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QUALITY ATTRIBUTES OF FERMENTED FISH (MOMONE) PROCESSED BY DIFFERENT PERIODS

BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's signature ……. Date …….

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Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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ABSTRACT

The study investigated the quality attributes of fermented fish processed by different fermentation periods. The factorial design was used to test the effect of the period of fermentation on the nutritional composition, bacterial count and sensory properties of fermented fish samples using the locally fermented fish as the control. Freshly harvested cassava croaker fish was purchased from Elmina, Central Region and transported to the laboratory in an ice box. Processing of the fermented fish was carried out using standard procedures and methods. Nutritional composition and bacterial count of fish samples were then determined. A self-developed sensory evaluation questionnaire was used to assess the sensory properties and consumer acceptability of the fermented samples. ANOVA and Chi- Square were used to test for differences among the nutritional composition, bacterial count and sensory properties of samples processed by different fermentation periods. The results showed that the longer the fermentation period, the more the nutrients (protein and fats) are reduced. It was also observed that the fish samples processed by different fermentation periods had reduced bacteria counts whiles the local fermented recorded the highest bacteria counts. The results also indicated that the fish sample fermented for three days (MD3F) had a comparable sensory attributes and consumer acceptability with the control but with a reduced bacterial count. Therefore the study recommends that producers of fermented fish adopt standard procedures in processing fermented fish to reduce bacterial count.

KEY WORDS

Fermented fish

Fermentation period

Nutritional composition

Bacterial count

Sensory properties

Consumer acceptability

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DEDICATION

To my parents, siblings, and cousins.

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ACRONYMS

AOAC- Association of Official Analytical Chemists

CDC- Centres for Disease Control

CAC/RCP- Codex Alimentarius Commission/Recommended Standard

FAO- Food and Agriculture Organisation

ICMSF- International Commission on Microbiological Specificatio1ns for Food

ISO- International Organization for Standardization

NZFS- New Zealand Food Safety

CHAPTER ONE

INTROODUCTION

Background to the Study

Fish is one of the inexpensive sources of protein as compared to other animal proteins (Mohanty, Behera, & Sharma, 2011). Invariably, the fight against hunger and undernutrition has encouraged the use of fish and fish products as a significant nutritive source of healthy fats and proteins, as well as essential nutrients such as vitamin D, calcium, long-chain omega-3 fatty acid and iodine (Kris-Etherton, Haris, & Appel, 2002; Uauy & Valenzuela, 2000). The additional nutrients (vitamin D, calcium, long-chin omega-3 fatty acid, and iodine) in the skin and bones of fatty and small fishes make the nutritive value of fish unique in human diet (FAO, 2013; Nestel et al., 2015), and most importantly, in the prevention of cardiovascular diseases (Kris-Etherton et al., 2002; Uauy & Valenzuela, 2000). Although, much study has been done on varied aspects of fish, little data is available on how different fermentation periods affect the nutritional, microbial load and sensory properties of fermented fish.

According to Eyo (2002), fish is one of the protein foods that require careful handling since it has a relatively short shelf life which makes it susceptible to deterioration after capture, given the limitations in preservation. It is noteworthy that fresh fish after its capture decompose within a matter of 12 hours, through a sequence of bacterial, chemical and complex enzymatic changes (Burt, 2003). This is typical of fish in tropical African countries such as Ghana, where spoilage easily occurs after capture because of high temperatures which tend to accelerate the oxidation of fat, bacteria growth and

enzymatic reaction (Berkel, Boogaard, & Heijnen, 2004; FAO, 2005). It is estimated that 30-50% of fish captured deteriorate as a result of poor handling in Nigeria; a situation which can be prevented or reduced by appropriate handling, processing and preservation methods (Bate & Bendall, 2010).

According to Abbas, Saleh, Mohamed, and Lasekan (2009), high fat content, weak muscle tissue, moisture content, ambient temperature, high protein content and unhealthy handling, processing and preservation contribute to the decomposition of fish. The adoption of an innovative but less costly way of processing and preserving fish as a means of sustaining the commodity, particularly during the bumper season, is therefore crucial.

In the view of Eyo (2002), using preservation to treat foods means drying, curing, fermenting, salting (which include both wet salting and dry salting) and smoking in order to extend the shelf life of food items. Preservation methods are those applied strategically to reduce all factors that may cause fish spoilage in order to keep fish fresh. Pandey and Shukla (2005) affirmed that preservation and the processing of fish are very important especially during bumper harvest. When fish is preserved and processed, there is a considerable increase in its shelf life while its nutritive value, odour, flavour, palatability and skin digestibility are maintained (Pandey & Shukla, 2005). Specifically, people living close to sea regions, rivers and lakes preserve fish through sun drying, fermentation, salting and smoking which are used to prepare food and also eaten as condiment (Salampessy, Kailasapathy, & Thapa, 2010).

Fermentation is one of the oldest methods of preserving fish worldwide (Wafula, Franz, Rohn, Huch, Mathara, & Trierweiler, 2016). In the process of fermenting fish, more complex compounds are broken down into simple

compounds to make the commodity more nutritious, as well as the production of lactic acid to attack every microorganism that may be present in the fish (Mokoena et al., 2016). Globally, fermented fish offers an additional benefit of being used as the protein part of meals apart from being used as a condiment (Mokoena, Mutanda, & Olaniran, 2016). In Ghana, the idea of using fermented fish to support the nutritional value of meals has not been adequately considered because of its putrid smell (Berkel et al., 2004). This could partly be due to the process of fermentation. Fermented fish (*Momone*) is a popular Ghanaian condiment noted for its strong repellent smell. Fermented fish as a condiment is used nationwide to compliment the taste and flavour of meals.

In Ghana, *Momone* is a traditional type of fish processed through fermentation and is produced in some areas, including coastal and non-coastal areas. It is processed by monitoring particular factors which may induce fish to go bad (FAO, 2006; Kleter & Marvin, 2009). The fish is cleaned, washed, allowed to ferment, salted and arranged in layers in pots, barrels or bottles for between a week and three months, depending on the size of the fish. The fermented fish products are then packaged as a whole fish, fish paste or fish sauce to be consumed by individuals depending on the taste, odour and flavour of the fish.

Rajapakse, Mendis, Jung, Je, and Kim (2005) and Thurman and Webber (1984) found that the chemical composition of fish is basically made up of proximate compositions, free fatty acids, free amino acids, peptides, probiotics, pH, enzymes and many more. The proximate composition is usually made of moisture, ash, minerals, carbohydrate, fat/lipid and crude protein content (AOAC, 2005). These compositions may differ in levels, even with similar fish

species though they may have been in the same environment (Jabeen & Chaudhry, 2011). Jeyaram, Singh, Romi, Devi, and Singh (2009) added that other factors that may bring about the differences in the chemical compositions of fish are time and season of catching the fish, feeding of the fish, and the area from which the fish is captured (whether deep sea or shallow sea).

Additionally, these chemical compositions go through various changes which if not well handled, can affect the compositions negatively by reducing the nutritional level significantly (Gandotra, Meenakshi, Sweta, & Shallini 2012). However, while fish undergoes a balanced processing and preservation, it enhances the chemical compositions which in turn play important roles in individuals' diets as well as their health (Tam, Bao, & Marie, 2004). This process makes it important for individuals (including cooks and nutritionists) involved in meal planning to have information on the chemical compositions of fish. This will also help use the information effectively to reduce possible challenges and obtain the maximum amount of nutrients.

