بِسمِ اللهِ الرَّحمنِ الرَّحِيَم

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Nutritional Value and Fillets Yield of Four Fish Species from River Nile State.

القيمة الغذائية وإنتاج اللحم الصافي لأربعة أنواع من الأسماك من ولاية نهر النيل.

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(وَهُوَ الَّذِى سَخَّرَ البَحرَ لِتَأكُلُواْ مِنهُ لَحماً طَرِيّاً وَتَستَخرِجُواْ مِنهُ حِليَةً تَلبَسُونَهَا وَتَرَى الفُلكَ مَوَاخِرَ فِيهِ وَلِتَبتَغُواْ مِن فَضلِهِ وَلَعَلَّكُم تَشكُرُونَ)

صدق الله العظيم
سورة النحل الآية **(14)**

DEDICATION

To my family

Father,

Mother,

Sisters,

Brothers,

Wife

And

Son.

ACKNOWLEDGEMENT

My praise to Allah, the cherisher and sustainer of the words, who gave me the knowledge and the power to complete of this research.

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ABSTRACT

The study was conducted during November 2018 - April 2019 in and around Berber locality which is located in River Nile State in the north western part of the Sudan, to determine the body weight composition, approximate analysis (moisture, protein, fat and ash), some minerals (phosphorus (P), calcium (Ca), potassium (K) and zinc (Zn) and some heavy metals (lead (Pb), cadmium (Cd) and mercury (Hg). of four commercial freshwater fish in Sudan.

These were (*Mormyrus caschive* (Linnaeus, 1758) (Khashm al banat), *Hyperopisus bebe* (Lacepede, 1803) (Sawya), *Marcusenius cyprinoides* (Linnaeus, 1758) (Um shiffa) and *Mormyrops anguilloide*s (Linnaeus, 1758) (Taraza).

Results of body weight composition revealed that *Mormyrus anguilloide*s and *Marusenius cyprinoides* gave the highest percentages of fillets yield. (50%). While *Hyperopisus bebe*, *Mormyrus caschive* gave the lowest value. (49%, 47%. respectively).

In approximate composition, moisture of (*Hyperopisus bebe, Mormyrus caschive*, *Marcusenius cyprinoides* and *Mormyrops anguilloide*s). (67.14±0.29, 67.05±0.17, 66.95±0.07 and 66.84±0.12. respectively). Protein of (*Mormyrops anguilloide*s, *Marcusenius cyprinoides*, *Mormyrus caschive* and *Hyperopisus bebe).* (21.66±0.89, 21.19±0.40, 19.85±0.09 and 19.79±0.06. respectively). Fat of *Mormyrus caschive, Hyperopisus bebe*, *Marcusenius cyprinoides* and *Mormyrops anguilloide*s (5.23±0.14, 5.16±0.07, 4.93±0.09 and 4.71±0.06. respectively). Ash of *(Mormyrops anguilloide*s, *Marcusenius cyprinoides, Hyperopisus bebe* and *Mormyrus caschive).* (2.23±0.08, 2.2±0.05, 1.98±0.10 and 1.96±0.11. respectively). They have significant difference in fish species and sex. ($P<0.05$).

Results of elements (P, Ca, K and Zn) Revealed that *Mormyrops anguilloide*s and *Macrusenius cyprinoides* indicates the highest values of elements and have significant difference ($P<0.05$), in fish species and sex.

Results of heavy metals (Pb, Ca and Hg) present low values that lower than permissible limits reported by Food and Agricultural Organization (1984 - 2012), World Health Organization (1984 - 2012) and other organization (Appendix-1).

Studied fish species have reported high nutritional values and fillets yield and low heavy metals content which reflect healthy environment in the study areas.

الخلاصة

تم إجراء الدراسة في الفترة ما بين نوفمبر2018م - ابريل2019م بمحلية بربر ولاية نهرالنيل شمال السودان وذلك بغرض معرفة التركيب الوزني، التحليل الكيميائي (الرطوبة، البروتين، الدهن والرماد) وتحديد بعض المعادن الاساسيه مثل الفسفور،الكالسيوم، البوتاسيوم و الزنك. وكذلك تحديد وجود بعض المعادن الثقيلة مثل الرصاص، الكادميوم والزئبق لإربع أنواع من أسماك المياه العذبة التجارية وهي :-

Marcusenius الساوية، *Hyperopisus bebe*، خشم البنات *Mormyrus caschive* *cyprinoides* ، أم شفاه *Mormyrops anguilloides* الترزا.

حيث أظهرت نتيجة التحليل الإحصائي للتركيب الوزني أن النوعين الترزا وأم شفاه قد أعطيا أعلي نسبة شرائح لحم صافيه (50%) بينما النوعين الساوية و خشم البنات أعطيا أقل نسبة من الشرائح الصافية (49%، 47%. على التوالي).

أظهرت نتيجة التحليل الاحصائى لبيانات التحليل الكيميائي و جود اختلاف معنوي ($P<0.05$)، في مكونات الرطوبه، (الساوية، خشم البنات، أم شفاه و الترزا) (67.14±0.29، 67.05±0.17، 66.95±0.07، و 66.84±0.12. على التوالي)، البروتين (الترزا، أم شفاه، خشم البنات والساوية) (21.66±0.89، 21.19±0.40، 19.85±0.09، و 19.79±0.07 . على التوالي)، الدهن (خشم البنات، الساوية، أم شفاه والترزا) (5.23±0.14، 5.16±0.07، 4.93±0.09 و 4.71±0.06. على التوالي) والرماد (الترزا، أم شفاه، الساوية و خشم البنات) (2.23±0.08، 2.2±0.05، 1.98±0.010 و 1.96±0.11. على التوالي). بين كل الانواع قيد الدراسه باعتبار عاملي النوع و الجنس.

أظهرت نتيجة التحليل الاحصائى لبيانات تحليل المعادن الاساسيه أنها توجد بنسبة تراكم أعلى في عضلات اسماك الترزا واسماك أم شفاه، كما توجد فروق معنويه بين الاسماك المدروسه باعتبار عامل النوع و الجنس.

أظهرت نتيجة التحليل الاحصائى لبينات تحليل المعادن الثقيلة نسب أقل من الحد المسموح به في عضلات الاسماك من منظمة الاغذية والزراعة العالمية (1984م - 2012م) و منظمة الصحة العالمية (1989م - 2012م) و بعض المنظمات الاخري كما هو مبين في ملحق (1).

نتائج الدراسة أظهرت أن الأسماك المدروسة تحتوي على نسب عالية من المغذيات كما أعطت نسب شرائح صافية جيدة و نسب أقل من الحد المسموح به من المعادن الثقيلة مما يعكس الحالة البيئيه الجيدة لمناطق صيد هذه الأسماك.

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CHAPTER ONE

INTRODUCTION

The fisheries sector makes an essential contribution to human development, food and nutrition security throughout the world, supplying vital nutrition to millions of people. Fish, as a source of “rich food for poor people”, can play an important role in improving food security and nutritional status. **(Suganthi *et al*., 2015)**. About one - third of the world catch of fish is not used for direct human consumption but for the production of fishery by-products. **(Akter *et al*., 2017)**.

In Africa, fishery sector supported about 200 million people with food and nutritional security and also provides income for 10 million people engaged in fish production, processing, and trade. (**Teame *et al*., 2015**). Sudan is endowed with diversified surface and underground water resources, and arable lands that are suitable to support vigorous capture fishery activities which are centered around the river Nile and its tributaries, and the territorial water of Sudan on the Red Sea. **(Adam *et al*., 2015 and Mohamed *et al*., 2016)**. Fish is one of the most important sources of animal protein available, and has been widely accepted as a good source of protein and other elements for the maintenance of a healthy body. **(Pirestani *et al*., 2009)**. Fish is one of the most important foods and is valued for its nutritional qualities. Fish flesh is a good source of high quality protein containing essential amino acids in the amount and proportion required for good nutrition. It also provides a good source of vitamins and minerals **(Aberoumand, 2012)**. So fish muscle contains all the nutrient components that are required most for human body maintenance. **(Begum *et al*., 2012)**.

Fish and fish products are the most important sources of animal protein in the human diet. It comprises of all the ten essential amino acids in desirable quantity for human consumption. (**Begum *et al*., 2012)**.

In many regions of the world freshwater fish are a significant source of animal protein. But freshwater fish contain also considerable quantities of valuable lipids as well as minerals and vitamins. **(Steffens, 2006)**.

Fish is associated with improved cardiovascular health and other related health conditions. Fish as food is finding more acceptances because of its special nutritional qualities. In this context a proper understanding about the biochemical constituents of fish has become a primary requirement for the nutritionists and dieticians. **(Mohamed *et al*., 2016).**

The measurements of some proximate profiles such as protein contents, carbohydrates, lipids, moisture contents and ash percentages are often necessary to ensure that they meet the requirements of food regulations and commercial specifications. **(Kasoz *et al*., 2014).**

Fillet and carcass yields are very important parameters for both fish processing industry and fish farmers, because they can assess the economic value of a fish species as well as to add value to the final product. **(Geraldo *et al.*, 2015)**. Fish products are known to be good sources of many elements and contents in several marine fish species are well documented. Freshwater fish species, however, are often neglected as a source of these nutrients and little information is available on the mineral and essential trace element composition of these fishes. Freshwater species are frequently used as indicators of heavy metal pollution, and thus there are more data available on contents of such elements as mercury and cadmium. **(Julshamn *et al*., 1986)**.

Objectives:-

The objectives of this study are to

1. Determine the body weight composition and fillet yield of four commercial important species of freshwater fish in the Sudan (*Mormyrus caschive, Hyperopisus bebe*, *Marcusenius cyprinoides* and *Mormyrops anguilloide*s).
2. Determine the chemical compositions (proximate analysis) of the studied species.
3. Determine the content of some essential minerals (P, Ca, K and Zn).
4. Investigate any heavy metals (Pb, Cd and Hg) in the studied species if found.

