CLARIID CATFISH AQUACULTURE: A PANACEA FOR QUALITY ANIMAL PROTEIN SECURITY

An Inaugural Lecture By

Prof Bernard Obialo Mgbenka

The Vice Chancellor, Professor Benjamin Chukwuma Ozumba,
Deputy Vice Chancellors (Academic, Administration and Enugu Campus),
Members of the Governing Council of this Great University of this Great University,
Other Principal Officers of the University,
The former 84 past inaugural lecturers of the University here present,
Distinguished professors,
Other academic and non-academic staff of the University
Ordained men and women of God,
Lions and Lionesses,
Distinguished Ladies and Gentlemen.

Preamble

It gives me great pleasure to stand before this august assembly in August to deliver 85th inaugural lecture of the University of Nigeria as the second inaugural lecturer from my Department of Zoology and Environmental Biology and 8th lecturer from the Faculty of Biological Sciences this time in our country's development when the government is giving required emphasis to agriculture including aquaculture. I am happy to be on those encouraging people to culture the clariid catfishes. From my time in school, I have looked forward to when Nigerian farmers will embrace fish culture.

This lecture will cover the following areas:

Catfishes and which of them are the big head (large) catfishes.

- Anatomy of catfish, zoogeography and systematics

2. Aquaculture
- Definition and early history of aquaculture
- Aquaculture in Africa including Nigeria
- Why culture and/or use the big head clariid catfishes?

3 Some of my clariid catfish researches to enhance the culture of the large catfishes.

I thank you for attending this 85th inaugural lecture despite your busy schedules. May I now invite you to please be patient and give audience. I promise not intend to keep you longer than necessary.

1. INTRODUCTION

a. Catfishes anddescription of the big head catfishes

Catfishesare a big group of whisker-bearing fishes which are widely distributed worldwide and live primarily in freshwater.Their greatest diversity in pan-tropical waters – South America, Africa and Asia – is noteworthy and they are associated especially with large rivers of Amazon, Niger and Zaire. Most catfishes prefer slow-flowing parts of lakes and rivers though a few like the South African *Amphilius uranoscopus* live in the rapids (Bruton, 1988). Catfish are usually hardy and adaptable. They are able to survive outside water for a good amount of time provided they are moist.

b. Anatomy, zoogeography and systematics

Anatomically, they possess a single long or short rayed dorsal fin. Some however, have a second non-rayed adipose fin. Others possess strong, sharp, pointed spines in the pectoral fin and/or dorsal fin. Catfishes derive their name from the whisker-like barbels that resemble those of cats which they have In the mouth region (Fig. 1). These are gustatory being used to sense or taste food. The eyes are small relative to their size compared to other non-catfish species. They all have swim bladders with help to buoy them up in water and Weberian apparatus in the inner ear. The apparatus which is a string of bones helps to connect the inner ear to the swim bladder. Some catfish can produce sounds with this structure. Some catfish can also produce electricity e.g. the electric catfish (*Malapteruruselectricus*) of the family Malapteruridae found in our rivers and widely distributed from Senegal to Ethiopia; fish is the only vertebrate that can generate electricity.

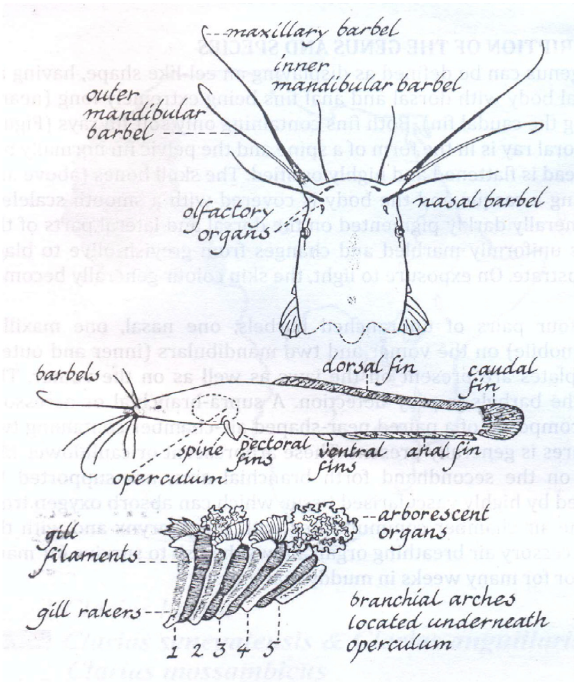


Fig. 1.Morphology of Clarias gariepinus (After Viveen et al., 1985)

In the systematics of catfish, they are grouped into the order Siluriformes, a name derived from the European catfish *Silurus,*family Siluridae found in the River Rhine and also found in Asia. *Silurus*is native to Europe. Up to 2000 species of catfish have been described with over 42 unidentified species. The catfishes of interest in this discussion are those of the Family Clariidae, characterized by breathing airusing aborescent organs in their opecular regioni.e. air-breathing catifishes. Using morphological characters such as form of vomerine teeth, ratio of vomerine to premaxillary teeth band and the number of gill rakers, five species of the large African catfish species were recognized within the subgenus *Clarias*. These included: *Clarias anguillaris, Clariasgariepinus*, *Clarias lazera*, *Clarias mossambicus*, *Clarias senegalensis.*

By revisions of the systematics of the genus *Clarias* by Teugels (1986) many widespread species have been synonymized under the name *Clariasgariepinus* (Fig. 2). These included*C.capensis* of southern Africa, *C. mossambicus* of central Africa and *C. lazera* of west and North Africa, and Asia Minor. Of the *Clarias* spp. , based on the number of gill rakers on the first branchial arch, only two species were considered to belong the subgenus *Clarias*, namely, C. *gariepinus* (with 20 – 100 gill rakers) and *C. anguillaris* (with 14 – 40 gill rakers) (Fig. 1). The *C. anguillaris* is separated from C. *gariepinus* majorly by the fact that *C. gariepinus* has pointed cleithrum.

In terms of distribution, *Clariasgariepinus* was reported to range from southern Natal and the Orange River, South Africa in the south northwards through central, west and North Africa through the Middle East and into Eastern Europe (Bruton, 1988). A study by Mwita and Nkwengulila (2008) has corroborated this revision. In their study, mitochondrial cytochrome b (cyt b) DNA sequence variation among seven species of clariid fishes of Lake Victoria and the Malagarasi wetland Tanzaniatogether with 26 cyt b sequences from GenBankwere used to construct phylogenetic relationships in the family Clariidae and two clades were revealed, namely, the big head species (*Clarias gariepinus* and *Heterobranchus longifilis*) and other small-sized species (*C. werneri, C. alluaudi, C. liocephalus and Clariallabes petricola*).

Few catfishes are amenable to being held in captivity and growing fast enough to large size at maturity within a short time to be acceptable for culture. *Clariasgariepinus*is one of the most important catfish species for tropical catfish aquaculture that meets these criteria.FAO described it as “one of the most important freshwater fishes of Africa … the total catch reported in 1999 was 27,220 t. the countries with the largest catches were Mali (15,091 t) and Nigeria (9, 994 t). It has been imported for purposes of aquaculture and game fish, marketed live, fresh and frozen; eaten broiled, fried and baked.”It is a very tasty and highly sought after fish native to Africa, Niger and Nile Rivers. It is, however, almost pan-African in distribution from the Nile to West Africa basins. It generally lives sympatrically with *Clarias anguillaris* in the regions where *C. anguillaris* is available (Fig. 4).*C. anguillaris* has no dorsal spine, has 60 – 82 dorsal soft rays, 16 – 40 rakers in the first branchial gill arch. *Clarias anguillaris* measures a maximum of 100 cm and weighs a maximum weight of about 7 kg while *C. gariepinus* measures up to 150 cm with a maximum weight of 60 kg.

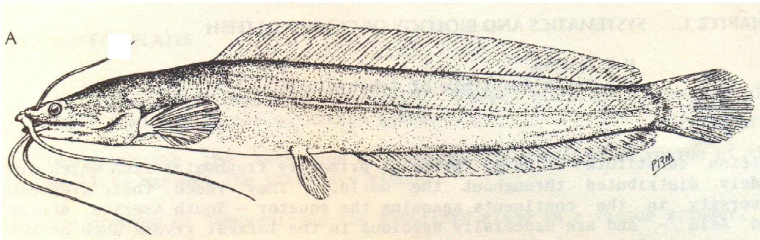


Fig. 2a. Clarias gariepinus After Bruton (1985)

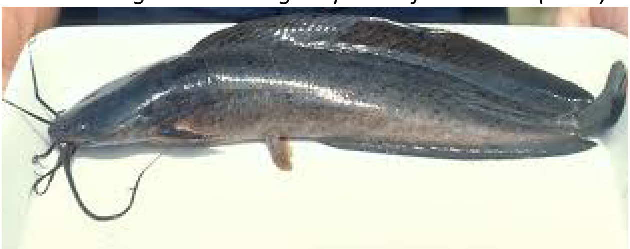


Fig. 2b. Farm gate Clarias gariepinus freshly out of water

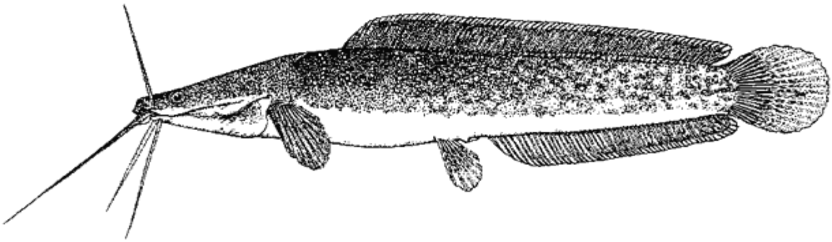


Fig. 3. Clarias anguillaris

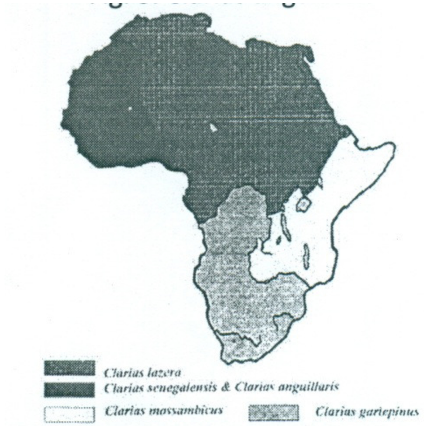


Fig. 4. Map showing the distribution of Clarias species in Africa.

Another large tasty, fast growing clariid of importance is the genus *Heterobranchus* which is native to Africa. The members of this species are closely related to*Clarias gariepinus* but morphologically *Heterobranchus* has adipose fin in addition to the dorsal fin (Fig. 5).The living and described members of this species include: *Heterobranchus bidorsalis, H. boulengeri, H. isopterus* and *H. longifilis.* Mainly two members of this species, *Heterobranchus bidorsalis* and *Heterobranchuslongifilis* are of interest in this discussion. *Heterobranchus* have been reported to measure from 64.0 cm to 150 cm with *Heterobranchuslongifilis* reputed as being the largest freshwater species in southern Africa, reaching up to 150 cm and weighing up to 55 kg (Rainer and Pauly, 2011). This species, like *Clarias* is very wide spread in Africa. In its pan African distribution it is found:

a. In Central Africa in the Congo River basin, in lower Guinea, in the Cross, in Cameroun, Sanaga and Ogowe in Gabon.
b. In East Africa it is found in the Lake Tanganyika, Malagarasi River, Lake Rukwa drainage, Rufiji and Wami, lower Shire River, Lake Rukwa system, Lake Edward, Murchision Nile, and Lake Turkana (Seegers *et al*., 2004).

c. In Northeast Africa, it is found in Ghazal and Jebel system, White Nile, Nile and LakeNasser, Sudan, and in Ethiopia, Baro and Omo Rivers
d. In North Africa, however, though present in Lower Egyptian Nile, it is rare.
e. In southern Africa, it is found from the middle Zambezi and north into central Africa and Rovuma River.
f. In West Africa, it is found in Gambia, from upper Senegal, Niger, Benue, Lake Chad, Volta and coastal basins from Guinea to Nigeria including the Niger delta and Cross River in Nigeria.

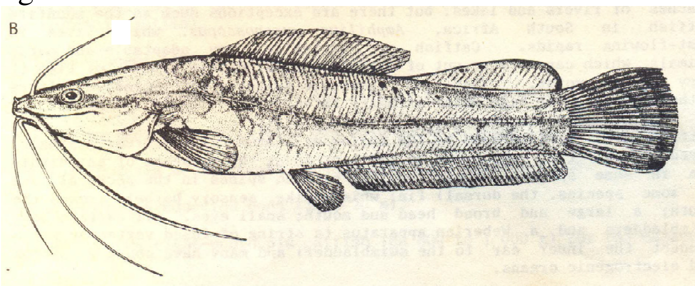


Fig. 5. *Heterobranchus longifilis.*(Bruton, 1988)

Heterobranchus longifilis is a demersal, potamodromous species. It is found in quiet waters with deep pools and stretches, not necessarily associated with vegetation, in larger waterways and main river channels (Teugels, 1990).

2. <u>Aquaculture</u>

a. Definition and early history

Aquaculture is defined as the farming of aquatic organisms including fish, molluscs, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultured (FAO, 1998). Bardach *etal.* (1972) defined aquaculture as the husbandry of plants and animals i.e. a practice comparable to livestock keeping or poultry. Cultured fish are held in structures e.g. earthen pond, cage, concrete tank, raceway, molded plastic tanks, wooden structures lined with plastic or other impermeable materials. The farmer has some type of control on the fish e.g. the fish is fed and protected. The kind of input into the culture system determines the type of output expected of the system. For example, the culture can range from: i. extensive culture in which the farmer stocks a few fingerlings usually collected from the wild, puts in some organic fertilizer, occasionally throws in some food items such as kitchen sweepings into the structure, to ii. semi-intensive in which higher density of fish is stocked, the culture media is fertilized to enhance production of aquatic food for the fish, some agricultural by-products are offered to the fish daily to iii. intensive where everything from stocking of high density of fingerlings from specially designed hatchery, feeding intensively many times a day or from demand feeders with nutritionally complete formulated feed in media independent of fertilization, constant monitoring of media for dissolved oxygen and other water quality parameters (to ensure good health and growth), monitoring for and treatment of disease in the system are under the control of under the farmer.

Aquaculture is an ancient practice starting about 400 years ago though the science of aquaculture is a more recent practice about 50 – 60 years old. Raising of fish in ponds have been reported to have started in ancient China, no wonder the old Chinese adage of "**give a man fish, you have given him food for the day, teach him to grow fish, you have given him food for the rest of his life".** The first of China's five Emperors developed some knowledge of pond culture of carp and grey mullets from 2852 BC to 2737 BC. From 2052 – 1786, Egyptian hieroglyphics suggest the Egyptians of the Middle Kingdom worked to culture fish in an intensive way. They certainly domesticated sea fishes to supply to luxurious tables of their richer houses; they appointed special "fish keepers" to do the fish husbandry (Jesse and Casey, 2006).The art of fish farming was said to have been developed in the Chinese Chou dynasty by its founder Wang Fang who built ponds and stocked them with fish between 1135 – 1122 BC. A classic Chinese manuscript, "cult of the carp", on carp farming was written by Fan Li (also known as Fan Lai or Fan Lee) by 475 BC in which he described the structure of pond, the method of raising carp and detailing some aspect of the money to be made. Aquaculture in ancient China was more of an art that a science as can be seen from excerpts from the manuscript that also had metaphysical aspects and fantasies, thus:

> *"Introduce these carp into the pond during the early part of the second moon of the year, leave the water undisturbed, and the fish will spawn. During the fourth moon, introduce into the pond one turtle, during the sixth moon, two turtles, and during the eight moon, two turtles. The turtles are heavenly guards, guarding against inversions of flying predators. When the fish swim round and round without finding the end, they would feel as if they are in natural rivers and lakes. By the second moon of the following year, you can harvest 15,000 carp of one chih (1 chih = 35.8 cm) in length, 45,000 carp of two chih and 10,000 carp of three chih."*

Fan Li conducted many experiments on fish culture and these were compiled into a book by 460 BC. The keeping of carp for pleasure which later transited to rearing of carp for food was much practiced in nearby countries of Asia - Cambodia, India, Indonesia and Vietnam. This ancient practice gave the people of Asia a head start in aquaculture such that even today, most aquaculture is practiced in Asia; China is the number one country in the world in aquaculture production.

FAO (2014) reported that China has been responsible for most of fish availability, owing to the dramatic expansion in its production, particularly from aquaculture. Chinese aquaculture production went from 7 percent in 1961 to 35 percent in 2010. Its per capita apparent fish consumption also increased from 31.9 kg in 2009, with an average annual rate of 6.0 percent in the period 1990–2009 to about 35.1 kg per capita apparent fish consumption in 2010. Annual per capita fish supply in 2010 in the rest of the world was about 15.4 kg (11.4 kg in 1960s and 13.5 kg in 1990s) when despite the surge in annual per capita, apparent fish consumption in developing regions was low (5.3 kg in 1961 to 17.8 kg in 2010) and very low in low-income food deficit countries (LIFGCs) (4.9 kg to 10.9 kg). The total world fish production by 2012 was about 158.0 million tonnes with aquaculture providing about 66.6 million tonnes with China producing 61.6% of this as food fish excluding other aquaculture products. This value increased to 70.5 million tonnes by 2013. China alone produced 43.5 million tonnes of food fish and 13.5 million tonnes of algae by 2013. Aquaculture worldwide produced 90.4 million tonnes by 2012 i.e. increase from an average of 9.9 kg in the 1960s to 19.2 kg in 2012.

