

**NUTRITIONAL VALUE AND ORGANOLEPTIC ASSESSMENT OF BREAD
FORTIFIED WITH SCUBIA [*Scomber scombrus*]**

BY

Igbekele Junior AKINBI

AGR1900251

DEPARTMENT OF AQUACULTURE AND FISHERIES MANAGEMENT

FACULTY OF AGRICULTURE

UNIVERSITY OF BENIN

BENIN CITY.

FEBRUARY, 2025.

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**A PROJECT SUBMITTED TO THE DEPARTMENT OF AQUACULTURE AND
FISHERIES MANAGEMENT, FACULTY OF AGRICULTURE, UNIVERSITY OF
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THE DEGREE OF BACHELOR OF AGRICULTURE (OPTION IN AQUACULTURE
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CERTIFICATION

This is to certify that the research was carried out by Igbekele Junior, AKINBI with Matriculation Number AGR1900251 and he is a student of the Department of Aquaculture and Fisheries Management, Faculty of Agriculture, University of Benin, Benin City.

DR. K. OMORUYI
(PROJECT SUPERVISOR)

DATE

DR. M. EGWENOMHE
(HEAD OF DEPARTMENT)

DATE

DEDICATION

I dedicate this project to God Almighty for his mercies, guidance and protection throughout the period of the study, my lovely foster parents Mr. and Mrs. Emmanuel Isijola, my uncle Mr. Idowu Akinbi and his family, Mr. Damilola Akinbi and his family, my cousin Sunday Sandra and his family for their moral and financial support. Thank You and God bless all.

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I wouldn't forget my wonderful and priceless course mates {all AGR19 students}, AGR Football Team, Boblass Football Club, Gba Boys and to all whom God used to favor me throughout my sojourn in this school. Thank you all and God bless.

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ABSTRACT

This study investigated the nutritional value and organoleptic assessment of bread fortified with fish concentrate from commercially important fish species. Fish is a highly nutritious source of protein and essential fatty acids, but its incorporation into staple foods like bread remains underexplored. The research aimed to evaluate the impact of fish concentrate on the proximate composition and sensory characteristics of bread. Bread samples were produced with varying levels of fish concentrate (0%, 10%, 20%, and 30%) and analyzed for moisture, protein, fat, ash, fiber, and carbohydrate content. Organoleptic properties, including appearance, taste, texture, and aroma, were also assessed.

The results showed that fortification with fish concentrate significantly enhanced protein, fat, and ash content while reducing carbohydrate levels. Sample D (30% fish concentrate) had the highest protein (20.18%) and fat (9.16%) content, whereas the control sample (0% fish concentrate) exhibited the highest carbohydrate content (63.44%). Sensory evaluation indicated that moderate fortification (10–20%) improved taste, aroma, and texture without negatively affecting consumer acceptability. However, higher levels (30%) introduced stronger flavors that may not be well received by all consumers.

KEYWORDS: Bread, fish concentrate, fortification, proximate analysis.

CHAPTER ONE

INTRODUCTION

Fish is a unique source of both essential macro and micronutrients; it is found in limited amounts in the diet and is highly consumed worldwide (Wake & Geleto, 2019). Fish is a source of protein in high amounts, fatty acids, and minerals (calcium, iron, zinc, and iodine). However, fish has trace amounts of carbohydrates and essential vitamins, especially vitamin A (Abelti, 2017).

Fisheries and aquaculture are extremely important for providing food, nutrition, and employment to millions of people worldwide. Fisheries are an important part of food security, particularly for many poor people in developing countries. In low-income food deficient countries (LIFDCs), they make up 22% of animal protein consumption overall (FAO, 2005). This rapid increase in Nigeria and the world population in general, has led to high competition for natural resources, especially food resources. To attain global food security, the fisheries and aquaculture sector has been identified as an important sector (FAO, 2020). Fishery production is significant to the Nigerian economy given its importance in providing a cheap source of food/nutrition security, income, employment and serves as a source of foreign exchange particularly those of the riverine communities (NBS, 2017). It is not a hidden fact that fish is a major source of animal proteins in the diet of most Nigerians, especially those living in rural areas. Akinsorotan *et al.*, (2019) reported that the yearly fish demand of Nigeria is about 2.1 million metric tons with Nigeria only able to meet up just about 38.1% of its fish needs and depends on imports to cover the shortfall of about 61.9% off its population need yearly.

Fish is one of the most perishable of all the foods due to suitable medium for growth of micro organisms after death (Ojutiku, Kolo, & Mohammed, 2009). The loss of fish due to spoilage in

the world is estimated to be 10–12 million tons per year, accounting for 10% of total production. Generally, the wastage of fish through spoilage has been estimated to range from 18% to 30% in developing nations (Mphande & Chama, 2015). It indicates that the habit of preserving and processing fish into different products before spoilage is poor or not enough. Fish deterioration or spoilage is one of the fishing industry's most significant problems. To limit post-capture loss, various preservation methods such as frying, fermentation, drying, salting and smoking are used individually or in association (Anihouvi *et al.*, 2005; Issa, Mopate, & Missohou, 2012; Yacouba, 2009). These methods aim to inactivate micro-organisms and endogenous enzymes which are involved in the spoilage mechanism.

Fish processing is the process associated with fish and fish products between the time in which fish are caught or harvested and the time in which the fish product is delivered to the consumer. Fish preservation refers to the methods and techniques used to extend the shelf life of fish by reducing spoilage through physical, chemical, and biological means (Eyo, 2001). The operations in fish processing are washing, degutting, salting, fermentation, drying and smoking. These operations contribute to the development of flavour, texture, colour and improved storage characteristics of the product. Some of the processes employed in fish processing include boiling, frying, roasting, smoking and so on, and these could have varying effects on their nutrient contents and organoleptic properties (Eriksson, 1987).

1.2 Justification of the Study

The consumption of bread is very popular in most developing countries (Sanful & Darko, 2010). It is consumed by all age groups especially among children. Nutritionally, bread contains high percentage of carbohydrate and fat which are needed for energy and source of calories. However, it has no adequate sources of protein, minerals and essential oil to address malnutrition. The

problem of malnutrition in Nigeria although different in magnitude and severity among different areas are due to protein, vitamins, iron and other mineral deficiency (Adebooye, 1996). Therefore, there is the need to enrich or fortify bread in order to improve its nutritional value.

Food fortification is the addition of one or more essential nutrients to food whether or not it is normally contained in the food, for the purpose of preventing or correcting a demonstrated deficiency with one or more nutrient in the population or specific population group (Brekkan, 1996).

Ahmed *et al.* (2017) investigated the use of fish flour made from various fish species, specifically tilapia and mackerel in bread production.

This study was carried out to develop a nutritious bread made from all-purpose flour and fortified with scubia [*Scomber scombrus*] concentrate. This fish – *Scomber scombrus* is abundantly available in Nigeria and quite low in cost, it is desirable to use this abundant resources for the development of value-added protein, enriched bread products could be of high acceptability in the growing market of fish-based foods.

1.3 Aim and Objectives of the Study

The aim of this study was to determine nutritional value and organoleptic assessment of bread fortified with some commercially important fishes in Benin metropolis.

The specific objectives were to;

- (1) evaluate the proximate composition of bread fortified with scubia fish *Scomber scombrus* concentrate in Benin City, Edo State.

(2) assess the organoleptic value of bread fortified with *Scomber scombrus* concentrate in the study area.

