia.

Tunde, A. B., Kuton,M.P.,Oladipo, A.A. and Olasunkanmi, L.H. 2015. Economic analysis of cost and return of fish farming in Saki LGA of Oyo State, Nigeria.*Journal of Aquaculture and Research Development* 6:306.

Turnbull, J.F., Bell, A., Adams, C., Bron, J. and Huntingford, F.A. 2005.Stocking density and welfare of cage farmed Atlantic salmon: application of multivariate analysis, A*quaculture,*243:121-132.

Ugbajah, M.O. 2014. Provision of credit and loan facilities by Nigerian Agricultural Cooperative and Rural Development Bank (NACRDB) toFarmers: Implications for extension delivery. *Greener J. Agric. Sci.*4(5):199-204.Available from: http://dx.doi. Org./1o.15580/GJAS.2014.5.011014028.

Ugwumba, C.O. A. 2005. The economics of Homestead Concrete Fish Pond in Anambra State, Nigeria. *African Journal of Fisheries and Aquaculture.*4: 28-32.

Ukuedojor,M. January, 05, 2013. Adequate drinking water sill a tall dream in Nigeria. *Weekly Trust*, Sat. 05 Jan. 2013.

Umaru, J., Auta, J., Oniye, S. J. and Bolorunduro. 2016. Growth and economic performance of African catfish, *Clarias gariepinus* (Buechell, 1822) juveniles to imported and local feeds in bamboo cages. *International Journal of Fisheries and Aquatic Studies,* 4 (2): 221-226.

UNDESA, 2015. World population projected to reach 9.7 billion by 2050. Available from: https:/www.un.org/en/development/desa/news/population/2015-report.html.

USAD (2014). Nigeria Introduces Import Quota on fish-USDA. *Gain.fas.usda.gov/Recent Publications/Nigerian… PDG file.*

Vaishnav, M., Sharma, S.K., Shaema, B.K. and Ojha, M.L. 2017. Growth performance of Pangasius species cultured at different stocking densities floating net cages in Mahi Bajaj Sagar Dam of Banswara (Rajasthan). *Journal of Entomology and Zoology*

Studies, 5 (5): 649-652. Retrived Oct. 17, 2017 from www.entomoljournal.com//archives/2017/vol.5 issue5/Part/5-4-38-179.

Vanguard, 2017. Lagos State Government harvests 50 tonnes of catfish in 6 Months via cage culture system. *Vanguard News,*February 12, 2017. Retrived March 10, 2017 from http://www.vanguard. Com/2017/02.

Vanguard, 2018. Reps move for Nigeria's self-sufficiency in fish production. *Vanguard News.*January 26, 2018.Retrieved Feb. o2, 2018 fromwww.vanguardng.com/....

Vidzro, F.M., 2014. Environmental and socio-economic impacts of cage aquaculture at Kpeve Tornu section of Volta Lake. Master of Philosophy (M.Phl) Thesis, University of Ghana, Legon.x+112pp. Available on fromhttp://ugspace.u.gh/handle/123456789/21128.

Wijsman, I.J. 2015. Mission report on carring capacity cage farming in Nigeria. Available online from library.www.wur.nl/WebQuery/wurpubs/fulltex/328537.

WIKIPEDIA: Goegraphical Coordinates of Lagos, State, Nigeria. Available online fromhttps:// en.wikipedia.org/wiki/Lagos_State.

WIKIPEDIA;Goegraphical Coordinates of Ogun State, Nigeria. Available online from https:// en.wikipedia.org/wiki/Ogun_State.

WIKIPEDIA; Goegraphical Coordinates of Osun State, Nigeria. Available online from: https:// en.wikipedia.org/wiki/Osun_State.

Williams, S.B, Kareem, R.O. and Ojolowo, O.A. 2012. Economic analysis of catfish production in Ile-Ife, Osun State, Nigeria. *Journal of Human Ecology*, 40 (1):1-7.

Wilson, R.P. 1989.Amino acid Protein requirement of fish. In: *nutrion and feeding in fish.* Academic Press London.

World Bank, 2014. *Fish Farms to Produce Nearly Two Thirds of Global Food Fish supply by 2030.*Retrived June 14, 2015 from http://www.worldbank.org/en/news-press-release/ 2014/02/05/fish-farms-global-food-fish supply-2030.

Wurts, W.A. and Durborow, R.M., 1992. Interactions of pH., Carbon Dioxide, Alkalinity and Hardness in Fish ponds. *SRAC publication.*No. 464.