Ancient Roman civilization developed the art of culture of oysters. It has also been reported that in ancient Rome by circa 100 BC, the Roman “Sergius Orata”developed oyster beds at Balae on Lucrine sea and at circa 100 BC. The Roman General ‘Lucullus’ built the Fish Pond of Sculum, near the Bay of Naples. There was a fun Circular Pond of Lago di Paola possibly for breeding (Fig.67) (Jesse and Casey, 2006).Certain facts lend credence to the early age of aquaculture. FAO reported that early efforts to spread aquaculture to African by mainly by some Europeansfrom the time they embraced aquaculture about 2000 years ago did not succeed because of the normadic nature of most of the people(Jesse and Casey, 2006). However, a bas relief (Fig. 7) on the walls of tombs of pharaohs in ancient Egypt that depicts fish as being reared in ponds have been said to date back to 2500 BC (Chimits, 1957). The drawing depicts well-constructed pond that can be drained and fish collected for food. Even the Bible is replete with is mentions of raising of fish in ponds and that shows how ancient a practice it had been –

> *"the Lord said to Moses, "Tell Aaron, 'Take your staff and stretch out your hand over the waterof Egypt – over the streams and canals, over the ponds and all the reservoirs' – and they will turn to blood." (Exodus 7: 19 NIV) and fish "And they shall be broken in the purposes thereof, all the sluice and pond for fish" (Isiah 19:10 KJV).*

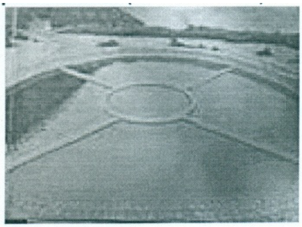


Fig. 6. Ancient Circular fishponds in Roman Italy probably for hatchery (Jesse and Casey, 2006)

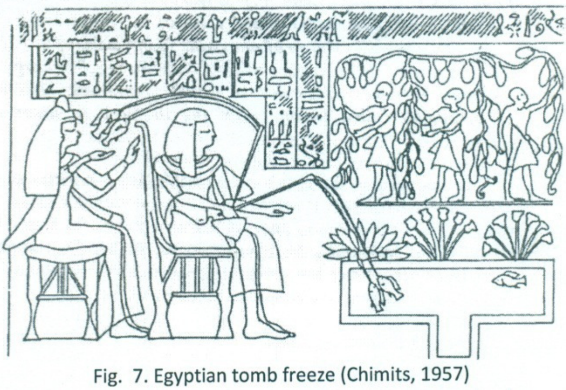


Fig. 7. Egyptian tomb freeze (Chimits, 1957)

But for ancient Egyptian's raising of fish in ponds, very few African countries have a background in fish culture (Fig. 7). Brushpark or *acajas*which are constructed enclosures mostly with sticks and netting materials to exclude predators and to ensure food for the fish was practiced in West African lagoons(Fig. 8) (FAO, 1984**;** Welcomme, 1972). Also, traditional ponds called *whedos* orfish holes fish which have been excavated to a depth of about 1 m in a network all over a floodplain used in West Africa e.g. the Ouémé River, South Benin and Madagascar have been practiced in Africa.

Fig. 7a. Ancient Egyptian hard at work fishing and fish keeping

Fig. 7b. Shell necklace for a bearded mermaid to wear probably depicting mussel (rope) culture well on its way to becoming established.

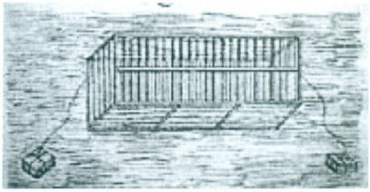


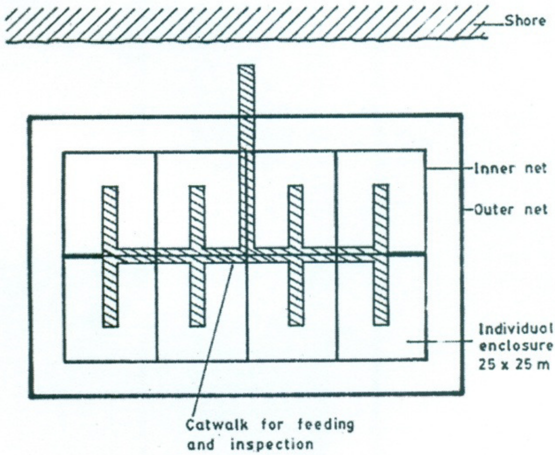
Fig. 7c. Fish cage (weighted down) before 1856. A similar system was being used in Indonesia by around 1956 for carp culture.

Fig. 7. Structures used in early fish culture operations (Jesse and Casey, 2006).

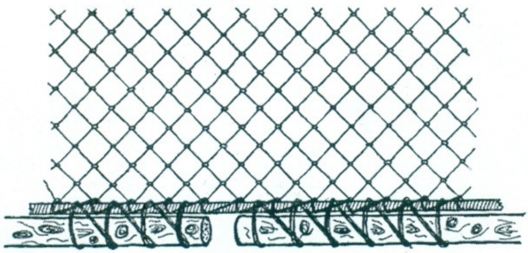
b. Aquaculture in Africa including Nigeria

More modern aquaculture in Africa started in the early 1900s. Rainbow trout (*Salmo gairdnerii*) was introduced in Malawi in 1906 followed by aquaculture experiments in Kenya in 1924 (Huisman, 1986). The culture spread to other countries after the Second World War due to the necessity for scarce animal protein. In the 1940s tilapia culture was introduced in Zaire (Lazard, 1990).

Aquaculture in Nigeria started in the 1950s. It, however, became more relevant in the 1970s when aquaculture of carp and tilapia was mostly practices in the western Nigeria and spread from there to a few other states. The first fish farm was in Onikan, Lagos State in 1951 (Longhurst, 1961) then the Panyam, Plateau State (Ajayi, 1971). To encourage the spread of aquaculture a few state governments in the 1970s and the Federal
Government through the Directorate of Food, Road and Rural Infrastructure (DFFRI) set up fish farms in the 1980s to serve as models and to provide fish farms which are largely no longer in production largely because of large of expertise by the operators and lack of fish farm inputs. State Government fish model farms included the one in Akure in Ondo State and the Okigwe Fish Farm in Imo State. More lucrative clariid catfish fish species of *Clarias*were introduced following the work by De Kimpa and Micha (1974) and Hogendoorn and Wieme (1976) and *Heterobranchus*by Legendre, 1988). More recently, there has been renewed emphasis and interest in fish farming in Nigeria. This is in line with tremendous worldwide increase in aquaculture production within the past few decades given that aquaculture today accounts for about one third of the global supply of fish products compared to 4% in the 1970s and growing at an annual growth rate of 7% implying that aquaculture grows faster than most other animal products providing substantial fish products and revenue.



a. Plan of enclosures (pen) at Grand-lahou lagoon in Cote d'Ivoire



b. Footrope of netting with wooden pieces attached
Fig. 8 a. and b. Diagram of *acadja* brush park culture system. Welcomme, 1972

c. **Why culture fish and/or use the big head clariids**?

Fish is a good source of protein for supply of required essential amino acids and, unlike fatty meat products e.g. beef, it is not high in saturated fat (NEPAD, 2005). The amino acid profile of protein is good major of ascertaining its quality (Watanabe and Kiron, 1994). From the amino acid profile of *Clarias gariepinus* (Table 1), it is seen that but for the sulphur amino acid methionine all other amino acids meet the requirements for man. The most abundant amino acids in *C. gariepinus* were glutamic acid, aspartic acid, leucine and lysine ranging from 9.49% to 18.16%.Amino acids are important in healing processes and the composition of amino acids in fish is similar to that in man, people can acquire essential amino acids in abundance and proper balance by eating clariid catfish. The essential amino acids cannot be manufactured in human bodies, but can be obtained from food (Osibona*et al*., 2009).

Fish is also a good source of omega-3 (n-3) fatty acids. Omega-3 fatty acids benefit the heart of healthy people, and those at high risk of developing cardiovascular disease. Research has shown that omega-3 fatty acids decrease risk of arrhythmias (abnormal heartbeats), which can lead to sudden death. Omega-3 fatty acids also decrease triglyceride levels, slow growth of atherioscerotic plaque, and slightly lower blood pressure. Increasing omega-3 fatty acid consumption through food (fish) is preferable swallow of fish oil (Kris-Etherton *et al*., 2002).

Table 1.Mean[1] amino acid composition of *Clarias gariepinus (*Burchell, 1822) as a percentage of total protein.

Amino Acid	*Clarias gariepinus*
Cystine	1.16 ± 0.06
Taurine	0.53 ± 0.03
Aspartic acid	11.35 ±0.61
Methionine sulphone	3.17 ±0.17
Threonine	4.81 ±0.26
Serine	4.48 ±0.24
Glutamic acid	17.81 ±0.96
Glycine	5.07 ±0.27
Alanine	6.45 ±0.35
Valine	5.34 ±0.29
Isoleucine	5.22 ±0.28
Leucine	9.53 ±0.51

Tyrosine	1.15 ±0.06
Phenylalanine	4.19 ±0.23
g-aminobutyric acid	0.51 ±0.03
Ornithine	0.65 ±0.04
Lysine	10.64 ±0.57
Arginine	6.82 ±0.37
Hyroxyproline	0.30 ±0.00
Proline	3.81 ±0.21
Total amino acids	168.84

[1]*Values are mean of triplicate ± Standard deviation.*
(Modified from Osibona et al., 2006).

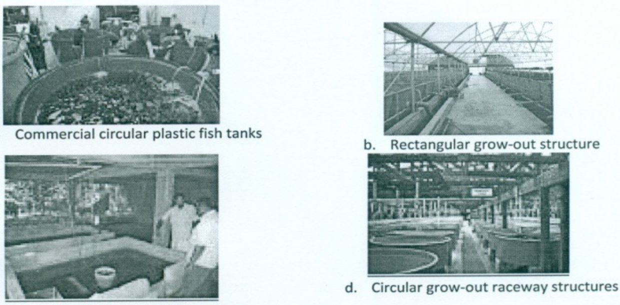
Some marine fish species, however, may contain high levels of toxic substances such asmercury, polychlorinated biphenyls (PCB), dioxins and other unhealthy environmental contaminants (Kris-Etherton *et al*., 2002). The level of these contaminants generally gets higher the older the fish gets.As a result of this, the U.S. Food and Drug Administration (FDA) has advised children and pregnant women to desist from consuming large fish with potential for high levels of mercury e.g. shark(Suborder Selachimorpha), swordfish (*Xiphias gladius*), king mackerel (*Scomberomorus cavalla*), or tilefish (Family Malachanthidae)but to rather consume those fish lower in mercury e.g. canned light tuna (a small tuna variety comprising a mix of fish of tribe Thunnini of mainly yellow fin(*Thunnus albacares*), some tongol or big eye tuna(*Thunnus obesus*)), salmon (*Salmo* spp.), pollock (*PollachiusI sp.*), catfish at the rate of about 179 g per week. It advised that for middle-aged, older men and postmenopausal women, the benefits of eating fish far outweigh the potential risks. It is also recommended that potential exposure to unhealthy contaminants can be reduced by removing the surface fat from these fish before cooking the fish, baked or grilled not fried.

Added to omega-3 fatty acids, fish supplies quality protein in the diet. A 150 g fish can provide 50 – 60% of adult's daily protein requirement. By 2010, fish accounted for 16.7% of global population's intake of animal protein and 6.5 % of all protein consumed. Fish provides 2.9 billion people with almost 20% of their intake of animal protein and 4.3 billion 15% of such protein. Fish protein is a crucial nutritional component in some densely populated countries where total protein intake level may be low (FAO, 2014). In terms of costs, generally in Nigeria, fish is less expensive than many other meat products. From the foregoing, for all age brackets therefore, it can be inferred that eating cultured freshwater catfish will give the benefits of eating fish while avoiding the risks of getting some unhealthy contaminants from eating some unwanted types of fish, hence the assertion here that the bighead clariid aquaculture is the way to go in Nigeria to ensure quality protein nutrition.In fact a study by Jardine *et al.* (2009), on mercury content comparisons between farmed and wild Atlantic salmon (*Salmo salar* L.) and Atlantic cod (*Gadus morhua* L.) conclusively proved that farmed fish had highly significantly ($P < 0.001$) less mercury in its flesh and liver compared to the same fork length of wild fish though neither fish's mercury concentration exceeded federal consumption guidelines.

Modern aquaculture was undertaken to satisfy the demands for fish and fish products with increasing human population as it has long been recognized that the fish catch from the wild can no longer meet thesedemands because fishery yields have stabilized at about 70 – 72 million tonnes per year. The non-rising catch was because of fishing pressure on dwindling resources and increased fishing effort had not seemed to improve these needs (Hogendoorn, 1983). A solution to supplement catches from the wild is aquaculture. Under the conditions that prevail in African subsistence fish farming, Hogendoorn (1983) pointed out that *Clarias* outyielded tilapia by more than 250% and under optimal conditions in tanks, *Clarias* grow more than 200 g in 5 months from birth with a feed conversion rate (feed given to fish/weight gain) below unity**.**This is a very high rate of growth indeed. In a study of polyculture of *Heterobranchus bidorsalis, Clarias gariepinus* and *Tilapia guineensis* in homestead pond in Lagos, H. bidorsalis grew at 2.49 g/day, *C. gariepinus* 1.6 g/d and *T. guineensis* 0.6 g/day i.e. a total mean weight of fish of 32.3 kg/32 m2. *Clarias*is very popular with fish farmers, is disease resistant and commands a very good commercial price in Nigeria affording a good return on investment. In Nigeriapresently,the big head clariid catfishes are used in culture in many places. Of clariid species,the ones most used in culture are *C. gariepinus, H. longifilis, H. bidorsalis* and a hybrid of *C. gariepinus* ♂ x *H. bidorsalis*♀called *Heteroclarias*.

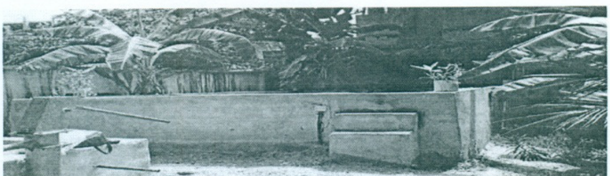
d. Structures used in aquaculture

Commercial fish farming on the other hand is usually done in tanks or enclosures usually in the form plastic, concrete or fibre glass (Fig. 9). Some are circular, some rectangular in the form of raceways. Also used are earthen ponds. Earthen ponds more permanently deform the land used than tanks.Homestead culture in homes is done with homestead (8 x 4 x 1.5 m^3) concrete tanks or small plastic pools kept in homes. These are rain-fed structures or fed from public water supply stocked at 8 - 10 fish per square metre and maintained to supply occasional family needs (Fig. 10).



a. Commercial circular plastic fish tanks
b. Rectangular grow-out structure
c. Commercial concrete tanks
d. Circular grow-out raceway structures

a - d
From:
https://www.google.com.ng/search?q=fish+culture+tanks&tbm=isch&tbo=u&source=univ&sa=X&ei=7XHNU7egD4KyyATxrYCYDg&ved=0CFMQ7Ak&biw=1366&bih=667 Assessed 21th July, 2014.
Fig. 9. Fish culture structures.



b. Homestead plastic tanks

Fig. 10. Family fish culture structures

For commercial earthen ponds, it is important to have professional aquaculturist, knowledgeable agricultural engineers and soil scientists to conduct necessary soil tests to ensure proper soil quality e.g. soil of $\geq$ 20% clay in addition to proper construction of required structures to approved standards before use. In addition, there is need to employ trained fisheries/aquaculture staff to ensure profits or proper return on investment and sustenance.

a. Induced breeding of the clariids

Though desirable for aquaculture because of high growth rate, disease resistance and amenability to stocking density, these clariids do not breed in captivity in ponds and artificial breeding with exogenous hormones to induce oocyte maturation, ovulation and spawning have to be employed in their culture. In the wild their breeding involved elaborate rituals. Synthetic hormones of different types such a chorionic gonadotropin, ovaprim, deoxyclomephene citratrate and pituatry extract from fish e.g. *Clarias* spp., tilapia and many animals such as common toad (*Buforegularis*), African bullfrog (*Ranaadspersa*) have been employed for the homoplastic hypophysation these clariids to induce them to spawn (Salami et al., 1992; Inyang and Hettiarachchi, 1994). Generally it is more efficient to induce breed fish with pituitary gland extract or gonadotropin from a teleostean source because of the phylogenetic closeness between the donor and the recipient (Lam, 1982) but farmers are reluctant to sacrifice valuable fish synthetic hormones are more used. Ovaprim have been found to be effective in inducebreeding of these clariids and the spawning after intramuscular injection with a dose of 0.5 ml/kg body weight of fishat 22 ^{o}C. the fish was ovulated and was ready for stripping to take place in about 11 hours from injection (Abolude *et al*., 2013). Using tilapia pituitary extract Salami *et al*. (1997) reported that with a single injection of 6 – 10 mg/kg of fish with acetone dried pituitary extract at ambient temperature of 27^{o}C, the ovulation took place between 14 – 18 hours. After strippingthe eggs, the male clariid issacrificed, the gonads excised to press out the semen on the eggs to fertilize them. Thereafter the eggs are hatched usually on some substrate in non-flowing water.