CHAPTER TWO

2.0

LITERATURE REVIEW

Fish is widely recognized for its impressive nutritional profile. It serves as an excellent source of high-quality protein, providing all the essential amino acids necessary for the maintenance and repair of body tissues. The high bioavailability of protein in fish makes it an ideal choice for individuals of all ages, including those with increased protein needs, such as children, athletes, and the elderly (Smith, 2020). One of the most significant nutritional benefits of fish is its high content of omega-3 fatty acids, particularly Eicosa Pentaenoic Acid (EPA) and Docosa Hexaenoic Acid (DHA). These essential fats are predominantly found in fatty fish such as salmon, mackerel and sardines. Omega-3 fatty acids are crucial for cardiovascular health, as they help to reduce inflammation, lower blood triglyceride levels, and decrease the risk of heart disease (Johnson, 2021). They support brain health, contributing to cognitive function and potentially reducing the risk of neurodegenerative diseases. Fish is also a rich source of various vitamins and minerals that are vital for health. It is particularly noted for its high vitamin D content, which is essential for bone health, immune function, and the regulation of calcium in the body. Fish provides B vitamins, including B12, which are important for energy production, nervous system function, and the formation of red blood cells (Brown, 2019). In addition to vitamins, fish contains important minerals such as iodine, selenium, and zinc. Iodine is essential for thyroid function, selenium acts as an antioxidant protecting cells from damage, and zinc supports immune function and wound healing. The mineral content of fish can vary depending on the species and the environment in which they are found, but overall, they are considered a valuable source of these essential nutrients (Davis, 2022). Another significant nutritional advantage of fish is its low saturated fat content and high levels of healthy unsaturated fats.

These unsaturated fats, including omega-3 fatty acids, can help reduce the risk of cardiovascular diseases by improving blood lipid profiles, reducing blood pressure, and preventing the formation of arterial plaques (Wilson, 2020). Studies have consistently shown that regular fish consumption is associated with numerous health benefits, including a lower risk of heart attacks, strokes, and other cardiovascular events.

2.1 Fish Value

Fish plays a crucial role in both marine and freshwater ecosystems, often acting as a key indicator of environmental health. Fish contribute to the control of aquatic plant populations and help maintain the balance of ecosystems by serving as both predators and prey within the food web (Okaeme, 1992). Fish are involved in nutrient cycling within aquatic environments, aiding in the redistribution of nutrients through their feeding and excretion activities (Olopade *et al.*, 2015). Fish also holds significant economic, nutritional, and cultural value, making it an essential resource for societies around the world.

2.1.1 Economic Value of Fish

Fish represents a valuable commodity in global markets, with an estimated trade value of over \$150 billion annually (Smith, 2019). Commercial fisheries provide employment opportunities for millions of people, particularly in coastal regions where fishing is a primary economic activity (Johnston *et al.*, 2020). Beyond direct market value, fish also contribute to other sectors such as aquaculture, tourism, and recreational fishing, all of which generate additional economic benefits (Sanchirico *et al.*, 2018). Fish products such as fish oil and fishmeal are widely used in various industries, including animal feed, pharmaceuticals, and cosmetics, further enhancing the

economic value of fish by supporting livelihoods and driving economic growth, fish holds substantial monetary value (Belton *et al.*, 2021).

2.1.2 Nutritional Value of Fish

Fish is highly regarded for its nutritional value, being a rich source of high-quality protein, omega-3 fatty acids, vitamins (such as vitamin D), and minerals (University of Chicago Medicine, 2021). Regular consumption of fish has been associated with numerous health benefits, including reduced risk of cardiovascular diseases, improved cognitive function, and better mental health (Schuchardt *et al.*, 2019). In regions where access to diverse food sources is limited, fish serves as an important source of essential nutrients, contributing to food security and overall well-being (Thilsted *et al.*, 2016). The nutritional value of fish extends beyond its immediate consumption, as fish byproducts can be used in fortifying food staples and addressing nutrient deficiencies (Spijkers *et al.*, 2017).

2.1.3 Cultural Value of Fish

Fish holds immense cultural significance in various societies, often being deeply intertwined with local traditions, beliefs, and rituals (Berkes *et al.*, 2006). Fishing practices have shaped the cultural identities of coastal and indigenous communities, influencing their social systems, art, and storytelling (Acheson, 2015). Fish-based cuisines and culinary traditions have become integral parts of regional and national cultural heritage, contributing to the diversity and richness of global gastronomy (Korsmeyer, 2019). Fish festivals and events celebrate the cultural value of fish, fostering community cohesion and promoting cultural tourism (Loureiro *et al.*, 2020). The cultural value of fish transcends economic considerations, reflecting the deep connections between humans and aquatic ecosystems.

2.2 Processing and Preservation of Fish

Fish is a valuable source of protein and essential nutrients. The highly perishable nature of fish requires adequate processing and preservation techniques to maintain its quality and safety. Fish harvested needs to be processed promptly because of enzymatic and microbial approaches which deteriorate the quality of dead fish 12-20 hours after being caught to spoil and deliver unpleasant taste, smell and texture relying upon the size and type of fish species, decreasing consumer acceptability for that unique fish species (FAO, 2005). Fish processing is the processes associated with fish and fish products between the time in which fish are caught or harvested and the time in which the final product is delivered to the customer. The purpose of processing and preserving fish is to get fish to an ultimate consumer in good, usable condition. The steps necessary to accomplish this begin before the fishing expedition starts, and do not end until the fish is eaten or processed into oil, meal, or a feed (Karube *et al.*, 2001).

2.3 Methods of Fish Preservation

Fish preservation is the process of applying techniques that extend the shelf life of fish while maintaining its quality, safety, and nutritional value (Akinola *et al.*, 2010). Preservation methods aim to inhibit the growth of microorganisms and prevent spoilage, which is crucial given the high perishability of fish due to its high water content (Eyo, 2001). Effective fish preservation ensures that fish remains consumable for a longer time, particularly in regions like Nigeria, where storage infrastructure may be limited (Afolabi *et al.* 2015). Preservation is essential for reducing post-harvest losses, thereby enhancing food security and the availability of fish products throughout the year (Adebayo-Tayo *et al.* 2013). Preservation can be done both for short and long duration (Eyo, 2002).

2.3.1 Preservation for Short Duration

2.3.1.1 Chilling

The first and simplest method to both preserve and process fish is to keep it cool. Cool fish keeps longer than uncooled fish, although both will spoil in a matter of hours (Tawari and Abowei, 2011). This is obtained by covering the fish with layers of ice. Ice alone is not effective for long preservation, because melting water brings about a sort of leaching of valuable flesh contents which are responsible for the flavour. But ice is effective for short term preservation as such as is needed to transport landed fish to nearby markets or to canning factories. Here, autolytic enzymic activities are checked by lowering the temperature (FAO, 2007). Most fish caught are preserved with ice at some stage in their processing. Trained taste panels are usually unable to distinguish well-iced fish kept less than six or seven days from fresh fish, and storage life can be extended somewhat if antibiotics are added to the ice. Ice works in two ways;

1. It reduces the growth rate of bacteria by reducing the temperature of the fish; and
2. It also washes the bacteria and slime away as it melts. Because of this, it is important to keep melt water drained away from the fish (Idachaba, 2001).

2.3.2 Preservation for Long Duration

2.3.2.1 Salting

There are many different kinds of salt, some being better than others for fish curing. However, in islands or in outlying places there is often no choice, and whatever is available in the way of salt has to be used, whether it is bought in a shop, prepared on the spot, or extracted from earth

containing salt. A distinction must be made between the two chief techniques of salting: wet salting and dry salting (FAO, 2005).

2.3.2.1.1 Wet Salting

The principle is to keep the fish for a long time in brine. The equipment needed consists of a watertight container, which can be a tin, drum, canoe, barrel and so on. To make the brine, one takes four parts of clean water (sea or fresh water) and one part of salt. If the salt is coarse, it has to be ground or pounded first (Tys and Peters, 2009). It is then dissolved into the water by stirring with a piece of wood. To be good, the brine must float a fish. The next step depends on what kind of fish one wants to salt. It is best first to cut off the head, and gut and clean the fish, though small fish can also be salted whole. Large fish must be cut open, and it is preferable to take out the backbone. Fish with a heavy armour of scales must be scaled. In places where the flesh is thick, slashes must be made so that the salted brine can penetrate the flesh. Very large fish should be cut in thin fillets. After the fish has been prepared according to its size, it must be cleaned and put in the brine (FAO, 2008). A plank or matting is laid over it and weighted with rocks so that the fish is entirely covered with brine. This salted fish can be kept for a long time in a dark or at least a shady place. The remaining brine can be used three times, but water and salt must be added every time until a fish can again float on the liquid. In any case, fresh brine is always best (Leistner and Gould, 2002).