CHAPTER TWO

LITERATURES REVIEW

2.1. Fish in Sudan

Sudanese fishes were distributed over an area of 100,000 km of freshwater and 760 km of marine environment revealing the total sustainable production accounted for 114,100 tons per year, **(Mohamed *et al*., 2016)**. Which is consumed fresh or processed for later marketing and distribution?. It was noted that most of the fish landings from this sector were subjected to very poor condition because of lacking facilities, bad handling and processing which negatively affected quality and the value of the products. **(Abdalla, 2017)**. Fish was not much used for food in Sudan, before is a great demand for it to fill the gap in animal proteins. **(AwadElkareem, 1998)**.

Sudanese people generally are less flesh eaters and the national average fish consumption is low 1.5 kg/ person / year in comparison with African average of 7 kg / person / year by with world average 12 - 13 kg / person / year. (**Ahmed, 2007**). The expansion in consumption has been driven not only by increased production, but also by a combination of many other factors, including reduced wastage, better utilization improved distribution channels and growing demand, linked with population growth, rising incomes and urbanization. **(FAO, 2018)**.

In Sudan there are different types and grades of freshwater fishes used fresh or processed to products consumed locally. Limited quantities of dried and salted fish were exported. **(Ahmed, 2007)**. Fish processing in Sudan is by salting, drying, fermenting and smoking. The history of fermented foods has early records in Sudan. The Sudanese fish products include kejeik (large sun-dried split fish); Fasiekh (salted fermented whole *Hydrocynus spp* "Kass", *Alestes spp* "Kwaraa" and *Labeo spp* "Dabs"); Mindeshi (pounded small fish paste, fermented, and may be dried later); and Terkeen or Maloha (fermented fish sauce or paste). **(Hamza *et al*., 2017).** Fasiekh is the most popular fish food in Sudan and it is sold either wet or dried and distributed all over the country where local demand is very high. As consequence, its price highly exceeds the price of fresh fish. Another is (seer), a very small fried fish sold cheap. The home made Terkeen encourages the use of illegal gear, since the smaller the fish size the higher the market value of this product. The poultry industry is also obtaining undersized fish for preparation of chicken feed. **(Hamza *et al*., 2017)**.

Fish in the Sudan have been a major source of protein and energy for many communities especially among the Nilotic tribes of the south and some of Nubian ethnic groups of the far North Sudanese people use fish sometimes as the only source of animal protein throughout the year as substitute for meat particularly in the central Nile valley where fish is one of most highly perishable commodities. (**Alawad and Mohammad, 2017)**.

Fish are one of the main sources for the provision of animal protein for a growing demand in a world of ever growing population and increasing consumption. In this respect, the Sudan is not an exception and the various aquatic resources (marine, freshwater, brackish, groundwater and others) are tapped in order to fulfill the needs in this direction. **(Mohammed, 2018)**.

2.2. Classification and Description of Fish Studies

African *mormyriformes* are one of two groups of freshwater fishes (the other group is South American *Gymnotiformes*) that use their highly specialized electric and electro receptive organs for location and communication. All species of the family *mormyridae* generate Electrical Organ Discharges (EODS) with alternating interpulse intervals. **(Baron *et al*., 2017)**.

They are mostly bottom-living fish. Some (*Mormyrus*) have small mouths at the end of snouts by means of which they poke around in the mud, catching worms, insect larvae, etc. for food. Some others (*Mormyrops*) have relatively large mouths and feed on fish and crustacean, while the smaller members mainly feed on small animals or on more or less decaying animal and vegetable matter. **(Sandon, 1950)**. Fishes with distinctive, but variably shaped, slender caudal peduncles, tiny scales, small skin-covered eyes and narrow gill openings. Fifteen species belonging to 8 genera. **(Bailey, 1994).**

2.2.1. *Mormyrus caschive* (Linnaeus, 1758)

Genus *Mormyrus* (Elephant-Snout)

Mormyrus caschive, Local name "Khashm al banat". Anal fin less ½ the length of the dorsal fin and with no more than 26 rays; terminal mouth and body not strongly compressed. **(Abu-gideiri, 1984).** Snout produced, about as long as post ocular part of head and curving downwards; dorsal fin more than 5 times as long as anal fin and bears more than 75 rays; anal fin with 18 - 21 rays. Olive above, whitish below. **(Abu-gideiri, 1984 and Laan, 2016).** Inhabits the main Nile, White Nile and Bahr el Gebel. Grows up to more than 1 metre. **(Abu-gideiri, 1984).**

2.2.2. *Hyperopisus bebe* (Lacepede, 1803)

Genus *Hyperopisus*. Anal fin more than 5 times the length of the dorsal fin and with more than 50 rays; terminal mouth; body strongly compressed. **(Abu-gideiri, 1984 and Laan, 2016)**. *Hyperopisus bebe* (Lacepede, 1803). Local name "Sawya". Snout about half as long as post-orbital part of head; dorsal fin with 12 - 16 rays and 2½ - 3½ times as far from head as from caudal ; anal fin with 58 - 68 rays, originating at equal distance from end of snout and from Root of caudal, or a little nearer letter. The upper part of the body is strongly iridescent and varies from grey-olive to greenish-brown or purplish colour. Inhabits the main Nile, Blue Nile and White till Bahr el Gebel. Grows up to 46 cm. **(Abu-gideiri, 1984)**.

2.2.3. *Marcusenius cyprinoides* (Linnaeus, 1758)

Genus *Marcusenius*, *Marcusenius cyprinoides* (Linnaeus, 1758). Local name "Um shiffa". The commonest species is *M. cyprinoides*. **(**Linnaeus, 1758) which is found along the whole of the Nile and White Nile but has not been recorded from the Blue Nile. **(Sandon, 1950 and Bailey, 1994)**. A large swelling on chin; dorsal fin with 25 - 30 rays; first ray of dorsal fin situated slightly behind that of the anal fin; anal fin with 30 - 37 rays; 70 - 86 scales in lateral line with 15 - 20 above and 19 - 24 below in transverse series on body; 12 - 18 above and below in transverse series between dorsal and anal, 16 round caudal peduncle. Silvery, back darker, bluish or greenish; some young specimens with small blackish spots scattered on the body. (**Abu-gideiri, 1984)**. Breeds in the flood season. It is a bottom feeding insectivore. **(Bailey, 1994)**. Inhabits the main Nile, White Nile and Bahr el Gebel. Grows up to 30 cm. **(Abu-gideiri, 1984)**.

2.2.4. *Mormyrops anguilloides* (Linnaeus 1758)

Genus *Mormyrops*, Anal fin ranges between 3/5 and twice length of dorsal fin and contains more than 20 rays (shared with genera *Petrocephalus, Marcusenius* and *Gnathonemus*), teeth found along entire margin of both jaws; nostrils remote from eyes and from each other. **(Abu-gideiri, 1984 and Laan, 2016)**. *Mormyrops anguilloides* (Linnaeus, 1758). Local name "Taraza". Depth of body 5 - 6 times its total length; head less than twice as long as deep; upper profile slightly concave; 87 - 96 scales in lateral line with 16 - 20 above and 22 - 28 below in transverse series on body as well as 14 - 16 above and 12 - 14 in transverse series between dorsal and anal, 20 round caudal peduncle. Blue or grayish-brown above, whitish beneath, sometimes dotted all over with black. Inhabits the main Nile; occurs in northern White Nile in the vicinity of Khartoum and also in Lake Rosaries. Grows up to 31cm. **(Abu-gideiri, 1984)**.

2.3. Importance of Fish Processing

Processing of fish involves essentially the utilization of conservation procedures in order to retain quality and increase shelf life. It might likewise mean increasing the value to produce a wide assortment of products. Various techniques are utilized to preserve fish. Most of these techniques based on temperature control, utilizing ice, refrigeration or freezing; others on the control of water activity that includes drying, salting, smoking and freeze-drying. The different types of deterioration and food poisoning caused by micro-organisms are preventable to a substantial degree by various preservation techniques, the majority of which act by averting or moderating microbial development. These include freezing, chilling, drying, curing, conserving, vacuum packing, modified atmosphere packing, acidifying, fermenting, and adding preservatives. (**Sulieman *et al*., 2018).**

The fish industry is a major economic source for a number of countries worldwide. The fish processing industry produces more than 60% by-products as waste, which includes head, skin, trimmings, fins, frames, viscera and roes, only 40% fish products are used for human consumption. Commercial filleting of fish such as Cod, Salmon, Tilapia, Sea bream, and Pollack typically yields approximately 60 - 70% of by-products and 30% to 40% fillets of the whole fish weight. Fish industry by-products can account for up to 75% of the catch depending on post harvest or industrial preparation processes, solid wastes generated from seafood factories ranged from 30% - 85% of the weight of landed fish. **(Ibrahim, 2015).** Total of more than 90 million metric tons wild-caught fish and a global aquaculture production of more than70 million metric tons, the amount of marine by-products is thus huge. Usually these huge quantities of fish by-product waste create serious pollution and disposal problems in both developed and developing countries; but there is a large potential for making more value-added products from this raw material. The amounts of by-products in fish vary depending on species, size, season and fishing ground. **(Ibrahim, 2015)**.

2.4. Body Weight Composition of Fish

2.4.1. Fish measurements

Position fish measurement refers to the measuring of the length of individual fish and of various parts of their anatomy. These length data are used in many areas of Ichthyology, taxonomy and fish biology. The most common method to measure the fish is using a simple fish measuring board made out of hardwood or acrylic plastic. On the board there is a scale of various units such as millimeter or inches. The head of fish is place on the headboard and the tail on the ruler for measurement. The head should be on the left side and the caudal fin on the right side of the measuring board with the mouth closed. **(Man *et al*., 2016)**.

2.4.1.1. Weight measurements

Weight can be measured from a number of fishes *(e.g.* all fish in a catch), from the individual fish or from a part of the fish such as the gonads, the liver, the visceral fat etc. The weight of a fish changes as it dries and so weighing should occur as soon as possible after capture. It is important to make measurements at a standard degree of wetness and for this reason fish are sometimes kept wet by pouring water over them, or they are dried with a piece of cloth to make them towel dry. **(Mous *et al*., 1995)**.