Xiangping, L. 2006. The Essentials of cage culture. *A paper presented at National Programme on food security (NPFS) fish cage culture training workshop held at Maizube farms, Minna, Niger State*, 10-13 (unpublished).

Yi, Y., Lin, C. K. and Diana, J. S. 1996. Influence of 9*Orechromis niloticus)* stocking density in cages on their growth and yield in cages and ponds containing the cages. *Aquaculture,* 146: 205-215.

Yokogawa Electrical Corporation, 2016. pH in fish farming. Available from https://www. yokogawa.com/library/resources/application-notes/ph-in-fish-farming/

Zusková, E., Máchová, J., VeliŠek, J., Statrá, A., Svobodová, Z and Kroupová, H.K. 2013. Recovery of rainbow trout (*Oncorhynchus mykiss*) after subchronic nitrite exposure. *Act.Vet.Brno,* 82:073-079. Retrieved May 30, 2015 from https://actvet.vfu/media/pdf/.

APPENDICES

APPENDIX 4.1.1: SOCIO-ECONOMIC SURVEY STUDY OF FLOATING NET CAGE FARMERS IN LAGOS, OGUN AND OSUN STATE, NIGERIA

QUESTIONNAIRE

Dear Respondent,

This study is been conducted mainly to obtain information on socioeconomic impact of cage culture in South West Nigeria. Confidentiality is guaranteed as the study is only required for research purposes.

Thank you in anticipation for your cooperation.

Instruction: Pleas tick or fill as appropriate.

DEMOGRAPHIC CHARACTERS

1. Name of respondent/farmer**……..**
2. Location of Farm**:** Town/village……Local Government Area……State……..
3. Marital Status**:** Single ( ); Married ( ); Widow/ Widower ( ).
4. Sex: Male ( ); Female
5. Numbers of children:……..
6. Educational Level:Did not go to school ( ); Primary School ( ); Polytechnic( );University ( )
7. Age Range:20 years and below ( ); 21 -30 years ( ); 31-40 ( ); 41-50 ( ); 51-60 ( );61years and above ( ).

TECHNICAL

1. How many cages do you have? .....
2. What species of fish do you culture? .....
3. How many cages are for:
   a. *Clariasgariepinus*……
   b. *Tilapia*……..
4. How many persons are involved in this project?
   a. Owners / shareholders …….
   b. Employed workers ……
   c. Others (specify) ……..

5. What is the size of cage? ; Length …….; Breath …….; Depth ……

6. Are all cages of the same sizes? If not please specify ……

7. How long can the net cage last? ……Years

8. Source of fingerling/juvenile fish?Catfish andtilapia……

9. What are the purchased size of the fingerling/juvenile? ……

10. In your opinion what size is the best?

a. Fingerling……

b. Juvenile ……

Why? ……

11. What are the current prices (ex-farm) of the fingerling to juvenile?

Species Length/weightPrice

a. Cat fish

b. Tilapia

13. How long is the culture cycle?

a. Catfish ……..

b. Tilapia ……

c. Other species (specify)…….....

14. What is the stocking density by species and size? .....

Catfish.....

Tilapia.....

15. What is the type of fish dietused in feeding the fish?.

a. Floating pelletized type ……

b. Sinking pelletized type …….

TRAINING

1. How many years' experience do you have in cage culture? ……..years
2. Do you obtain any technical aid or advice from any government institution e.g. Federal or state fisheries department or Agricultural Development Programme (ADP). Yes ( ) ;No ( )

MANAGEMENT

1. When did you start cage culture operation? …….

2. What is the arrangement to secure security of your fish?

a. Night guard/watchman.

b. Others (specify)

3. Do you experience any management problems or difficulties in fish cage culture since operation commenced?

a. Lack of skilled man power

b. Lack of knowledge

c. Loss/damage of cage and equipment

d. Poaching of fish

e. Lack of fingerling/juvenile

f. High cost of overall operation

g. Low survival rate

h. Others (specify)

FINANCIAL ANALYSIS

1. What is the cost of making a cage of specify size used in your farm?
2. What is the economic live of the cage? (……..years)
3. How many cages were stocked? (……..cages)

Species and numbers stocked

a.

b.

Total numbers fish stocked ……

Total cost of fingerlings/juveniles (₦……..)

4. Average total cost of feed:
   a. Per month (₦……)
   b. Per culture cycle (₦……..)
5. Labour cost: Numbers of labourers? ……

Salary per month: ₦……..