2.3.2.1.2 Dry Salting

In this method the fish is salted but the juices, slime and brine are allowed to flow away. Dry salting can be done in an old canoe, or on mats, leaves, boxes and so on. In any case, the brine formed by the fish juices and the salt must be allowed to run away. For two parts of fish, one

needs one part of salt (Kauffeld *et al.*, 2005). Layers of fish must be separated by layers of salt. It is a valuable method when one has no containers. This method is used to salt down flying fish in open fishing boats while at sea, and the fish in this case are kept whole. Some people like the salty taste of fish prepared in this way, but it is always possible to wash the salt away by soaking it in fresh water before use (FAO, 2005).

2.3.2.2 Drying

Very small and thin fish can be dried straight away in the sun if they are brought in early enough in the morning (and if, of course, the sun is shining). If these conditions are not fulfilled the fish must be put for one night in brine, or dry salted. They can then be dried the next morning (Deepchill, 2010). If it happens to be raining the next day, it is necessary to wait until the weather has cleared up, which could take from a few hours to a couple of days. In this latter case, it will be necessary to wash the salt away from the fish by soaking it in fresh or sea water for a couple of hours before drying it; this depends again on the tastes of the consumers and on the purpose for which the fish is cured (Huss, 2009). Small fish are mostly sun dried on mats, or suspended. When it rains the fish must be kept dry by covering or transferring them under shelter. If fish are laid on mats or other material to dry, it is best to turn them over every two hours so that they will dry quickly and not become maggoty. In the case of large fish, hanging is better if they are merely split (Ananou *et al.*, 2007).

Dry salted fish can also be dried, but they should first be cleaned in water. Normally, the fish will be dried after three days. If a great quantity of fish has been dried and is to be kept for some time, the best way is to pile it up in a dark place, off the ground and preferably on wooden boards. It should then be covered with a sack or mat. After a fortnight, the fish should again be laid in the

sun for one or two hours and then put away as before. These are only indications of the main principles of fish drying; variations are possible (Leister and Gould, 2002).

2.3.2.3 Smoking

Any kind of fish can be smoked. There are three main methods of smoking:

- (a) Smoking and roasting;
- (b) hot smoking;
- (c) long smoking.

2.3.2.3.1 Smoking and Roasting

This is a simple method of preservation, for consumption either directly after curing or within twelve hours. Re-smoking and roasting can keep the product in good condition for a further twelve hours (Kauffeld *et al.*, 2005). Fresh unsalted fish is put over a wood or coconut husk fire. This should be kept very small and the fish turned over every five minutes. In about half an hour the fish is ready for consumption or, if it is the intention to keep it for a while, it should be put in an aerated container (Tys and Pieters, 2009). Fish can be preserved in this way even in open fishing boats, but the smoking has to be done in a tin or a half-drum. Salted fish can also be smoked by this method, but this is used mostly for immediate consumption or in order to bring the produce in smoked form to a nearby market.

2.3.2.3.2 Hot Smoking

The hot smoking system can be used for immediate consumption or to keep the fish for a maximum of 48 hours. Small fish can be salted first for half an hour (see wet salting). After salting, they are put on iron spits and dried in a windy place or in the sun for another half hour. It is necessary to have an oil drum to make the smoking stove. The top of the drum is cut out and holes are made 8 inches below the rim to place spits. Near the bottom, a rectangular opening is

made to control the fire. This opening should be closed with a small door or piece of steel plate. A fire of hardwood or coconut husks is made in the stove, and once it is well started it is regulated so as to give no flames (Tys and Pieters, 2009). The fish are then placed over the spits. During the smoking operations the top of the drum must be covered with a sack or with palm fronds laid as close together as possible; the fire control opening should also be closed. The fire must be watched from time to time. The fish will be ready in about one hour. An indication that they are done will be found in the golden yellow colour of the skin. For big fish, 1 to 2 feet long, the best method is to split them in halves, to the right and left of the backbone. Each half fish is fixed between two flat bamboo slats or sticks. These halves are then rested head down on racks built four feet above ground. A number of split fish can be lined up next to each other. A fire of hardwood or coconut husks, or several separate fires are then lit under the rack. The number of fires depends on the quantity of fish one has to smoke. There should be a slow fire for about half an hour followed by a brisk one for one hour. A small fire is then kept going for six hours (just smoking) (Alasalvar *et al.*, 2011). After this treatment, the fish is ready for transport and will keep in good condition for two to three days under tropical conditions. This method is used in particular in the Celebes for skipjack and other tunas (Ananou *et al.*, 2007).

2.3.2.3.3 Long Smoking

If fish must be kept in good condition for a long time, for instance, two or three months or even longer, it can be done by smoking, provided the fish is not oily. For this purpose, a small closed shed made of palm leaves or other local material can be used. The dimensions of the shed depend, of course, on the quantities of fish to be smoked, but the height should in no case be less than six feet. In this shed, racks are built to hang the fish from or to lay them upon. Hanging the fish on

spits is the best method, but they can also be laid on loosely-woven matting. One can start hanging fish three feet from the bottom up to the roof (Deepchill, 2010).

The preservation of fish is effected by smoke only in this method, and it is best to use coconut husks which should burn very slowly so that the fish is dry smoked after 48 hours. After such a treatment, the flesh is dried throughout. If it is necessary to transport these fish to other islands, they should be packed in small packages wrapped in dry leaves and reinforced with bamboo or sticks. In Eastern Indonesia, packages of smoked fish are sent over great distances (Idachaba, 2001).

2.3.2.4 Fish Canning

This is a process involving heat treatment of fish in sealed containers made of tin plates, aluminum cans or glass, until the product has been fully sterilized (Idachaba, 2001). During canning, heat treatment should be sufficient to destroy all heat sensitive bacterial and spores, inactivate the enzymes and cook the fish so that the product remains acceptable to the consumer after prolonged storage (FAO, 2005) i.e commercialized sterilization, this is used in thermal processing to describe the heat treatment designed to kill substantially all microorganisms and spores which is present and cable of growing in the product (FAO, 2008). The canned food fish is also prevented from contamination by pathogenic organisms by storing them in a virtually airtight package. If heat treatment is properly carried out, canned fish may remain in storage for several years without refrigeration (Leistner and Gould, 2002). Traditional canned fish are obtained from small pelagic fish species such as Herrings (*Clupea* spp), Sardines (*Sardinella* sp), Mackerels (*Scomberomerus* sp), Anchovies (*Engraulis* sp), Tuna (*Thunnus* sp). Bonga (*Ethmalosa* sp) (Gopakumar, 2010). Fish intended for canning must be in first class condition

and must be handled in a hygienic manner to reduce microbial load on the fish. Poor quality fish will produce canned fish with offensive odour and flavour, poor texture (Burt, 2003).

2.4 Fish Utilization

The most common use for fisheries resources is food. Fisheries resources are now producing a record quantity of food and other benefits for humanity. The proportion of global fish production used for direct human consumption is now over 77 percent – a significant rise of the last decades, with consumption of fresh fish outstripping other fish products such as canned fish (FAO, 2018).

Fish landed not used for direct human consumption is reduced to fishmeal and oil. The proportion of world capture production reduced to fish meal has doubled since 1950 and oscillates around 30-35 million tonnes. Fishmeal was historically used as feed, mainly for pigs and chickens (Tacon, 2008). During the last decade, a growing part of the production has been used for raising carnivorous aquatic species (such as salmon, shrimp, sea bass, sea bream and so on.) representing less than 10% of world aquaculture production (Naylor *et al*, 2009).

Fish represents a valuable source of proteins and nutrients in the diet of many countries and its importance in contributing to food security is rising significantly (Beveridge *et al*, 2013). The total food supply available from fisheries in live weight terms is estimated to be slightly higher than 16 kilos per year for each of the world's inhabitants (FAO, 2018). This figure has more than doubled since 1950 (at about 7 kilos per capita) as production has kept pace with population growth. These figures need to be viewed with some caution as they do not represent individual consumption, which can only accurately be assessed in countries where food consumption surveys have been carried out (Beveridge, 2013).