3. Some of My Clariid Catfish Researches

Some of the clariid catfishes research that I was involved in so as to enhance the culture of the large clariid catfishes are grouped into five areas in this discussion, namely: a. feed ingredient studies, b. breeding and fish seed studies, c.anthropogenic xenobiotics studies and aquatic environment, d. fisheries, reservoir and river studies and e. fish handling and processing.

a. Feed ingredient studies

i. Nutrition Studies in the 1980s and 1990s

As soon as I was hired in the University of Nigeria in 1983, I took on the development of fish diets especially diet of the cherished African sharp tooth catfish (*Clarias gariepinus,* Burchell 1822) since no feed had been developed for *Clarias* and fish feed accounts for over 50% of the operating cost of modern aquaculture. *Clarias gariepinus* was long known to be widely accepted, to be omnivorous and hardy but not much was then recorded in literature about its nutrient requirements and tolerance of artificial fish feed. The African experiments in the culture of the African catfish started in the Central African Republic and in the Cameroun. In Nigeria, some culture was practiced in western Nigeria in some private farms and government farms e.g. at Akure and Ibadan. No standard feed was, however, developed for this fish or other fish species.

I started with my students to experiment on which feed ingredients were good for rearing the African catfish and how well it digested them in culture. Our research included the use of by-products of agriculture so that man does not have to compete with the fish for ingredients in demand for human nutrition. In one of these studies, percent digestibility of carbohydrate, lipid, and protein by the African catfish (*Clarias gariepinus*) was determined for wood-fire-dried fish waste, plantain peelings and yam peelings by the indirect chromic oxide method. The growth of fish was determined. We found that the fish digested plantain peelings satisfactorily. Percent digestibilities of the carbohydrates, lipid, and crude protein were 56.5, 60.1 and 75 for fish waste, 73.2, 67.3 and 71.8 for plantain peeling, and 65.7, 63.9 and 69.5 for yam peelings (Table 2). Percentage weight gains were significantly different ($p < 0.05$) between the fish fed on fish waste and those fed on plantain and yam peelings. Fish fed on fish waste diet had the least gain in weight. Compared to results of protein digestibility of menhaden fishmeal to some omnivorous warm water fish, the protein digestibility was satisfactory. Also, digestibilities for the three agricultural by-products except carbohydrate, were above 60 percent indicating that each ingredient is good for use in formulation of feed for the aquaculture species at some level of inclusion(Mgbenka and Agua, 1990).

Table 2. Nutrient content of fish waste, plantain peeling, digestibility of the nutrients by the Africancatfish (*Clarias gariepinus*), and growth of the fish fed on these feedstuffs for five weeks.

Means in a row with common superscripts are not significantly different ($P > 0.05$).

Parameters	Feedstuffs		
	Fish waste	Plantain peeling	Yam peeling
Initial weight of fish (g)	200.6^{a}	199.1^{a}	200.3^{a}
Final weight of fish (g)	204.6^{a}	213.2^{b}	212.5^{b}
Weight gain (%)	2.0^{a}	9.0^{b}	9.3^{b}
Carbohydrate content of feedstuff (%)	10.0^{a}	93.0^{b}	90.0^{c}
Lipid content of feedstuff (%)	8.3^{a}	1.5^{b}	1.5^{b}
Protein content for feedstuff (%)	81.4^{a}	1.1^{b}	1.0^{b}
Carbohydrate digestibility	56.5^{a}	73.2^{b}	65.7^{c}

(%)			
Lipid digestibility (%)	60.1[a]	67.3[b]	63.9[c]
Protein digestibility (%)	75.0[a]	71.8[a]	65.7[b]
Digestible carbohydrate (%)	4.7[a]	68.1[b]	59.1[c]
Digestible lipid (%)	5.0[a]	1.1[b]	1.0[c]
Digestible protein (%)	61.1[a]	0.8[b]	0.7[c]

[1]For calculation of mean values, N = 10 for weight and N = 3 for any other parameter.

L-Ascorbic acid (AA,vitamin C)is a known antioxidant was another ingredient that we worked on.It is not produced in teleost fishes (Lachapelle and Drouin, 2010). We investigated the ascorbic acid requirement of the African catfish,the optimum level of inclusion of ascorbic acid in African catfish diet and the stability of AA in formulated diet. The fish were fed wood-fire-dried fish waste dietsupplemented with six levels (0, 30, 60, 90, 120 and 240 mg ascorbic acid/kg of diet in 20 weeks feeding trials. Some of the L-ascorbic acid was lost both during processing and storage of diet (20 – 50%). We found that 48 mg L-ascorbic acid/kg of fish feed was the optimal level of ascorbic acid which provided maximum growth in the African catfish and prevented scoliosis and gill malformations. Fish fed ascorbic acid-free diet demonstrated poor growth and showed deficiency sign of crack head and lateral spinal curvature of vertebrae from poor vertebral collagen of 33μg/g compared to 70 μg/g collagen of ascorbic acid-fed fish. These presented with clubbed gills and scattered gill arch chondrocytes. The research was published (Eya and Mgbenka, 1984). Again, in a further study carried out on the optimum level of inclusion of ascorbic acid (AA) in the African catfish diet,we reported that AA was unstable such that at supplementations of 0, 30, 60, 120 and 240mg AA/kg of diet the actual rates of AA (mg/kg diet) fed to the fish were 0, 22.3 – 24.0, 44.8 – 48.0, 67.8 – 72.5, 91.1 – 96.6 and 181.7 – 102.9, respectively. Fish fed diets containing 0 and 30 mg/kg of AA in the diet had poor growth and high mortality rates of 36% and 20%, respectively (Mgbenka and Eya, 1991). Broken skull syndrome occurred in the catfish fingerlings fed at less than 30 mg/kg of inclusion.

One of the major obstacles in raising fish is getting larval fish to consume artificial diet in captivity. An experiment done by Mgbenka and Eya (1991) to determine the palatability of some agricultural waste (bambara nut waste), wood-fire-dried fish waste and soybean meal with high level of crude protein using time to strike pellet and number of rejections per pellet by the fish we found that some ingredients were not quite palatable to catfish. The order of palatability was: fish waste > compounded diet >bambara nut waste > soybean meal.

From observations made on a fast rate with which the African catfish was attracted to the fresh palm fruits in aquarium in my office, I designed research published in Mgbenka and Orji (1997) on the use of fresh palm fruit extract as an attractant feed ingredient for larval African catfish (*Clarias gariepinus*) and along with *Spirulina* a known attractant to some fish species. Three experiments were conducted. In Experiment 1, the acceptance time of pelleted diets sprayed with fresh palm fruit extract (FPFE), commercial palm oil (COM), or a control diet to the African catfish larvaewere investigated. In Experiment 2, the effects of five diets on growth and survival of the catfish larvae were determined, namely: (a) bambaranut waste-based (BW) diet; (b) bambara nut waste-based diet with 5% of diet formula of FPFE (BWP);(c) a bambara nut waste-based diet with 5% of diet formula of FPFE plus 1.5% of diet formula of *Spirulina*was included (BWPS) as an additionalattractant (d) fish waste-based diet (FWP), and (e) brine shrimp (*Artemia*sp.)nauplii (control).In Experiment 3, the effect of seven diets on growth and survival of the African catfish larvae were investigated: (a) BW; (b) BWP; (c) FWP; (d) a bambara nut-waste-based diet with 5% of formula as COM (BWC); (e) a fish-waste-based diet with 5% of diet formula as COM (FWC) (f) a fish-waste-based diet with neither FPFE nor COM, and (g) brine shrimp nauplii (control). The African catfish fingerlings consumed the pellets containing FPFE in 2.3 times faster rate than control diet with no attractant i.e. in significantly less time (16.0 ± 2.0 seconds) (P< 0.01) than they did the other pelleted diets. Inclusion of FPFE as 5% of diet formula of larvae significantly (P < 0.05) improved the growth and survival of the African catfish larvae fed formulated diets though not as high as in larvae fed *Artemiasalina*nauplii (control) (Table 3).

In another experiment to determine the shelf life of the freshness of the palm fruit extract published in Mgbenka (2001) it was found that the freshness of the palm fruit extract as an attractant can only be retained for up to three days from extraction and it was better to use the extracts immediately after preparation (Table 3, 4 and Fig. 11).

Table 3. Mean weight gain of *Clarias*gariepinus larvae fed different diets sprayed with fresh palm fruit extract stored for different periods of time.

	Weight of larvae (mg)					
(Days of Storage)	**Day 7**	**Day 14**	**Day 21**	**Day 35**	**Day 42**	**Mean ± SEM**
1 (0 day)	8.7	9.8	12.7	13.0	15.0	11.83 ± 1.144[a]
2 (1 day)	8.6	9.8	12.8	14.0	16.0	12.11 ± 1.436[a]
3 (2 days)	8.8	9.8	12.3	13.0	16.0	11.97 ± 0.75[a]
4 (3 days)	8.8	9.4	11.2	12.1	13.5	11.01 ± 0.873[a]
5 (4 days)	8.7	9.0	9.9	10.3	10.5	9.67 ± 0.352[b]
6 (5 days)	8.6	9.3	9.6	12.0	12.8	10.33 ± 0.897[b]
7 (6 days)	8.6	9.0	9.8	10.4	11.2	9.68 ± 0.560[b]
8 (7 days)	8.6	9.1	9.9	10.7	11.4	9.94 ± 0.490[c]

[a, b, c]Means followed by the different superscripts are significantly different (P<0.05)

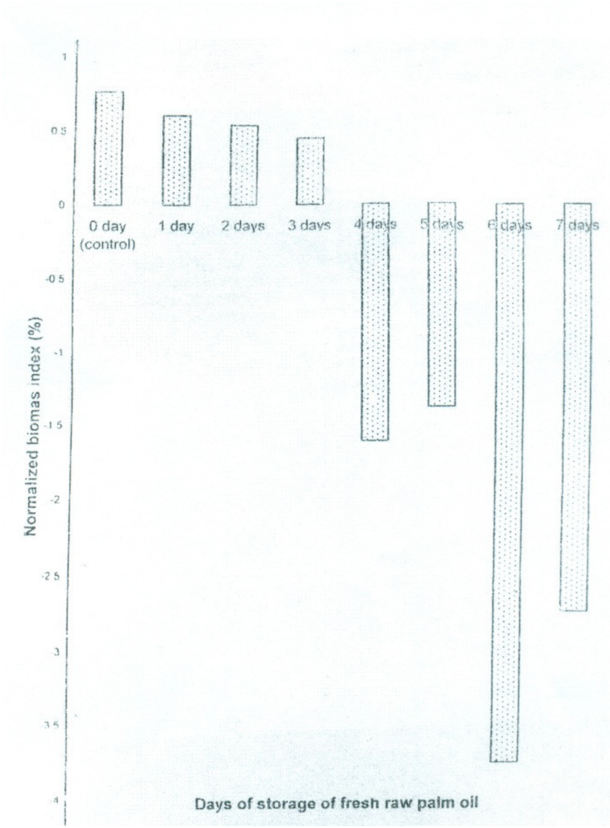


Fig. 11.Effect of storage period on normalized biomass index of Clarias gariepinus.

Table 4. Mean ± SEtotal length (cm) of African catfish larvae fed different diets in Experiment 2. Meansfollowed by different letter in the same column are significantly different (P < 0.05).

Abbreviations for the diets are: BWC = Bambara nut waste-based diet with 5% of formula comprised of commercial, bleached palm oil; BWP = Bambara nut waste-based diet with 5% of formula comprised of fresh, raw palm fruit extract (FPFE) as feed attractant; BWPS = bambara nut waste-based dietwith 5% of formula of FPFE plus 1.5% of formula of *Spirulina powder* as additional feed attractant; FWP = fish waste-based 5% of diet formula of FPFE, and *Artemia*nauplii.

Diet	Day							Growth rate (G)[1] (mm/day)	Sv[2] (%)
	5	10	15	20	25	30	35		
Artemia	5.2±0.12a	13.4±0.37a	19.7±0.30a	21.0±0.49a	30.1±0.79a	34.5±0.40a	39.2±0.78a	0.98±0.02a	66±2a
BWC	5.2±0.10a	8.6±0.26c	11.0±0.42c	12.2±0.42e	14.1±0.78d	19.1±0.97c	29.5±1.20d	0.71±0.02d	20±4d
BWP	5.2±0.30a	13.5±0.82a	18.5±0.54a	19.2±0.85b	23.4±1.21b	32.2±1.62a	37.4±0.67b	0.93±0.04a	50±3b
BWPS	5.2±0.10a	12.4±0.21b	13.0±0.30b	17.8±0.42c	23.7±0.10b	26.2±1.72b	32.0±0.88c	0.78±0.01c	40±2c
FWP	5.2±0.28a	8.9±0.82c	10.9±0.54c	15,4±0.85d	19.1±1.21c	27.1±1.62b	33.6±1.67c	0.82±0.01b	40±1c

[1]*Growth rate (G) = (Final length (mm) – Initial length (mm) x1/Time of culture).*
[2]*Sv = Survival.*

During the feed ingredient studies with the African catfish, it was necessary to find out which strain of catfish in the eastern Nigerian zone would grow better on the compounded feed using the available feed ingredients. A study was therefore done to determine the effect of stocking density (5, 7 and 9 fish/12 litres) and 34% crude protein feed on the growth and survival of fingerlings of the Agulueri and the Aluu strains of the African catfish(*Clarias gariepinus*). The results,based on specific growth rate and final weight of fish,showed that though with identical survival rates between the two strains, the Aluu strain clearly had better growth rate than the Aguleri strain for fish stocked at 5 per 12-litre tanks (Fig. 12). Based on this study the use of the Aluu strain was recommended for African catfish culture in the eastern Nigerian zone. This work was published (Mgbenka and Udeozor, 2001).

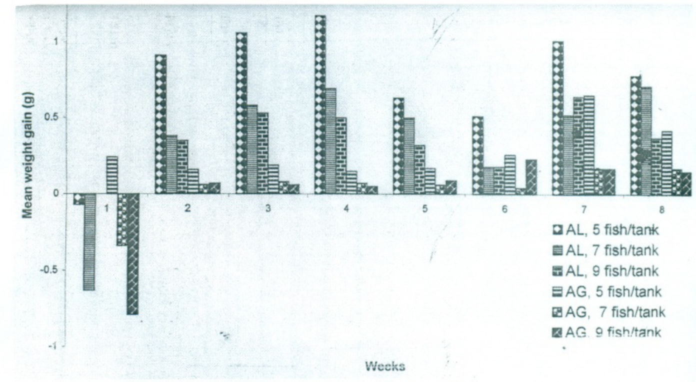


Fig. 12. Mean weight of Aluu (AL) and Aguleri (AG) strains of Clarias gariepinus reared for 8weeks.

In a study to determine the extent of inclusion of some other agricultural wastes in a corn-soya diets of *Heterobranchus bidorsalis,* another clariids, we substituted a mix of palm kernel (*Elaeis guineensis*) cake and shear butter (*Butyrospermum paradoxum*) nut waste in the ratio of 6:4 for corn graded levels and fed to fish. At the end of the study, using total weight gain, specific growth rate and normalized biomass index which takes care of percent survival and weight gain,it was found that the inclusion level of 32.38g/kg of the palm kernel cake and shear butter nut waste mix produced the same growth and survival of the *H. bidorsalis* as the control fed only corn-soya diet (Table 5 and 6, and Fig. 13). This indicated that the mix can be used in fish feed at the said inclusion level. The result was published in Mgbenka and Oche (2003).

Table 5. Total fish weight gain per treatment per week (g) of 27 *Heterobranchus bidorsalis* fed diets containing oil palm kernel cake (PKC)-shear butter nut waste (SBN) mix. Page 204.

Treatment	SGR x 10^{-1} ± Standard Error of Mean (SEM)[1]
A (0 g PKC-SBN (Control)	1.91 ± 0.37[a]
B (32.38 g PKC-SBN)	1.54 ± 0.20[ab]
C (68.05 g PKC-SBN)	0.84 ± 0.18[c]
D (97.62 g PKC-SBN)	1.01 ± 0.14[bc]
E (160.21 g PKC-SBN)	0.56 ± 0.12[c]
F (158.71g PKC-SBN)	0.92 ± 0.17[c]

[1]SGR ± SEM with different superscripts differ significantly (P < 0.05

Table 6: Specific growth rate (SGR) of *Heterobranchusbidorsalis* fingerlings fed diets containing oil palm kernel cake-shear nut waste mix for 63 days

Treatment	SGR x 10^{-1} ± Standard Error of Mean (SEM)
A (0 g PKC-SBN (Control)	1.64 ± 0.21[a]
B (32.38 g PKC-SBN)	1.32 ± 0.19[a]
C (68.05 g PKC-SBN)	0.79 ± 0.30[b]
D (97.62 g PKC-SBN)	1.04 ± 0.05[b]
E (160.21 g PKC-SBN)	0.70 ± 0.20[b]
F (158.71g PKC-SBN)	0.87 ± 0.11[b]

[1]SGR ± SEM with different superscripts differ significantly (P<0.05

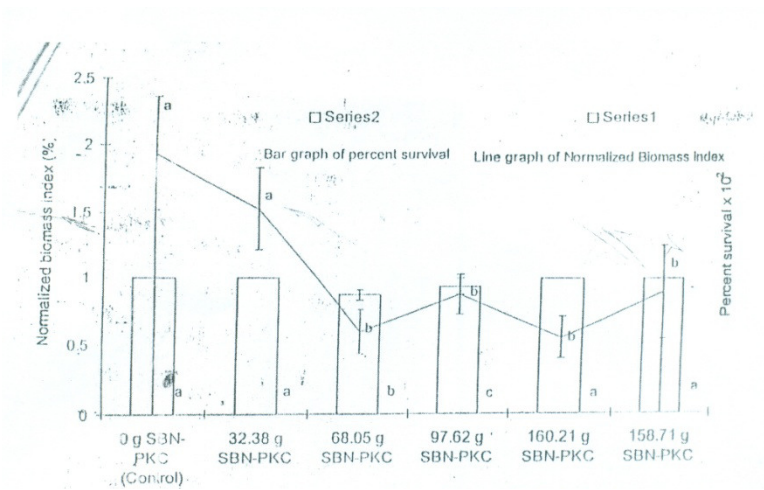


Fig. 13. Normalized biomass index and % survival of *Heterobranchus bidorsalis* fed diets containing
shear butter nut waste-palm kernel cake mix for 63 days. Treatments with same letters are not
significantly different ($P > 0.05$).