6. Total miscellaneous cost such aschemicals, drugs etc. ₦…….
7. What was the harvest in kilogramme by fish species
8. a.*C. gariepinus*

   b.Tilapia

   c. Other species
9. What was the annual revenue from the harvest by species?

   a. ₦……

   b. ₦……..
10. Numbers of fingerling/juveniles purchased by species

    a.

    b.

11. Is cage culture fish farming profitable?

Appendix 4.2.1: ANOVA Test of within-subject effect of the treatments on fortnightly weight increase of *C. gariepinus* reared in floating net cages

Source	SS	Df	MS	F	Sig.	Remarks
Diet	23854.053	1.000	23854.053	861.087	0.00	Main effect is significant in the model
Diet * Days	72095.340	10.00	7209.534	260.251	0.00	Interactive effect is significant in the Model
Error(Diet)	609.450	22.00	27.702			
Density	625630.077	2.00	330500.449	8048.960	0.00	Main effect is significant in the model
Density * Days	251357.607	19.00	13278.422	323.381	0.00	Interactive effect is significant in the Model
Error(Density)	1710.017	42.00	41.061			
Diet * Density	23881.534	2.00	12131.238	309.488	0.00	Interactive effect is significant in the model
Diet * Density * Days	24420.594	20.00	1240.507	31.647	0.00	Interactive effect is significant in the Model
Error(Diet*Density)	1697.623	43.00	39.198			

Significant difference at $p<0.05$

Appendix 4.2.2 Mean fortnightly weight increase of *C. gariepinus* among treatment groups for the periodof experiment

Days	SD_1-EFD	SD_2-EFD	SD_3-EFD	SD_1-PSD	SD_2 –PSD	SD_3- PSD
0	70.00±0.03^{a}	70.00±0.04^{a}	70.00±0.04^{a}	70.02±0.02^{a}	70.00±0.05^{a}	69.98±0.01^{a}
15	117.83±2.31^{a}	114.23±4.33^{a}	103.00±2.03^{ab}	115.30±1.76^{a}	108.53±4.33^{ab}	100.00±1.73^{ab}
30	145.33±2.60^{a}	144.67±3.18a^{a}	139.35±1.15^{b}	142.33±2^{a}	136.33±1.45^{b}	135.00±1.76^{b}
45	296.33±1.20^{a}	215.00±1.45^{a}	210.00±2.08^{a}	206.38±4.04^{a}	197.33±1.20^{b}	194.75±0.58^{b}
60	327.17±2.31^{a}	323.15±2.03^{a}	287.33±0.58^{b}	314.00±2.31^{a}	299.33±6.06^{b}	255.00±0.33^{b}
75	447.50±2.52^{a}	436.00±1.15^{a}	398.00±2.60^{b}	426.00±2.08^{a}	419.33±2.60^{a}	375.67±3.76^{b}
90	665.63±22.21^{a}	612.67±1.53^{a}	476.00±2.03^{c}	586.00±5.21^{b}	567.67±6.96^{b}	456.67±3.46^{c}
105	778.67±0.88^{a}	756.33±1.45^{a}	589.00±1.15^{c}	726.00±21.07^{a}	668.33±4.3^{ab}	553.00±0.58^{c}
120	892.67±1.73^{a}	858.67±3.48^{a}	648.67±2.33^{c}	806.33±3.28^{a}	760.67±1.20^{b}	601.00±1.15^{c}
135	999.89±18.84^{a}	897.67±1.20^{b}	713.33±2.91^{c}	856.00±4.04^{b}	820.00±5.51^{b}	660.67±1.73^{d}
150	1178.33±3.18^{a}	992.33±3.48^{b}	805.33±5.46^{d}	973.00±11.55^{b}	885.33±3.76^{c}	739.33±2.03^{e}

Mean ±Std. Error values with the same superscript are not significantly different along the row at 5% level ($p>0.05$)

SD_1-EFD = Stocking density of 100 fish/m^3 with extruded floating diet, SD_2-EFD = Stocking density of 200 fish/m^3 with extruded floating diet, SD_3-EFD = Stocking density of 300 fish/m^3 with extruded floating diet, SD_1-EFD = Stocking density of 100 fish/m^3 with pelleted sinking diet, SD_2-EFD = Stocking density of 200 fish/m^3 with pelleted sinking diet, SD_3-EFD = Stocking density of 300 fish/m^3 with pelleted sinking diet.