Post-harvest handling, processing and transportation of fish require particular care in order to ensure proper quality and safety. Retaining the nutritional value of the fish, preserving the benefits of its rich composition and avoiding costly and debilitating effects of fish-borne illnesses are vital (Huss, 2009).

The usually stated limits of production from all intents and purpose definitely capture fisheries, coupled with the widening gap between the supply and demand of fish for human consumption, reaffirms that post harvest losses are an unacceptable waste of scarce natural resources (Akande and Diel-Quadi, 2010). Post harvest losses of fish occurs in quite a number of forms. Economic losses appear when spoilage of moist fish results in a value-decrease or when there is no need to reprocess cured fish, elevating the cost of the complete products. Inadequate handling, utilization and processing methods can minimize nutrients, leading to nutritional loss. Similarly, the lowering of large quantities of fish catches into animal feeds can be considered under conditions as a loss for human food security (Hazell *et al*, 2007).

2.5 Food Packaging

Food packaging is a critical aspect of food processing, serving to protect products from contamination and physical damage (Afolabi *et al.*, 2016). Packaging ensures the safety, quality, and freshness of food during storage, transportation, and distribution, which is essential for maintaining food security and reducing post-harvest losses (FAO, 2020). Effective food packaging helps to extend the shelf life of food items, preserving their nutritional value and sensory qualities, such as taste, texture, and aroma (Akinyemi *et al.*, 2015). In Nigeria, packaging materials such as polyethylene bags, cartons, and glass jars are commonly used for both local and industrial food products, offering varying levels of protection and durability (Oladele and Akinyemi, 2018). Packaging is not only a means of protection but also plays a

significant role in marketing, providing information about the product to consumers through labeling (FAO, 2019). Clear labeling and attractive packaging are crucial for consumer appeal, especially in competitive markets (Adetunji *et al.*, 2017). Proper packaging also helps to minimize food waste by reducing spoilage and preserving food quality during transportation over long distances, which is particularly important in Nigeria's diverse climatic regions (Adesina, 2013).

Packaging materials must be selected based on the type of food and the intended storage conditions to ensure optimal performance (FAO, 2017). In Nigeria, vacuum packaging is increasingly used for perishable products like fish and meat, as it helps in maintaining freshness by limiting exposure to air (Akinola *et al.*, 2016). High cost of advanced packaging technologies often limits their use to larger commercial enterprises, while small-scale producers rely more on affordable options like plastic films (Nwachukwu *et al.*, 2014).

2.6 Organoleptic Assessment

In order for processed fish product to be considered as essentially finished product, the processor will have to produce a product that satisfy the consumer as well as statutory food legislation (Olley and Thrower, 1977). Organoleptic tests are essential in the fish industry as they help to detect spoilage, ensuring that products meet acceptable standards for human consumption (FAO, 2020). The requirements of a consumer without a doubt are pretty more difficult to satisfy due to the fact that customers examine the quality of a product via subjective means, that is by the way of sensory assessment of food appearance, odour, colour, taste and texture, plus the visual appeal of its packaging and renovation in a subtle way (Rahaman *et al.*, 2012). Trained sensory panels are often used to carry out detailed organoleptic assessments, providing consistent and reliable

results that are vital for quality assurance (Akinola *et al.*, 2016). Regular organoleptic checks, combined with other quality control measures, ensure compliance with food safety regulations, which helps to protect consumers and maintain market standards (FAO, 2019). Organoleptic properties significantly influence consumer preferences, making them important for the successful marketing of fish products (Adewumi and Adesina, 2013).

2.7 Nutritional Qualities of Fish Products

Protein is a principal key supply of antibodies and enzymes of all living beings. And it mostly makes up a vital phase of the muscles, hair, and other body components. Processed fish products, such as dried, smoked, and canned fish, retain much of the nutritional quality of fresh fish, making them vital for dietary diversity, especially in regions where access to fresh fish may be limited (Afolabi *et al.*, 2015). The protein content in fish products is high, providing all essential amino acids necessary for growth and development, which is particularly important in developing countries like Nigeria (Akinola *et al.*, 2016). Fish products are also rich in omega-3 fatty acids, which are beneficial for heart health and cognitive function (FAO, 2019). These products, including fish fillets, fish meal, and fish oil, are often fortified with additional nutrients to enhance their health benefits (Olusegun *et al.*, 2017). Preservation methods used in processing fish products, such as smoking or drying, can help maintain the nutritional value while providing a longer shelf life (Adebayo-Tayo *et al.*, 2013). Processed fish products contribute essential vitamins and minerals, such as vitamin D, iodine, and selenium, which are crucial for various physiological functions (Afolabi *et al.*, 2015). Promoting the consumption of fortified fish

products can significantly improve nutritional outcomes, particularly in populations vulnerable to nutrient deficiencies (FAO, 2018).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Study Area

This study was carried out in Benin City, Edo State. It lies within latitude 6.3⁰N and longitude 5.6⁰E. The Binis are known for their beads, body mark as well as their raffia work and subsistence farming. The Bini people have four market days; Ekioba, Ekenaka, Agbado and Eken. Benin City is predominantly urban society and agriculture in Benin City supports more than 70% of the population (FAO, 2014). It is characterized by minor industrialization activities and it is epicentre of business and other activities in Edo State (Tafemi and Idolor, 2008). It is the four-largest city in Nigeria with a population of 1,782,000 (Wikipedia, 2021).

3.2 Collection of Samples

The commercial fish species [*Scomber scombrus*] was obtained from a cold room in Benin City, Edo State. A total of 40 table size fish was obtained and used. The fish samples were collected using a plastic bowl sealed with jute bags to prevent contamination.

3.3 Preparation of Materials

The working area was properly cleaned and the equipments were be thoroughly washed.

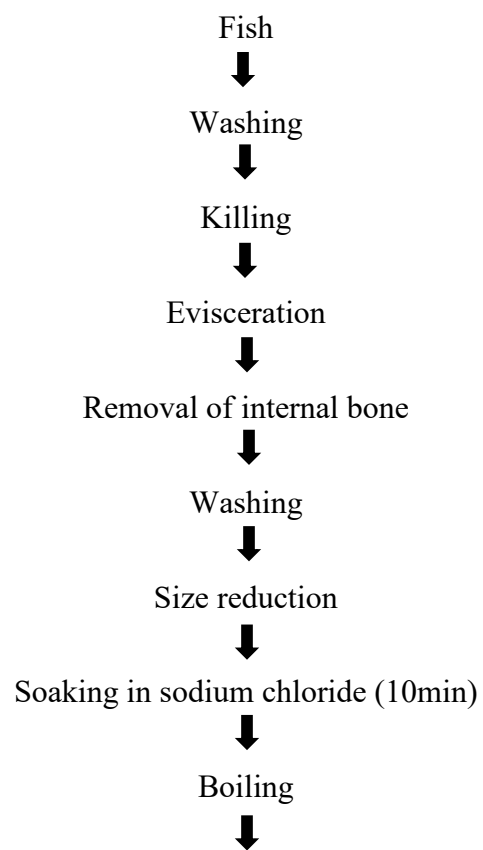
3.4 Processing Apparatus

This study was carried at the Department of Aquaculture and Fisheries Management processing unit. Some of the apparatus that were used during the study include; pot, gas oven, knife, mixer among others.

3.5 Processing Methods

3.5.1 Production of Fish Concentrate

The fish were washed thoroughly with clean water so as to remove all extraneous matter. The heads were removed and thereafter the fish were eviscerated. The fleshes of the fish were separated from the bones using a sharp knife. The fish were washed again in order to remove blood and other intestinal waste from the fish. The eviscerated fish were sliced into different sizes and then soaked in sodium chloride (salt) at room temperature for 10 minutes to reduce moisture content through osmotic dehydration and to improve taste. They were boiled for about 20 minutes. Thereafter, they were allowed to cool and were drained. The drained samples were stored in an air-tight polyethylene container for further use.



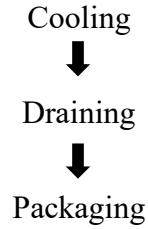


Fig 1: Flow chart for fish concentrate production (Horner, 1997).