2.4.1.2. Length measurements

The length of the fish can be measured as total length which is the greatest length of the fish from its anterior extremity to the end of its tail fin. In fishes having a forked tail, for example, the two lobes are moved to the position which gives the maximum length measurement (which ever may be the longer lobe is used). Standard length is the greatest length of a fish from its anterior extremity to the hidden base of its median tail fin ray (where these meet the median hypural plate). (**Mous *et al*., 1995)**. Fishermen, fisheries administrators and fisheries biologists prefer to express the length of fishes as total length, since this is usually length measurements are to be made in metric scales (e.g. cm or mm). A common goal is a measurement accurate to 0.5% of the overall length, but anything finer than the nearest millimetre is rarely attempted. Fork length is the length measured from its anterior extremity to the tip of the median rays of its tail. This measurement is the same as the total length in species in which the tail fin is not notched or forked. **(Mous *et al*., 1995)**.

2.5. Filleting

When you're done fishing, you have to prepare your catch for cooking or storage. This is called "cleaning" fish. Fish can be cleaned using a number of methods. Filleting and pan dressing are the two most common ways to clean fish. Field dressing is another way to both clean and keep fish fresh until you get them home. **(Internet web site)**. The edible portion of the fish flesh from some Nile fish ranges between 50 to 60%.The yields of some fish species was estimated to be 29.7 - 48.6%. While the fillet yields of *Oreochromis niloticus* and *Ictalurus punctus* range between 25.0 to 30.9%. The edible portion of the fish flesh from some Nile fish ranges between 50 to 60%. The yield of some fish species was estimated to be 29.7 - 48.6% while the fillet yields of *Oreochromis niloticus* and *Ictalurus punctus* range between 25.0 to 30.9%. **(Alawad and Mohammad, 2017)**. Fillet and carcass yields are very important parameters for both fish processing industry and fish farmers, because they can assess the economic value of a fish species. As well as to add value to the final product. **(Geraldo *et al*., 2015)**. Fillet and carcass yields depend on several factors, such as size, age, sex, anatomic shape of the body, head size and weight of viscera, skin and fins. The efficiency of the fillet machine and the expertise in handling are aspects that should be taken into account. **(Alawd and Mohammed, 2017)**. Fish and fish products are some of the most traded food items in the world today. In 2016, about 35 percent of global fish production entered international trade in various forms for human consumption or non-edible purposes. **(FAO, 2018)**. The consumer is interested mainly in the edible part of the fish that is the flesh or muscle; the fish meal manufacturer is concerned with the composition of the whole fish. So, to know the composition of nutrients of the body of fish is very important for different users. **(Begum *et al*., 2012)**.

Values for edible portions are variable and those presented in the data sheets should be considered as typical and may not correspond to the edible portion known by consumers in practice: some material may be discarded as inedible by some consumers compared to others, while also country- and culture-specific traditions and habits need to be considered. For most foods, two edible coefficients are provided in the datasheets, one refers to 'from whole fish/shellfish to fillet/flesh', the second refers to 'from purchased portion to edible'. For most foods a clear description on the edible coefficient is provided where possible (e.g. whether the factor refers to 'from whole fish to fillet', or 'from drawn/gutted fish to fillet'), but some references do not provide sufficient detail to give a fully accurate description. **(FAO, 2016)**. Filleting is used to clean a variety of fish species, from larger trout and walleye, to smaller sunfish and perch. The filleting technique shown is one of several different techniques used.

This method produces two boneless (or nearly boneless) pieces of meat (fillets), one from each side. **(Internet web side).**

All that is needed is a sharp fillet knife and a hard surface, such as a cutting board.

1. Begin by laying the fish flat on its side. Make a cut behind the pectoral fin down to, but not through, the backbone.

2. Without removing the knife, turn the blade and cut through the ribcage toward the tail with the knife blade running flat along (but not through) the backbone and just on the up side of the dorsal fin.

3. Stop cutting just before you separate the fillet from the body. While keeping the body in the same position, flip the fillet over with the skin side down.
4. Insert your knife between the flesh and the skin. Holding the knife almost flat and using a back and forth motion, remove fillet from skin.
5. The fillet still contains the rib cage, so use the knife blade to carefully cut around and remove it.
6. Turn the fish over and repeat the previous five steps on the other side for the second fillet.
7. Rinse the fillets with cold, clean water. **(Internet web side).**

2.6. Nutritional Value of Fish

Information concerning the chemical composition of freshwater fishes is useful to ecologists and environmentalists who are interested in determining the effects of changing biological/environmental conditions on the composition, survival, and population changes within fish species. It is also valuable to nutritionists concerned with readily available sources of low-fat, high-protein foods such as most freshwater fishes, and to the food scientist who is interested in developing them into high-protein foods while ensuring the finest quality flavor, color, odor, texture, and safety obtainable with maximum nutritive value. **(Kinsella *et al*., 1978)**.

Fish processing is essentially concerned with the transformation of a raw material into an almost limitless array of products offering a range of different values. Historically, processing was undertaken to preserve fish to enable its storage and later consumption when alternative protein sources were not available. (**Young and Muir, 2002)**.

Fish is a major source of food for human nutrition providing an important amount of protein and lipid in the world. Generally, chemical composition of whole fish is 70 to 80% of water, 20 to 30% of protein, and 2 to 12% of lipid.

Knowledge of the proximate composition of fish is essential to estimate their energy value and to plan the most appropriate industrial and commercial processing. **(Suseno *et al*., 2014)**. The nutritional component of the freshwater fish was found to differ between species, sexes, sizes, seasons, and geographical localities it was also found to influence post-harvest processing and affect the shelf-life of the fish changes in fatty acid and amino acid concentrations were found to be useful as an index of freshness and decomposition of marinated fish in storage likewise, different cooking methods affect the quality of fish meat. **(Mohamed *et al*., 2010)**. Fish is highly nutritious, tasty and easily digested. It is much sought after by a broad cross-section of the world's population, particularly in developing countries. It is estimated that around 60 percent of people in many developing countries depend on fish for over 30 percent of their animal protein supplies, while almost 80 percent in most developed countries obtain less than 20 percent of their animal protein from fish. **(Osibona *et al*., 2009)**. The nutritional value and prices of fish depend on meat texture, chemical composition, fillet and carcass yields and factors related to capture and processing methods. **(Geraldo *et al*., 2015)**. The consumer acceptance of fishery products depends on various a attributes of food quality. The most important attributes are food security, nutrition, taste, texture, color and appearance and suitability of raw materials for processing and preservation. The relative importance of any of these features depends on the particular material and its intended use. **(Porto *et al*., 2016)**. Fish consumption has been shown to have anti-cancerous effects and minimizes the risks of cardiovascular ailments in humans. **(Anene *et al*., 2013)**. The chemical composition traditionally is used as an indicator of the nutritional value of the fish. It varies widely from species to species and it is also greatly affected by the feeding habit, sex and seasonal variations **(Odiko and Obirenfoju, 2017)**. Proximate composition of fish varied widely from species to species and even within the same species from one individual to another. This individual variation is normally due to some factors such as size, age, season, sex and geographical location. **(Begum *et al.*, 2012)**. The measurement of some proximate profiles such as protein, carbohydrate, lipid and moisture content is often necessary to ensure that they meet the requirements of food regulations and commercial specifications**. (Ganesan *et al.*, 2017)**. Proximate composition generally means percentage composition of basic constituents such as water, protein, lipids, carbohydrate and mineral within a fish body. **(Odiko and Obirenfoju, 2017)**.

2.6.1. Moisture content

Water is the major component of all species and types of fish. Typically, water content ranges from 70 to 80 % of the fresh weight, **(FAO, 1991 and Suseno *et al.*, 2014)**. Although some deep water species may contain in excess of 90%. There are seasonal variations, and a slight increase occurs when the fish is starving (typically a rise of 1 - 2% in demersal species but perhaps as much as 17% in pelagic species). The water content may also rise slightly if the fish are stored in melting ice or refrigerated sea water. In most bony fish, the fat and water content combined make up approximately 80% of the fresh weight. In simple terms, the high water content can be held responsible for the perishability of fish. Although water is essential for life it is not usually considered to be a food or a nutrient. However, other drinks such as milk and alcoholic beverages are classified as foods because they provide energy and other nutrients. **(FAO, 1991)**.

2.6.2. Protein content

The protein content generally amounts to 15 - 20% of wet weight in the muscle. In lipid rich fish species the protein level is lower than in species with poor lipid content in their flesh. **(Steffens, 2006)**. Fish and fish products are the most important sources of animal protein in the human diet. It comprises of all the ten essential amino acids in desirable quantity for human consumption. Fish protein is very rich in such amino acid as methionine, lysine and low in tryptophan compared to mammalian protein. Fish have rich source of essential nutrients required for supplementing both infant and adult diets. (**Begum *et al*., 2012**).

2.6.3. Fat content

Fats are important in the diet for the following three reasons: they provide a concentrated energy source; they provide fat soluble vitamins; and they affect the texture and palatability of food. Excess intake of calories maybe stored as body fat, providing insulation against heat loss, protection of internal organs and a store of energy for when dietary requirements are not met. **(FAO, 1991)**. Lipid is regarded as one of the most important food reserves and has led to the use of fat indices as a measure of relationship between percentage of water and fat. **(Osibona *et al*., 2009)**. Fish oil is one of the most important natural sources of polyunsaturated fatty acids having eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which have been proven to have useful effects on human body. The live weight of majority of fish usually consists of about (2 - 12%) lipid. **(Begum and Minar, 2012)**.