Appendix 4.2.3. Summary of ANOVA test of within-Subject effect of treatments on mean length of *C. gariepinus* for the period of experiment

Source	SS	DF	MS	F	Sig.	Remarks
Diet	6.952	1.000	6.952	25.775	0.00	Main effect significant
Diet * Days	10.793	10.000	1.079	4.002	0.00	Interaction effect significant
Error(Diet)	5.933	22.000	0.270			
Density	363.014	1.469	247.157	1033.603	0.00	Main effect significant
Density * Days	396.123	14.688	26.970	112.787	0.00	Interaction effect significant
Error(Density)	7.727	32.313	0.239			
Diet * Density	1.388	1.832	0.758	4.623	0.02	Interaction effect significant
Diet * Density * Days	46.082	18.321	2.515	15.345	0.00	Interaction effect significant
Error(Diet*Density)	6.607	40.307	0.164			

Significant at 5% level ($p>0.05$)

Appendix 4.2.4: ANOVA Models testing the effects of Diet and Stocking Density on growth and feed utilization parameters

	Source	S S	Df	M S	F	Sig.
Feed Intake (g)	Corrected Model	427145.	5.000	85429.15	39.200	0.00
	Intercept	21972851.69	1.000	21972851.69	10082.33	0.00
	Diet	74734.08	1.000	74734.08	34.29	0.00
	Stocking Density	341454.76	2.000	170727.38	78.34	0.00
	Diet × Stocking Density	10956.90	2.000	5478.45	2.51	0.12
Protein Intake	Corrected Model	86497.01	5.000	17299.40	39.200	0.00
	Intercept	4449502.47	1.000	4449502.47	10082.33	0.00
	Diet	15133.650	1.000	15133.65	34.292	0.00
	Stocking Density	69144.59	2.000	34572.30	78.339	0.00
	Diet × Stocking Density	2218.77	2.000	1109.39	2.51	0.12
Weight Gain (g)	Corrected Model	387465.01	5.000	77493.00	764.07	0.00
	Intercept	13177728.76	1.000	13177728.75	129930.21	0.00
	Diet	79298.88	1.000	79298.88	781.87	0.00
	Stocking Density	295968.49	2.000	147984.25	1459.10	0.00
	Diet × Stocking Density	12197.639	2.000	6098.82	60.13	0.00
Protein Efficiency Ratio	Corrected Model	0.075	5.000	0.015	2.69	0.07
	Intercept	52.99	1.000	52.988	9445.57	0.00
	Diet	0.020	1.000	0.020	3.630	0.08
	Stocking Density	0.04	2.00	0.02	3.186	0.08
	Diet × Stocking Density	0.02	2.00	0.01	1.720	0.22
Food Conversion Ratio	Corrected Model	0.04	5.00	0.01	2.385	0.10
	Intercept	30.36	1.00	30.36	8422.71	0.00
	Diet	0.01	1.00	0.01	2.998	0.11
	Stocking Density	0.02	2.00	0.01	2.730	0.11
	Diet × Stocking Density	0.01	2.00	0.01	1.734	0.22
Specific Growth Rate	Corrected Model	0.00	5.000	0.00	795.98	0.00
	Intercept	0.01	1.000	0.01	1060019.39	0.00
	Diet	0.00	1.000	0.00	776.568	0.00
	Stocking Density	0.00	2.000	0.00	1573.578	0.00
	Diet × Stocking Density	0.00	2.000	0.00	28.087	0.00
Total	Corrected Model	7.53	5.000	1.51	16.047	0.00

Length (cm)	Intercept	10110.42	1.000	10110.42	107684.947	0.00
	Diet	0.80	1.000	0.80	8.544	0.01
	Stocking Density	6.73	2.000	3.37	35.840	0.00
	Diet × Stocking Density	0.00	2.000	0.00	0.006	0.99
K-factor	Corrected Model	.00	5.000	0.00	17.931	0.00
	Intercept	0.07	1.000	0.07	9991.845	0.00
	Diet	0.00	1.000	0.00	25.294	0.00
	Stocking Density	0.00	2.000	0.00	29.423	0.00
	Diet × Stocking Density	0.00	2.000	0.00	2.757	0.10
Production Index	Corrected Model	17.13	5.000	3.43	596.991	0.00
	Intercept	577.08	1.000	577.08	100577.83	0.00
	Diet	3.48	1.000	3.43	597.52	0.00
	Stocking Density	13.19	2.000	6.60	1149.49	0.00
	Diet × Stocking Density	0.51	2.000	0.25	44.23	0.00
Survival Rate	Corrected Model	0.81	5.000	0.16	0.820	0.55
	Intercept	177310.13	1.000	177310.13	897632.51	0.00