3.5.2 Production of Bread Fortified with Fish Concentrate

All the ingredients which comprised flour (110.78g), water (57.3g), salt (2.87g), sugar (9.55g), yeast (3.82g), shortening agent (5.73g) were weighed using a precision meter balance. The ingredients were added to the mixer and thoroughly mixed. The mixed dough was then placed in a large container or trough to allow fermentation. During fermentation, the mass of dough was kneaded several times to allow escape of air which was continuously produced during fermentation. After fermentation, the dough was divided into smaller sizes which eventually made up the loaves. Fish concentrates were added to the loaves in different proportions to create different treatment groups.

Treatment A (control): 0% fish concentrate (191g dough)

Treatment B: 10% fish concentrate (171.9g dough, 19.1g fish concentrate)

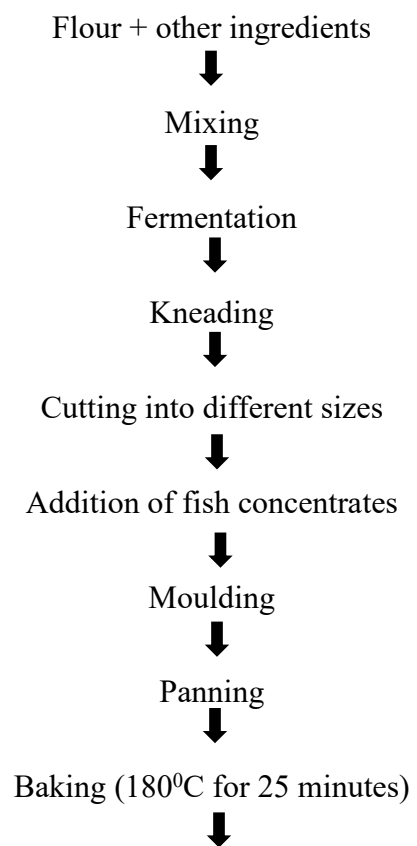
Treatment C: 20% fish concentrate (152.8g dough, 38.2g fish concentrate)

Treatment D: 30% fish concentrate (133.7g dough, 57.3g fish concentrate)

The loaves were moulded, shaped and dropped into baking pans that had been cleaned and rubbed with oil. They were allowed to bake in an oven. The bread was baked at 180°C for about 25 minutes. The baked loaves were cooled and thereafter packaged and stored for laboratory analysis organoleptic assessment.

Table 1: Weight of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates Before and After Baking

Treatment	Weight before baking (g)	Weight after baking (g)
Sample A (control)	191	161
Sample B (10%)	191	163
Sample C (20%)	191	166
Sample D (30%)	191	170



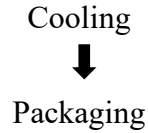


Fig 2: Flow chart for bread production (Cauvain, 2007).

3.6 Proximate Composition

The bread was analyzed for the moisture, protein, fat, ash, fiber and nitrogen free extract content, according to the method of Association of Official Agricultural Chemists (AOAC), (2003).

3.6.1 Moisture Content Determination

Bread sample of 2g was placed into a 50ml beaker of a known weight. It was then dried in a drying oven at 105⁰C – 110⁰C for 3 hours to a constant weight. The attained moisture content was calculated as loss of weight in percentage

$$\% \text{ moisture} = \frac{\text{Weight of wet sample} - \text{Weight of dried sample}}{\text{Weight of wet sample}} \times 100$$

3.6.2 Ash Content Determination

Bread sample of 2g was weighed into a previously weighed crucible. The crucible plus the sample were put into the muffle furnace and the sample was ignited and regulated to 500°C – 600°C for a period of 3 hours. Ash percentage was calculated as

$$\% \text{ Ash} = \frac{\text{Weight of Ash}}{\text{Weight of sample}} \times 100$$

3.6.3 Crude Protein Determination

The procedure was as follows;

3.6.3.1 Digestion

Ground sample of 1g was weighed into a 250ml conical flask. 2.5g of the mixed catalyst (potassium sulphate + copper sulphate + pinch of selenium) and 20ml of concentrated hydrogen sulphate were added and the mixture was heated till the solution became clear to light green. It was allowed to cool. About 20ml of water was added and the solution was filtered using Whatman number one filter into a 100ml volumetric flask and was made up to mark. It was stored in a 100ml flask reagent bottle and digest.

3.6.3.2 Distillation

Aliquot measuring 10ml was measured into 50ml of a Kjeldahl flask; 30ml of water was added. Excess 40% of sodium hydroxide was also added. Heat was applied and it was distilled into a 5ml boric acid indicator where 25ml of distillate was collected.

3.6.3.3 Titration

The distillate was titrated with 0.1N of hydrochloric acid to an end point and % crude protein was calculated as follows;

$$\% \text{ CP} = \frac{\text{Na} \times \text{Va} \times 14\text{V}_1 \times 100 \times 6.25}{1000\text{V}_2\text{W}}$$

Where: Na = concentration of HCL used for titration (0.1N)

1000 = constant

Va = volume of HCL used for titration

14 = atomic number

V₁ = final volume of digest (1000ml)

V₂ = volume of aliquot (10ml)

W = weight of sample used

3.6.4 Crude Fibre

Bread sample of 2g was weighed into 250g conical flask. 1.25% of concentrated hydrogen sulphate (1000ml) was added and boiled for 30 minutes. A 100ml volume was maintained constantly by adding water. It was then allowed to cool, filtered and washed to neutrality. The residue was washed back into the conical flask 1.25% NAOH and made up to 100ml mark. It was then boiled for 30 minutes, maintaining the same 100ml. It was filtered after cooling and washed to neutrality. The residue was washed into a crucible of known weight with 1:1 ethanol/acetone and oven dried to a constant weight. The sample was then placed into the muffle furnace and ash for 1 hour at 300°C.

The crude fibre was calculated as:

$$\% \text{ crude fibre} = \text{Ash weight} \times 100 \div \text{weight of sample}$$

3.6.5 Ether Extract Determination (Fat Extract)

Bread sample of 2g was weighed into a thimble of known weight and placed in a sohxlet extractor and connected to the extractor flask containing half full petroleum ether (60-80°C boiling point) and a condenser connected to a running tap water. It was heated for 6 hours till the extractor became very clean and petroleum ether was no longer containing fat. The thimble was removed from the extractor, oven dried at 100°C for 1 hour and weighed thereafter.

Ether extract was calculated as ;

$$\% \text{ crude fat} = \frac{\text{Weight loss}}{\text{Weight of sample}} \times 100$$

3.6.6 Carbohydrate (Nitrogen Free Extract)

% Nitrogen free extract = 100 - % moisture content + % crude protein + % ash + % lipid + % crude fibre.

3.7 Organoleptic and Sensory Assessment

A panel of 15 persons comprising staffs, students and passers by was set up to evaluate the organoleptic qualities of the bread. The samples was graded based on appearance, taste, texture and aroma using a 10 point hedonic scale. Hedonic scales are well tried and tested in consumer research for capturing data. The 10 point hedonic scale was adopted, (0-2 = poor, 2-4= fair, 4-6 = good, 6-8 = very good, 8-10 = excellent) to determine the level of acceptability/likeness or rejection by indicating their preference for each parameter as shown on the hedonistic scale of 0-10, which 10 point indicated the highest acceptability and 0 was the least.

3.8 Statistical Analysis

Data was subjected to one way analysis of variance (ANOVA) using computer software (Genstat Version 8.1, 2005). Significant differences between means was determined using Duncan's multiple range tests at $P < 0.05$.



Plate 1: Panned loaves with fish concentrates

CHAPTER FOUR

RESULTS

4.1 Organoleptic Assessment

4.1.1 Appearance of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates

Table 2 shows the organoleptic assessment of bread fortified with different levels of *Scomber scombrus* concentrates (0%,10%, 20%, and 30%) over six days of storage. There was significant difference ($P<0.05$) in appearance of breads fortified with various levels of *Scomber scombrus* concentrates over study period. The best appearance (8.0 ± 0.73^a) was seen in the 10% fortified bread while the least (6.8 ± 0.75^c) was observed in the 30% fortified bread. All breads fortified with various levels of *Scomber scombrus* concentrate had very good (6.0-8.0) appearance after 6 days of storage.