2.6.4. Ash content

Most of the known inorganic elements or minerals can be detected in the human and fish body, but only about fifteen of those known to be essential to man need to be derived from food. A further five or more are necessary in minute amounts for normal life in some animal species. (Calcium, phosphorus, magnesium, potassium, sodium, chlorine and iron) are the best understood and, in general, needed in the largest quantities by the body tissues. This plus sulphur from sulphur-containing amino acids may be considered as the major minerals. The remainder, which include cobalt, copper, chromium, fluorine, iodine, (of which marine products are a good source), manganese, selenium and zinc, are all equally essential but are needed in much smaller quantities. These may be termed the minor minerals. It should be noted, however, that most minor minerals can be poisonous in excess. In most species, the total mineral or ash content ranges from 1 to 2%. **(FAO, 1991)**.

2.7. Some Minerals Content

Fish tissue is an excellent source of macro and essential trace elements such as iron (Fe), zinc (Zn) and selenium (Se).The accurate determination of the elements is therefore important in nutrition studies, particularly because meat, as a biological material, exhibits natural variations in the amounts of nutrients contained. **(Odiko and Obirenfoju, 2017)**. The macro elements calcium, magnesium, sodium, potassium, and phosphorus are essential to human health. Microelements such as zinc, iron, copper, and manganese, which occur in physiological concentrations, play key roles in living processes. Heavy metals are important from the point of view of public health. These metals are also indicators of water pollution because they accumulate in aquatic animals. Contended that every living organism belongs to a definite level of the trophic chain. The bioaccumulation of heavy metals (Zn, Cu, Mn and Fe) also depends on fish weight, body length and age. **(Luczyñska *et al*., 2009)**.

2.7.1. Phosphorus (P) content

Phosphorus is a major constituent of bones together with calcium and magnesium. This mineral showed significant concentration variability between species ranging from 435 - 1375mg/100g, the highest P content of 1375mg/100g obtained from the small fish species (*B. Poechii)* which is consumed whole. **(Mogobe *et al*., 2015)**.

2.7.2. Calcium (Ca) content

Calcium is important for bone formation and fish is known to be a good source of this mineral, especially small fish. The recommended daily intake of calcium for adults is 1000 - 1300 mg. Fishes of Chanoga as excellent sources of calcium, especially the small fish species, *B. lateralis* and *B. poechii* which had higher calcium levels of 959 mg/100 g and 1290 mg/100 g respectively. **(Mogobe *et al*., 2015)**.

2.7.3. Potassium (K) content

Potassium is important for muscle contractions, transmission of impulses in the nerves and sugar metabolism. The Recommended Daily Allowance (RDA) of K for males aged between 25 - 50 years is 800 mg. Consumption of 100 g of *M. altisambesi* fish flesh will provide 31 - 55% of the potassium daily requirement, assuming cooking will not affect the quantity of the mineral. **(Mogobe *et al*., 2015)**.

2.7.4. Zinc (Zn) content

Zinc plays a number of roles in body functions; it is a component of many metallo-enzymes, important for gene expression and cellular growth. The FAO ranges of 0.23 - 2.1 mg/100g. Zinc recommended dietary allowance for adults is 8 - 11 mg and *B. Poechii* can provide 100% of this requirement in a 100g plate portion, making this species a high quality source of zinc, superior to most species in other parts of the world. **(Mogobe *et al*., 2015)**. Zinc is an essential element but at greater concentrations it may be toxic to fish. Zn accumulates in the gills of fish and creates adverse effects on fish by causing structural damages that affects growth, development and survival. It also alters fish behavior, hatchability, hematological parameters, balance and swimming ability. **(Elbeshti *et al*., 2018)**.

2.8. Some Heavy Metals Content

Even though some of the heavy metals such as zinc, iron, cobalt and copper are essential for enzymatic activity and other biological processes at low levels they become toxic when they exceed certain limit. On the other hand other metals such as lead, cadmium and mercury have no essential role in living organisms and are toxic even at too low concentrations. **(Elbeshti *et***

***al*., 2018)**. Heavy metals are persistent contaminants in the environment that come to the forefront of dangerous substances such as cadmium, lead, mercury, copper and zinc that cause serious health hazards to humans and animals. **(AwadElkareem *et al*., 2014)**.

2.8.1. Lead (Pb) content

Lead is a hazardous candidate; it usually accumulates because excretion is very low. In the literature, the maximum allowed level for Lead is 2 ppm. **(AwadElkareem, 1998)**. Increase of lead levels in water may cause adverse effects in some aquatic living beings and may lead alterations of blood parameters and nervous system in fish and other animals. Pb is a dangerous environmental pollutant and it has become much thought of due to its considerable danger risks for human health. **(Elbeshti *et al*., 2018)**.

2.8.2. Cadmium (Cd) content

Cadmium exhibits high toxicity at even very low concentrations and has acute and chronic effects on fish and environment. Long exposure of cadmium poses various acute and chronic effects on aquatic living beings. Such effects are enhancement of humoral immune response, inducement of structural and functional changes in gill, intestine, liver and kidney, pathological alterations in liver such as congestion, necrosis of pancreatic cells and fatty changes in the peripancreatic hepatocytes, congestion and engorgement of blood vessels. It also causes disruption of calcium metabolism, hypercalciuria and leads kidney stones to form. Toxicity varies in fish; salmonids are highly susceptible to cadmium exposure and sub lethal effects such as obvious spine malformation were reported. **(Elbeshti *et al*., 2018)**.

2.8.3. Mercury (Hg) content

Mercury: It is classified as a hazardous heavy metal (slight exposure can endanger human health. It is strictly a poison with no role in human metabolism. The Food and Drug Directorate of Canada and the U.S Food and

Drug Administration placed a maximum acceptable level for Mercury in food at 0.5 PPM. **(AwadElkareem, 1998)**.

2.9. Water Pollution with Heavy Metals in River Nile State

Mining axis; mining in Berber district began to be randomized, and the companies involved in the development of the Gold extraction were codified, and co-markets were established to provide basic and essential services to the metal. Companies engaged in mining (large mining companies; Reda, Omdurman, in El Ibediyya city, Haggagia, Sahari, in El Bauga city, and Monas, in Darmali city). (Small mining companies; Moroccan, in square 24, and El Sakhra El Hamra, in valley Singeir). There are also cement, plastic, gypsum and ice manufacturers. **(GBLIC, 2019)**. From various water resources in the Sudan, the Nile River and its tributaries are considered to be the primarily source of water for human, agriculture, live stock, and wildlife. Despite this importance, the Nile River water and its suspended sediments are subjected to possibility of contamination by various hydro-chemical pollutants; especially heavy metals from various reasons mainly sanitation problems. River Nile sediments considered as a group of metals that could be released to the overlying water from natural and anthropogenic processes such as dredging and bioturbation, may lead up to potential adverse health effects. On the other hand the presence of heavy metals in the Nile River sediments is influenced by the particle size of the sediments, this actually attributed to co-precipitation, sorption, and complexity of metals on particle surfaces and coatings. **(Bakhiet, 2015)**.

In Sudan, research in the Nile River water and its adjacent sediment contamination with heavy metals derived as a result of anthropogenic activities and its impacts on environment is not yet clearly understood. The toxic actions of trace elements or heavy metals occur due to bioaccumulation and biomagnifications of the elements in the tissues of living organisms. With the increased urbanization and industrialization; there has been a rapid increase in the municipal waste water (sewage water and industrial effluents) which in turn has intensified the environmental pollution. The presences of pollutants have been associated with decreased fertility and other reproductive abnormalities in birds, fish, shell fish and mammals and also altered immune function. Heavy metals like Mercury and Cadmium are known to accumulate in marine organisms and cause rapid genetic changes. **(Bakhiet, 2015)**.

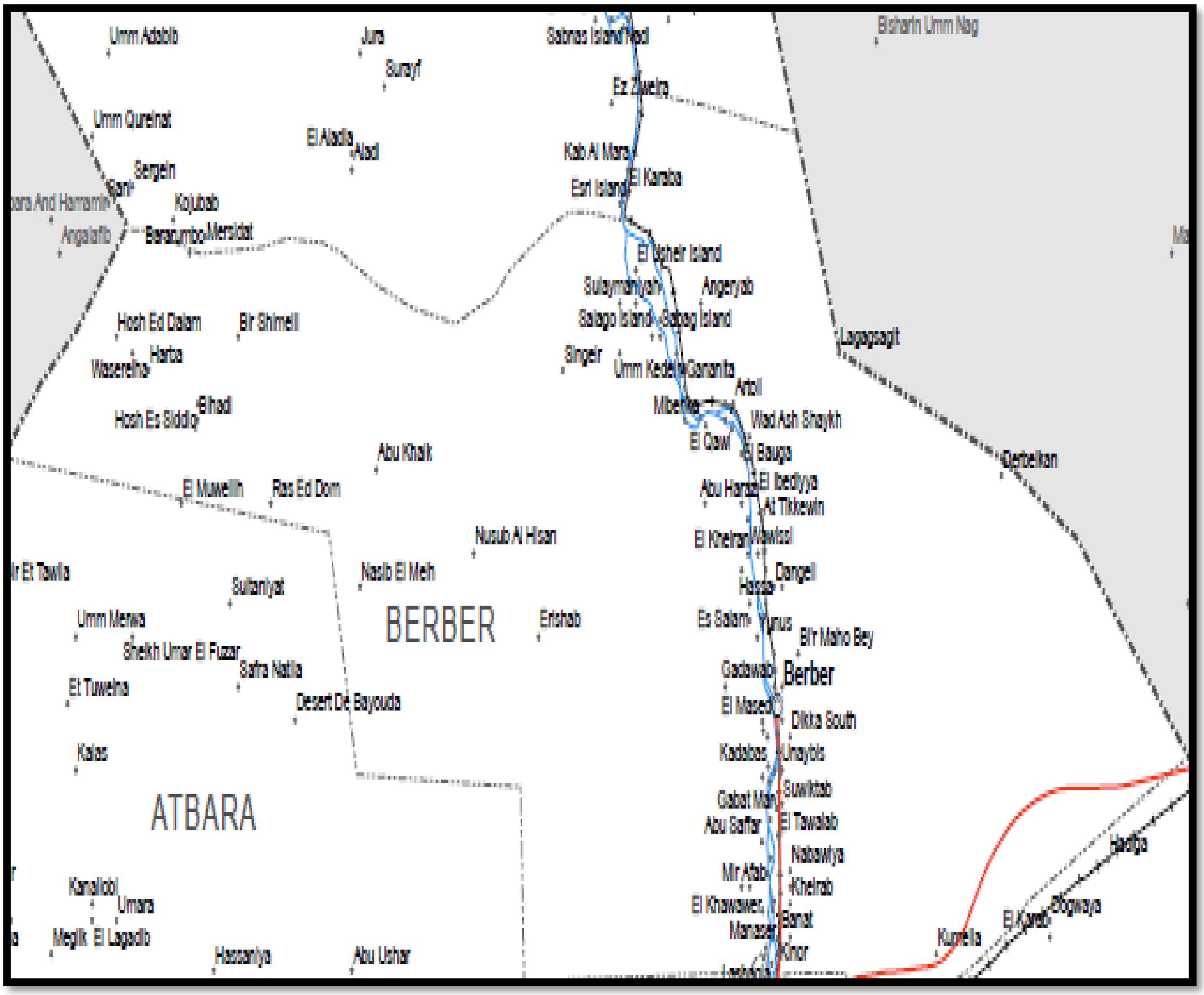
Fish consumption is a major route of trace metal exposure for human, and children are more at risk because of their greater intestinal absorptions fish sample can be considered as the most significant indicators in freshwater system for estimation of metals pollution level. **(Elsaim *et al*., 2018)**.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study Area