Studies on the mineral requirements of fish have demonstrated that phosphorus (P) is one of the most important nutrients and the most limiting for growth and normal development of bones in fish (Shin and Ho, 1989; Kim et al., 1998). From feeding graded levels of P or calcium (Ca) to carp (*Cyprinus carpio*) (Ogino and Takeda, 1976) demonstrated that the growth of carp was correlated only with dietary P level but not with the Ca level. Increasing concentration of available P from 0.28% to 0.88% increased growth linearly in milkfish (*Chanos chanos*) (Borlongan and Satoh, 2001) while increase of P from 0.24% to 0.88% modestly enhanced growth in the rainbow trout but growth levelled off beyond 0.88% dietary level (Coloso et al., 2003). Minimizing the amount of P supplemented in catfish feeds, however, is important for both economic and environmental reasons; unretained P contributes to eutrophication of the aquatic environment (Eya and Lovell, 1997). To save cost (NRC, 1993), while reducing P waste output (Cho and Bureau, 2001) commercial channel catfish (*Ictalurus punctatus*) feeds contain primarily plant ingredients that are relatively low in available P. To optimize available P content of the diet so as to meet P requirements of the fish (Cho and Bureau, 2001), feeds are traditionally supplemented with inorganic P from various sources. There was dearth of information on use of inorganic phosphorus on the big head clariid catfishes in culture. We carried out a series of studies on these clariids to investigate, namely:

1) effects of inorganic phosphorus on feed intake, protein intake, feed conversion, and phosphorus gain/loss of the hybrid African catfish *Heterobranchus bidorsalis*Geofroy Saint-Hilaire, 1809 (♂) x *Clarias gariepinus* Burchell, 1822 (♀) fry (Ugwu and Mgbenka, 2004).
2) source of inorganic phosphorus that will provide the P requirement of the fish and yet be less polluting of the water i.e. effects of inorganic phosphorus on water, feed, protein phosphorus intake on hybrid African catfish fry (Ugwu et al., 2005).
3) aspects of mineral composition and growth rate of the hybrid African catfish fry fed inorganic phosphorus-supplemented diets (Mgbenka and Ugwu, 2005).
4) effect of calcium on dietary phosphorus uptake by African hybrid catfish, heteroclarias fry (Ugwu et al., 2005).
5) effect of dietary phosphorus on protein intake and productive protein value of young hybrid African catfish (Ugwu et al., 2005c).
6) nutrient utilization and growth responses of the frys of the African hybrid catfish (*Clarias gariepinus* x *Heterobranchus bidorsalis*) to inorganic phosphorus supplements (Ugwu *et al.*, 2005d).
7) survival and growth responses of fry of the African catfish hybrid (*Clarias gariepinus* x *Heterobranchus b*idorsalis) to soluble dietary supplements of inorganic phosphorus (Ugwu *et al.*, 2005).

8) the phosphorus source-duration interaction on protein intake and tissue phosphorus levels of the hybrid African catfish fry, fed phosphorus-enriched diets.
9) effects of mega levels of dietary supplemental phosphorous on three digestive enzymes activities in *Clarias gariepinus* fry.
10) effect of different sources of inorganic phosphorus and inclusion levels in enhancing growth and survival of hybrid African catfish, *Heteroclarias* fry.
11) effect of phosphorus source-duration interaction on gross efficiency of feed conversion and daily rate of growth of the hybrid African catfish fry.

From the series of studies with inorganic phosphorus, the major results included the following: monosodium phosphate (MSP) supplemented diet elicited better response (15.28%) in the fish than any other P-supplemented diets (monocalcium phosphate (MCP), monopotassium phosphate (MPP) dicalcium phosphate (DCP) if food conversion ratio was used as the criterium. A loss (-0.04%) in the percent phosphorus content of fish flesh fed MSP diet was observed. MSP diets were best for enhancing growth (Tables 7 and 8) (Ugwu and Mgbenka, 2004).

Table 7: Effect of inorganic phosphorus dietary supplementation on the proximate composition of the African

catfish hybrid fry fed for 70 day

Proximate composition	A MSP	B MPP	C MCP	D DCP	CD	PD	Overall mean	S.E	L.S.D	Sign level
	Inorganic Phosphorus Source									
Crude Protein (CP)	15.28	13.96	14.13	19.10	19.12	19.00	14.75	0.19	0.42	***
Ether Extract (EE)	7.05	5.95	4.83	3.50	8.69	8.66	5.70	0.25	0.55	***
Ash (AS)	2.25	1.85	2.13	2.04	3.59	4.31	2.34	0.10	0.22	***
Moisture Content	7.12	68.46	65.36	66.12	66.34	65.53	67.16	1.14	0.56	***
Nitrogen Free Extract (NFE)	5.00	9.78	13.35	12.79	2.17	2.50	7.14	6.14	3.14	***
Total	100.00	100.00	100.00	100.00	100.00	100.00				

Table 8: Growth performance of the African catfish hybrid fry fed different inorganic phosphorus supplemented diets

Diet	Feed Intake (FI – g)	Protein Intake (PI - %)	Food conversion ratio (FCR)	Phosphorus gain/loss (PGL - %)
Supplementation with monosodium phosphorus				
Diet 1 (0.40%P)	0.39	1.31	4.33	-0.03
Diet 2 (0.60%P)	0.45	1.21	4.33	-0.04
Diet 3 (0.80%P)	0.46	1.17	3.52	-0.04
Diet 4 (1.20%P)	0.47	1.47	3.23	-0.05
Mean	0.44	1.29	2.95	-0.04
Supplementation with monopotassium 3.51 phosphate (MPP)				
Diet 5 (0.40%P)	0.45	1.18	4.94	0.00
Diet 6 (0.60%P)	0.38	1.03	4.02	0.01

Diet (0.80%P)	7	0.41	1.09	3.84	0.00
Diet (1.20%P)	8	0.46	1.43	3.65	0.02
Mean		0.43	1.18	4.11	0.01
		Supplementation with monocalcium phosphate (MCP)			
Diet (0.40%P)	9	0.53	1.28	3.71	0.01
Diet (0.60%P)	10	0.44	1.17	3.77	0.02
Diet (0.80%P)	11	0.46	1.24	3.60	0.02
Diet (1.20%P)	12	0.50	1.45	3.80	0.03
Mean		0.48	1.28	3.72	0.02
		Supplementation with dicalcium phosphate (DCP)			
Diet (0.40%P)	13	0.46	1.17	4.32	-0.01
Diet (0.60%P)	14	0.45	1.03	3.74	-0.01
Diet (0.80%P)	15	0.41	1.12	3.49	0.04
Diet (1.20%P)	16	0.54	1.40	4.61	-0.01
Mean		0.47	1.18	4.04	0.003
Diet (controlled diet)	17	0.43	1.13	1.82	0.08
Diet (purified diet)	18	0.37	1.01	1.65	0.04
Overall mean		0.45	1.22	1.61	0.01
S.E. of mean		0.007	0.012	0.001	0.001
L.S.D		0.021	0.033	0.004	0.001
Significant level		***	***	***	***

L.S.D =Least significance difference, *** = Significant at 0.1% (P<0.001), S.E. = Standard error

However, at a pH of 6.8 ± 0.1 and temperature of 27□ - 28□ C, based on total soluble phosphorus (TSP), reactive phosphorus (SRP) and soluble unreactive phosphorus, indices that determine phosphorus load in water when diets containing phosphorus from different sources (monosodium phosphate (MSP), monocalcium phosphate (MCP), monopotassium phosphate (MPP) dicalcium phosphate (DCP) supplemented at graded levels (0.4, 0.6, 0.8, 1.2)% P of administration were used, it was found that MSP supplemented diets were prone to pollute water faster than any of the other P-supplemented diets (MPP, MCP, DCP). Since the DCP diet was least soluble in water, it might maximize nutrient retention in fish as well as minimize P-loads in water (Tables 9 - 11) (Ugwu *et al.*, 2005a).

Table 9. Effect of inorganic phosphorus dietary supplementation on phosphorus loads of water, feed intake and survival of the hybrid African fish catfish fry

Table 7: Effect of inorganic phosphorus dietary supplementation on the proximate composition of the African catfish hybrid fry fed for 70 day

Proximate composition	A MSP	B MPP	C MCP	D DCP	CD	PD	Overall mean	S.E	L.S.D	Sign level
	Inorganic Phosphorus Source									
Crude Protein (CP)	15.28	13.96	14.13	19.10	19.12	19.00	14.75	0.19	0.42	***
Ether Extract (EE)	7.05	5.95	4.83	3.50	8.69	8.66	5.70	0.25	0.55	***
Ash (AS)	2.25	1.85	2.13	2.04	3.59	4.31	2.34	0.10	0.22	***
Moisture Content	7.12	68.46	65.36	66.12	66.34	65.53	67.16	1.14	0.56	***
Nitrogen Free Extract (NFE)	5.00	9.78	13.35	12.79	2.17	2.50	7.14	6.14	3.14	***
Total	100.00	100.00	100.00	100.00	100.00	100.00				

MSP = Monosodium phosphate, MPP = Monopotassium phosphate, MCP = Monocalcium phosphate, DCP = Dicalcium phosphate, S.E.= Standard error, L.S.D.= Least significant difference, * * * = Significant at 0.1% (PC0.001)

Key: MSP = Monosodium phosphate, DCP = Dicalcium phosphate, MPP = Monopotassium phosphate, MCP = Monocalcium phosphate, CD = Control diet, PD = Purified diet, ***=Significant at 0.1% (P<0.0001), S.E.= Standard error, L.S.D.= Least significant difference. If the difference between 2 means > L.S.D., then it is significant at 5% (P<0.05)

Table 10. Effect of dietary supplementation with inorganic phosphorus sources on phosphorous loads of water, feed intake, phosphorus gain/loss and gain/loss of tissue protein of the hybrid African catfish fry

Diet	TSP[1]	SRP[2]	SUP[3]	FIW[2]	PGL[5]	GLP[6]

	(mg/l)	(mg/l)	(mg/l)	(mg/l)		
	Supplementation with monosodium phosphorus (MSP)					
Diet 1 (0.40%MSP)	0.044	0.011	13.99	3.36	-0.03	-0.08
Diet 2 (0.60%MSP)	0.028	0.015	12.16	3.19	-0.04	-9.41
Diet 3 (0.80%MSP)	0.034	0.020	14.14	3.21	-0.04	-8.65
Diet 4 (1.20%MSP)	0.032	0.026	14.32	2.67	-0.05	-8.69
	Supplementation with monopotassium phosphate (MPP)					
Diet 5 (0.40%MSP)	0.027	0.006	13.74	3.11	0.00	-7.20
Diet 6 (0.60%MSP)	0.024	0.010	13.86	2.70	0.01	-7.33
Diet 7 (0.80%MSP)	0.028	0.015	14.16	2.89	0.00	-7.20
Diet 8 (1.20%MSP)	0.26	0.012	13.93	3.77	0.02	-6.88
	Supplementation with monocalcium phosphate (MCP)					
Diet 9 (0.40%MSP)	0.022	0.008	13.85	3.36	0.01	-6.53
Diet 10 (0.60%MSP)	0.024	0.011	13.88	3.07	0.02	-6.69
Diet 11 (0.80%MSP)	0.028	0.017	14.01	3.27	0.02	-6.37
Diet 12 (1.20%MSP)	0.26	0.014	14.15	3.82	0.03	-6.45
	Supplementation with dicalcium phosphate (DCP)					
Diet 13 (0.40%MSP)	0.018	0.004	13.41	3.10	-0.01	-7.87
Diet 14 (0.60%MSP)	0.021	0.007	13.47	2.71	-0.01	-7.77
Diet 15 (0.80%MSP)	0.026	0.012	13.48	2.95	-0.04	-7.70
Diet 16 (1.20%MSP)	0.023	0.0019	13.62	3.68	-0.01	-7.30
Diet 17 (controlled diet)	0.029	0.008	11.57	2.99	-0.08	1.82
Diet 18 (purified diet)	0.009	0.007	6.30	2.66	-0.04	3.01
Overall mean	0.026	0.023	13.22	3.20	-0.01	-3.90
S.E. of mean	0.0036	0.047	0.017	0.001	-0.001	0.018
L.S.D	0.010	0.132	0.047	0.004	-0.004	0.051
Significant level	***	*	***	***	***	***

[1]TSP = Total Soluble Phosphorus,[2]Soluble reactive phosphorus, [3]Soluble unreactive phosphorus, [4]Feed intake per week, [5]Phosporus gain/loss, *** = Significant at 0.1% (P<0.001), * = Significant at 0.1% (P<0.005).

Table 11. Effect of Duration (Days) on the Phosphorus loads in Water, Feed Intake and Survival of the Hybrid African Catfish Fry

Variables	7	14	21	28	35	42	49	56	63	70	Statistics		
											±S.E	L.S.D	Significant level
Total Soluble Phosphorus (TSP) (mg/l)	0.042	0.042	0.022	0.020	0.24	0.19	0.25	0.26	0.21	0.17	0.0028	0.0079	***
Soluble Unreactive Phosphorus (SUP) (µg/l)	0.027	0.010	0.003	0.015	0.011	0.013	0.007	0.010	0.014	0.017	0.035	0.089	*
Soluble Reactive Phosphorus (SRP) (mg/l)	19.15	34.14	13.89	12.46	10.75	10.80	10.62	8.57	6.68	5.18	0.13	0.35	***
Feed Intake per Week (F/W) (g)	0.53	1.16	1.73	2.21	2.71	3.40	4.09	4.39	4.96	6.81	0.001	0.003	***
Gain/Loss of Tissue Protein (GLP) (%)	0.70	0.52	-0.10	0.06	0.31	0.24	-8.14	0.22	0.15	0.12	0.15	0.37	***
Phosphorus Gain/Loss (PGL) (%(	0.07	0.05	0.04	0.05	0.08	0.04	-0.34	-0.01	0.05	0.01	0.001	0.003	***
Normalized Biomass Index (NBI) (%)	53.37	46.03	40.94	37.70	34.86	32.17	27.83	24.02	19.78	13.13	0.087	0.253	***

±S.E.= Standard error, L.S.D.= Least significant difference, ***=Significant at 0.1% ($P<0.0001$), *=Significant at 5% ($P<0.05$).

Results from determined gross efficiency of food conversion (GEFC), daily rate of growth (DRG), tissue ash, tissue phosphorus (TP), calcium (Ca) and Ca:P ratio after feeding the different P-supplemented diets, monocalcium phosphate-supplemented diets showed better response to five of these six parameters while Ca:P ratio was best exhibited by dicalcium phosphate-supplemented diets. In plant ingredient-based diets where phosphorus supplementation is needed supplementation with 0.6% monocalcium phosphate is recommended for better growth, feed conversion and mineral deposition in the hybrid catfish than other inorganic phosphorus sources (Mgbenka and Ugwu, 2005).

Increasing P content of fish tissue corresponded with dietary increase in P but decrease in Ca. The effect of dietary fortification with P and Ca probably suppressed weight gain and feed conversion ratio in hybrid catfish between 25 to 35 days. The value of P content of fish was positively influenced by increasing level of dietary Ca up to 2% when raised in calcium-replete water (Ugwu*et al*., 2005b).

Results from the hybrid catfish fed P-supplemented diets (0.4, 0.6, 0.8, 1.2)% P where weekly feed intake (FFW), protein intake (PI), feed conversion ratio (FCR), proximate composition of fish and the P-supplemented diets, productive protein value (PPV), the ratio of retained body protein-to-protein intake were measured show that mean weekly feed intake increased with dietary P increase for 0.6% (1.46 g), 0.8% P(1.57 g), but not for 1% P (1.44 g). The increasing response trend was demonstrated in FCR and PPV of fish where the 1% dietary P had the best fish of protein and fat deposition recorded for 1.2% dietary P level whereas the other dietary P levels and Control were comparatively higher. It was evident that the experimental fish probably demonstrated a consistent response to increasing dietary P level between 0.6% to 0.8% P while the Control diet paralleled that of 0.6% P for FFW, FCR, PPV and PI, and the values obtained were respectively lower than the values for the Control. There was depression in protein deposition between 0.6% P (19.25%) and 0.8% P (18.94%) while fish fed the Control diet deposited more quantity of protein (19.63%). Conversely, there was an enhanced fat deposition as the dietary P increased from 0.6% to 0.8% while the Control diet paralleled that of 0.6% P. However, the mean lipid content of fish decreased with increasing P level. Generally, there was no significant effect ($P > 0.05$) of increasing the dietary P level on the response of fish to FFW, FCR, PI and PPV (Ugwu *et al*., 2005c).
When growth of fish fed the P-supplemented diets at the rates of inclusion mentioned above are monitored based on protein intake, protein efficiency ratio, nitrogen metabolism, feed conversion, specific growth rate, gain or loss of tissue protein, proximate composition of the diets, the results show that monosodium phosphate was a better source of inorganic phosphorus supplement in the hybrids diet than other sources. The hybrids however

responded nutritionally better to control diets than to supplemented diets (Ugwu*et al.,* 2005d).
In the study where soluble reactive concentration level of the inorganic phosphorus (SRP) in experimental water, growth response and survival of the fish were investigated there was not pattern of increase or decrease in the values of the daily rate of gain (DRG), protein intake (PI), the phosphorus gain/loss (PGL) or survival of fish in relation to increase in soluble reactive inorganic phosphorus in water as dietary supplements of P increased from 0.6 – 1.2%. Water treated with Control diet had higher concentration of SRP than water of P-supplemented diets. Dietary supplementation of 0.8% and below is recommended (Ugwu *et al.,* 2005d).
Results from determination of phosphorus source-duration interactions on weekly protein intake PIW) and phosphorus gain/loss, it was found that losses in tissue phosphorus of fish were obvious from day 49. PIW and PGL of fish were both significantly affected by P sources-duration interactions ($P < 0.01$) (Ugwu *et al.,* 2006).