Significant at 5% level ($p>0.05$)

Appendix 4.2.5: Bivariate Correlation among thegrowth and feed utilization parameters of fish in net cages under varying densities and feed forms

	Feed Intake (g)	Protein Intake	Weight Gain (g)	Protein Efficiency Ratio	Food Conversion Ratio	Specific Growth Rate	Total Length	K-factor	Production Index	Survival Rate
Feed Intake (g)	1	1.000**	.952**	.406	-.367	.954**	.836**	.908**	.953**	.228
Protein Intake	1.000**	1	.952**	.406	-.367	.954**	.836**	.908**	.953**	.228
Weight Gain (g)	.952**	.952**	1	.664**	-.631**	.997**	.895**	.932**	1.000**	.189
Protein Efficiency Ratio	.406	.406	.664**	1	-.999**	.658**	.651**	.564*	.661**	-.007
Food Conversion Ratio	-.367	-.367	-.631**	-.999**	1	-.626**	-.630**	-.526*	-.627**	.012
Specific Growth Rate	.954**	.954**	.997**	.658**	-.626**	1	.910**	.921**	.996**	.186
Total Length	.836**	.836**	.895**	.651**	-.630**	.910**	1	.678**	.896**	.210
K-factor	.908**	.908**	.932**	.564*	-.526*	.921**	.678**	1	.931**	.137
Production Index	.953**	.953**	1.000**	.661**	-.627**	.996**	.896**	.931**	1	.214
Survival Rate	.228	.228	.189	-.007	.012	.186	.210	.137	.214	1

***. Correlation is significant at the 0.01 level (2-tailed).*

**. Correlation is significant at the 0.05 level (2-tailed).*

Appendix 4.2.6: Summary of ANOVA of Cost and Return of C. Gariepinus reared at three stocking densities and two feed forms in cages

Variables	SS	Df	MS	F	Sig.
Yield					
Between Groups	46583.005	5	9316.601	2358.311	.000
Within Groups	47.406	12	3.951		
Total	46630.411	17			
Revenue					
Between Groups	12801974990.500	5	2560394998.100	1944.505	.000
Within Groups	15800799.000	12	1316733.250		
Total	12817775789.500	17			
Juvenile fish					
Between Groups	192000000.000	5	38400000.000	.000	.000
Within Groups	0.000	12	.000		
Total	192000000.000	17			
Feed Cost					
Between Groups	8630708042.706	5	1726141608.541	10066.232	.000
Within Groups	2057741.089	12	171478.424		
Total	8632765783.796	17			
Total variable cost					
Between groups	11816222981.185	5	2363244596.237	12653.733	.000
Within groups	2241151.614	12	186762.635		

Table 4.2.6 Cont'd

Variables	Sum of Squares	Df	Mean Square	F	Sig.
Total	11818464132.799	17			
Feed as % Total Cost					
Between groups	203.979	5	40.796	2587.470	.000
Within groups	.189	12	.016		
Total	204.168	17			
Juveniles as % Total cost					
Between groups	84.016	5	16.803	4610.660	.000
Within groups	.044	12	.004		
Total	84.060	17			
Total cost					
Between groups	11816222200.95	5			
Within group	2241151.694	.12	2363244440.185	12653.732	.000
Total	11818463352.619	17	186762.641		
Gross Revenue					
Between group	686703503.305	5	137340700.661	213.860	.000
Within groups	7706387.514	12	642198.960		
Total	694409890.819	.7			
Net Revenue					
Between Groups	686703503.305	5	137340700.661	213.860	.000

Table 4.2.8 11 cont'd

Variables	Sum of Squares	Df	Mean Square	F	Sig.
Within groups	7706387.514	12	642198.960		
Total	694409890.819	17			
Production Cost/kg of fish					
Between groups	31642.492	5	6328.498	380.512	.000
Within groups	199.578	12	16.632		
Total	31842.070	17			
Net Revenue/kg of fish					
Between groups	27145.445	5	5429.089	326.333	.000
Within groups	199.640	12	16.637		
Total	27345.085	17			
	.213				
Benefit cost ratio					
Between groups	.213	5	.043	294.800	.000
Within groups	.002	12	.000		
Total	.215	17			

Significant at 5% level (p>0.05)