Fish harbours both beneficial microorganisms and safe levels of harmful organisms (CODEX, 2013; Ifediora, Nkere, & Iroegbu, 2006). The types of microorganisms in fish are first determined by where they are captured (If captured in warm water, fish may have high bacteria counts than those from cold and clean water). Furthermore poor handling, processing and preservation, having direct contact with pests and poor hygienic practices make fish equally susceptible to microorganism (Arias, 2009; Hancock, Besser, Lejeune, Davis, & Rice, 2001). These pathogens present on fish are not harmful at the initial stage where their counts are low, but can become harmful when they multiply on the fish through spoilage or decay. As Adebayo-Tayo, Anyamele, Igwiloh,

and Okonko (2012) indicate, fishes can be contaminated by pathogens which normally invade the commodity making it unwholesome and dangerous for consumption.

Many studies on different fishes have shown numerous bacteria (such as *Pseudomonas angulluseptica*, *Streptococcus Spp*. among others) as toxic under specific condition of the fish (Emikpe, Adebisi, & Adedeji, 2011). This is alarming as about 80 million health cases reported yearly in the USA are seafood borne illnesses and infections; and in treating such incidents, billions of dollars are used (Adebayo-Tayo et al., 2012). Additionally, most fish spoilage pathogens when in contact with fish remain on the fish, especially when the fish is not washed and cleaned well. These bacteria quicken the action of decaying the fish when not processed as soon as possible (Emikpe, Adebisi, & Adedeji, 2011). Fish spoilage pathogens however can be controlled by adopting proper handling practices and good manufacturing practices (GMPs) as well as using appropriate methods for processing and preserving fish.

Additionally, the shelf life of fish is dependent on the initial load of microorganisms present on the fish, and the possible contaminants getting into contact with the fish during processing as well as the conditions of keeping the fish after preservation (Arias, 2009). Literature on fish spoilage microorganisms acknowledge that bacteria causing fish decomposition can have effects on the sensory qualities and safeness of fish (Kolodziejska, Niecikowska, Januszewska, & Sikorski, 2002). This is because when bacteria invade fish and multiply to unsafe levels, they deplete the nutrients in the fish, thus reducing the quality of fish as well as making fishes harmful for consumption. The resulting effects tend to be on the sensory characteristics like, the texture, appearance,

colour and taste. These effects render the fish unwholesome for purchasing and consumption (Ross & Sumner, 2002).

Such sensory properties of fish are portrayed either in its fresh or preserved state (Lauritzsen, Johansen, Joensen, Sorensen, & Olsen, 2004) and these qualities subsequently determine the freshness and wholesomeness of fish. Acceptability or otherwise of fish by consumers depends on the quality attributes of fish (Sharifian, Alizadeh, Mortazavi, & Shariari-Moghadam, 2014). In view of this, consumers across the globe constantly endeavour to purchase fishes that are of high quality. It is argued that the quality and freshness of fish are paramount factors which consumers consider when buying fish and fish products (Alasalvar, Miyashita, Shahidi, & Wanasundara, 2011). In the global fishery industry, the quality and freshness of fish play a major role. This is because fish is one of the extremely delicate foods that are likely to be rejected due to poor quality and unwholesomeness (FAO, 2009).

Statement of the Problem

Fermented fish (*momone*) is a popular condiment with an appetite-stimulating aroma characteristic when used for food. It is a type of condiment used by most Ghanaians to prepare food, especially stews and soups (Abbey, Hodari-Okae, & Osei-Yaw, 1994). Certain types of delicacies in Ghana such as *mpotompoto* (Irish stew) and *oto* (mashed semi-ripe plantain) are considered delicious when *momone* is added in their preparation.

The desire of consumers for fermented fish products is primarily due to the appetising flavour and unique taste it generates when used in food preparation (Ji et al., 2017). Alternatively, most people believe that there are no nutrients in fermented fish since the main reason for its use is for the taste and

flavour. Also, its texture and strong smell does not allow individuals to use it as the protein part of food.

In Ghana, *momone* is produced by allowing the fresh fish to deteriorate completely. Depending on the size of the fish, it may be left to stay for 2 to 6 days with the aim of developing the enzymes responsible for fermentation before further processing is carried out. According to some researchers, this makes the fish lose its nutritive value and become vulnerable to harmful microorganisms, which in turn makes the fish unwholesome for consumption (Gopakumar, 2000; Ryser & Marth, 2007). Al-Jufisome and Opara (2006); Gram and Dalgaard (2002) indicated that when food stinks, the probability of microorganisms being present is high as a result of the decomposition process. This raises questions about the wholesomeness of fermented fish. A study conducted by Nartey-Djaba, Muala, Amankwaa, and Amo-Yeboah (2018) identified traces of microorganisms in some selected *momone* but did not specify the types of microorganism. Consequently, the researchers recommended studies to be carried out in order to identify the specific types of microorganisms (both safe and disease-causing microorganisms) present in *momone*.

Contrary to the findings of Gopakumar (2000); Pandey and Shukla (2005); Ryser and Marth (2007) and noted that preservation and processing should increase and maintain the nutritive value, odour, flavour, palatability and digestibility of the fish but not to reduce the identified properties drastically, so as to serve the purpose of consumption by individuals. Rajapakse, Mendis, Jung, Je, and Kim (2005) emphasised that despite the unwholesomeness and unbearable smell of the locally fermented fish (*momone*), the benefits that could

be derived from a properly processed fermented fish include appreciable nutritional value comprising simple compounds like amino acids, peptides and other nitrogenous elements. Antioxidants and healing properties are also beneficial components of properly fermented fish essential for healthy living (Rajapakse et al., 2005).

Furthermore, Martinsdottir (2002) indicated that all fishes possess distinct sensory properties such as appearance, texture, flavour and aroma which may change with temperature and time. It could therefore be possible that fishes in the same environment captured at the same time and preserved using the same method, can have different sensory properties. In this viewpoint, sensory evaluation of fish can be a mandatory process for the fish industry to assess the freshness and sensory properties of fish. This evaluation is important as it serves as a means of informing consumers to enable them make informed decision as far as nutrition and safety of fish are concerned (Hyldig, Bremner, Martinsdóttir, & Schelvis, 2007).

According the studies of El-Bassir, Karar, Altayeb, Azrag and Yasir (2015); Oranusi, Abah, and Anosike (2019), it was observed that the addition of salt in the quest to preserve the fish reduced the water capacity in fish, but eventually decreased the nutrients (protein) in the fish samples. However, Oranusi et al., (2018) associated the reduction of nutrients to the activities of bacteria in the fish during the preservation process and not the salt added to the fish samples.

Also, previous studies on fermented fish have not considered the different periods used to process fermented fish and their effects on the quality attributes of fish, with very little studies in Ghana. This study therefore finds it

necessary to investigate the quality attributes of fermented fish processed by different fermentation periods to determine their nutritional composition, microbial load and sensory properties.

Purpose of the Study

The main purpose of this study was to determine the nutritional composition and bacteriological quality of fish samples processed by different fermentation periods and also assesses their sensory properties.

Research Objectives

The specific objectives of the study were to:

1. determine the nutritional composition of fresh fish, fish samples processed by different fermentation periods and the control,
2. assess the microbial counts in the fresh fish, fish samples processed by different fermentation periods and the control,
3. evaluate the sensory properties and consumer acceptability of fish samples processed by different fermentation periods and control.

Research Questions

In order to achieve the objectives above, these research questions were formulated.

1. What is the nutritional composition of fresh fish, fish samples processed by different fermentation periods and the control?

2. What is the bacteria count of the fish samples?
3. What are the sensory properties of the fish samples?
4. To what extent do consumers accept the fish samples processed by different fermentation periods?

Assumptions

1. All the dependent variables used are approximately normally distributed for each category of the independent variable.
2. There is homogeneity of variances between the independent groups.