Table 2: Appearance of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates

Treatment	Day 0	Day 3	Day 6
Sample A (control)	7.6±0.95 ^a	7.1±0.77 ^b	6.8±0.75 ^c
Sample B (10%)	8.0±0.73 ^a	7.5±1.31 ^b	7.3±0.70 ^b
Sample C (20%)	7.5±0.88 ^a	7.3±0.70 ^a	6.9±0.62 ^b
Sample D (30%)	7.3±0.77 ^b	6.9±0.77 ^c	6.8±0.75 ^c

KEY: (Excellent = 8-10, very good = 6-8, good = 4-6, fair = 2-4, poor = 0-2)

4.1.2 Taste of Tread fortified with Various Levels of *Scomber scombrus* Concentrates

Table 3 shows the organoleptic assessment of bread fortified with different levels of *Scomber scombrus* concentrates (0%,10%, 20%, and 30%) over six days of storage. There was significant difference ($P<0.05$) in taste of breads fortified with various levels of *Scomber scombrus* concentrates over study period. The best taste (8.3 ± 0.6^c) was seen in the 30% fortified bread while the least (5.9 ± 0.68^b) was observed in the control. All breads fortified with various levels of *Scomber scombrus* concentrate had very good (6.0-8.0) taste after 6 days of storage.

Table 3: Taste of Tread fortified with Various Levels of *Scomber scombrus* Concentrates

Treatment	Day 0	Day 3	Day6
Sample A (control)	6.8±1.05 ^a	6.3±0.70 ^{ab}	5.9±0.68 ^b
Sample B (10%)	7.3±1.66 ^a	6.8±0.98 ^b	6.6±0.95 ^b
Sample C (20%)	7.2±0.91 ^a	6.9±0.68 ^b	6.7±0.68 ^b
Sample D (30%)	8.3±0.6 ^c	8.2±0.65 ^c	7.7±0.68 ^d

KEY: (Excellent = 8-10, very good = 6-8, good = 4-6, fair = 2-4, poor = 0-2)

4.1.3 Texture of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates

Table 4 shows the organoleptic assessment of bread fortified with different levels of *Scomber scombrus* concentrates (0%,10%, 20%, and 30%) over six days of storage. There was significant difference ($P<0.05$) in texture of breads fortified with various levels of *Scomber scombrus* concentrates over study period. The best texture (7.8 ± 0.91^a) was seen in the control while the least (6.9 ± 0.96^b) was observed in the 10% fortified bread. All breads fortified with various levels of *Scomber scombrus* concentrate had very good (6.0-8.0) texture after 6 days of storage.

Table 4: Texture of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates

Treatment	Day 0	Day 3	Day6
Sample A (control)	7.8±0.91 ^a	7.4±0.92 ^b	7.2±1.08 ^b
Sample B (10%)	7.3±1.14 ^a	7.0±0.97 ^a	6.9±0.96 ^b
Sample C (20%)	7.7±0.94 ^a	7.4±0.80 ^b	7.1±0.81 ^b
Sample D (30%)	7.3±0.77 ^a	7.1±0.72 ^a	6.9±0.81 ^b

KEY: (Excellent = 8-10, very good = 6-8, good = 4-6, fair = 2-4, poor = 0-2)

4.1.4 Aroma of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates

Table 5 shows the organoleptic assessment of bread fortified with different levels of *Scomber scombrus* concentrates (0%,10%, 20%, and 30%) over six days of storage. There was significant difference ($P<0.05$) in aroma of breads fortified with various levels of *Scomber scombrus* concentrates over study period. The best aroma (8.4 ± 0.95^b) was seen in the 20% fortified bread while the least (6.0 ± 0.82^d) was observed in the control. All breads fortified with various levels of *Scomber scombrus* concentrate had very good (6.0-8.0) aroma after 6 days of storage.

Table 5: Aroma of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates

Treatment	Day 0	Day 3	Day6
Sample A (control)	6.7±1.14 ^c	6.3±0.75 ^{cd}	6.0±0.82 ^d
Sample B (10%)	7.5±0.72 ^a	7.1±1.00 ^a	6.9±0.88 ^b
Sample C (20%)	8.4±0.95 ^b	8.0±0.73 ^b	7.8±0.65 ^c
Sample D (30%)	7.4±1.08 ^b	6.9±0.72 ^c	6.6±0.49 ^c

KEY: (Excellent = 8-10, very good = 6-8, good = 4-6, fair = 2-4, poor = 0-2)

4.2.1 Proximate Composition of Bread Fortified with *Scomber scombrus* Concentrates After Processing

Table 6 shows the proximate composition of breads fortified with different levels of fish concentrates (0%,10%, 20%, and 30%) immediately after processing. There was significant difference in the breads fortified with various levels of *Scomber scombrus* concentrates under the study period of six days.

Moisture content decreased with increased fish fortification, the highest (35.59%) moisture content was seen in the control while the 30% fortified bread had the lowest (24.45%).

The 30% fortified bread had the highest (20.18%) protein content while the control had the least (9.12%).

The 30% fortified bread had the highest (9.16%) fat/oil content while the control had the least (1.98%).

The 30% fortified bread had the highest (2.98%) ash content while the control had the least (0.52%).

The control had the highest (0.49%) fibre content while the 30% fortified bread had the least (0.36%).

The highest (52.30%) carbohydrate was seen in the control while the 30% fortified bread had the lowest (42.87%).

Table 6: Proximate Composition of Bread Fortified with *Scomber scombrus* Concentrates After Processing

PARAMETERS (%)	A	B	C	D
MOISTURE	35.59 ^a	30.26 ^a	29.12 ^b	24.45 ^b
PROTEIN	9.12 ^a	16.48 ^b	18.24 ^b	20.18 ^c
FAT/OIL	1.98 ^c	5.2 ^c	7.33 ^d	9.16 ^d
ASH	0.52 ^b	2.48 ^b	2.69 ^b	2.98 ^b
FIBRE	0.49 ^a	0.41 ^a	0.38 ^a	0.36 ^a
CARBOHYDRATE	52.30 ^a	45.17 ^b	42.24 ^b	42.87 ^b

Values with the same subscripts are not significantly different (P>0.05)

4.2.2 Proximate Composition of Bread Fortified with *Scomber scombrus* Concentrates After 3 days of Storage

Table 7 shows the proximate composition of breads fortified with different levels of fish concentrates (0%,10%, 20%, and 30%) after three days of storage. There was significant difference in the breads fortified with various levels of *Scomber scombrus* concentrates under the study period of six days.

Moisture content decreased with increased fish fortification, the highest (35.61%) moisture content was seen in the control while the 30% fortified bread had the lowest (24.42%).

The 30% fortified bread had the highest (20.15%) protein content while the control had the least (9.13%).

The 30% fortified bread had the highest (9.17%) fat/oil content while the control had the least (1.99%).

The 30% fortified bread had the highest (2.95%) ash content while the control had the least (0.51%).

The control had the highest (0.50%) fibre content while the 30% fortified bread had the least (0.34%).

The highest (52.26%) carbohydrate was seen in the control while the 30% fortified bread had the lowest (42.97%).

Table 7: Proximate Composition of Bread Fortified with *Scomber scombrus* Concentrates After 3 days of Storage

PARAMETERS (%)	A	B	C	D
MOISTURE	35.61 ^a	30.28 ^a	29.14 ^b	24.42 ^c
PROTEIN	9.13 ^c	16.46 ^d	18.25 ^d	20.15 ^d
FAT/OIL	1.99 ^a	5 ^a	7.32 ^b	9.17 ^b
ASH	0.51 ^a	2.48 ^a	2.67 ^a	2.95 ^a
FIBRE	0.5 ^a	0.4 ^a	0.36 ^a	0.34 ^a
CARBOHYDRATE	52.26 ^a	45.38 ^b	42.26 ^b	42.97 ^b

Values with the same subscripts are not significantly different (P>0.05)

4.2.3 Proximate Composition of Bread Fortified with *Scomber scombrus* Concentrates After 6 days of Storage

Table 8 shows the proximate composition of breads fortified with different levels of fish concentrates (0%,10%, 20%, and 30%) after six days of storage. There was significant difference in the breads fortified with various levels of *Scomber scombrus* concentrates under the study period of six days.