Table 12. Protein intake and phosphorus (P) gain or loss intake per week

P source P source	Mean values of protein intake per week (PIW) ($g\%^{-1}$)									
Duration (Days):	7	14	21	28	35	42	49	56	63	70
Monosodium phosphate	0.20	0.47	0.68	0.87	1.13	1.35	1.66	1.79	1.94	2.84
Monopotassium phosphate	0.20	0.43	0.65	0.80	1.01	1.26	1.52	1.58	1.77	2.64
Monocalcium phosphate	0.20	0.45	0.68	0.87	1.08	1.32	1.75	1.83	2.03	2.63
Dicalcium phosphate	0.20	0.44	0.66	0.84	1.03	1.21	1.42	1.64	1.87	2.48
Control diet	0.21	0.41	0.60	0.80	0.98	1.27	1.45	1.64	1.89	2.11
Purified diet	0.21	0.37	0.56	0.75	0.96	1.40	1.15	1.34	1.57	1.79
	Phosphorus gain or loss per week (g% -1)									
Monosodium phosphate	-0.46	0.30	0.03	0.00	0.01	0.05	-0.19	0.02	0.03	0.05
Monopotassium phosphate	0.20	0.06	0.05	0.08	0.28	0.11	-0.66	-0.11	0.05	0.02
Monocalcium phosphate	0.54	0.05	0.05	0.05	0.02	0.02	-0.54	0.00	0.05	0.01
Dicalcium phosphate	0.00	0.05	0.04	0.02	0.02	0.03	-0.12	-0.01	0.00	0.00
Control diet	0.15	0.24	0.07	0.11	0.00	0.02	-0.01	0.02	0.20	0.01
Purified diet	0.00	-0.02	0.00	0.08	0.11	0.08	-0.08	0.18	0.17	0.01

In a study in which we supplemented mega levels (1.0%, 1.2%, 1.4% and 1.6%) of inorganic phosphorus (monosodium phosphate) to African catfish (*Clariasgariepinus*) fry and determined the enzyme activity for amylase, trypsin, and lipase, we found that the intestinal tract pH optimum for activity recorded for amylase, trypsin and lipase were pH 8.0, 7.5 and 7.5, respectively from the Control while the pH range for the intestinal tract of fish fed P-supplemented diets ranged from 9.00 – 9.5 implying the P supplementation resulted in high alkaline medium for enzyme activity. At 1.6% level of P inclusion the pH ranged from 10.0 - 10.5 and the enzymes were inactive (Fig. 13). Trypsin enzyme, however, proved to be more tolerant of pH increases within the gut (10.5). The high temperature (60□ - 60.5□ C) effects of enzyme activity suggested that P supplementation might have prevented excessive rise in temperature in the gut of fish (Fig. 14). Inhibitory activity of P in the diets of *C.gariepinus* fry was dependent on the pH and temperature of the digesta as it flowed through the intestinal tract of the fish (Ugwu*et al.,*2007a).

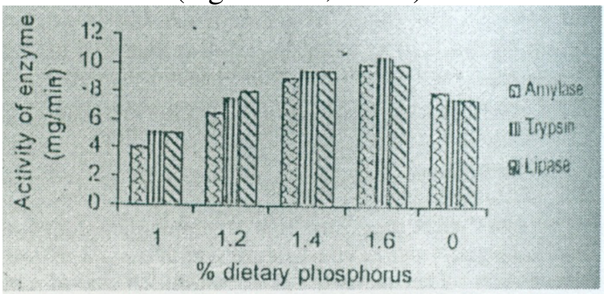


Fig. 13.pH effect of applying mega levels of dietary supplemental inorganic phosphorus on three enzymes in the digestive tract of Clarias gariepinus.

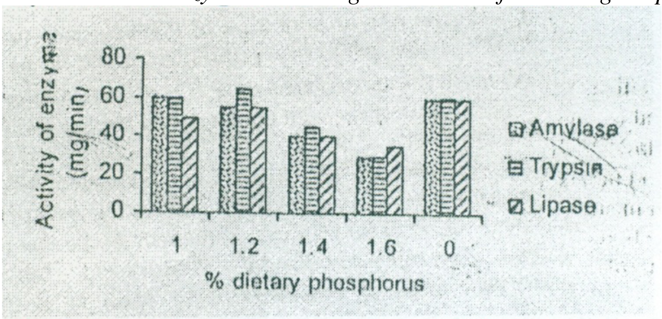


Fig. 14. Temperature (□C) effect of applying mega levels of dietary supplemental inorganic phosphorus on three enzymes in the digestive tract of Clarias gariepinus.

ii. Toxicity of anthropogenicsxenobiotics to *Clarias*

Fish lives in water which is a reservoir for all sorts of xenobiotics that come in forms like fertilizer, chemical effluents from factories or manufacturing plants, insecticides, to mention a few. The effects of these compounds are not well known. We embarked on some studies to determine the effect of some of these xenobiotics on *Clarias albopunctatus* (Lamonte and Nichole, 1927) (Mgbenka *et al*., 2003a; Mgbenka *et al*., 2003b). We studied the haematological changes in the fish subjected to sublethal concentration (0, 0.24, 0.5, 0.75 and 1.0 µg/L) Gammalin 20 for 21 days in static bioassay system. Compared to control, the erythrocytic count, haematocrit values and haemoglobin concentrations were significantly reduced ($P < 0.5$) in the treatment groups. There was also significant leukocytosis ($P < 0.05$) in the fish exposed to sublethal concentrations of Gammalin 20. The Gammalin-20-exposed fish suffered macrocytic anaemia.

Since it is important to anesthetize fish before handling and commercioal anesthtice susch as quinaldine and MS222 are expensive in Nigeria, we worked on finding a substitute anesthetics from local plantafter a preliminary study. The effects of crude extract, pure extract, aqueous fraction of pure extract and lipid fraction of the extract of air-dried leaves of *Erythrophleum suaveolens* as anesthetic on African sharptooth, *Clarias gariepinus,* and the African vundu catfish, *Heterobranchus longifilis,* fingerlings were studied. They were exposed to different doses of extracts in tanks. The time for each fish to reach anesthesia were recorded. The two clariids were anesthetized in up to 3.5 g/L crude extract and recovered in the fresh water. Soaking the leaves for 24 hours or 48 hours produced no significant difference ($P > 0.05$) in the time to reach anesthesia for the African vundu catfish. These fingerlings reached anesthesia in significantly shorter time (24.5 minutes at 2.4 g/L concentration) in pure unseparated extract than in the crude extract (70.5 minutes in 2.4 g/L concentration). All fingerlings exposed to 4 g/L extract did not recover. Those exposed less than 3.5 g/L of plant material were anesthetized and recovered only to die later within 24 hours (Table 13). The time to reach anesthesia decreased with an increase in concentration of the plant extract. Of the two fractions, only the lipid fraction had anesthetizing effect on fish. It, however, took longer to produce the effect than the unseparated pure extract. The aqueous fraction of the pure extract and the control produced no observable anesthetic effects on the fish within 180 minutes. That suggests that the anesthetizing active ingredient resided in the lipid fraction but some factor in the aqueous layer was necessary to quicken its action. Similar results were got with the sharptooth catfish. Since the fingerlings died after recovering from anesthesia it was concluded that the stafety margin of *E. suaveolens* for fingerlings was very narrow at the concentrations used. It is, therefore, not recommended for use on the fingerlings of clariid catfishes.

Table 13. Mean time of anesthesia for African catfish using dried powdered leaves of *Erythrophleumsuaveolens* soaked in doinized water.

Water quality parameter and level	Mean weight of fish (g)	Mean time of anaesthesia (min)
Total hardness (mg/L as $CaCO_3$)		Mean time of anaesthesia[1]
20	31.3	63.9 ± 0.16[a]
60	30.8	60.1 ± 0.31[b]
100	31.3	55.0 ± 0.08[c]
150	32.0	51.2 ± 0.29[d]
pH		
6.01	33.3	59.3 ± 0.39[a]
7.00	32.5	62.9 ± 0.35[b]
8.00	31.4	67.3 ± 0.14[c]
9.02	31.3	69.5 ± 0.62[d]
Salinity (psu)		
0.032	30.8	64.0 ± 0.15[a]
0.034	31.3	62.7 ± 2.18[b]
0.35	32.5	55.0 ± 0.34[c]
0.037	33.3	51.2 ± 0.27[d]

[1]*Value followed by different superscripts are significantly different (P<0.05).*

Similarly¸ we studied the effect of Gammalin 20 on differential white blood cell counts of the African catfish. Compared to control monocytes were significantly lower in Gammalin 20-exposed fish and were absent in fish exposed to 0.75 and 1.0 µg/L Gammalin 20 by day 21. Eosinophils were as abundant as the neutrophils. In groups where they were identified, eosinophils increased with Gammalin 20 concentration. Total white blood cell count increased with degree of exposure of Gammalin 20. The fish generally suffered monocytopenia. The observation in the study was considered adaptive response mechanism to protect the fish against the effect of Gammalin 20 intoxication and associated infections.

In another study, we exposed the fish to graded concentration of Actellic 25 EC (0, 0.3, 0.5, 0.8 and 1.0 µg/L) in a static renewal bioassay system (Oluah *et al*., 2004). Similar observations as in Gammalin 20 were made (Tables 13 – 16), Fig. 13). Compared to Control, there was significant lymphocytosis (P < 0.05) in the Actellic 25 EC-exposed fish. The total leucocyte counts differed significantly (P < 0.05) in the treatment groups.Decreased eosinophils, monocytopenia and neutropenia were evident in the treatments groups, indicative of mobilization of the body’s defense system due to Actellic 25 EC challenge leading to leucopoiesis.

Table 14: The mean[1] total and differential leucocyte count *lariasalbopunctatus* exposed to 0.3µg/l actellic

Types of leucocytes (%)	Exposure Period (days)			
	Control	6	12	18
Agranulocytes (%)				
Lymphocytes	60.50 ± 1.69	64.50 ± 1.38	72.50 ± 1.04	71.00 ± 1.64
Monocytes	13.50 ± 0.82	12.50 ± 0.62	11.50 ± 0.39	9.50 ± 1.03
Ganulocytes (%)				
Neutrophils	22.0 ± 1.74	17.5 ± 1.09	16.00 ± 1.17	18.50 ± 1.42
Eosinophils	4.0 ± 0.08	4.0 ± 0.10	-	1.00 ± 0.01
Basophils	-	1.50 ± 0.52	-	-
Total leucocyte	4.70 ± 1.80	11.70 ± 1.75	20.5 ± 1.46	54.84 ± 1.51

[1]*Value of means of 5 determinations.*

Table 15. The mean[1] total and differential white blood cell count in *Clarias. albopunctatus* exposed to 0.5µg/l actellic

Types of leucocytes (%)	Exposure Period (days)			
	Control	6	12	18
Agranulocytes **(%)**				
Lymphocytes	60.50 ± 1.69	65.0 ± 1.48	81.0 ± 1.92	80.5 ± 1.86
Monocytes	13.50 ± 0.82	16.0 ± 0.66	3.5 ± 0.11	3.5 ± 0.02
Ganulocytes				
Neutrophils	22.0 ± 1.74	18.0 ± 1.20	15.5 ± 1.09	16.0 ± 1.40
Eosinophils	4.0 ± 0.08	1.0 ± 0.02	-	-
Basophils	-	1.0 ± 0.01	-	-
Total leucocyte	4.70 ± 1.80	15.05 ± 1.03	27.60 ± 1.26	25.00 ± 1.58

[1]Value of means of 5 determinations.

In another study we found the erythropoietic response and haematological parameters of fingerling catfish exposed to sublethal concentrations of actellic. The fish was exposed to graded concentration of the actellic (0.3, 0.5, 0.8 and 1/0 mg/l), the gill were cut, fixed in Bouin's fluid, dehydrated in different grades of alcohol, embedded in paraffin wax, sectioned (10µm), stained in haematoxylin-eosin and examined. Haematological assay was done using standard methods. The result showed that erythrocyte count, haemoglobin, haematocrit decreased significantly (P < 0.05) in the actellic-exposed fish (Tables 14 – 16). The changes in haematological parameters were concentration dependent except for leucocyte.The fish suffered from macrocytic anaemia and the acetellic-exposed fish developed clogged gill filaments (Tables 17 – 18, Fig. 13) (Mgbenka *et al*., 2005).

Table 16. Changes in hematological parameters in Clarias albopunctatus during exposure to 0.3µg/L actellic

Variables	Duration of Exposure (days)			
	Control	6	12	18
Haemoglobin (g/dl)	16.0 ± 0.86	15.0 ± 0.17	15.0 ± 0.17	17.0 ± 0.92
Erythrocyte (10^6/mm^3)	3.55 ± 0.11	3.25 ± 0.08	2.63 ± 0.42	2.24 ± 0.51
Hematocrit (%)	36.0 ± 1.26	44.5 ± 1.8	15.0 ± 1.08	31.0 ± 1.40
MCV (µm3)	130 ± 2.81	137.08 ± 1.76	57.03 ± 1.6	138.39 ± 1.56
MCH (pg)	44.74 ± 0.28	46.15 ± 0.91	60.84 ± 0.48	75.89 ± 0.65
MCHC (%)	34.41 ± 1.60	33.67 ± 1.04	106.67 ± 1.84	54.89 ± 0.65
WBC (10^4/mm^3)	4.70 ± 1.50	11.70 ± 1.75	20.50 ± 1.32	54.84 ± 1.46

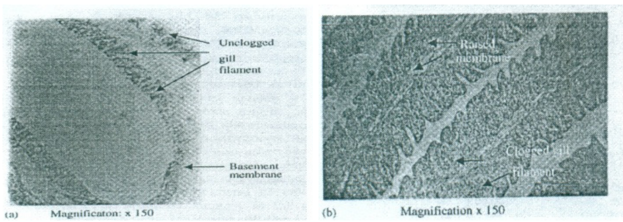


Fig. 13. a. Clearer gill filaments of Clarias not treated with acetellic (control). b. Acetellic-treated (03µg/l *Clarias* gill filaments showing clogging by mucus.

Table 17.Changes in hematological parameters in *Clarias albopunctatus* during exposure to 0.5µg/L actellic.

Variables	Duration of Exposure (days)

	Control	6	12	18
Haemoglobin (g/dl)	16.0 ± 0.86	12.0 ± 0.56	12.5 ± 0.24	12.0 ± 0.62
Erythrocyte (10^6/mm^3)	3.55 ± 0.11	2.95 ± 0.58	2.42 ± 0.80	2.13 ± 0.61
Hematocrit (%)	46.5 ± 1.26	36.0 ± 1.02	12.0 ± 1.01	28.0 ± 0.81
MCV (µm3)	130.99 ± 2.1	122.03 ± 1.58	49.57 ± 1.36	131.46 ± 1.61
MCH (pg)	45.07 ± 0.47	40.68 ± 0.85	51.63 ± 0.44	56.34 ± 0.96
MCHC (%)	34.41 ± 1.60	33.33 ± 1.09	104.17 ± 1.80	42.88 ± 1.43
WBC (10^4/mm^3)	4.70 ± 1.80	15.05 ± 1.03	27.60 ± 1.26	25.00 ± 1.58

Table 18.Changes in hematological parameters in *Clarias albopunctatus* during exposure to 0.8µg/L actellic.

Variables	Duration of Exposure (days)			
	Control	6	12	18
Haemoglobin (g/dl)	16.0 ± 0.86	5.3 ± 0.22	7.0 ± 0.04	8.5 ± 0.46
Erythrocyte (10^6/mm^3)	3.55 ± 0.11	2.05 ± 0.10	2.22 ± 0.51	2.08 ± 0.36
Hematocrit (%)	46.5 ± 1.26	15.9 ± 1.27	7.0 ± 0.89	23.0 ± 1.09
MCV (µm3)	130.99 ± 2.81	60.0 ± 1.56	13.53 ± 1.01	110.58 ± 1.48
MCH (pg)	45.07 ± 0.47	20.0 ± 0.44	31.53 ± 0.84	40.87 ± 0.09
MCHC (%)	34.41 ± 1.60	33.33 ± 1.56	100.00 ± 1.25	36.96 ± 1.70
WBC (10^4/mm^3)	4.70 ± 1.80	20.65 ± 1.03	32.6 ± 1.74	39.9 ± 1.83

Table 19: Changes in hematological parameters in *Clarias albopunctatus* during exposure to 1.0µg/L actellic.