Research Hypothesis

These research hypotheses were stated to confirm whether there were statistically significances among the fish samples in terms of their nutritional composition, bacterial count and sensory properties.

1. H_{0a}: There are no statistically significant differences among the nutritional composition of the fresh fish, fish samples processed by different fermentation periods and the control.

   H_{1a}: There are statistically significant differences among the nutritional composition of the fresh fish, fish samples processed by different fermentation periods and the control.

2. H_{0b}: There are no statistically significant differences among the microbial counts of the fresh fish, fish samples processed by different fermentation periods and the control.

   H_{1b}: There are statistically significant differences among the microbial counts of the fresh fish, fish samples processed by different fermentation periods and the control.

3. H_{0c}: There are no statistically significant differences among the sensory properties and acceptability of the fish samples processed by different fermentation periods and the control.

   H_{1c}: There are statistically significant differences among the sensory properties and acceptability of the fish samples processed by different fermentation periods and the control.

Significance of the Study

Fermented fish is a widely used fish product both locally and internationally due to the flavour and nutritional value it adds to food. The locally processed fish however could have poor nutritive value as expected due to the way it is processed.

This study therefore sought to determine the nutritional composition and bacteriological quality of fish samples processed by different fermentation periods to ascertain whether there were any changes. Literature available had little data on fermentation and fermentation periods as well as their effects on quality attribute of fish, therefore the study sought to add to knowledge since it provided detailed data on the effect of the various fermentation periods on the quality attributes of fish. The study also sought to evaluate the sensory properties and establish consumers' acceptability of the modulated fish products. It helped to identify the lapses in the procedure adopted by the local folks in processing fermented fish, and revealed the best fermentation period and practice that offers the best quality attributes of fermented fish produced in Ghana.

Similarly, the study sought to help educate individuals who are involved in the production of fermented fish about the health and nutritional implications

of the procedures used to ferment fish locally. Additionally, the results of the study sought to help the researcher collaborate with stakeholders in the food regulatory system, such as the Foods and Drugs Authority and other relevant NGOs, in organising in-service training for the local fermented fish producers. The training would help them produce quality and wholesome fermented fish.

Furthermore, the study sought to expose some hygienic practices personnel in the hospitality industry, as well as local restaurants can use to prepare and serve meals with fermented fish. This will go a long way of providing wholesome meals to individuals who enjoy meals with fermented fish.

Delimitation

This study sought to assess the quality attributes of fermented fish processed by different fermentation periods. However, it was limited to the assessment of the nutritional composition, bacteria counts and sensory properties of fish fermented by three different periods (Day 1, 3 and 5). Also, only one type of fish (cassava croaker) was studied since different types of fish may have different nutritional composition. Additionally, the locally fermented fish sample was collected from Elmina fermented fish producers even though there were other fermented fish producers in and around the Cape Coast metropolis.

Limitations

Due to the unpleasant smell of the fermented fish samples, the microbial analysis was done only when there were very few people in the laboratory. Thus, the fish had to be stored in the laboratory's freezer for some time. Also, due to the strong smell that emanated from some fermented fish samples, some

consumers could not taste the sauces made from them well. This may have affected the results obtained.

Organization of the Study

The study report is organised and presented in five chapters. Chapter one is the introduction; comprising the background to the study, statement of the problem, purpose of the study, research objectives, as well as research questions and hypothesis. It also contains sections on the significance, delimitation and limitations of the study. The second chapter reviews literature related to the study. The literature covers the conceptual and empirical review, as well as the conceptual and theoretical framework. Chapter three also describes the methodology that was adopted for the study. This chapter covers the research design, population, sampling procedure and size, data collection instrument, study area, sample preparation, laboratory analysis of the chemical and microbiological characteristics of the fermented fish, sensory evaluation, data processing and analysis.

Additionally, chapter four presents the results and discussion of the study. Lastly, chapter five summarises the findings of the study, draws conclusions based on the findings gathered and makes recommendations for policies and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

This section of the study is on reviewing literature related to the purpose of this study. The research problem was to assess the quality attribute of different fermentation period of fish (*momone*). The main purpose of the study was to determine the nutritional composition and bacteriological quality of fish samples processed by different fermentation periods and also assesses their sensory properties to know whether the samples differed from each other in terms of quality. The study made use of conceptual and empirical review, as well as conceptual and theoretical framework to seek direction for the study.

Conceptual Review

The first part of the review presents the concepts and relevant subjects related to the study. The concepts include fish, fish spoilage and fish preservation.

Concept of Fish

Ordinarily, fish is considered one of the important sources of protein and other nutrients such as fatty acids, vitamins, and mineral elements. Globally, in most regions, several species of fish form part of the daily meals of individuals. Also, it could be said that most households in Ghana and beyond include fish in their daily meals to obtain balanced diets. Lacto vegetarians depend solely on fish and some meat products making the commodity an essential part of their diets. This is in line with the Food and Agricultural Organization (FAO) (2007) assertion that human beings should make fish products a major source of protein in their meal plans.

Studies have indicated that the nutrients in fish help to reduce Diet Deficiency Diseases such as kwashiorkor, marasmus, goitre and rickets (FAO, 2010). The additional nutrients such as vitamins, minerals and long-chain omega-3 fatty acid in the skin and bones of fatty and small fishes make the nutritive value of fish unique in human diet (Nestel et al., 2015). It is accepted as heart-friendly and aids in the development of the human brain and processes (Irish Sea Fisheries Board, 2008; Kris-Etherton, Harris, & Appel, 2002). The quality or freshness of fish is paramount to the acceptability and consumption rates of most people. Normally, individuals follow the simple way of cleaning fish and food products by rinsing them before use. Although this process may help remove some unclean substances from the fish or food before it is used, some chemical or biological infections may still be present in the fish or food substance. According to Yousuf (2008), protein giving foods such as meat, fish and their products are mostly referred to as high risk commodities with the notion that they contain pathogens, natural toxins and possibly other contaminants and adulterants. For Koffi-Nevry and Koussémon (2012), these types of food substances when not consumed immediately or preserved after they have been obtained, could spoil or deteriorate.

Nutritional value of cassava croaker (Cassava fish)

Cassava croaker, scientifically known as *Pseudotolithus Senegalensis*, is a type of white fish that is rich in protein, amino acids, minerals and vitamins (Nunoo, Boateng, Ahulu, Agyekum, & Sumaila, 2009).

The authors added that cassava croaker is commonly consumed by most people across the world, especially in the coastal areas of West Africa. Cassava croaker is the least member of the fish kind called the *Sciaenidae* family, which is found

in seas, rivers and sandy, rocky and muddy waters (Paugy, Leveque, & Teugels, 2003). The fish feeds on small fishes and shrimps which therefore explains why it is rich in nutrients (Buchheister & Latour, 2015; Chaol & Trewavas, 1990). The fish is named 'croaker' due to the loud croaking noise it makes (Chesapeake Bay Program, 2011). Cassava croaker is fleshy, firm, and tender, and has edible skin. Since cassava croaker is a white fish, it possesses snow white colour when it is in it fresh state and has flavour and pleasant taste when cooked. Because cassava croaker tastes like other fishes such as catfish, snappers, white perch and others, it is usually used as a substitute for these other fishes.

According to a study conducted by Akpambang (2015), on the proximate composition of some selected fresh fishes including cassava croaker, it was found that cassava croaker had a moisture content of 68.5%, protein content of 21.5%, fat content of 8.5g and ash content of 1.45g.