Moisture content decreased with increased fish fortification, the highest (35.64%) moisture content was seen in the control while the 30% fortified bread had the lowest (24.38%).

The 30% fortified bread had the highest (20.11%) protein content while the control had the least (9.14%).

The 30% fortified bread had the highest (9.18%) fat/oil content while the control had the least (2.00%).

The 30% fortified bread had the highest (2.90%) ash content while the control had the least (0.50%).

The control had the highest (0.52%) fibre content while the 30% fortified bread had the least (0.32%).

The highest (52.20%) carbohydrate was seen in the control while the 30% fortified bread had the lowest (43.11%).

**Table 8: Proximate Composition of Bread Fortified with *Scomber scombrus* Concentrates
After 6 days of Storage**

PARAMETERS	A	B	C	D
MOISTURE	35.64 ^a	30.30 ^a	29.15 ^b	24.38 ^b
PROTEIN	9.14 ^a	16.43 ^b	18.26 ^b	20.11 ^b
FAT/OIL	2.00 ^c	4.90 ^c	7.30 ^d	9.18 ^d
ASH	0.50 ^a	2.48 ^a	2.66 ^a	2.90 ^a
FIBRE	0.52 ^a	0.33 ^a	0.33 ^a	0.32 ^a
CARBOHYDRATE	52.20 ^a	45.50 ^b	42.30 ^b	43.11 ^b

Values with the same subscripts are not significantly different (P>0.05)

CHAPTER FIVE

DISCUSSION

5.1 Organoleptic Assessment

Organoleptic properties which include appearance, taste, texture, and aroma, are crucial in determining the acceptability of food products (Meilgaard et al., 2016). The assessment of these parameters in bread fortified with fish concentrate provides insight into how fortification affects sensory perception over time.

5.1.1 Appearance of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates

Appearance plays a significant role in consumer acceptability, as it influences the first impression of a food product (Pathare et al., 2013). Table 2 shows that Sample B (10%) had the highest appearance rating on Day 0 ($8.0 \pm 0.73a$), while Sample D (30%) had the lowest ($7.3 \pm 0.77b$). Over time, all samples experienced a decline in appearance scores, which could be attributed to moisture loss, crust hardening, and potential oxidative changes in the fish concentrate (Yadav et al., 2021).

5.1.2 Aroma of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates

Taste is a key determinant of consumer preference and is influenced by ingredient interactions (Stone et al., 2012). Table 3 indicates that Sample D (30%) consistently had the highest taste ratings across all days ($8.3 \pm 0.6c$ on Day 0, $8.2 \pm 0.65c$ on Day 3, and $7.7 \pm 0.68d$ on Day 6), this indicated that the presence of fish concentrate contributed to an umami flavor profile. In contrast,

the control sample (Sample A) had the lowest taste scores over time, possibly due to the lack of additional protein and fat from the fish concentrate. The gradual decline in taste scores across all treatments may be associated with lipid oxidation and staling effects, which are common in stored bakery products (Manisha et al., 2020).

5.1.3 Texture of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates

Texture is a critical quality parameter affecting mouthfeel and overall sensory experience (Sanz et al., 2008). As shown in Table 4, all samples exhibited a decrease in texture scores over time, with Sample A (control) showing a more noticeable decline. The incorporation of fish concentrate appeared to help maintain texture quality, as seen in Sample C (20%) and Sample D (30%), which retained relatively higher texture ratings ($7.7 \pm 0.94a$ and $7.3 \pm 0.77a$, respectively, on Day 0). This may be attributed to the protein and fat content from the fish concentrate, which could contribute to moisture retention and structural integrity (Akhtar et al., 2015).

5.1.4 Aroma of Bread Fortified with Various Levels of *Scomber scombrus* Concentrates

Aroma is a crucial sensory attribute influenced by ingredient composition and storage conditions (Chauhan et al., 2021). According to Table 5, Sample C (20%) had the highest aroma rating on Day 0 ($8.4 \pm 0.95b$), while Sample A (control) had the lowest ($6.7 \pm 1.14c$). The fortified samples generally maintained higher aroma scores compared to the control throughout storage. However, the decline in aroma ratings across all treatments over time suggests possible oxidative changes in the fish concentrate, leading to slight off-flavors (Singh et al., 2019).

This study shows that moderate levels of fortification (10–20%) enhance sensory attributes, particularly in taste, texture, and aroma. However, higher concentrations (30%) may introduce stronger flavors that may not be preferred by all consumers.

5.2 Moisture Content

Moisture content plays a crucial role in determining the texture, shelf-life, and quality of baked goods (Muio et al., 2020). Immediately after processing, sample A had a moisture content of 35.59% which slightly increased to 35.65% after 6 days. This trend is consistent with the findings of Smith et al. (2018), who reported that bread products with high moisture content tend to retain their moisture levels over time. In contrast, sample D with a moisture content of 24.45% immediately after processing showed a slightly decrease to 24.38% after 6 days. Sample B and C had moisture contents of 30.36% and 29.12% on day 0 respectively. These samples showed minimal changes in moisture contents over the 6-day period, with sample B having a moisture content of 30.30% and sample C having a moisture content of 29.15% after 6 days. The stability of moisture content in these samples could be attributed to the type of ingredients used for the storage conditions (Williams et al., 2019).

5.3 Protein Content

Fortifying bread with fish species substantially increases its protein content, as fish are rich in high-quality proteins (Ajala et al., 2015). Protein is a vital component of human nutrition, essential for body maintenance, enzyme activity, and immune function (Rasane et al., 2015). In this study, the protein content increased from 9.12% in sample A to 20.18% in sample D immediately after processing (Table 6). This trend remained consistent over time, with sample D maintaining the highest protein content at 20.15% and 20.11% after 3 and 6 days respectively,

while sample A retained the lowest protein content at 9.13% and 9.14% . The substantial increase in protein content in the bread fortified with fish flour is due to the high levels of essential amino acids present in fish, which significantly improve the nutritional profile of the bread (Ajala et al., 2015). This effect is particularly beneficial in regions where access to animal protein sources may be limited as fish concentrate offers a sustainable and relatively inexpensive way to enhance protein intake (Rasane et al., 2015). The increase in protein content over time suggests that the fortification method used in this study is highly effective in boosting the protein quality of the bread (Ajala et al., 2015).

5.4 Fat/Oil Content

The fat content in the bread also increased significantly with the addition of fish concentrate, particularly in the samples that received higher levels of fortification (Fasoyiro et al., 2005). Immediately after processing, sample A had a fat content of 1.98%, whereas sample D, the most heavily fortified, had a fat content of 9.16% (Table 6). This trend continued across the storage periods: after 3 days, the fat content in sample A was 1.99%, and sample D increased to 9.17%; after 6 days, sample A showed 2.00%, while sample D had 9.18%. The increase in fat content is attributed to the oil-rich nature of many fish species, especially oily fish like mackerel and sardines, which are commonly used in fish concentrate fortification (Ajala et al., 2015). The fats present in fish concentrate are also a valuable source of omega-3 fatty acids, which have well-documented health benefits, such as improving heart health and reducing inflammation (Haug et al., 2016). However, while the increased fat content improves the bread's nutritional quality, it may also affect the bread's texture, making it softer and richer but potentially increasing its overall caloric content (Nwachukwu et al., 2016). This increase in fat could be a concern for

individuals looking to reduce fat intake but remains beneficial for those requiring higher energy and omega-3 fatty acids in their diet (Fasoyiro et al., 2005).

5.5 Ash Content

Ash content serves as an indicator of the mineral content in bread, reflecting the contribution of minerals from the ingredients used (Mujo et al., 2020). The data shows a clear increase in ash content with higher levels of fish concentrate fortification. Immediately after processing, sample D had an ash content of 2.98%, while sample A had only 0.52% (Table 6). This pattern remained consistent across the storage periods, with sample D having 2.95% and 2.90% after 3 and 6 days respectively, and sample A showing 0.51% and 0.50%. The higher ash content in the bread fortified with fish concentrate indicates the significant contribution of minerals such as calcium, phosphorus, and magnesium from the fish flour (Mujo et al., 2020). These minerals are crucial for bone health, enzyme function, and general physiological processes (Haug et al., 2016). The stability of ash content over time suggests that the minerals in fish concentrate remain intact during bread storage, further enhancing the nutritional value of the bread (Mujo et al., 2020).