The study was conducted during November 2018 - April 2019 in and around Berber locality which is located in River Nile state in the north western part of the Sudan. The study area is located between latitudes 39 - 18 and 42 - 17 N and longitudes 52 - 34 and 34 - 42 E. It is stretches 100 Km on the two Nile ranges from the Atbara locality border south to the Abu hamad locality border to the north and is bordered to the east by the Red Sea State and from the west by the Northern State.



Source of the map: **(Internet web side).**

3.2. Materials

3.2.1. Samples

All samples (Total 100 fish sample, 25 fish per species) were collected and purchased fresh at Berber city and El Ibediyya city markets at early after catching (catching by gill nets).

The samples were collected and transported in an insulated container under frozen condition to refrigerate below 0°c prior to use.

Hyperopisus bebe (Lacepede, 1803).

Mormyrus caschive (Linnaeus, 1758).

Marcusenius cyprinoides (Linnaeus, 1758). *Mormyrops anguilloides* (Linnaeus, 1758).

3.2.2. Equipments

The equipments for preparation, include knives, cutting boards, containers, trash bags, remove scales (flaky), gloves, face mask, measuring board (100 cm), sharpened, ice, digital scale capacity 50 kg and digital scale capacity 200g. (Appendix-2).

3.3. Methods

3.3.1. Washing and weighting

Fish samples were washed thoroughly with tap water and weighed individually by digital balance 50 kg.

3.3.2. Length measurement

Total length and standard length of fish samples were determined in (cm). By putting the fish in table surface with the mouth closed and the fish laying a long a tape measure, using measuring board (100 cm).

3.3.3. Body weight composition and filleting

3.3.3.1. Scaling

Removed fish scales were weighed individually by digital balance 200g.

3.3.3.2. Cutting fins

The dorsal, anal, caudal, pelvic, pectoral and tail fins were cut from the natural line separating them from the body and weighed together (fins weight) by digital balance 200g.

3.3.3.3. Evisceration

Fish lying on its side and with the tip of knife opening behind anal vent and run to the top of fish, after opening the fish. The abdominal fat and all internal organs were removed and weighted together by digital balance 200g.

3.3.3.4. Deheading

The head is cut in front of the pectoral fins from the natural seems and weight by digital balance 200g.

3.3.3.5. Skeleton

Work the blade along the backbone all the way to the tail. At this point the fish is half filleted on one side. After that the fillet and the bones are weighted separately by digital balance 200g.

3.3.3.6. Filleting

The meat was cut away from the back bones where the top barb sits on all the way from the head to behind the barb and it was also cut it loose from the bones below it and from the head. With the fish laying on its side, the tip of the knife is inserted just behind the anal vent and run it to the top staying very close to the backbone until it comes out on the top.

3.3.4. Treatment of fish samples

The treated samples were washed again to remove all the adhesive material and blood, representing and divided into four groups (four species), each group contained 6 samples (3 male and 3 female), packet in the plastic bags transport in container and ice and sent to the National Food Research Center (NFRC) laboratory {Shambat, Khartoum North} to determine chemical composition parameters (moisture, protein, fat, and ash), some minerals and heavy metals. As described by **AOAC (2005)**.

3.3.5. Analytical methods

3.3.5.1. Approximate analysis

Moisture content, crude protein, fat and ash were determined for wet samples according to standard methods of Association of Official Analytical Chemists. **(AOAC, 2005)**. Fillets were minced and chilled prior chemical analysis using standard method of to determine proximate composition. For each size group, (5) g of homogenized samples were weighed out in triplicate into preconditioned moisture dishes.

The dishes with samples were placed in oven and dried for 16 hours at 98 °C, as this temperature avoids loses of volatile food components. After the 16 hr of drying, the dishes were cooled down in desiccators and the moisture content of the samples calculated accordingly. **(Kasozi *et al.*, 2014)**.

3.3.5.1.1. Moisture content

A sample of (5) g was weighed into a pre-dried and tarred dish. Then, the sample was placed into an oven (kat-nr.2851, Elektrohelios, Sweden) and left to dry at 105 ºc until a constant weight was obtained. After drying, the covered sample was transferred into desiccator and cooled to room temperature before reweighing. Triplicate results were obtained for each sample and the mean value was reported two decimal points according to the following formula:

Calculation:

Moisture content % = $\frac{(w1-w2)}{W1}$×100

Where: W1= Original weight of sample.

W2 = Weight of sample after drying.

W = Weight of sampling. **(AOAC, 2005).**

3.3.5.1.2. Protein content

Weight of (5) g of sample was accurately weighed and transferred together with 2 - 3 glass pellets, Kjeldahl catalyst and 20 ml concentrated Sulphuric acid into kjeldahl digestion flask. After that, the flask was placed into a Kjeldahl digestion unit for about 3hours, until a color less digest was obtained. Following, the flask was left to cool to room temperature. The distillation of Ammonia was carried out in 30 ml Boric Acid (2%) by using 40 ml distilled water and 60 ml Sodium Hydroxide solution (33%). Finally, the distillate was titrated with standard solution of 0.1 NHCL in the presence of 2 - 3 drops of indicator (Bromocreasol Green and Methyl Red) until a brown reddish color was observed. The total nitrogen and protein were calculated using the following formula:

N% = $\frac{\text{Volum Of Hcl}\times N\times 14}{\text{Weight Of Sample}\times 1000}\times 100$

P% = N% × 6.25 (Factor).

Where:

N% = Crude nitrogen.

P% = Crude protein.

N = Normality of HCL.

14 = Equivalent weight of nitrogen. **(AOAC, 2005).**

3.3.5.1.3. Fat content

A sample of (5) g was weighed into an extraction thimbles (30 - 100 mm) and covered with cotton that previously extracted with petroleum ether. Then, the sample and a pre-dried and weighed Erlenmeyer flask containing about 100ml petroleum ether were attached to the extraction unit (Electrothermal, England) and the temperature was adjusted to produce about 150 to 200 drops of the condensed solvent per minute for 16 hours. At the end of the distillation period, the flask was disconnected from the unit and the solvent were redistilled. Later, the flask with the remaining crude ether extract was put in an oven at 105 °c for 3 hours, cooled to room temperature in a desiccator, reweighed and the dried extract was registered as crude fat according to the following formula:

Calculation:

Fat % = $\frac{(W2-W1)}{W} \times 100$

Where:

W1 = Weight of empty flask.

W2 = Weight of flask with oil.

W = Weight of sampling. **(AOAC, 2005).**

3.3.5.1.4. Ash content

A sample of (5) g was weighed into a pre-heated, cooled weighed in porcelain crucible. Before a shing, the sample was pre-washed on an electrical pre-asher and placed into a muffle furnace (Carbolite, Sheffeild,

England) at 550 °c. After complete a shing, the crucibles with ash were transferred directly to a desiccator, cooled, weighed and the ash content was calculated as percent of the original weight of sample:

Ash content % = $\frac{(W1-W2)}{W} \times 100$

Where:

W1 = Weight of crucible with ash.

W2 = Weight of empty crucible.

W = Weighting of sample. **(AOAC, 2005).**

3.3.5.2. Minerals determination

The major elements, comprising macro (P, Ca, K and Zn) were determined using corning 400, flame photometer (AAS) - 986.

Approximately (5) g of each sample (wet weight) was placed in a Teflon digestion vessel and double acid digested with Nitric acid (HNO_3) and Perchloric acid ($HCLO_4$). Samples were then analyzed for mineral contents of Phosphorus (P), Calcium (Ca), Potassium (K) and Zinc (Zn) using the Atomic Absorption Spectrophotometer (Shimadzu AAS, AA - 6300). **(AOAC, 2005).**

3.3.5.3. Heavy metals determination (Pb, Cd and Hg)

Ten gram from each sample was taken into small beaker the beaker was placed in muffle furnace and dried shed at 550C° for 5 hour then cooled. 10 ml of concentrated HCl (20%) was added to the obtained ash and dissolved in10 ml of demonized water and the solution was filtered in 50ml conical flask using filter paper, the digested sample was quantitatively into 50ml volume tric flask and then the volume was completed 50ml with distilled water. The heavy metals were measured according to International Organizations (Codex Alimentarius Commission, 2003) using Atomic Absorption Spectrophotometric Method (AASM). **(AOAC, 2005)**.