Table 1: *Nutrients in Cassava croaker (Cassava fish)*

Nutrients	Amount (in 100g)
Proteins	21.21%
Total fat	1.19 g
Water	69.70 g
Ash	2.01 g
Calcium	220.40 mg
Magnesium	18.40 mg
Manganese	1.18 mg
Phosphorus	27.80 mg
Potassium	125.60 mg
Sodium	111.20 mg
Zinc	20.42 mg

Source: Nigerian Institute for Oceanography and Marine Research (2016).

Fish Spoilage

Fish spoilage is the state in which fish go through deterioration and becomes unfit (putrid smell, soft to touch, brown gills instead of bright red) for

consumption (Ikape & Cheikyula, 2017). More than 5 million different kinds of fishes are lost annually to microbial, chemical and enzymatic spoilage due to the unfavourable storage conditions (Ovissipour, 2009; Unklesbay 1992). When fish is freshly caught, it takes 12 hours for it to deteriorate, especially when the climate is warm (Baird, 2000). The deterioration brings about some compositional changes which result in fat oxidation, destroying of proteins in fish, as well as loss of essential nutrients in the commodity. Fish spoilage goes through three stages which are: rigor mortis, autolysis of enzymes and microbial food spoilage. These stages are also characterised as the causes of food spoilage.

Types of Fish Spoilage

Rigor mortis

Rigor mortise is the stiffening of muscles, skin and joints of fresh fish. Rigor mortise is also known as post-mortem rigidity which happens after a few hours of the death of fish when all respiration stops (Saladin, 2010). The rigor activity then circulates to different parts of the body, including the internal organs, within four to six hours of death. The rigor mortise in fish generally begins at the tail end of the fish where it hardens the muscles and gradually moves towards the body and head. Rigor mortise is initiated by a chemical change which physically affects the muscle tissue of fish.

When the fish is alive, the presence of glycogen in the tissue changes the water and carbon dioxide immediately after the supply of oxygen to the fish cells. When the fish dies, this conversion of chemicals stops, thus making the fish to get into rigor mortis. The other factors that cause rigor mortise in fish are the internal body temperature in fish, decedent motion of the fish before it dies, and the temperature in the environment where the fish is kept. Temperature also

plays a role in rigor mortise because when temperature is increased, it causes rigor mortise (Ozaw & Maebashi, 2013).

Enzymatic fish spoilage (Autolytic)

The breakdown of fish happens as its compositional compounds go through decomposition and self-digestion. This process is generally known as autolytic change. Autolytic spoilage or fish spoilage caused by enzymes is accountable for the initial loss of fish quality after rigor mortis activity. Once fresh fish is captured, biological and chemical changes take place as the fish dies due to enzymatic breakdown of the major molecules in the fish (FAO, 2005). When autolytic change begins, it attracts bacteria such as *Shewanella putrefaciens* and *Pseudomonas spp*. to the surface of the dead fish and produces a chemical called hypoxanthine. This chemical is vital and helps in the multiplication of bacteria by providing a favourable environment for their growth (Huss, 1995).

After fish is captured, a group of proteolytic enzymes are found in the viscera and muscle of the fish. These groups of enzymes support post mortem deterioration in fish and its products during processing, preservation and storage. Studies have shown an association between the sensory properties of products and alterations that can be contributed by proteolytic enzymes to aid in the spoilage of fish (Engvang & Nielsen, 2001). When whole fishes are not properly preserved or stored, proteolysis enzymes contribute to the deterioration of proteins in fish and results to solubilisation (Lin & Park, 1996). Also, apart from the production of proteolysis enzymes to degrade fish, free amino acids and peptides can be manufactured due to self- digestion of fish muscle proteins, which may cause spoilage of food with fish.

Microbial fish spoilage

Fresh fish spoilage is among the 25% of food commodities that are lost as a result of bacterial spoilage (Emikpe, Adebisi, & Adedeji, 2011). Normally the surface and inner parts (gills, gastro intestinal tract and skin) of fresh fish are predisposed to the attack of microorganisms (Gram & Huss, 1996). Many studies conducted on fish spoilage recorded that most fish deteriorated through the activities of microorganisms, be it fresh or processed (Emikpe et al., 2011; Gram & Huss, 1996). Normally, the constituents of the microorganisms on freshly caught fish depend on the bacterial contents of the water where the fish was caught (Gram & Huss 2000). Gram and Huss also indicated that fish microbes identified included bacterial species such as *Serratia*, *Vibrio*, *Pseudomonas*, *Micrococcus* and *Alcaligenes*, found in water in which fresh fishes were caught. Bacterial growth and replication are key to fish spoilage as they produce biogenic amines and amines, such as histamine, putrescine and cadaverine, sulphides, organic acids, ketones, alcohols and aldehydes with undesirable and unpleasant off-flavors (Dalgaard, Madsen, Samieian, & Emborg, 2006; Emborg, Laursen, & Dalgaard, 2005; Gram & Dalgaard, 2002).

Freezing is one of the methods used in preserving fish. Freezing involves keeping fish in a temperature lower than the temperature in which it was caught so as to reduce the invasion of microbes, as well as keep them from growing to the state where fresh fish will deteriorate. Certain types of microorganisms are found on fish immediately after capture which include *Pseudomonas*, *Bacillus*, *Coranebacterium*, *Acinetobacter*, *Shewanella*, *Moraxella*, *Flavobacterium*, and *Lactobacillus*, of which some can survive in a climate as cold as 0^{o}C, while some multiply at 25^{o}C (Gram & Dalgaard, 2002). This means that even

processing and preserving fish with different methods do not guarantee the wholesomeness of fish since microorganisms can survive and multiply in temperatures and environment that are least expected.

In a study conducted by Berkel et al., (2004), it was detailed that the potentials for keeping fresh fish at low temperatures, such as chilling at -1° to +4°C hinders the replication of microorganisms, and freezing at -18 to -30°C entirely stops microbes from growing. Alternatively, Gram and Dalgaard (2002) indicated in their study that there are some microbes that can survive and multiply in the above stated low temperatures. An example of such microbe is *Listeria* which is very typical in fresh and uncooked foods. Also, this microbe stops its activity (becomes dormant) while in low temperatures rather than dying and starts multiplying when the temperature increases and becomes favourable.

Accordingly, preservation of fish with the use of salting technique produces antimicrobial to reduce bacteria (Clostridium botulinum) growth and survival as well as enhance the appearance of fish (Ray, 2004). At the same time, some bacteria known as halophiles are salt-loving and can survive and multiply in salt concentration as high as 10-20% (Slonczewski, Foster, & Gillen, 2008). Furthermore, heating or pasteurisation as an act of applying high temperature to food products is used to kill bacteria on food as well as to preserve them to increase their shelf life.

Nonetheless, some types of bacteria known as thermophiles can survive at comparatively very high temperatures between 41ºC and 122ºC (106ºF and 252ºF) (Gram & Dalgaard, 2002). Although fish treated with mild heat at a specific temperature tends to kill heat-sensitive bacteria, these thermophiles, including *Clostridium sp.* and *Bacillus anthracis* produce a protective sheath

called spores which makes their cells dormant and thus able to withstand heat (Gram & Huss, 1996). In support, Slonczewski, Foster, and Gillen (2008) added that when heat is reduced and returned to normal room temperature, multiplication starts immediately as they change back to the bacteria form.

Additionally, in preserving fish to prevent it from spoiling, chemicals and preservatives such as sorbate and benzoate are used to reduce the growth of bacteria. These chemicals are often combined with potassium to preserve food by reducing the pH level to acidic state in order to stop the growth of bacteria, yeast, and mould (Gram et al., 2002). Though this method of preserving fish tends to increase the shelf life of fish and reduce fish spoilage, bacteria such as *Lactobacillus*, yeast, and moulds which are adaptive to acid continue to be active and multiply, thus, causing fish spoilage (Gram & Dalgaard, 2002).