Variables	Duration of Exposure (days)			
	Control	6	12	18
Haemoglobin (g/dl)	16.0 ± 0.86	5.0 ± 0.08	3.0 ± 0.039	5.0 ± 0.26
Erythrocyte (10^6/mm^3)	3.55 ± 0.11	2.5 ± 0.06	2.18 ± 0.03	2.0 ± 0.01
Hematocrit (%)	46.5 ± 1.40	15.0 ± 0.68	3.0 ± 0.09	22.0 ± 1.005
MCV (µm3)	130.99 ± 2.81	62.0 ± 0.54	13.7 ± 0.78	110.0 ± 1.29
MCH (pg)	45.07 ± 0.80	20.0 ± 0.86	13.76 ± 0.48	25.0 ± 1.07
MCHC (%)	34.41 ± 1.60	32.26 ± 1.11	100.0 ± 1.29	22.73 ± 1.38
WBC (10^4/mm^3)	4.70 ± 1.80	31.45 ± 1.19	39.7 ± 1.24	39.8 ± 1.60

Further in our study on anthropogenics xenobiotics, we studied the effects of effluents from the Nigerian Breweries Plc 9th Mile Corner on the aquatic environment. In the study, we monitored the physicochemical parameters of the effluent at various source points of discharge into the water using standard analytical methods both for upstream water samples collected before the factory and downstream from the factory effluent discharge. We found that but for the chemical oxygen demand (COD) and lead which were high in the receiving river (200.6 mg/l and 14.31, respectively, compared to the Federal Ministry of Environment standards of 40 mg/l and 1 mg/l, respectively), all other mean values of measured parameters (pH, temperature, dissolve oxygen (DO), biological oxygen demand (BOD), copper and zinc) were generally within acceptable specifications for Federal Ministry of Environment (FMENV) and international effluent standards for municipal and industrial effluents discharged into surface waters (Tables 19 and 21) (Mgbenka and Atama, 2005). That implied that water from the 9th mile corner stream can be used to produce clariid fishes though lead presents a challenge if the level is not checked.

Table 20. Physiochemical parameters in relation to sampled sites (Mean ± Standard Error or Mean)[1].

Location	Physiochemical parameter										
	Temp (°C)	pH	COD (mg/l)	DO (mg/l)	BOD (mg/l)	TA (mg/l)	TH (mg/l CaCO3)	Zinc (Zn) (mg/l)	Copper (Cu) (ppm)	Lead (Pb) (ppm)	As (mg/l)
Fermentation unit (A)	26.20 ±0.25^{a}	5.31 ±0.03^{a}	8.54	ND	ND	29.97 ±0.34^{a}	13.80 ±0.28^{a}	0.60 ±0.01^{ab}	0.14 ±0.03^{ab}	14.1 ±0.06^{a}	ND
Brew house (B)	48.30 ±0.26^{b}	4.84 ±0.06^{c}	5.30 ±1.69^{ab}	ND	ND	28.00 ±0.54^{f}	28.00 ±0.46^{b}	0.55 ±0.00^{a}	ND	13.93 ±0.00^{a}	ND
Bottling washing unit (C)	40.60 ±0.20^{c}	8.45 ±0.02^{c}	193.20 ±1.56^{c}	2.80 ±0.03^{a}	1.12 ±0.05^{a}	46.70 ±2.67^{b}	18.30 ±0.36^{c}	0.56 ±0.00^{a}	ND	13.93 ±0.00^{a}	ND
Point of discharge of mixed effluent (D)	29.10 ±0.36^{d}	6.36 ±0.01^{d}	284.70 ±1.48^{d}	2.79 ±0.02^{a}	1.40 ±0.04^{a}	39.20 ±0.72^{c}	22.30 ±0.53^{d}	0.92 ±0.01^{bc}	0.24 ±0.02^{bc}	17.00 ±0.21^{b}	ND
1km from discharge point (E)	27.20 ±0.3^{e}	6.85 ±0.05^{e}	2.85 ±1.10^{b}	2.99 ±0.05^{b}	1.47 ±0.03^{b}	36.00 ±0.34^{cd}	13.10 ±0.33^{a}	0.68 ±0.02^{d}	0.42 ±0.05^{bc}	15.63 ±0.21^{c}	ND
Point of entry into receiving river (F)	26.70 ±0.23^{ae}	5.78 ±0.09^{f}	244.30 ±1.24^{e}	5.59 ±0.06^{c}	5.00 ±0.05^{d}	36.63 ±0.86^{cd}	16.60 ±0.40^{e}	0.61 ±0.02^{a}	0.30 ±0.17^{bc}	14.61 ±0.10^{d}	ND
250m upstream of Ajali River (G)	22.20 ±0.31^{f}	7.01 ±0.02^{g}	80.00 ±1.00^{f}	5.61 ±0.03^{c}	3.96 ±0.03^{c}	18.00 ±0.32^{e}	11.76 ±0.26^{f}	0.53 ±0.00^{b}	ND	14.08 ±0.06^{a}	ND
250 m downstream (H)	25.90 ±0.25^{a}	6.53 ±0.02^{h}	200.60 ±1.59^{b}	5.66 ±0.03^{c}	4.67 ±0.07^{e}	34.60 ±0.71^{a}	21.80 ±0.34^{d}	0.67 ±0.01^{d}	0.20 ±0.02^{ac}	14.31 ±0.11^{ad}	ND

[1]As = Arsenic; BOD = biochemical oxygen demand; COD = chemical oxygen demand; DO = dissolved oxygen; ND = not detectable; TA = total alkalinity; TH = total hardness. Means in the same column followed by the same superscript are not significantly different (P>0.05).

[1]As = Arsenic; BOD = biochemicaloxygen demand; COD= chemical oxygen demand;DO = dissolved oxygen; ND= not detectable; TA = total alkalinity; TH = totalhardness. Means in the same column followed by thesamesuperscriptare not significantlydifferent (P>0.05).

Table 21. Mean physiochemical parameters of the Nigeria Breweries effluent at the point of entry into thereceiving Ajali River and 250m down on the receiving river compared with the Nigerian Federal Ministry of Environment (FMENV) standards.

Parameter	Mean value at point of entry into Ajali River	Main value at 250m downstream	FMENV Standard
pH	5.78	6.53	7.0 - 10
Temperature	26.7	25.9	35
BOD (mg/l)	5.00	4.70	10
COD (mg/l)	244.3	200.6	40
DO (mg/l)	5.59	5.66	>4.0
Lead (mg/l)	14.61	14.31	1.0
Copper (mg/l)	0.30	0.20	1.0
Zinc (mg/l)	0.61	0.67	1.0

We similarly monitored the *Mmiriele* stream, Nnewi for the effect of effluents from a vegetable oil factory. The parameters included: BOD, COD, DO, ammonia nitrogen, total hardness, pH, arsenic, copper, lead and zinc. The results again showed when compared with FMENV and international standards that but for leadwhich was high mean values of other parameters were within acceptable standards (Table 22) (Atama and Mgbenka, 2005). From the two studies done with the streams that receive effluents from industries, the presence of lead is noteworthy due to its public health implications. The high levels of lead is probably to battery charging business and indiscriminate dumping of lead containing products, and there is need for strict adherence to environmental quality standards for municipal and industrial effluents as this is tangential to production of good quality catfish with water from streams and rivers.

Table 22. Mean distribution of physiocochemical parameters along a vegetable oil factory effluent discharge route in Nnewi, Nigeria.

	Water Quality Parameter								
Sites	Chemical oxygen demand (mgl^{-1})	Dissolved oxygen (mgl^{-1})	Biochemical oxygen demand (mgl^{-1})	Ammonia nitrogen (mgl^{-1})	Total hardness (mgl^{-1})	pH	Copper (mgl^{-1})	Zinc (mgl^{-1})	Lead (mgl^{-1})
Fat trap	720.00 $\pm5.94^a$	1.81 $\pm0.06^a$	0.97 $\pm0.07^a$	15.50 $\pm0.09^a$	18.30 $\pm0.63^a$	7.53 $\pm0.02^a$	0.41 $\pm0.04^a$	0.54 $\pm0.02^a$	14.38 $\pm0.17^a$
Oil discharge point	196.00 $\pm3.57^b$	2.00 $\pm0.08^a$	1.82 $\pm1.08^b$	4.68 $\pm0.06^b$	20.00 $\pm0.82^b$	6.86 $\pm0.09^b$	0.46 $\pm0.05^a$	0.56 $\pm0.02^a$	15.43 $\pm0.46^b$
Sedimentation tank	148.70 $\pm2.27^c$	3.43 $\pm0.07^b$	2.94 $\pm0.04^c$	2.62 $\pm0.04^c$	24.00 $\pm0.68^c$	6.69 $\pm0.02^b$	0.47 $\pm0.04^a$	0.64 $\pm0.03^b$	16.73 $\pm0.31^c$
Effluent receiving stream	117.30 $\pm2.36^d$	5.00 $\pm0.08^c$	4.41 $\pm0.08^d$	3.67 $\pm0.06^d$	11.20 $\pm0.04^d$	6.94 $\pm0.04^c$	0.31 $\pm0.06^b$	0.56 $\pm0.02^a$	14.61 $\pm0.21^a$
250 m downstream	106.20 $\pm2.62^a$	6.69 $\pm0.07^d$	4.28 $\pm0.09^d$	2.42 $\pm0.06^e$	16.40 $\pm0.62^e$	7.29 $\pm0.06^d$	0.18 $\pm0.03^a$	0.57 $\pm0.02^a$	14.68 $\pm0.29^c$

[1]Mean values in a column followed by the same superscripts are not significantly different (P>0.05)

Mean values in a column followed by the same superscripts are not significantly different ($P>0.05$)

We conducted studies on the effect of diethyl phthalate (DEP) used as a plasticizer, a detergent base, in aerosol sprays, as a perfume binder and after shave lotion on fingerlings of *Clarias gariepinus*. Among the variables studied and published in five journal papers on the exposure to graded concentrations of DEP to *Clariasgariepinus* fingerlings were the effects DEP on toxicity, haematology, histopathology, the gills and the enzymes. In summary, we determined the acute toxicity effects of DEP on the fish. The fish was treated with 50, 75, 100 and 150 µg/l. DEP was dissolved in distilled water to determine the LC50. There was 100% mortality observed in 150 µg/l. The LC50 of DEP was estimated at log toxicant concentration as 2.217, 2.734, 3.435 and 3.931 µg/l at 24, 48, 72, 96 h and 1.871µg/l for the total death. This shows that the impacts are dose and time dependent with respect to marked reduction in mortality rate. At sub-lethal concentrations of the DEP of 30, 40, 60 and 80 µg/l in a renewal bioassay system, the water and the test compound were changed intermittently. One group was maintained as a control in dechlorinated water. There was significant difference ($P < 0.05$) in brain and muscle acetylcholine-esterase (AchE) activity compared to the control. The liver alkaline phosphatase (ACP) activity was statistically significant ($P < 0.05$) at day 15 while the muscle ACP in other treatment groups showed no significant difference ($P > 0.05$). Liver alanine aminotransferase (AST) showed no significant difference in all treated groups ($P > 0.05$) and liver ALT activity was statistically significantly different ($P < 0.05$) at day 30 only. The analyses of haematological parameters (haemoglobin (HB), packed cell volume (PCV), mean cell volume (MCV), mean cell haemoglobin (MCH), red blood cell (RBC) and white blood cell (WBC)) carried out showed that HB and RBC levels showed no significant difference ($P > 0.05$) compared to the control. The parked cell volume showed a significant difference ($P < 0.05$) at day 30 only. The leucocyte count throughout the exposure period showed that the mean values are statistically significantly different ($P < 0.05$) at day 15 only compared to the control. The MCV showed a significant difference at day 15 ($P < 0.05$) whereas MCH and mean cell haemoglobin concentration showed no significant difference ($P > 0.05$) throughout the exposure period. No significant difference was seen between the lymphocytes and the neutrophils. In day 0 and 15 only, the monocytes and the lymphocytes showed a significant difference ($P < 0.05$) compared to control. There was gill damages indicative of toxicity of DEP with raised lamella, oedema of the lamella epithelia, loss of lamellar epithelium, mild oedema and raising of the filament. There was liver damage which showed focal necrosis and vacuolization, hepatocyte degeneration in the liver. These alterations may have long term effects on that are continuously exposed to DEP in the aquatic environment and DEP exposure should be avoided in big head clariid catfish aquaculture (Mgbenka et al., 2011a; Mgbenka et al., 2011b; Mgbenka et al., 2012a; Mgbenka et al., 2012b and Obiezue et al., 2014)..

iii. Breeding and fish seed studies

We undertook some breeding and fish seed studies in which we determined the oocyte diameter, fecundity (number of ripening eggs in the female prior to the next spawning) and sex ratio (the ratio of male to female) of the African catfish (*Clarias gariepinus*, Pisces:Clariidae) collected with a fleet of gill nets (mesh size 7 – 12 cm) for 222 males and 207 females from the Anambra River for one year. We also determined the six stage modified maturity groups of Clay (1979) and condition factor of the fish in the Anambra River basin. We found that the oocyte diameter had bimodal size distribution suggesting possibility of multiple spawning cycles in a year. Fecundity was between 9,000 and 25,000 ova and was linearly related to fish ovarian weight, gonodosomatic index, fish weight and standard length (Figs. 14

and 15, Table 23). The mean yearly ratio of male:femalewasclose to unity at 1:1.07 (Eyo and Mgbenka, 1992).

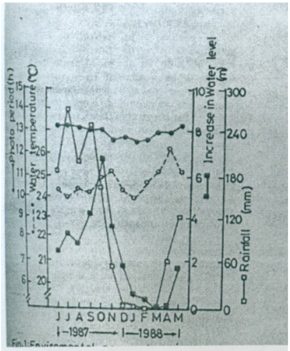


Fig. 14. Environmental parameters in Anambra
River basin from June 1987 – May 1988

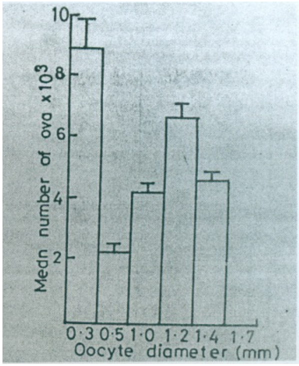


Fig. 15. Variation of oocyte diameter in *Clarias*
gariepinus from Anambra River Basin

Table 23. Monthly variation in sex ratio of *Clarias gariepinus*
caught from Anambra River.

Month	Year	Number of ♂	Number of ♀	♂:♀ratio	Calculated value x^2
J	87	18	20	1:0.9	0.1
Jy	87	14	26	1:0.5	3.6
A	87	17	22	1.07	0.6
S	87	20	22	1:0.9	0.1
O	87	23	6	1:3.8	10.0*
N	87	23	12	1:1.9	3.6
D	87	18	10	1:1.8	2.3
Ja	88	23	12	1:1.9	3.5
F	88	26	14	1:1.8	3.6

M	88	20	16	1:1.2	0.4
A	88	11	19	1:0.6	2.1
My	88	9	28	1:0.3	9.8*
Total:		222	207		
Annual sex ratio:				1:1.07	0.5

C. gariepinus showed distinct cycle of maturation. Condition factor showed an annual cycle of low and high values relative to peak and minimum spawning, respectively (Table 24, Fig. 22) (Mgbenka and Eyo, 1992).

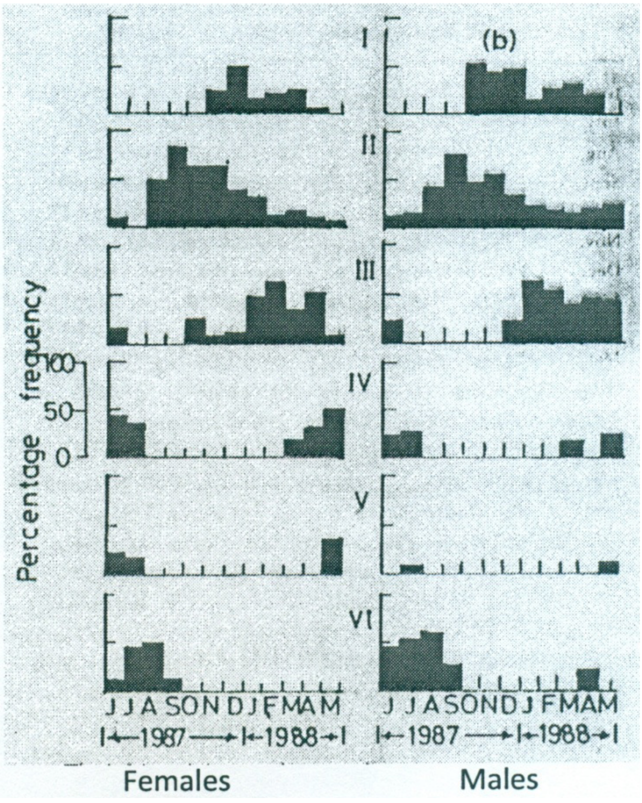


Fig. 22.Monthly variation in the frequency of *Clarias gariepinus* at different maturation stages of a.

females and b. males.