3.3.6. Statistical analysis

Statistical analysis were performed using the Analysis of variance one way (ANOVA) and Duncan's multiple Range Test, to determine differences between means at significance rate of ($P<0.05$). All statistics were carried out using Statistical Analysis program, Statistical Package for Social Sciences, version 16.0 (SPSS 16).

CHAPTER FOUR

RESULTS

4.1. Body Weight Composition

Body weight composition of *Mormyrus caschive, Hyperopisus bebe, Marcusenius cyprinoides* and *Mormyrops anguilloides* have significant differences (P<0.05) in T.W: Total Weight, T.L: Total Length, S.L: Standard Length, W. Fillet: Weight of Fillet, W. Head: Weight of Head: W. Fin: Weight of Fin, W. Scale: Weight of Scale, W. Viscera: Weight of Viscera.

Table (1). Shows the body weight composition of fish species studies. M± SD.

Fish species / Parameters M±SD	*Mormyrus caschive*	*Hyperopisus bebe*	*Marcusenius cyprinoides*	*Mormyrops anguilloides*	*Sig*
T. W	282.8±84.7^{b}	246.0±90.2^{b}	197.6±35.4^{c}	354.2±114.0^{a}	**
T. L	31.4±2.47^{b}	31.6±4.7^{b}	27.2±1.4^{c}	36.4±4.7^{a}	**
S. L	27.0±2.57^{b}	27.5±4.3^{b}	23.2±1.4^{c}	32.7±4.4^{a}	**
W. Fillet	135.4±46.0^{b}	122.9±47.3^{bc}	100.1±19.5^{c}	180.5±58.3^{a}	**
Fillets%	47%	49%	50%	50%	
W. Skeleton	54.6±20.6^{a}	42.9±18.2^{b}	33.1±8.3^{b}	55.7±23.0^{a}	**
W. Head	46.1±11.8^{b}	47.3±17.1^{b}	32.0±5.1^{c}	69.2±22.6^{a}	.**
W. Fin	10.9±2.7^{a}	6.8±3.0^{b}	7.1±1.2^{b}	11.0±3.8^{a}	**
W. Scale	2.5±1.0^{b}	1.8±0.7^{c}	2.8±0.8^{b}	4.5±1.8^{a}	**
W. Viscera	26.1±10.2^{a}	17.9±8.6^{b}	15.4±4.8^{b}	23.5±9.2^{a}	**

[abc] Means in the same rows without common letter are significantly different at P<0.05

Results of body weight composition revealed that *Mormyrus anguilloide*s and *Marusenius cyprinoides* gave the highest percentages of fillets yield. (50%).

While *Hyperopisus bebe*, *Mormyrus caschive* gave the lowest value. (49%, 47%. respectively).

4.2. Approximate Composition

Approximate composition of *Mormyrus caschive*, *Hyperopisus bebe*, *Marcusenius cyprinoides* and *Mormyrops anguilloides* have significant differences (P<0.05) in moisture, protein, fat and ash.

Table (2). Shows approximate composition, (moisture, protein, fat and ash) value of fish species (1g/100g) in wet basis. M±SD.

Factors		Parameters			
Fish species	Sex	Moisture M±SD	Protein M±SD	Fat M±SD	Ash M±SD
Mormyrus caschive	Male	66.93±0.03	19.88±0.12	5.12±0.03	2.04±0.03
	Female	67.17±0.17	19.81±0.05	5.34±0.10	1.87±0.11
Hyperopisus bebe	Male	66.94±0.03	19.81±0.08	5.10±0.05	2.07±0.04
	Female	67.33±0.30	19.78±0.06	5.21±0.01	1.89±0.03
Marcusenius cyprinoides	Male	66.90±0.03	21.37±0.56	4.86±0.05	2.06±0.01
	Female	67.00±0.05	21.02±0.06	5.01±0.02	1.99±0.03
Mormyrops anguilloides	Male	66.74±0.08	22.20±1.03	4.66±0.04	2.28±0.08
	Female	66.93±0.04	22.11±0.03	4.76±0.04	2.18±0.03
Main effect					
Fish species					
Mormyrus caschive		67.0±0.1[a]	19.85±0.09[b]	5.23±0.14[a]	1.96±0.11[c]
Hyperopisus bebe		67.1±0.2[a]	19.79±0.06[b]	5.16±0.07[b]	1.98±0.10[bc]
Marcusenius cyprinoides		66.9±0.0[b]	21.19±0.40[a]	4.93±0.09[c]	2.02±0.05[b]
Mormyrops anguilloides		66.8±0.1[b]	21.66±0.89[a]	4.71±0.06[a]	2.23±0.08[a]
P. value		*	**	**	**
Sex					
Male		66.8±0.0	20.8±1.1	4.9±0.2	2.1±0.1
Female		67.1±0.2	20.4±0.6	5.08±0.2	1.9±0.1
P. value		**	*	**	**
Fish species X Sex					
P. value		*	*	*	*
[abc] Means in the same column without common letter are different at P<0.05					

H. bebe and *M. caschive* are highest in moisture but *M. cyprinoides* and *M. anguilloide*s are lowest in moisture. *M. anguilloide*s and *M. cyprinoides* are highest in protein but *M. caschive* and *H.bebe* are lowest in protein.
M. caschive and *H. bebe* are highest in fat but *M. cyprinoides* and *M. anguilloide*s are lowest in fat. *M. anguilloide*s and *M. cyprinoides* are highest in ash but *H. bebe* and *M. caschive* are lowest in ash. Female of four species are highest in moisture and fat but are lowest in protein and ash. Male of four species are highest in protein and ash but are lowest in moisture and fat. They have significant difference in fish species and sex. (P<0.05).

4.3. Some Minerals Contents

Minerals contents of *Mormyrus caschive, Hyperopisus bebe*, *Marcusenius cyprinoides* and *Mormyrops anguilloides* have significant differences (P<0.05) in Phosphorus (P), Calcium (Ca), Potassium (K) and Zinc (Zn).

Table (3). Shows some minerals contents in the muscles of fish species studies (1g/100g) in wet basis. M±SD.

Factors		Parameters			
Fish species	Sex	P M±SD	Ca M±SD	K M±SD	Zn M±SD
Mormyrus caschive	Male	89.22±6.6	98.3±10.3	25.8±0.27	0.02±0.0
	Female	76.33±1.5	90.0±0.03	21.6±0.69	0.01±0.0
Hyperopisus bebe	Male	85.48±7.9	94.4±5.11	24.6±0.61	0.02±0.0
	Female	71.08±1.3	83.9±2.89	20.5±0.56	0.01±0.0
Marcusenius cyprinoides	Male	94.33±1.5	114.0±1.01	26.4±0.75	0.02±0.0
	Female	94.00±1.0	112.1+0.07	23.7±0.59	0.01±0.0
Mormyrops anguilloides	Male	97.34±0.5	118.1+0.89	28.5±0.52	0.02±0.0
	Female	96.02±0.0	115.6+1.53	26.7±1.14	0.02±0.0
Main effect					
Fish species					
Mormyrus caschive		82.7±8.2^{b}	94.2±7.9^{b}	23.7±2.3^{c}	0.02±0.01^{ab}
Hyperopisus bebe		78.2±9.3^{b}	89.1±6.8^{b}	22.5±2.3^{c}	0.01±0.01^{b}
Marcusenius cyprinoides		94.1±1.1^{a}	113.0±1.2^{a}	25.0±1.6^{b}	0.01±0.01^{b}
Mormyrops anguilloides		96.6±0.8^{a}	116.9±1.7^{a}	27.6±1.2^{a}	0.02±0.01^{a}
P. value		**	**	**	*
Sex					
Male		91.59±6.53	106.23±11.60	26.38±1.57	0.02±0.01
Female		84.36±11.36	100.47±14.35	23.14±2.55	0.01±0.01
P. value		**	**	**	**
Fish species X Sex					
P. value		**	*	NS	NS
^{abc} Means in the same column without common letter are different at P<0.05					

Results of elements (P, Ca, K and Zn) Revealed that *Mormyrops anguilloide*s and *Macrusenius cyprinoides* indicates the highest values of elements and have significant difference (P<0.05). In fish species and sex.

4.4. Some Heavy Metals Contents

Some heavy metals contents of *Mormyrus caschive, Hyperopisus bebe*, *Marcusenius cyprinoides* and *Mormyrops anguilloides* have significant differences (P<0.05) in Lead (Pb), Cadmium (Cd) and Mercury (Hg).

Table (4). Shows content of some heavy metals in the muscle of fish species studies (1g/100g) in wet basis. M±SD.

Factors		Parameters		
Fish species	Sex	Pb M±SD	Cd M±SD	Hg M±SD
Mormyrus caschive	Male	0.09±0.00	0.07±0.01	0.02±0.01
	Female	0.07±0.01	0.06±0.01	0.01±0.01
Hyperopisus bebe	Male	0.06±0.01	0.04±0.01	0.02±0.01
	Female	0.06±0.01	0.04±0.01	0.01±0.00
Marcusenius cyprinoides	Male	0.09±0.00	0.07±0.01	0.02±0.00
	Female	0.08±0.01	0.06±0.01	0.01±0.01
Mormyrops anguilloides	Male	0.09±0.00	0.07±0.01	0.03±0.00
	Female	0.08±0.01	0.06±0.01	0.02±0.01
Main effect				
Fish species				
Mormyrus caschive		$0.08±0.01^a$	$0.06±0.01^a$	$0.02±0.01^b$
Hyperopisus bebe		$0.06±0.01^b$	$0.04±0.01^b$	$0.01±0.01^b$
Marcusenius cyprinoides		$0.09±0.01^a$	$0.06±0.01^a$	$0.02±0.01^b$
Mormyrops anguilloides		$0.08±0.01^a$	$0.07±0.01^a$	$0.03±0.01^a$
P. value		**	**	.**
Sex				
Male		0.08±0.01	0.06±0.01	0.02±0.01
Female		0.07±0.01	0.05±0.01	0.02±0.01
P. value		**	**	**
Fish species X Sex				
P. value		*	NS	NS
^{abc} Means in the same column without common letter are different at P<0.05				

Results of heavy metals (Pb, Cd and Hg) Revealed that *M. anguilloide*s, *M. cyprinoides* and *M. caschive* indicates the highest but *H. bebe* indicates the lowest values and have significant difference (P<0.05). In fish species and sex.