Fish Preservation

Fish is one of the perishable food commodities that is vulnerable to spoilage when it does not go through any processing and preservation. An estimated one-third of most food commodities including fish, fruits and vegetables harvested across the world are wasted through food spoilage (Kader, 2005). Proper handling methods are required in order to control the rate of spoilage so as to increase wholesomeness of such commodities.

Fish preservation is very essential globally to ensure an increase in the shelf-life of fish, by making conscious effort to maintain the texture, flavour, nutritional value and wholesomeness (Okonta & Ekelemu, 2005). The preservation of fish with different preservation methods must be a sustainable means of preventing fish spoilage and improving upon the quality of fish rather than reducing its quality. Achieving this will help in increasing shelf life and

availability of fish all year round to support the protein needs of the growing world population (Leister, 2000). Fresh fishes processed by drying, salting and smoking have high preservative characteristics; and these preservative methods increase the nutritive value in fish, particularly protein content (Eves & Brown, 1993; Madu et al., 1984). However, there are concerns that most traditional methods used in preserving fish, notwithstanding the food value, contaminate the fishes and make them unwholesome for consumption (Eves & Brown, 1993).

According to Michael, Cai, Akwasi, and Adele (2012), smoking is one of the traditional method of processing fish which involves the treatment of filleted, unfillet or pre-salted fish with smoke from pieces of burning wood. During the smoking of fish, the water content of fish is reduced and sometimes eliminated to prevent the action of microorganisms since they multiply in the presence of moisture.

Another preservation technique that is currently used by most people is freezing. It is one of the best methods of preserving fish to maintain its freshness and wholesomeness. The climate in a freezer can be related to the climate from which most fishes like cod and haddock live and thus it helps to preserve the texture and taste of fresh fishes (FAO, 1996; 2002). The freezing of fish usually involves time. Therefore, the freezing time can be defined as the period taken for the temperature of the warmest part of fish, typically the middle, to be reducing to 20°C (FAO, 2001). Most fish mongers and consumers freeze harvested fish to preserve them and prevent spoilage.

Traditional fish preservation techniques such as salting, drying, and fermentation are similarly employed to keep fish from deteriorating.

Traditionally, fermentation by salt method is one popular preservation method used to preserve fish. This method helps fish muscles to be more acidic so that bacterial multiplication is stopped while the pH drops below 4.5 (Ababouch, 2005). Fermentation as a method of preserving fish attacks the capacity of microorganisms that make fish vulnerable to spoilage.

Fermentation of fish is done using different periods. In some parts of the world, specifically in Asian countries, fishes are fermented for months to years and the various fermentation periods (months or years) have their own way of affecting the chemical composition of the commodity (Lopetcharat & Park, 2002). For instance, in the fermentation of sardines in industrial processing, Pombo et al., (2009) showed 90 days as the period for processing the fish and containers used for the fermentation were kept at a temperature of 25^{o}C to prevent any bacteria contact.

In another study conducted to observe microbial counts in fermented fish, Lee, Kung, Huang, Huang, and Tsai (2015) used 100 days for the fermentation while other studies showed different fermentation periods. This implies that the fermentation periods depend on the people involved in the fish processing. Per the number of days as stipulated by some researchers, it is possible to record different results in terms of the nutritional compositions, microbial counts, sensory properties, as well as the acceptability of the fermented fish product (Lee, Kung, Huang, Huang, & Tsai, 2015; Lopetcharat & Park, 2002; Pombo et al., 2009). In light of this, the researcher in this study developed the model as presented in Figure 1 for traditional fish processing that are used as condiments.

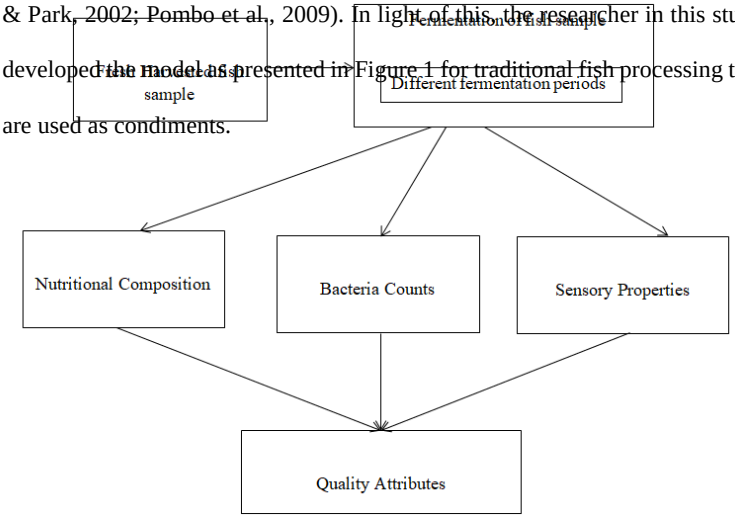


Figure 1: Processes in salt fermentation of fish (Researcher's construct)

Source: Amedekanya (2019)

It is depicted in Figure 1 that the processing of salt fermented fish products may affect the quality attributes based on the fermentation periods. However, untreated fish (harvested or fresh fish) samples may possess similar chemical composition, microbial load and sensory properties at the beginning of the fermentation process. It is highly possible that the chemical composition (nutritional composition), microbial counts and physical (sensory properties) of the fish may change as the number of fermentation days increases. As a result, the end products of different fermented fish samples may possess different nutritional composition, microbial counts, and sensory properties, as compared to the freshly harvested fish.

Empirical Review

The second part reviews current literature in line with the specific objectives of the study, with recent studies on; nutritional decomposition of

fermented fish, microbial counts of fermented fish and evaluation of sensory properties and consumer acceptability of fermented fish.

Fermented fish

Fish processing is paramount in many cultures where people engage in fishing activities. Also, it is a common practice to observe that some of the fishes being used as condiments have salt as the main ingredient used in the preservation process. For instance, in Indonesia, fish fermentation is done by using concentrated salt of about 20 to 30%; the result of this process produced what is called among local Indonesians *inasua* (fish fermentation using salt solution) (Mahulette, Mubarik, Suwanto, & Widanarni, 2018; Nendissa, 2013). Mahulette et al., (2018) noted that other fermented food products such as coconut sap does not have the same effect as fermented fish. *Momone*, one of the condiments produced in Ghana, goes through similar preservation methods as *inasua*. It is therefore argued that, the processing of *inasua* could be compared to that of *momone* since they are all forms of preserving fish with salt as the main catalyst.

According to Koffi-Nevry and Koussémon (2012), this type of food preservation is common among people of West Africa but have different names; for instance, in Benin, the traditional fermented fish which is treated with salt is called *Lanhouin*, in Ghana it is called *momone* while in Ivory Coast, it is called *Adjuevan*. This shows that the use of fermented salted fish is common among the people in African countries on the coast FAO (1971).

Any food substance that undergoes fermentation may experience some levels of chemical and physical changes since it is a normal practice for the food to be allowed some period to break down or decompose. During this period of

fermentation the fish undergo microbiological and physiochemical changes that are usually not controlled, as these changes may happen unexpectedly (Mahulette et al., 2018). According to Wongkhalaung (2004), it is paramount to observe changes such as the colour, flavour, and physical quality of products obtained from salted fish. Additionally, there is bacteria involvement in the processing of fermented salt fish (Sato, Horiuchi, & Nishimura 2005). It could be also inferred that the spread of these bacteria may lead to the depletion of the food nutrients present in the fish before the start of the fermentation process which also further reduces the nutrients.