Table 24. Monthly variation in condition factor and maturation stages of Clarias *gariepinus*in the Anambra River Basin

Month	Year	Mean condition factor ♀	Mean condition factor ♂	Monthly condition factor	Maturation stages percent	Dominate for females	Dominate for ♂	% dominance for ♀	% Maturity dominance
J	87	0.69±0.08	0.67 ± o.o4	0.67 ± 0.08	II,III,IV,V,V1	IV	VI	45.00	34.21
Jy	87	0.61±0.09	0.66 ± 0.07	0.63 ± 0.08	II,IV,V,VI	VI	VI	46.20	47.50
A	87	0.53±0.01	0.61 ± 0.07	0.58 ± 0.11	II,VI	VI	VI	50.00	53.48
S	87	0.53±0.02	0.57 ± 0.07	0.54 ± 0.06	II,VI	II	II	86.40	80.95
O	87	0.56±0.02	0.61 ± 0.11	0.60 ± 0.11	I,II,III	II	I	66.70	51.72
N	87	0.52±0.07	0.61 ± 0.13	0.61 ± 0.14	I,II,III	II	II	66.70	50.00
D	87	0.70±0.17	0.62 ± 0.10	0.65 ± 0.13	I,II,III	I	I	50.00	46.43
Ja	87	0.62±0.17	0.63 ± 0.08	0.63 ± 0.08	I,II,III	III	III	50.00	60.00
F	88	0.62±0.06	0.64 ± 0.07	0.63 ± 0.07	I,II,III,IV	III	III	64.30	57.50
M	88	0.63±0.07	0.64 ± 0.07	0.63 ± 0.07	I,II,III,IV	III	III	37.35	38.89
A	88	0.69±0.11	0.61 ± 0.11	0.66 ± 0.11	I,II,III,IV,VI	III	III	52.60	50.00
My	88	0.66±0.05	0.55 ± 0.08	0.63 ± 0.08	II,III,IV,V	IV	III	50.00	43.34

[1]I = Immature, II = Unripe, III = Almost ripe, IV = Ripe, V = Running ripe, VI = Spent. 87 = 1987, 88 = 1988. J, Jy, A, S, O, N, D, Ja, F, M, A, My = June, July, August, September, October, November, December, January, February, April, May, respectively

[1]I = Immature, II = Unripe, III = Almost ripe, IV = Ripe, V = Running ripe, VI = Spent. 87 = 1987, 88 = 1988. J, Jy, A, S, O, N, D, Ja, F, M, A, My = June, July, August, September, October, November, December, January, February, April, May, respectively

[1]I = Immature, II = Unripe, III = Almost ripe, IV = Ripe, V = Running ripe, VI = Spent. 87 = 1987, 88 = 1988. J, Jy, A, S, O, N, D, Ja, F, M, A, My = June, July, August, September, October,

Gonad maturation of 320 specimens of *Heterobranchus longifilis* (Valenciennes, 1840) similarly collected for 17 months with a fleet of gill nets (5.1 – 7.1 mm stretched) in Idodo River was also studied. The gonad maturation stages of immature (Stage 1), developing (stage 2), maturing/ripening (Stage 3), ripe (Stage 4) and spent (Stage 5) of Ezenwaji (1992) were used. The main spawning periods was found to occur from May to September, a period of water elevation while the second period was in January and February, a period of reduced water level (Figs. 23 and 24). This coincided with the main rainy season and the short rainy season, respectively. There was no significant difference (P > 0.05) in the male:female ratio of the pooled sample. Fecundity ranged from 6,001 to 51,216 eggs per female (mean 24,816 ± 14,676; weight of female, 374 ± 297 g). Fecundity was positively correlated with total length (r = 0.96) of fish and fish weight (r = 0.94) and ovary weight (r = 0.98) (Inyang et al., 1997).

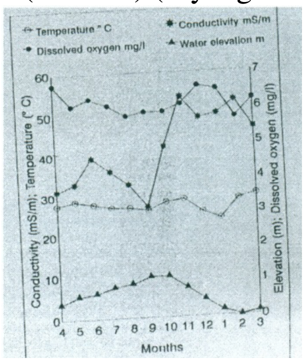


Fig. 23. Mean monthly values of the physicochemical parameters of the Idodo River. X axis: numbers 1 to 12 stand for the months of January to December; y axis: elevation designates mean water level above dry season level at sampling stations.

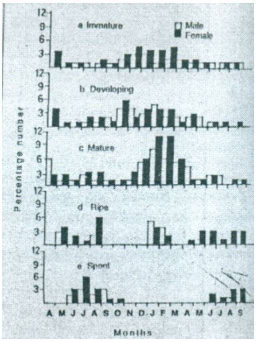


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Fig. 24.Monthly variation of gonad maturation in Heterobranchus longifilis occurring in the Idodo River.

In a collaborative study in the laboratory in which the fecundity of four batch weights (10 samples each) of gravid *Clariasgariepinus* weighing 60 ± 0.17 g, 125 ± 0.15 g, 250 ±0.21 g and 500 ± 0.16 g raised in a hatchery was studied from paired ovary of each fish dissected out, weighed (g), its length measured (mm). Each paired ovary eggs was hardened and egg clumping removed in 1 % formalin in 06 % saline solution for 3 weeks. After 3 weeks, each paired ovary was torn apart on a 2 mm mesh circular sieve over a stream of water. The eggs that passed through the 2 mm mesh were sub-sampled from each paired ovary, counted and all the eggs in each paired ovary were determined thereafter by volumetric method. The total fecundity of the 40 gravid fish studied ranged from 6,450 to 71,450 eggs per fish. The mean fecundities of the 60 g125 g, 250 g and 500 g fish were 8,501.9 ± 295.5,13,364.0 ± 1734.3, 41087.9 ± 12258.1 and 51,186.0 ± 13851.0 eggs respectively. The higher fecundity of *C. gariepinus* (range: 6,450 to 71450) obtained from this study (Table 25) compared with the range of 9,000 to 25,000 we earlier reported from the wild stock from the Anambra River *(*Eyo and Mgbenka, 1992) indicates that hatchery-raised *C. gariepinus* was more fecund than the wild fish in the Anambra area of the sub-region. Therefore, hatchery-raised *C. gariepinus* appeared to be better for fish breeding in fingerlings production than the wild fish (Egwui *et al*., 2007).

Table 25. Mean fecundity ± SEM1 of different weights (g) of *Clarias gariepinus* brood fish.

Weight of fish (g)	Total number of fish	Mean fecundity	Fecundity range
60	10	8,501 ± 295.5a	6,450 - 10,087
125	10	13,364 ± 734.3a	11,650 - 19,400
250	10	41,087.9 ± 2258.1b	31,973 – 59,819
500	10	51,186.0 ± 3,851.0	22,995 – 71,450

The relationships between fecundity and fish weight (FW) (n = 40, r = 0.8761), fish total lengh (TL) (n= 40, r = 0.8266), fish ovarian weight (OW) (n = 40, r = 0.7609), fish ovarian length (OL) (n = 40, r = 0.7236), gonadosomatic index (GSI) (n = 40, r = 0.5992) and fish condition factor (K) (n = 40, r = 0.9046) obtained were linear and positive and the condition factor appeared to be the best predictor of fecundity in *C. gariepinus* studied.

In another such study it was recognized that induced breeding of *Clarias gariepinus* in cages, ponds or concrete systems can be expensive. The use of rectangular (1.5 m x 1.5 m x 1.0 m) pen of polyamide monofilament netting to induce breed *C. gariepinus,* a less expensive structure was explored (Orji et al., 2002). Hypophysation was done using pituitary from *C. gariepinus* donor. For artificial induced breeding in papa pens stripping of eggs was done 9 – 11 hours from injection while males were cut open to squeeze out milt and fertilization effected and the fertilized eggs transferred to the pens set up in a river. In the induced breeding in hapa pens by natural spawning, the paired male and female spawners in the pens set up in river were given one knockout injection of homoplastic pituitary at the rate of 0.33 mg/120 g body weight. There were poor results from natural fertilization attributable to lack of adequate substrate in the pens for male fish to display courtship and subsequent fertilization of eggs but fertilization was satisfactory in artificially induced bred fish. It was established from the artificial fertilization that the latency period for *C. gariepinus* is 9 -11 h (Orji *et al*., 2002).

iv. Fisheries and river studies

Though I have been involved in 10 reservoir and river studies, I want to report here one of the early studies we did that highlights aspects of the reproductive biology of *Heterobranchus longifilis* (Val., 1840) in the Idodo River Basin, southeastern Nigeria (Inyang et al., 1996). In summary, the maturation stages of the gonads, size at maturity, sex ratio and fecundity of *Heterobranchus longifilis*
were examined on 320 specimens collected from the Idodo River from April 1991 to September 1992. Individuals with all stages of gonad maturation were collected throughout the year. The main spawning period based on gonad maturation occurred from May to September while a second period was in January and February. These periods coincided with the main rainy season and the short rainy season of the year, respectively. There was no significant difference ($P > 0.05$) in male : female ratio of the pooled sample. Fecundity range between 6,001 to 51, 216 eggs/female, 374 ± 297 g). Fecundity was highly and positively correlated with total length ($r = 0.941$), standard length ($r = 0.937$), body weight ($r = 0.941$) and ovary weight($r = 0.981$) of the fish.

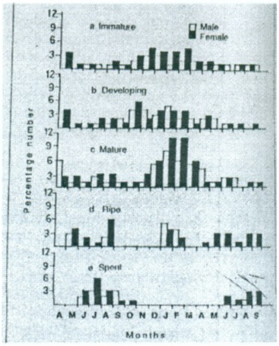

Fig. 25. Mean variation of gonad maturation of *Heterobranchus longifilis* occurring in the Idodo River.

a. **Fish processing studies**

We did some studies to determine the most cost effective ways of producing quality fish products after harvest. One of these was published in Eyo and Mgbenka (1992) and Oparaku *et al.* (2010). In Eyo and Mgbenka we undertook to teach some fishers and farmers more efficient ways of processing harvested fish. In Oparaku et al. (2010) we had a comparative study of solar and sun drying of Clarias gariepinus and two other fish species, thus: the sun and solar drier were evaluated for their drying effectiveness with three species of freshwater fish; *Gymnarchus* niloticus, *Heterotisniloticus* and *Clarias gariepinus*. The highest mean temperature that could be attained in the solar dryer was 70 ^{0}C at time 14.00 hour while the ambient temperature and insulation were 33.5 ^{0}C and 857.6 w/m^2 respectively. Proximate and organoleptic characteristics of the sun and solar dried products were carried out. It was found out that quality of the fish products dried in the solar drier were superior to those sun-dried. Organoleptic characteristics of the solar dried were better, especially the odour and moisture reduction was more in solar than in sun dried products. It took only three days for the fish to be completely dried to constant weight in the solar drier compared with sun dried fish products which took seven days to dry.

We also used recirculating system, an efficient way of conserving culture water to raise fingerlings of *Clarias gariepinus.* Recirculation leaves the water prone to high bacteria load due to waste from feaces from the fish and other inputs in the system such as waste feed. We therefore investigated the use of UV light since UV disinfection will require not chemical consumption, no transportation and handling, no harmful by-products formed, a minimum or no moving parts therefore low energy input in treating the waste water to reduce/eliminate the bacteria load. Water inlet points, followed by application of the UV rays, outgoing points of the culture tanks and the outlet of filter tanks were monitored for bacteria. Other parameters monitored were: temperature pH, $CaCO_3$, NO_3, NO_2 and NH_3. These were determined using water analysis kit by Hague while the microbial analysis was carried out using the MacConkey agar plate. Temperature was measured by mercury in glass thermometer. The UV disinfection method was found suitable for treatment of waste water from the recirculating system. This is obvious since the treated sample of water had lower coliform count than the other waste water samples. The favourable quality of the UV disinfected water was also observed in its improved chemical properties especially ammonia and dissolved oxygen (Oparaku *et al., 2011*).

Conclusion

I have informed this audience that aquaculture was an old art which has roots in China many years before the birth of Christ on earth. In Africa however, it has roots in ancient Egypt dating back also to at least 1000 BC. However, I have stated that aquaculture as a science and viable industry that gives returns on investment started 50 - 60 years ago. In Nigeria, aquaculture started in 1951 but had firmer branches in the western Nigeria in the 1970s.

I have in this lecture shown that catfishes in general are good source of animal protein with full complements of essential amino acids (though with low methionine level) and omega-3 fatty acids. I have also shown that the farming of the African catfishes of *Clarias gariepinus, Heterobranchus longifilis, Heterobranchus bidorsalis* and the hybrid*, Heteroclarias* hold the key to animal protein security in Nigeria. I have shown that culture of such fish is economically viable.

In this lecture I have shown that I have researched extensively in support of culture of the clariid catfishes, though I have done some work in other areas of zoology and environmental biology that were not discussed. My research has helped in the choice of strain of catfish for aquaculture, the nutrition of the fish, the river studies in search of better fish for culture, the fecundity and to gain knowledge of the best breeding time of year, the breeding and production of fish seed, processing of the fish to encourage good financial returns from the farmed fish. Good government policies to encourage clariid fish farming will ensure that quality animal protein security is here suggested.

Acknowledgements
I appreciate and remain indebted to many. I owe my successes and achievements first and foremost to the Almighty God, the author and finisher of all thing without who any good thing is not possible. I bow, adore and worship you with fear and trembling. Thank you immensely, God. Others to whom I owe appreciation are:

a. The schools that gave me education
- The teachers of St. Joseph's Primary School, Isseke especially the Headmaster at the time, late Mr. Gregory Onwuneme who gave us academic and Christian training

and who was very eager to have me attend a good secondary school.

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- The staff of Stella Maris College, Port Harcourt where I did my lower six class and started upper six class before we had to stop without completion because the Nigerian Civil War broke out.
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- Ginikachukwu, the baby of the family, studying in U.S.A, who wants to be the teacher of doctors, I wish you the best. May God grant your heart's desire.
-

f. My special benefactors

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-

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References

Abolude, D. S., Opabunmi, O. O., Davis, O. A. and Awotoye, O. E. (2013). Study on induced breeding in *Clarias gariepinus* (Burchell, 1822) using ovaprim hormone at Miracle Fish Farm, Zaria, Kaduna State, Nigeria. *Biological and Environmental Sciences Journal for the Tropics*, 10(4): 25 – 28.

Ajayi, S. S. (1971). Panyam fish farm and the introduction of the European carp (*Cyprinus carpio*). *Nigerian Field*, 36: 23 – 31.

Atama, C. and Mgbenka, B. O. (2005).Effect of effluent from a vegetable oil factory in southeastern Nigeria on the *Mmiriele* stream.*Animal Research International*, 2(1): 235 – 239.

Azeroual, A., Entsua-Mensah, M. Getahun, A. and Laleye, P. (2010).*Heterobranchus bidorsalis*.*The International Union for Conservation of Nature and Natural Resources, Red List of Threatened Species*.Version 2014.1.www.iucnredlist.org Assessed July 13, 2014.

Bardach, J. E., Ryther, J. H. and McLarney, W. D. (1972). Aquaculture: the farming and husbandry of freshwater and marine organisms. Wiley-Interscience, New York

Borlongan, I. G. and Satoh, S. (2001). Dietary phosphorus requirement of juvenile milkfish (*Chanos chanos*).*Aquaculture Research,* 34: 843 - 848.

Bruton, M. N. (1988). *Systematics and Biology of Clariid Catfish*.Pages 1 – 11.*In*: Hecht, T, Uys, W. and Britz, P. J. (Editors). The culture of sharptooth catfish, *Clarias* *gariepinus* in southern Africa.*South African National Scientific Programmes Report No. 153.*

Chimits, P. (1955). Tilapia and its culture: a preliminary bibliography. *FAO Fisheries Report,* 8((1): 1 – 33.

Cho, C. Y. and Bureau, D. P. (2001).A review of diet formulatiamon strategies and feed systems to reduce excretory and feed wastes in aquaculture. Aquaculture, 32: 349.

Clay, D. (1979). Sexual maturity and fecundity of the African catfish, *Clarias gariepinus* with an observation on the spawning behaviour of the Nile catfish (*Clarias lazera*).*Zoological Journal of Linnaeus Society, 65:* 351 – 365.

Coloso, R. M., King, K., Fletcher, J. W., Hendrix, M. A., Subramanyam, M., Weis, P. and Ferraris, R. P. (2003). Phosphorus utilization in rainbow trout (*Oncorhynchus mykiss*) fed practical diets and its consequences on effluent phosphorus levels. *Aquaculture,* 220: 801 - 820.

De Kimpe, P. and Micha, J. C. (1974).First guidelines for the culture of *Clarias lazera* in Central Africa.*Aquaculture*, 4: 227 – 248.

Egwui, P. C. (1986). Yields of African catfish (*Clarias gariepinus* Burchell)), from a low input homestead concrete pond.*Aquaculture,* 55: 87 – 91.

Egwui, P. C., Mgbenka, B. O. and Nwuba, L. A. (2007). Aspects of the reproductive biology of hatchery-raised *Clarias gariepinus* I: fecundity. *Animal Research International,* 4(3): 733 – 736.

Eya, J. C. and Lovell, R. T. (1997). Available phosphorus requirement of food size channel catfish (*Ictalurus punctatus*) fed practical diets in ponds. *Aquaculture,* 154: 283 - 291.

Eya, J. C. and Mgbenka, B. O. (1990).Ascorbic acid requirement of African catfish (*Clarias gariepinus* Burchell 1822). *Journal Aquatic Sciences, 5:* 65 - 72.