CHAPTER FIVE

DISCUSSION

5.1. Body Weight Composition

Body weight composition of the fish is important aspect in fish processing as it is gives an idea in amount of the pure fillets and the fish by product. The species investigated in the present study *Mormyrus caschive, Hyperopisus bebe*, *Marcusenius cyprinoides* and *Mormyrops anguilloides*. Are popular market fishes in rural and urban areas, and belong economically to the different traditional grades, according to consumers and fishermen preference in Sudan. The total weight, total length and standard length of *Mormyrops anguilloides* are the higher than *Mormyrus caschive* and *Hyperopisus bebe*, but the species *Marcusenius cyprinoides* is the lower. (Table1). Were lower than average estimated by **Adam *et al*, (2015)** for *Oreochromes niloticus* (T.W: 930±21.60, T.L: 36.5±0.58, S.L: 29.75±0.50), *Labeo niloticus* (T.W:1210±106.15 g, T.L: 49±1.16 cm, S.L: 39.5±1.29 cm) and *Clarias spp* (T.W: 977.5±71.82, T.L: 49±0.82, S.L: 45±82) in Sudan. Also with comparison estimate was reported by **Komolafe and Arawomo, (2011)** for the range of total weight and standard length with *Mormyrus rume* (T.W: 242.2±22.570 g, S.L: 26.4±3.543 cm), *Gnathonemus cyprinoides* (T.W: 55.8±14.815 g, S.L: 15.2±1.585cm), *Gnathonemus senegalensis* (T.W: 79.25±41.154 g, S.L: 16.3±2.470 cm), *Clarias gariepinus* (T.W: 135.4±7.240 g, S.L: 23.2±3.00 cm) and *Schilbe mystus* (T.W:49.14.720 g, S.L:14.5±0.030 cm) which was lower than the study results. Also with comparison estimate was reported by **Osibona, (2009)** for the range of total weight and standard length with *Clarias gariepinus* (T.W:106.2 - 274.6 g, S.L: 16.3 - 35 cm) and *Tilapia zillii* (T.W: 51.3 - 239.6 g, S. L: 9.3 - 20.1 cm) in Nigeria. The weight of fillets of studied fish: *Mormyrops anguilloides* and *Marcusenius cyprinoides* are the higher (50%), but *Hyperopisus bebe* and *Mormyrus* *caschive* are the lower (49% and 47%). (Table 1). Were higher than results obtained from other freshwater fishes in Sudan such as *Labeo niloticus* and *Synodontis schall*. 49%, 40% respectively. **(Bakhiet *et al.*, 2017).** Also previous results present were higher than results obtained from other freshwater fishes such as *Synodontis schall*. 41.37%. **(Adeyemo, 2013)**. Also previous results present were lower than results obtained from other freshwater in Sudan such as *Clarias gariepinus* (male and female: 49.86±1.95 and 52.11±2.59). **(Deng *et al.*, 2016).**

5.2. Chemical Composition

The biochemical analysis of edible parts of different fish species was carried out in order to find out the value of fish with regard to its quality and market value. Current study indicates that the body composition varied significantly ($P<0.05$) among the various fish species.

5.2.1. Moisture content

Result of the analysis of the moisture content is the higher in *Hyperopisus bebe* and *Mormyrus caschive* (67.1±0.2 and 67.0±0.1), but the lower in *Marcusenius cyprinoides* and *Mormyrops anguilloides* (66.9±0.0 and 66.8±0.1). Female of four species is the higher in moisture (67.1±0.2), but male is the lower in moisture (66.8±0.0). The moisture content is the lower than results obtained from other freshwater fishes in Sudan. (*Lates niloticus, Bagrus bayad, Oreochromes niloticus, Synodontis schall* and *Teteradon lineatus*) (75%, 76%, 76%, 73% and 80%. respectively). Reported by **Mohamed *et al*, (2010)**. In the other hand these results were lower those obtained from other freshwater fishes in Nigeria such as *Clarias gariepinus* and *Tilapia zillii*. (74.3%, 80.4%. respectively). **(Osibona *et al.*, 2009)**. Also they were lower than the results obtained from other freshwater fishes in Sudan such as *Bagrus bayad, Oreochromes niloticus*. Range between 75.33 - 78.0%. **(Ahmed *et al.*, 2016).** And lower than the results obtained from *Labeo* *niloticus* and *Synodontis schall*. (71.2±0.2, 73.5±0.6%). respectively. **(Bakhiet *et al*., 2017)**. And lower than the results obtained from other *Oreochromes niloticus*. 72.07±6.34%. **(Olopade *et al*., 2016)**. And lower than the results obtained from other *Clarias gariepinus* (72.8±5.94% in wild, 75.01±2.09% in farm). **(Deng *et al*., 2016).** That might be due to the difference in environmental conditions and feeding status.

5.2.2. Protein content

The result of the analysis of the protein content is the higher in *Mormyrops anguilloides* and *Marcusenius cyprinoides* (21.66±0.89 and 21.19±0.40), but is the lower in *Mormyrus caschive* and *Hyperopisus bebe* (19.85±0.09 and 19.79±0.06). Male of four species is the higher in protein (20.8±1.1), but female is the lower in protein (20.4±0.6). Are lower than the results obtained from other freshwater fishes in Sudan such as (*Lates niloticus, Bagrus bayad, Oreochromes niloticus, Synodontis schall* and *Teteradon lineatus*) (77.9%, 77%, 78.4%, 59.8% and 79.1%. respectively). Reported by **Mohamed *et al*., (2010)**. Also the protein content of the fish studied were higher than results obtained from other freshwater fishes in Nigeria such as *Clarias gariepinus* and *Tilapia zillii*, (18.8%, 19.0%). respectively. **(Osibona *et al*., 2009)**. Protein content of the studied fish were lower than results obtained from other freshwater fishes in the Sudan such as *Calaris gariepinus* in farmed and wild (30.86± 0.68 and 30.98± 0.55%). respectively. **(Deng *et al*., 2016)**. Also the protein content of the fish studied was lower than results obtained from other freshwater fishes in Nigeria such as *Oreochromes niloticus* from freshwater (22.23±2.19%). Reported by **Olopade *et al*., (2016)**. That might be due to location of catching the fish and environmental background.

5.2.3. Fat content

The result of the analysis of the fat content is the higher in *Mormyrus caschive* and *Hyperopisus bebe* (5.23±0.14 and 5.16±0.07), but is the lower in

Marcusenius cyprinoides and *Mormyrops anguilloides* (4.93±0.09 and 4.71±0.06). Female of four species is the higher in fat (5.08±0.2), but male is the lower in fat (4.9±0.2). Are in the same range of the same with other studied species in Sudan such as *Oreochromes niloticus* (5.1%), but is the higher than results obtained in *Tetraodon lineaties* (1.8%), also are the lower than results obtained in *Lates niloticus, Bagrus bayad* and *Synodontis schall* (6.8%, 13.2% and 17.3%. respectively). **(Mohamed *et al*., 2010)**. Also the fat content was lower than results obtained from other freshwater fishes in the Sudan such as *Mormyrops anguilloides* (47% in head), *Marcusenius cyprinoides* (26% in muscles and 46% in head), *Mormyrus niloticus* (23% in muscle and 15% in head) and *Calaris lazera* (11% in muscle). **(Mohamed, 2013)**. And lower than results obtained from other freshwater fishes in Nigeria such as *Clarias gariepinus* and *Tilapia zillii* (9.3%, 7.1%). respectively. **(Osibona *et al*., 2009)**. Also the fat content of fish study was in the same range of results obtained from *Labeo niloticus* and *Synodontis schall* (4.5±0.6 and 2.0±0.3). **(Bakhiet *et al*., 2017).**

5.2.4. Ash content

The result of the analysis of the ash content is the higher in *Mormyrops anguilloides* (2.23±0.08), but is the lower in *Marcusenius cyprinoides, Hyperopisus bebe* and *Mormyrus caschive* (2.02±0.05, 1.98±0.10 and 1.96±0.11). Male of four species is the higher in ash (2.1±0.1), but female is the lower in ash (1.9±0.1). Are the higher range of the results obtained from other freshwater fishes in Nigeria such as *Clarias gariepinus* and *Tilapia zillii*, (1.2%). **(Osibona *et al*., 2009)**. Also the ash content of fish study is the same range of results obtained from *Labeo niloticus* and *Synodontis schall* (2.1±0.6 and 2.3±0.5). **(Bakhiet *et al*., 2017).** And **(Olopade *et al*., 2016)**. Reported the same.

5.3. Some Minerals Contents

5.3.1. Phosphorus (P) content

The phosphorus (P) content is the higher in *Mormyrops anguilloides* and *Marcusenius cyprinoides* (96.6±0.8 and 94.1±1.1), but is the lower in *Mormyrus caschive* and *Hyperopisus bebe* (82.7±8.2 and 78.2±9.3). Male of four species is the higher in phosphorus (91.59±6.53), but female of four species is the lower in phosphorus (84.36±11.36). Are higher than the results obtained from other freshwater fishes in Sudan such as *Oreochromes niloticus* and *Bagrus bayad* (705 - 748 mg/1g). **(Ahmed *et al*., 2016).** Also higher than the results obtained from other freshwater fishes in Sudan such as *Calaris gariepinus* in farmed and wild (2.87±0.42 and 2.80± 0.45mg/1g). **(Deng *et al*., 2016)**. Also the phosphorus content is the higher than results obtained from other freshwater fishes in Sudan. (*Lates niloticus, Bagrus bayad, Oreochromes niloticus, Synodontis schall* and *Teteradon lineatus*) (7270, 730, 9350, 7370 and 7885mg/g in dry matter basis. respectively). Reported by **Mohamed *et al*, (2010)**.