Nonetheless, fermentation of food, including fish does not have an influence on the nutrient mineral element found in foods (Harland & Harland, 1980). The authors explained that there will be an influence of fermentation on mineral elements in food only when salt is added during the fermentation process, and also in instances where the liquid on the fermented foods is thrown away. Anecdotally, it could be said that the quality of fermented product depends on how the processing is done. The fermented fish product might lose its nutrients when the processing gives room for more bacterial to be introduced.

In support, Koffi-Nevry and Koussémon (2012) opined that contaminations could be introduced to the fermented fish product if the processing takes place in unhygienic conditions and the fishes are not handled well. Once the fermented fish product gets contaminated, it indicates a reduction in the quality attributes.

In a study conducted by Mansur et al., (2014), it was revealed that the quality of nutrient composition of the various types of preserved fish had variations, with some processed fish products recording higher levels of protein

than others. According to the findings from Mansur et al., (2014), protein considered as the most important nutrient of fish was 33.7% in wet fermented fish, while the dry fermented fish recorded 61.32% protein content. Furthermore, the aesthetic quality of semi-fermented fish product from wholesalers was in an acceptable form for consumption (Mansur et al., 2014). Those obtained from retailers however appeared to be faded with whitish colour, faint sour, odour and gone limp, which is an indication of unwholesome fish sample. The quality of fermented fish product therefore could be determined by the processing method used and how the end products are handled. Although the appearances of the fermented fishes were appealing to the eye when handled in bulk, when retailers started handling them, their appearance became unpleasant to consumers (Mansur et al., 2014).

Effect of salt in fish preservation

The use of salt in fish preservation is one of the ancient ways of preserving food. Salting is used widely across the world to prevent spoilage in food, such as fish and expand its shelf life. When salt is added to food, it cripples the action of microorganisms. In using salt to preserve food, different types of salts are used. They include sodium chloride (NaCl), calcium chloride ($CaCl_2$) and potassium chloride (KCl) (Bautista, Arroyo, Duran, & Garrido, 2008; Blesata et al., 2008). Additionally, the amount of salt used to preserve fish is dependent on the size of fish and the shelf life of fish (after preservation). Salt is usually used to improve the flavour of food, and serves as an additive, preservative and enhancer to the texture and palatability of food (Jay et al., 2005; Silva et al., 2003). When salt is used in high quantity to preserve food, it

helps reduce the water in the food, thus making it dry; this in turn contributes in making the food last longer without spoiling (Lawrence et al., 2003).

Similarly, sodium chloride is a type of salt that is commonly used and it is said to have a higher ability to preserve foods more than other salts (such as potassium chloride and calcium chloride). According to studies, the use of sodium chloride in food influences the protease enzyme and proteins, thereby controlling the action of microorganisms that are responsible for deteriorating food (Armenteros et al., 2009). A study conducted by Oranusi, Abah, and Anosike (2019) showed that the total protein in the fish samples investigated decreased during their storage after salt treatment. After the treatment, fish samples lost more protein as compared to the meat samples. This situation according to literature can also be associated to the effect of denaturation or spoilage (Gupta, 2017).

Similarly, strong decrease in total protein among food samples preserved by freezing and chilling methods both explain and support the findings of Gandotra, Koul, Gupta, and Gupta (2015) about low storage temperature influences the denaturation of protein. At the same time, Thorarinsdottir, Arason, Bogason, and Kristberdsson (2004) agree that using high salt in the quest to preserve fish and prevent it from spoiling reduces the proteins in fish. Karrar (2007) adds that the loss of nutrients in fish is often influenced by the unhygienic nature of preservation methods used, storage temperature and equipment used for the entire process.

In the study of El-Bassir et al., (2015), fresh harvested fish was compared with fish that had been treated with salt to determine the influence of

salt on the nutritional composition of fish (both proximate and mineral determination). The results obtained are shown in Table 2.

Table 2: *Proximate Composition of Fresh Harvested Fish and Salted Fish*

Parameters	Fresh Harvested Fish (Control)	Treated Fish (20% Salted)
Moisture %	70.754±1.469	23.138±2.609
Ash %	9.999±1.538	17.853±2.845
Protein %	72.345±2.679	66.825±3.927
Oil %	3.165±0.702	11.987±2.078

Source: El-Bassir et al., (2015).

According to Table 2, it was noticed that when the fish was in its fresh state, it had a high content of moisture (70.754%) and protein (72.345%). However, when salt was added, there was a reduction in the moisture (23.138%) and protein (66.825%). It can be said that the addition of salt influenced the moisture content in the fresh harvested fish, and helped in reducing the water activity in the fish. Also, with respect to the ash (9.999%) and lipid (3.165%) contents, they were low in the fresh harvested fish. Nonetheless, after salt was added to the fish sample, there were increases in the ash (17.853%) and lipid (11.987%) contents. With regard to this, it can be said that salt has the tendency to increase ash and lipid contents in fish. Table 3 shows the mineral determination of fresh harvested fish and salted fish.

Table 3: *Mineral Determination of Fresh Harvested Fish and Salted Fish*

Parameters	Fresh Harvested Fish (Control)	Treated Fish (20% Salted)
Na mg/l	92.75±6.671	403.81±12.504

K mg/l	76.57±4.068	82.92±7.180
Cal mg/l	123.48±13.416	111.77±8.332
Fe mg/l	0.712±0.053	0.635±0.024

Source: El-Bassir et al., (2015).

The determination of mineral content in freshly harvested fish and salted fish as highlighted in Table 3 showed that after the salt treatment, there were increases in contents of both sodium (92.75 mg/l to 403 mg/l) and potassium (76.57 mg/l to 82.92 mg/l). Alternatively, the study also showed decreases in calcium (123.48 mg/l to 111.77 mg/l) and Iron (0.712 mg/l to 0.635 mg/l) after salt treatment. The results from the proximate composition and mineral determination of fresh and salted catfish showed that there exist significant differences in the chemical composition of fresh harvested fish and the chemical composition of salt treated fish (El- Bassir et al., 2015).

In another study conducted to determine the physic-chemical and sensory properties of fermented fish mixed with other food ingredients, the results indicated no significant differences among the seven groups of samples used with varying levels of salt concentration (Jittrepotch, Rojsuntornkitti, & Kongbangkerd, 2015).

Per their analysis, Jittrepotch et al., (2015) indicated that moisture content of the samples used decreased from 62.05±0.20 to 62.09±0.30% at the beginning of the fermentation process, to 60.76±0.20 to 60.80±0.20% within a period of 7 days. According to Jittrepotch et al., (2015), the fall in the water holding capacity of the fermented fishes was due to the consistent decline in the pH value. Similarly, when the pH value of fish protein reaches its isoelectric point, its water holding capacity reduces (Huff-Lonergan & Lonergan, 2005;

Loje, Jensen, Hyldig, Nielsen, & Nielsen, 2007). The implication of the various findings is that as the fermentation period of fish increases, protein levels and water holding capacity decreases. Additionally, lipid or fat content in fish plays an important role in making it nutritious and palatable.

The use of salt in fish preservation however is said to have pro-oxidant activity and has been associated with lipid oxidation in seafood and meat (Mariutti & Bragagnolo, 2017). This is because when there is lipid oxidation, the quality of food preserved is reduced. In a similar way, increases in lipid peroxidation during the storage of food is associated with microbial, enzymatic and peroxidation activity of salt used. Again, the storage temperature of food and the concentration of salt are related to the level at which lipid reduction occurs (Oranusi, Abah, & Anosike, 2019).