Eyo, J. E. and Mgbenka B. O. (1992).Aspects of the biology of *Clariasgariepinus* in Anambra River Basin. 1. Oocyte diameter, Fecundity and Sex Ratio. *Journal of Agriculture, Science and Technology,* 2: 47 – 51.

(1992). Ezenwaji, H. M. G. The reproductive biology of four African catfishes (Osteichthyes: Clariidae) in the Anambra River Basin, Nigeria. *Hydrobiologia*, 242: 155 – 164.

Froese, R. and Pauly, D. (2011).Species of *Heterobranchus* in FishBase.December 2011 version.www.fishbase.org Assessed July 13, 2014.

FAO (Food and Agricultural Organization).(1984).Pen culture (enclosure culture) as an aquaculture system.http://www.fao.org/docrep/field/003/ac181e/AC181E07.htm Assessed July 20, 2014.

FAO (Food and Agricultural Organization).(1998). Fisheries Statistics. http//www.fao/waicent/faoinfo/fishery/fishery.html.Fisheries Statistics.

FAO (Food and Agricultural Organization). (2014). The State of Word Fisheries and Aquaculture 2014: Opportunities and Challenges. E-ISBN 978-92-5-108276-8 (PDF).Food and Agricultural Organization, Rome Italy.http://www.fao.org/3/a-i3720e/index.html Assessed July 17, 2014.

Hogendoorn, H. (1983). *The African catfish (Clarias lazera C. and V., 1840) – A New Species for Aquaculture.*Wageningen Agriculture University, Wageningen. Ph. D. Dissertation.

Hogendoorn, H. and Wieme, R. (1976). Preliminary results concerning the fish culture of in Cameroon. CIFA *Technical Paper No. 4 Supplement*, 1: 621 – 624.

Huisman, E. A. (1986). (1986). Current status and role of aquaculture with special reference to the African region. Pages 11 – 12.*In:* E. A. Huisman (ed). *Aquaculture Research in the Africa Region. Pudoc, Wageningen, The Netherlands.*

Inyang, N. M. and *Hettiarachchi, M. (1994).*Efficacy of human chorionic gonadotropin (HCG) and crude pituitary extract of fish and frog in oocyte maturation and ovulation in African catfish (*Clariasgariepinus* Burchell 1822) and (*C.anguillaris* (L.) 1762). Aquaculture and Fisheries Management, 25: 245 – 258.

Inyang, N. M., Anibeze, C. I. P. and Mgbenka, B. O. (1996).Aspects of the reproductive biology of *Heterobranchus longifilis* (Val., 1840) in the Idodo River Basin, southeastern Nigeria.*African Zoology,* 111(5): 373 - 379.

Jardine, L. B., Burt, M. D. B., Arp, P. A. and Diamond, A. W. (2009). Mercury comparisons between farmed and wild Atlantic salmon (*Salmo salar* L.) and Atlantic cod (*Gadus morhua* L.). *Aquaculture Research*, 40(10): 1148 – 1159.

Jesse, G. J. and Casey, A. A. (2006). Study in the chronological dates in world aquaculture (water farming) history from 2800 B.C. *World of Water*, 28: 103 - 129.

Kim, J. D., Kim, K. S., Song, J. S., Lee, J. Y. and Jeong, K. S. (1998). Optimum level of dietary monocalcium phosphate based on growth and phosphorus excretion of mirror carp, *Cyprinus carpio*. *Aquaculture*, 161: 337 - 344.

Kris-Etherton, P. M., Harris, W. S. and Appel, L. J.(2002). Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease.*Circulation,* 106: 2747 – 2757.

Lachapelle, M. Y. and Drouin, G. (2010). Inactivation dates of human and guinea pig vitamin C genes. *Genetica*, 139(2): 199 – 207.

Lazard, J. (1990). L'elevage du tilapia en Afrique. Donnes techniques sur sa pisciculture en entang (The rearing of tilapia in Africa. Technical data on pond culture) pp 5 – 22 in Lazard, J., Morrisens, P. Parrel, P., Aglingle, C., Ali, I., Roche, P. (editors).*Methodes artisanales d'aquaculturedu tilapia en Afrique* CTFT-CIRAD, Nogent-sur-Marine, France.

Lam, T. J. (1982). Applications of endocrinology to fish culture. Canadian Journal of Fisheries and Aquatic Sciences, 39: 111 – 137.

Legendre, M. (1988). Bilan de premiers essays d'elevage d'un Silure africain, *Heterobranchus longifilis* en milleu lagunaire (Lagune ebrie, Cote d'Ivoire) (Evaluatin of preliminary trials with an African catfish, *Heterobranchus longifilis* in.lagoons – Ebrie Lagoon, the Ivory Coast). In: Atelier sur la Recherche Aquacole en Afrique. Bouake, RCI; IDESS-PNUD/FAO-CRDI.

Longhurst, A. R. (1961). *Report on the Fisheries of Nigeria*. Federal Fisheries Services, Ministry of Economic Development, Lagos.

Mgbenka, B. O. (2001). Effects of storage of raw fresh palm oil incorporated into diets of larval *Clarias gariepinus* on their growth and survival. *Journal of Sustainable Agriculture and Environment,* 2(2): 297 – 302.

Mgbenka, B. O. and Agua, U. L. (1990).Digestibility of some agricultural by-products by African catfish (*Clarias gariepinus* Burchell 1822).*Journal Aquatic Sciences,* 5: 65 - 72.

Mgbenka, B. O. and Atama, C. (2005).Assessment of effluent from Nigerian Breweries Plc. (NBL), 9th Mile Corner, Enugu State, Nigeria.*Journal of Science of Agriculture, Food Technology and the Environment,* 5: 79 - 84.

Mgbenka, B. O. and Ejiofor, E. N. (1998).Effects of extracts of dried leaves of *Erythrophleum suaveolens as* anesthetics on clariid catfish.*Journal of Applied Aquaculture, 8*(4): 73 - 80.

Mgbenka, B. O. and Eya, J. C. (1991). Broken skull syndrome of the African catfish (*Clarias gariepinus* Burchell, 1822*)* fed L-ascorbic acid-deficient wood fire-dried, catfish waste-dried diet. Pages 171 – *In* Aquaculture in Africa, K. Koop (editor). A workshop on research in aquaculture held in Harare, Zimbabwe, 23rd-27th January 1991.

Mgbenka, B. O. and Eyo, J. E. (1992).Aspects of the biology of *Clariasgariepinus* in Anambra River Basin. 2. Maturation and Condition Factor. *Journal of Agriculture, Science and Technology,* 2: 52 – 55.

Mgbenka, B. O. and Oche, E. E. (2003). Effects of diets containing palm (*Elaeis guineenensis*) kernel cake, shear butter (*Butyrospermum paradoxum*) nut waste mix on the growth of *Heterobranchus bidorsalis. Journal of Science of Agriculture, Food Technology and Environment,* 3(1): 111 – 118.

Mgbenka, B. O., Oluah, N. S. and Arungwa, A. A. (2005). Erythropoietic response and hematological parameters in the catfish, *Clarias albopunctatus,* exposed to sublethal concentrations of Actellic. *Ecotoxicology and Environmental Safety*, 62: 436 – 440.

Mgbenka, B. O., Oluah, N. S. and Umeike, I. (2003a). Haematology and erythropoietic response in the catfish, *Clarias albopunctatus* (Lamonte and Nichole 1927), exposed to sublethal concentrations of Gammalin 20 (Lindane). *Bio-Research,* 1(2): 61 – 68.

Mgbenka, B. O., Oluah, N. S. and Umeike, I. (2003b). Effects of Gammalin 20 (Lindane) on differential white blood cell counts of the African catfish, *Clarias gariepinus. Bulletin of Environmental Contamination and Toxicology*, 71(2): 248 – 254.

Mgbenka, B. O. and Orji, R. (1997).Effect of fresh palm fruit extract as feed ingredient in the diet of larval African catfish, *Clarias gariepinus. Journal of Applied Aquaculture,* 7(4): 79 – 91.

Mgbenka, B. O. and Udeozor, J. N. (2001). The effect of stocking density and feed on the growth and survival of two strains of the African Catfish (*Clarias gariepinus*): the Aguleri and the Aluu strains. Pages 348 - 357. *In:* E. C. Oti, I. R. Keke, L. A. Chude, E. Akachukwu, U. H. Ukpabi and J. N. Aguigwo (eds.). Proceedings of the 16th Annual Conference/International Workshop of Nigerian Association for Aquatic Sciences (NAAS), presented at the Michael Okpara University of Agriculture, Umudike, Abia State 3rd – 6th October 2001. ISBN 987-052-871-7

Mgbenka, B. O. and Ugwu, L. L. C. (2005). Aspects of mineral composition and growth rate of the hybrid African catfish fry fed inorganic phosphorus-supplemented diets. *Aquaculture Research,* 36: 479 – 485.

Mgbenka, B. O., Ikele, C. B. and Oluah N. S. (2012a). Haematological studies of *Clarias gariepinus* fingerlings exposed to diethyl phthalate (DEP). *Journal of Aquatic Sciences,* 27(1): 23 – 28.

Mgbenka, B. O., Ikele, C. B. and Oluah, N. S. (2012b). Acute toxicity of diethyl phthalate on *Clarias gariepinus* fingerlings. *Journal of Aquatic Sciences,* 27(1): 35 – 39.

Mgbenka, B. O., Ikele, C. B. and Oluah, N. S. (2011a). Histopathological effect of diethyl

phthalate on *Clarias gariepinus* juveniles *Animal Research International,* 8(3): 1431 – 1438.
.

Mgbenka, B. O., Ikele, C. B. and Oluah, N. S. (2011b). Toxic effect of diethyl phthalate on the gills of African catfish (*Clarias gariepinus*) juveniles *Animal Research International,* 8(1): 1375 – 1379.

Mwita, C. J. and Nkwengulila, G. (2008). Molecular phylogeny of the clariid fishes of Lake Victoria, Tanzania, inferred from cytochrome b DNA sequences. *Journal of Fish Biology*, 73(5): 1139 – 1148.

NEPAD (2005).*The NEPAD Action Plan for development for Development of African Fisheries and Aquaculture.*The New Partnership for African's Development – Fish for All Summit, Abuja, Nigeria, 23 August 2005.

NRC (National Research Council) (1993).*Nutritional Requirement of Warm Water Fishes*.National Academy of Science, Washington, DC, USA.

Ogino, C. and Takeda H. (1976) Mineral requirement of carp.*Bulletin of Japanese Society of Scientific Fisheries*, 42: 793 - 801.

Oluah, N. S. and Mgbenka, B. O. (2004). Effect of actellic 25 EC on the differential leucocytes counts of the catfish *Clarias albopunctatus* (Nichole and Lamonte, 1953). *Animal Research International*, 1(1): 52 – 56.

Oparaku, N. F., Mgbenka, B. O. and Eyo, J. E. (2010). Proximate and organoleptic characteristics
of sun- and solar-dried fish. *Animal Research International*, 7(2): 1169 – 1175. J64

Oparaku, N. F., Mgbenka, B. O. and Ibeto, C. N. (2011). Waste water disinfection utilizing
ultraviolet light. *Journal of Environmental Science and Technology*, 4(1): 73 - 78. J65

Osibona, A. O., Kusemiju, K. and Akande, G. R. (2009).Fatty acid composition and amino acid profile of two freshwater species, African catfish (*Clarias gariepinus*) and tilapia (*Tilapia zillii*). *African Journal of Food, Agriculture, Nutrition and Development*, 9(1): 608 – 621.

Obiezue, R. N., Ikele, C. B., **Mgbenka**, B. O., Okoye, I. C., Attamah, G. N., Uchendu, C., Ezemachi, E. and Onyia, C. Q. (2014). Toxicity of diethyl phthaleate on *Clariasgariepinus* fingerlings.*African Journal of Biotechnology,* 13(7):884 - 896. http//www.academicjournals.org/AJB

Salami, A. A., Fagbenro, O., Edibite, L. and Fagbemiro, S. (1994). Induced spawning of the Clarias
gariepinus using non-piscine pituitary extracts. *Journal of the World Aquculture Society*,
25: 116 – 168.

Salami, A. A., Belloo-Olusoji, O. A., Fagbenro, O. A. and Akegbejo-Samsons, Y. (1997). Induced breed of
two clariid catfishes, *Clarias gariepinus* and *Heterobranchus bidorsalis* using tilapia pituitary
extracts. *Journal of the World Aquaculture Society,* 28: 113 – 117.

Shin, K. F. and Ho, C .S. (1989).Calcium and phosphorus requirement of guppy (*Poccilia reticulata*).*Nippensuisan Gakkaishi Bulletin of the Japanese Society of Scientific Fisheries,* 55: 1947 – 1953.

Teugels, G. G. (1982a). Preliminary data of a systematic outline of the African species of the genus *Clarias* (Pisces: Clariidae). *Revue de Zoologie Africaine,* 96(4): 731 – 748.

Teugels, G. G. (1982b). Preliminary results of a morphological study of five nominal species of the subgenus *Clarias* (Pisces: Clariidae). *Journal of Natural History,* 16(3): 439 – 464.

Teugels, G. G. (1986). Clariidae.Pages 66 – 101.*In*: Daget, J., Gosse, J. P. and Thys van den Audenaerde, D. F. E. (Editors). *Checklist of the Freshwater Fishes of Africa.Vol. 2*. Institut Royale del'Afrique Centrale, Tervuren, and Office de la Recherche Scientifique et Technique Outre- Mer, Paris.

Teugels, G. G., Denayer, B. and Legendre, M. (1990). A systematic revision of the African genus *Heterobranchus* Geoffroy-Saint-Hilaire, 1908 (Pisces: Clariidae). *Zoological Journal of Linnaeus Society,* 98: 237 – 257.

Ugwu, L. L. C. and Mgbenka, B. O. (2004).Effect of inorganic phosphorus on feed intake, protein intake, feed conversion and phosphorus gain/loss of the hybrid African catfish *Heterobranchus bidorsalis* (♂) x *Clarias gariepinus* (♀) fry. *Animal Research International*, 1(3): 133 – 139.

Ugwu, L. L. C., Mgbenka, B. O. and Asogwa, M. O. (2005a). Effects of dietary inorganic supplementation in water, feed, protein and phosphorus intake on hybrid African catfish fry. *Journal of Agriculture, Food Technology and Environment,* 5: 47 – 58.

Ugwu, L. L. C., Mgbenka, B. O. and Asogwa, M. O. (2005b).Effect of calcium on dietary phosphorus uptake by African hybrid catfish, *Heteroclarias* fry. *Ife Journal of Science,* 7(1): 71 – 77.

Ugwu, L. L. C., Mgbenka, B. O. and Asogwa, M. O. (2005c). Effect of dietary phosphorus on protein intake and productive protein value of young hybrid African catfish (Pisces: Clariidae). *Journal of Agriculture and Social Research*, 5(1): 18 – 24.

Ugwu, L. L. C., Mgbenka, B. O. and Asogwa, M. O. (2005d). Nutrient utilization and growth responses of the frys of the African hybrid catfish (*Clarias gariepinus* x *Heterobranchus bidorsalis*) to inorganic phosphorus supplements. *Journal of Agriculture and Social Research,* 5(1): 107 – 116.

Ugwu, L. L. C., Mgbenka, B. O. and Ekwe, O. O. (2007a). Effects of mega levels of dietary supplemental phosphorous on three digestive enzymes activities in *Clarias gariepinus* (Pisces: Clariidae) fry. *Journal of Science, Engineering and Technology,* 14(2): 7393 – 7304.

Ugwu, L. L. C., Mgbenka, B. O. Nwamba, H. O. and Ikwor, T. N. (2006). Studies on the phosphorus source-duration interaction on protein intake and tissue phosphorus levels of the hybrid African catfish fry, fed phosphorus-enriched diets. *Nigerian Journal of Tropical Agriculture,* 8: 141 – 147.

Ugwu, L. L. C., Mgbenka, B. O. and Nwazu, T. O.(2005). Survival and growth responses of fry of the African catfish hybrid (*Clarias gariepinus* x *Heterobranchus b*idorsalis) to soluble dietary supplements of inorganic phosphorus.*Journal of Technology and Education in Nigeria,* 10(1): 11 – 19.

Ugwu, L. L. C., Mgbenka, B. O., Onu, P. N. and Jegede, O. I. (2007b). Effect of different sources of inorganic phosphorus and inclusion levels in enhancing growth and survival of hybrid African catfish, *Heteroclarias* fry.*Nigerian Journal of Tropical Agriculture,* 9: 52 – 60.

Ugwu, L. L. C., Mgbenka, B. O., Otuma, M. O. and Eneje, L. O. (2007c). Effect of phosphorus source-duration interaction on gross efficiency of feed conversion and daily rate of growth of the hybrid African catfish fry. *African Journal of Sciences*, 8(1). 1702 – 1712.

Viveen, W. J. A. R., Richter, C. J. J., Van Oordt, P. G.W. J., Janssen, J. A. I. and Huisman, E. A. (1985). *Practical Manual for the Culture of the African Catfish* (*Clarias gariepinus*). The Netherlands Ministry for Development Cooperation, Section for Research and Technology, P. O. Box 20061, 2500 EB The Hague, The Netherlands.

Watanabe, T. and Kiron, V. (1994).Prospects of larval fish dietetics.*Aquaculture,* 124: 223 – 251.

Welcomme, R. L. (1972). An evaluation of the *acadja* method of fishing as practiced in the coastal lagoons of Dahomey (West Africa)). *Journal of Fish Biology,* 4(1): 39 – 55.

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