5.3.2. Calcium (Ca) content

The calcium (Ca) content is the highest in *Mormyrops anguilloides* and *Marcusenius cyprinoides* (116.9±1.7 and 113.0±1.2), but is the lowest in *Mormyrus caschive* and *Hyperopisus bebe* (94.2±7.9 and 89.1±6.8). Male of four species is the highest in calcium (106.23±11.60), but the female is the lowest in calcium (100.47±14.35). Are higher than the results obtained from other freshwater fishes in Sudan such as *Oreochromes niloticus* and *Bagrus bayad* (7270 - 7730 mg/1g). **(Ahmed *et al*., 2016)**. Also higher than the results obtained from other freshwater fishes in Sudan such as *Clarias gariepinus* in farmed and wild (4.15± 0.47 and 4.32± 0.59 mg/1g). **(Deng *et al*., 2016)**. Also the calcium content is the higher than results obtained from other freshwater fishes in Sudan. (*Lates niloticus, Bagrus bayad, Oreochromes niloticus, Synodontis schall* and *Teteradon lineatus*) (2305, 2920, 1075, 3113 and 5880 mg/g in dry matter basis. respectively). Reported by **Mohamed *et al*, (2010)**.

5.3.3. Potassium (K) content

The potassium (K) content is the higher in *Mormyrops anguilloides* (27.6±1.2), but is the lower in *Marcusenius cyprinoides*, *Mormyrus caschive* and *Hyperopisus bebe* (25.0±1.6, 23.7±2.3 and 22.5±2.3). Male of four species is the higher (26.38±1.57), but female is the lower (23.14±2.55). Are higher than the results obtained from other freshwater fishes in Sudan such as *Oreochromes niloticus* and *Bagrus bayad* (2060 – 2305 mg/1g). **(Ahmed *et al*., 2016).** Also higher than the results obtained from other freshwater fishes in Sudan such as *Clarias gariepinus* in farmed and wild (3.76± 0.41 and 4.07± 0.25 mg/1g). **(Deng *et al*., 2016)**. Also the potassium content is the higher than results obtained from other freshwater fishes in Sudan. (*Lates niloticus, Bagrus bayad, Oreochromes niloticus, Synodontis schall* and *Teteradon lineatus*) (11550, 12100, 9545, 10175 and 9990 mg/g in dry matter basis. respectively). Reported by **Mohamed *et al*, (2010)**.

5.3.4. Zinc (Zn) content

The zinc (Zn) content is the higher in *Mormyrops anguilloides* and *Mormyrus caschive* (0.02±0.01), but is the lower in *Marcusenius cyprinoides* and *Hyperopisus bebe* (0.01±0.01). Male of four species is higher in zinc content (0.02±0.01), but female lower in zinc content (0.01±0.01). The studied species was lower than the results obtained from other freshwater fishes in Nigeria *Oreochromes niloticu*s. (0.14±0.08 mg/100g). **(Olopade *et al*., 2016)**. Results agree with results obtain from other freshwater fishes in the Sudan such as *Clarias gariepinus* (Zn 0.096±0.01 and 0.097±0.01) (farmed and wild). **(Deng *et al*., 2016)**.

5.4. Some Heavy Metals Contents

5.4.1. Lead (Pb) content

The Lead (Pb) content is the higher in *Marcusenius cyprinoides*, *Mormyrops anguilloides* and *Mormyrus caschive* (0.09±0.01, 0.08±0.01 and 0.08±0.01), but is the lower in *Hyperopisus bebe* (0.06±0.01). Male of four species is the higher in lead content (0.8±0.01), but female is the lower in lead (0.07±0.01). The studied species are agreement with results obtained from other freshwater fishes in the Sudan such as *Oreochromes niloticus*. (The Pb in the muscle recorded low level ranges between 0.307 - 0.247 mg/g dw.). **(Bakhiet, 2015)**.

5.4.2. Cadmium (Cd) content

The cadmium (Cd) content is the higher in *Mormyrops anguilloides*, *Marcusenius cyprinoides* and *Mormyrus caschive* (0.07±0.01, 0.06±0.01 and 0.06±0.01), but is the lower in *Hyperopisus bebe* (0.04±0.01). Male of four species is the higher in cadmium content (0.06±0.01), but female is the lower in cadmium content (0.05±0.01). The studied species is lower than values obtained from other freshwater fishes in the Sudan such as *Oreochromes niloticu*s. (The Cd in the muscle tissues highest concentration with a value ranges between 0.455 - 0.188 mg/g dw in gill and lowest 0.113 - 0.121 mg/g dw. In muscle). **(Bakhiet, 2015)**.

5.4.3. Mercury (Hg) content

The mercury (Hg) content is the higher in *Mormyrops anguilloides* (0.03±0.01), but is the lower in *Marcusenius cyprinoides*, *Mormyrus caschive* and *Hyperopisus bebe* (0.02±0.01, 0.02±0.01 and 0.01±0.01). Male and female of four species is the same in mercury content (0.02.01). The studied species is agreed with results obtained from other freshwater fishes in the Sudan such as *Oreochromes niloticu*s and *Clarias lazera* (the Hg concentrations were determining in muscle *Oreochromes niloticu*s Fe ≥ Cr ≥ Hg ≥ Ni and *Calaris lazira* Fe ≥ Cr ≥ Ni ≥ Hg in three tested tissues muscles ≥ gills ≥ bones.). **(El-Bassir *et al*., 2017).** The studied species is agreed with results obtained from other freshwater fishes in Nigeria such as *Labeo cubie* and *Mormyrus rume* (0.01±0.00 and 0.02±0.00). **(Ikape *et al*., 2018).**

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

- Body weight composition of the fish is important aspect in fish processing which gives an idea in amount of the pure fillets and the fish by-product.
- The study of chemical composition of the studied species is essential in order to compare its value as food with other protein foods.
- It is also necessary to have data on the composition of fish in order to make the best use of them as food and in order to develop the technology of processing fish and fish products.
- Mineral content of the studied species in River Nile State is good quantity , So study recommend to include these species in human and animal feeding
- Heavy metals content were found in acceptable limits, regarding the location of catching the fish from the River Nile near the mining areas.

6.2. Recommendations

- More studies are needed to determine fillets yield and chemical composition of other fish species from different sources in River Nile State to make base line studies in this field.
- Fish processing sector have to use this information in which methods of processing to get the maximum use of fish.
- Continuous studies have to be conducted to assess the effects of different mining practices in this area in fish health and nutritional values.

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APPENDICES

Appendix (1). Shows maximum permissible limits of heavy metals in fish muscle mg/g. dry. Wt. according to the international standards.

Heavy metals	Permissible levels.	Organizations and countries	References
Lead (Pb)	P<0.05	WHO	**Elsaim *et al*., 2018**
	1.5 - 1.7ppm	FAO, US.	**AL-Ghanim *et al*., 2015**
	2.0mg/g	SASO 1977	
	2.00 mg/g	SASO 1997	**ELShehawy *et al*., 2015**
	2 ppm	US	**AwadElkareem, 1998**
	0.5 ppm	FAO/ WHO 1992	**Bakhiet, 2015**
	5.0 mg/g	Spain Boletin Official del Estado (1991)	
	0.005 ppm	WHO 1984	
	0.1mg/kg	Egypt, E.O.S.Q.C. (1993).	
	0.5µg/g	FAO/WHO	**Maurya *et al*., 2019**
	2.0µg/g	FEPA	
	0.5ppm	FAO 1983	**Brar, 2016**
	0.20mg/kg	Poland 2006	**Luczynska and Brucka-Jastrzebska., 2006**
	2mg/kg	MFA	**Baharon and Ishak., 2015**
	0.5mg/kg	FAO	
	0.2 - 0.4mg/kg	EC	
	0.5mg/kg	USFDA	
	0.20±0.00	FAO 1992	**Ikape *et al*., 2018**

Cadmium (Cd)	$P<0.05$	WHO	**Elsaim *et al*., 2018**
	3 - 4ppm	US, FAO, WHO (2011).	**AL-Ghanim *et al*., 2015**
	0.05ppm	FAO/WHO (1992)	**Bakhiet, 2015**
	1.0 pg/g	Spain Blotien(1991)	
	0.17µg/g	FAO/EC	**AL-Najjar *et al*., 2016**
	1.67µg/g	FAO/ WHO	
	0.67µg/g	England	
	1%	TWI. WHO 1973	**Julshamn *et al*., 1986**
	0.05ppm	FAO	**Brar, 2016**
	1mg/kg	MFA	**Baharon and Ishak., 2015**
	0.5mg/kg	FAO	
	0.05mg/kg	EC	
	0.01-0.21mg/kg	USFDA	
	0.50mg/g	FAO/ WHO 1994 and FAO/ WHO 2001	**ELShehawy *et al*., 2015**
	0.05mg/kg	Poland 2006	**Luczynska and Brucka-Jastrzebska., 2006**
Mercury (Hg)	0.5mg/kg	FAO. 1984 WHO. 1984	**El-Bassir *et al*., 2017**
	6 - 50%	TWI. WHO 1973	**Julshamn *et al*., 1986**
	0.222 0.50	IAEA 2003. EC 2006.	**AwadElkareem *et al*., 2014**
	0.01±0.00	WHO 1992	**Ikape *et al*., 2018**
	0.5ppm	WHO 1989	**Brar, 2016**
	0.50mg/kg	Poland 2006	**Luczynska and Brucka-Jastrzebska., 2006**

FAO: Food and Agricultural Organization. WHO: World Health Organization. EC: European Community. IAEA: International Atomic Energy Agency. US: United Nations. EOSQC: Egyptian Organization for Standardization and Quality Control.TWI: Tolerable Weekly Intake. SASO: Saudi Standards, Metrology and Quality Org. FEPA: Federation of European Producers of Abrasives. MFA: Malaysian Food Act. USFDA: United States Food and Drug A ministration. FDA: Food and Drug A ministration.

Appendix (2). Shows some experimental equipment.