Importance of fish preservation

Foodborne illness is one of the major illnesses reported in most countries (Van-Tonder, Lues-Jan, & Theron, 2007). It is normally caused by eating contaminated food, which subsequently pose a serious threat to consumers' health. The occurring types of microorganisms causing foodborne illness are *E. coli*, *Staphylococcus aureus*, *Salmonella enteritis*, and *Salmonella typhi* (Beuchat, 1996; Farber, 2000; Hussein, 2007). Therefore it is necessary to wash and preserve food according to acceptable standards to prevent or stop the action of these pathogenic bacteria. Using salt to preserve food also helps reduce the action of microorganisms; it has been reported that most microorganisms have slim chances of surviving in salty environments (Oranusi, Abah, & Anosike, 2019). This explains why sometimes fish is salted prior to the smoking, freezing or drying processes. Since majority of the food commodities cannot undergo

only one preservative process to make it wholesome and free from pathogens, they must go through a mixture of two or more methods. By combining the use of salt with other preservative methods, the water activity in food is reduced, and this helps ensure that the environment is not favourable for any activities of microorganisms (Fennama, 1996; Potter & Hotchkiss, 1995; Rahman, Wang, & Oh, 2013). The moisture content in food commodities contribute to the growth of microorganisms and in turn make food vulnerable to spoilage. Reducing or taking water out therefore prevents or stops pathogenic bacteria. This improves the safeness and wholesomeness of food, and subsequently extends its shelf life. However, the study did not indicate whether the addition of salt may contribute to the reduction of nutrients in the quest of preserving fish.

Effect of fermentation on the nutritional composition

It is an undeniable fact that fish is a popular food nutrient in most Ghanaian homes. Fish serves as a food nutrient that supplements other food nutrients present in our daily meals. It is a good source of protein and omega-3 fatty acids in a meal. According to Anggo, Ma'ruf, Swastawati, and Rianingsih (2014), fermented fish (or fish paste) is one of the popular condiments used during food processing due to its ability to stimulate people's appetite as it gives good aroma. It is therefore necessary to compare the composition of unfermented fish to the fermented ones based on the duration/period of fermentation. As stated by Takagi, Hayashi and Itabashi (1984), the processing of fish with salt normally produces some extent of fermentation. In support, Mahulette et al., (2018) and Voskresensky (1965) revealed that autolytic (enzymes) and microorganisms in fish are the main causes of fermentation which bring about the microbiological and physiochemical changes in

fermented fish. Studies also indicate that some mineral elements such as magnesium, calcium and phosphorus in fermented fish are reduced in values as a result of the utilisation by microorganisms present in the fermented fish for their metabolic processes (Bello & Akinyele, 2007; Rainbault, 1998).

The processing of local condiments such as *momone* could therefore present users with condiments at varying levels of nutritional values. In an experiment to determine the number of microbes present in a fermented fish, differences between the two treatments were highlighted (Mahulette et al., (2018) (See Table 4).

Table 4: *Number of Bacteria and Lactic Acid Bacteria Present in the Fermentation of Inasua*

Samples	Time of fermentation (weeks)	Total number of bacteria (CFU/g	Total number of lab (CFU/G)
Inasua-S	1	$2.2*10^8$	$4.5*10^7$
	2	$4.4*10^7$	$4.1*10^7$
	4	$3.5*10^7$	$3.3*10^7$
	8	$3.4*10^7$	$3.2*10^7$
	12	$3.2*10^7$	$3.0*10^7$
Inasua-NS	1	$5.3*10^6$	$4.5*10^6$
	2	3.5*10	$1.6*10^6$
	4	$3.3*10^6$	$1.3*10^6$
	8	$9.6*10^6$	$9.0*10^6$
	12	$5.4*10^6$	$3.5*10^6$

Source: Mahulette et al., (2018)

The results shown in Table 4 indicate that when the fish was treated with concentrated salt and sap (inasua-S), the total number of bacteria within the first week was lower ($2.2x10^8$ CFU/g) than when the fish was treated with concentrated salt without sap (inasua-NS) ($5.3x10^6$ CFU/g). On the contrary,

the amount of lactic acid bacteria in inasua-S was higher ($4.5x10^7$ CFU/g) than in inasua-NS ($4.5x10^6$ CFU/g).

According to Mahulette et al., (2018), the difference in the number of bacteria was because of the addition of coconut sap during the fermentation period. It could be said that, the process of making condiments may be used only for its aroma values but not nutritional values according to the results presented in Table 4, which shows that the nutrient levels of the fishes used tend to reduce drastically.

Further, other studies have shown significant difference between the fermentation processes of controlled fish and uncontrolled fish.

In a study carried out by Lee et al., (2015), it was shown that there was statistically significant difference between the fermentation of salted fish which was controlled and inoculated samples of fish samples over a period of 100 days. This result reaffirms the findings of Mahulette et al., (2018) which revealed a significant difference among the two types of fermented fish. Based on these findings, it could be said that when *momone* is subjected to two different kinds of treatment, it will produce chemical qualities that are significantly different from each other.

In relation to the period of fermentation, it could be said that there is no standardized duration assigned to the process. This means that, people involved in traditional processing of fermented fish may use varying number of days for the process. Lin et al., (2012) suggested that in the processing of salted fish products, about 10 to 20% of salt should be added to the raw fish. The fish can also be allowed to ferment for a period of 3 to 6 months based on the type of processing, until some changes are observed in the fish or till the fish tissue

becomes soluble. Also, according to Lee et al., (2016), there is no need of an induced bacterial culture since most salted fishes rely mainly on their own bacteria for the fermentation process.

Microorganisms in Fish

In assessing the quality attributes of food, microbial count is an important aspect to take into consideration due to how food is processed and preserved. It is said that food and water are the main environments microorganisms travel through (Ifediora, Nkere, & Iroegbu, 2006). Microorganisms are defined as very tiny living organisms that cannot be seen by the human eye, unless under a microscope. They come in different types. These types include bacteria, fungi, viruses, algae and protozoa (Fuerst, 2014).

Bacteria are single-celled organisms that belong to a microorganism kingdom called *monera*. These microorganisms are also known to have the shape of rods, spirals or spheres (Cabeen & Jacobs-Wagner, 2005). Additionally, bacteria are grouped into various types according to the environment suitable for their growth and multiplication. Some bacteria grow best in an environment where there is enough oxygen; they are known as aerobic bacteria. Other also grow and multiply best in an environment without oxygen; they are known as anaerobic bacteria. Also, some bacteria can typically survive in salt concentrations; they are known as halophiles (salt-loving bacteria). Some others are also unable to survive in salt concentrated environments (Oren, 2002).

Some bacteria are harmful and can cause food poisoning especially when consumed through foods and drinks. Others are also less harmful and beneficial. A study conducted by Mhango, Mpuchane, and Gashe (2010) indicated that when the bacteria count is high, it shows how the fish has

deteriorated in terms of quality. Thus, that specific fish is not safe for consumption, unless it undergoes some specific processing (such as application of heat) to make it wholesome. Similarly, studies conducted by some researchers also revealed that bacteria such as halophilic and proteolytic are the main bacteria present during fermentation; they have the ability to deteriorate proteins in fish (Dissaraphong, Benjakui, Vissenbanguan, & Kishmura, 2006; Palundan-Muller, Chol, & Daeschel, 2002).