5.6 Fibre Content

The fibre content in the bread remained relatively low, and there was a slight decrease over time. The highest fibre content was observed in sample A (0.49%), while sample D had the lowest at 0.36% immediately after processing (Table 6). This trend persisted across the subsequent days,

with sample D showing 0.34% after 3 days and 0.32% after 6 days, while sample A has 0.50% and 0.52% in the same periods. The reduction in fibre content over time may be due to the breakdown of fibre from the fish concentrate or its interaction with other ingredients during storage (Fasoyiro et al., 2005). Fish, especially non-oily varieties, are not significant sources of dietary fibre, and thus, fortifying bread with fish concentrate does not substantially increase the bread's fibre content (Muo et al., 2020). To improve the fibre content of the bread, additional fibre sources such as wheat bran or other plant-based ingredients would be necessary (Fasoyiro et al., 2005).

5.7 Carbohydrate Content

Carbohydrate content in the bread decreased with increasing fish concentrate fortification, reflecting the lower carbohydrate content of fish concentrate compared to wheat flour (Nwachukwu et al., 2016). Immediately after processing, sample A had the highest carbohydrate content at 52.30%, while sample D, with the highest fish concentrate fortification, had the lowest carbohydrate content at 42.87% (Table 6). This pattern was consistent across the three time points: after 3 days, sample A maintained 52.26%, and sample D had 42.97%; after 6 days, sample A showed 52.20%, while sample D had 43.11%. The decrease in carbohydrate content can be attributed to the partial replacement of flour with fish concentrate, which has a lower carbohydrate content (Nwachukwu et al., 2016). This change in carbohydrate composition may affect the energy density of the bread, reducing its caloric content, which could be beneficial for those seeking to lower their carbohydrate intake. However, it may also reduce the bread's appeal to individuals who rely on bread as a primary source of energy from carbohydrates (Nwachukwu et al., 2016).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study demonstrated that fortifying bread with fish concentrate significantly enhances its nutritional and organoleptic properties. The appearance, taste, texture, and aroma of the bread were influenced by the level of fish concentrate, with moderate fortification (10–20%) maintaining desirable sensory attributes over time. Higher fortification levels (30%) led to stronger flavors, which may not be preferred by all consumers.

The proximate analysis showed that moisture, protein, fat, and ash content increased with fish concentrate fortification, while carbohydrate content decreased. Protein content was significantly enhanced in fortified samples, making the bread a better protein source. Fat and oil content also increased, providing essential fatty acids beneficial to human health. However, higher moisture levels in fortified samples may contribute to reduced shelf-life due to increased susceptibility to microbial spoilage.

Overall, the findings indicate that fish concentrate fortification is a viable method for improving the nutritional quality of bread, especially in areas where protein deficiency is prevalent. The results suggest that a 10–20% fortification level provides an optimal balance between improved nutrition and consumer acceptability.

6.2 Recommendations

From this study, the following recommendations can be given;

- 1) Bakers and food manufacturers should consider incorporating fish concentrate into bread and other baked products to improve their protein content and overall nutritional value.
- 2) Government agencies and health organizations should promote the consumption of nutritionally enhanced bread as part of efforts to address protein-energy malnutrition.
- 3) Awareness campaigns should be carried out to educate consumers on the benefits of fish-fortified bread to encourage its acceptance in the market.
- 4) Additional studies should be carried out to explore the economic feasibility and market potential of fish-fortified bread on a larger scale.

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APPENDIX 1

Table 8: Organoleptic Assessment

Sample A

Appearance	Taste	Texture	Aroma	Appearance	Taste	Texture	Aroma	Appearance	Taste	Texture	Aroma
9	8	8	7	8	7	8	7	7	6	7	6
7	5	6	4	7	5	5	4	6	5	5	4
8	7	9	8	8	9	8	7	7	6	9	6

7	6	8	6	7	6	7	6	7	5	7	5
9	8	6	5	8	7	6	5	8	7	6	5
6	8	9	7	6	7	8	7	6	6	7	7
7	7	9	7	7	6	9	6	7	7	9	7
8	8	8	8	8	7	8	7	8	6	7	6
8	6	8	8	7	6	8	7	6	6	8	6
7	5	8	6	7	5	8	6	7	5	8	6
9	6	8	7	8	6	8	7	8	6	8	7
6	7	8	6	6	6	7	6	6	5	6	6
7	7	8	7	7	7	8	7	6	6	8	7
8	6	7	8	6	6	7	7	7	6	6	6
8	8	7	6	6	7	7	6	6	7	7	6
Day 0				Day 3				Day 6			

Sample B

Appearance	Taste	Texture	Aroma	Appearance	Taste	Texture	Aroma	Appearance	Taste	Texture	Aroma
9	8	8	10	8	7	8	9	8	7	7	8
8	5	7	6	8	5	6	6	8	5	6	6
8	8	8	8	8	6	8	7	8	6	8	7

8	7	9	9	7	7	8	8	7	7	8	8
9	7	8	8	8	7	8	8	7	7	8	8
8	6	8	8	7	6	7	7	6	6	6	6
7	8	6	7	7	7	6	7	7	6	6	7
9	9	5	7	8	8	5	7	8	7	5	7
9	8	7	6	9	8	7	6	8	8	7	6
7	9	6	9	7	8	6	8	7	8	6	7
8	7	8	8	8	7	8	7	8	7	7	7
8	7	8	6	8	7	8	6	8	7	8	6
7	9	9	8	6	8	7	8	6	8	8	8
7	5	7	7	7	5	7	7	7	5	7	7
8	6	6	5	7	6	6	5	7	6	6	5

Day 0

Day 3

Day 6

Sample C

Appearance	Taste	Texture	Aroma	Appearance	Taste	Texture	Aroma	Appearance	Taste	Texture	Aroma
9	6	8	9	8	6	8	9	7	6	8	9

9	6	7	7	8	6	7	7	8	6	7	7
7	7	9	10	7	7	9	9	7	7	8	8
7	8	6	9	7	7	6	9	7	7	6	9
8	7	7	9	7	7	7	8	6	7	6	8
6	7	7	8	6	7	7	8	6	7	6	8
8	8	8	8	8	7	8	8	7	7	8	8
7	6	7	9	7	6	7	8	7	6	7	8
7	8	8	9	7	8	7	8	7	7	7	8
7	6	8	7	7	6	7	7	6	6	7	7
8	7	8	7	8	7	8	7	7	6	8	7
7	7	6	8	7	7	6	8	7	7	6	7
8	9	9	8	8	8	8	7	7	8	7	7
6	8	9	10	6	8	8	9	6	8	8	8
8	8	8	8	8	7	8	8	8	6	8	8

Day 0

Day 3

Day 6

Sample D

Appearance	Taste	Texture	Aroma	Appearance	Taste	Texture	Aroma	Appearance	Taste	Texture	Aroma
8	9	8	6	7	9	8	7	7	9	8	7
7	9	7	7	7	9	7	7	7	8	7	6
7	10	7	8	7	9	7	7	7	9	7	7
8	8	8	8	8	8	7	7	7	8	7	7
8	8	6	7	7	8	6	7	6	7	6	7
6	9	8	9	6	9	8	6	6	7	7	6
7	9	8	9	7	8	7	7	7	8	7	7
8	8	7	8	8	8	7	8	8	8	6	7
7	7	7	6	6	7	7	6	6	7	7	6
8	8	7	5	8	8	7	8	8	8	7	7
8	8	8	7	7	8	8	7	7	7	7	7
6	7	8	7	6	7	8	6	6	7	8	6
6	8	6	8	6	8	6	6	6	8	6	6
8	9	6	8	8	9	6	8	8	8	6	7
7	8	8	8	6	8	8	6	6	7	8	6
Day 0				Day 3				Day 6			