Types of Bacteria

Heterotrophic plate count

Heterotrophic microorganisms are microorganisms generally known as aerobic plate counts. They are referred as aerobic because they survive best in environment with oxygen. Heterotrophic bacteria also include all microorganisms that are capable of surviving in an environment with oxygen and organic carbon, with a minimum temperature of 30 to 40°C. All heterotrophic bacteria cannot manufacture their own food and therefore break down organic compounds to meet their carbon requirements (Singleton & Sainsbury, 2001). These bacteria are said to be found in coastal waters and fishing harbours (Mahalakshmi et al., 2011; Robin et al., 2012). Additionally, total heterotrophic count provides information on how safe foods and water are for consumption. It also gives additional information on the state of how food and water are handled, processed and preserved (Bartram, Cotruvo, Exner, Fricker, & Glasmacher, 2003).

Coliforms

Coliforms are a group of bacteria which are mostly present in the digestive tracts of animals. They can also be found in water, plant and soil.

Coliforms are aerobic bacteria, thus they can survive and grow best in an oxygen environment. They are said to aid in the fermentation of food products. According to Shilklomanov (2000), coliforms do not usually cause serious foodborne illnesses. However, the presence of these bacteria show poor hygienic quality of the water in which fish was harvested or the water used to wash fish. Examples of coliforms include the total coliforms and faecal coliforms, with *E. coli* being a subset of faecal coliform (Rompre, Servais, Baudart, De-Robin, & Patrick, 2001). The total coliforms refer to all kinds of coliform bacteria present in food. The *faecal coliforms* are those specific bacteria found in the guts and digestive tracts of animals. Also, *E. coli* is one of the commonest coliform in *faecal coliform* and is also present in the intestines of animals. These bacteria are also known to grow best in aquatic environments (Geissler, Manafi, Amoros, & Alonso, 2000). A study conducted by some researchers revealed that even though there was an absence of *E. coli* in most of the fish samples investigated, the counts of coliforms make fish unwholesome for consumption (Mhango, Mpuchane, & Gashe, 2010).

Anaerobic bacteria

Anaerobic bacteria are species of bacteria that cannot survive and grow well in oxygen environment; they grow very well in environments without oxygen (Begum, Roy, & Yusuf, 2015). It is said that anaerobic bacteria are present during fermentation and are very common in fermented foods. Some types of anaerobic bacteria include *Staphylococcus aureus*, *Actinomyces*, *Salmonella spp*, *Clostridium*, *Escherichia coli*, *Streptococci*, *Enterobacter*, *Serratia*, *Shigellae*, *Prevotella*, *Salmonellae*, *Fusobacterium* and *Bifidobacterium* (Thomas, 2014). These examples are grouped into three types:

a. Facultative anaerobes: Bacteria that survive well in the presence of oxygen and continue to grow when oxygen is absent. Some examples of facultative bacteria are *Staphylococcus aureus* and *Enterobacter*.
b. Obligate anaerobes: These bacteria can only survive and grow in the absence of oxygen. Examples of such bacteria are *Peptostreptococcus*, *Clostridium*, *Propionibacterium* and *Actinomyces*.
c. Aerotolerant bacteria: Bacteria that are able to tolerate oxygen for a while but cannot survive and grow well in the presence of oxygen. *Clostridium spp* and *Streptococcus spp* are some examples of aero tolerant bacteria (Fox, 2016).

Staphylococcus aureus is an anaerobic bacteria and a dangerous toxin present in food. Its appearance in food makes the food dangerous for consumption (Soriano, Blesa, Rico, Molto, & Manens, 2002). *Staphylococcus aureus* can grow and multiply with or without oxygen (New Zealand Food Safety [NZFS], 2001), hence it is a facultative anaerobic. Additionally, these organisms are salt-loving bacteria and can therefore survive and multiply best in salt concentrated environments. Also, when the bacteria are in food, they respire and make fermentation of food possible during fermentation process (Achinewhu, Amadi, Barimalaa, & Eke, 2004).

Salmonella spp are a group of bacteria that are found in the intestinal tract of animals. Some examples of these bacteria include *Salmonella typhi*, *Salmonella paratyphi*, and *Salmonella entreritidis*. *Salmonella* is one of the commonest harmful bacteria that cause foodborne illness every year in the United States (Centers for Disease Control and Prevention, 2011). Typhoid fever, diarrhoea and food poisoning are some of the illnesses *Salmonella spp*

cause. These illnesses occur when an individual consumes food or water that is contaminated with *Salmonella spp*. These bacteria are also anaerobic bacteria; they therefore can survive in an environment where there is no oxygen (International Commission on Microbiological Specifications for Food [ICMSF], 1996).

Microorganisms in fermented fish

Freshly harvested fish can be contaminated by staphylococcus aureus and other harmful bacteria when not handled properly and stored in contaminated environment (CODEX, 2013; Pal et al., 2016; Topic-Popovic et al., 2010). These bacteria found on fresh fish when not handled hygienically, have the tendency to cause food poisoning when consumed. Food poisoning has also been reported when individuals consumed dry or semi-dry meat sausages that were fermented (Johnson, 1991). When the fermented dry meat sausages were investigated, the researcher also found staphylococcus in the sausages. Considering the author's observation, fresh and processed perishable foods must be thoroughly washed and cooked before consuming them to prevent food poisoning. Other researchers also conducted studies on microbial counts of some selected fermented foods, and the results confirmed that some bacteria such as *E. coli*, *Staphylococcus*, *Bacillus subtilis* and *Salmonella spp* were present in those fermented foods investigated (Elyass, et al., 2015).

Additionally, in the study conducted by Anihouvi, Ayernor, Hounhouigan, and Sakyi-Dawson (2006) on the quality characteristics of a traditionally processed fermented fish product, there was a high population count of total heterotrophic bacteria in the fermented fish, with a low count of total coliforms. The studies also revealed that there were no traces of *Salmonella*

spp. in all the fish samples evaluated, and this was attributed to the high salt concentration (5.2 to 7.3%) used in fermenting the fish. Nonetheless, there were low indications of *Staphylococcus aureus* and *Clostridium spp*. in some samples of fermented fish evaluated. The authors attributed the presence of *Staphylococcus aureus* and *Clostridium spp* to the salt concentration in the fermented fish. Additionally, the results of the researchers revealed that even though there were low counts of coliforms in the fish samples, there must be an improved way of handling and processing traditional fermented fish in order to produce bacteria-free fermented fish.

Furthermore, Ojokoh (2007) admitted that there are microbial actions during fermentation process of food. These microorganisms can create both negative and positive influences on food products. The positive influence was that these microorganisms make it possible to preserve food, develop and enhance flavour in food, and improve nutrients such as proteins, amino acids, vitamins and minerals in foods. The other positive influence is the fact that microorganisms' action in fermentation aids in the breakdown of complex food substances, thus making digestion of the food easy. Furthermore, Ojokoh (2007) explained that the negative influence of microorganisms in food fermentation can be the invasion of microorganisms, contamination of the food and food spoilage. These microorganisms multiply rapidly as soon as they are introduced to food during fermentation and cause the food to spoil.

Normally, fermented food substances present unpleasant smell with change in the appearance of the food. This process might be caused by the presence of bacteria on unpreserved food substances. From the study conducted by Lee et al., (2016), results revealed the presence of bacteria in both the

controlled and inoculated samples of the fishes used. According to Lee et al., (2016), the initial bacterial count of the controlled sample of 3.0 log CFU/g increased rapidly to 8.9 log CFU/g after 120 days of fermentation while that of the inoculated started at 5.8 log CFU/g and increased slightly to 6.5 log CFU/g. Lee et al (2016) showed that the level of aerobic bacterial counts before the 40th day of fermentation was significantly lower in the controlled sample as compared to the inoculated sample after day 40. These findings indicate that in the fermentation of fish, the bacterial counts continue to increase as the number of days increased as shown in Figure 2.

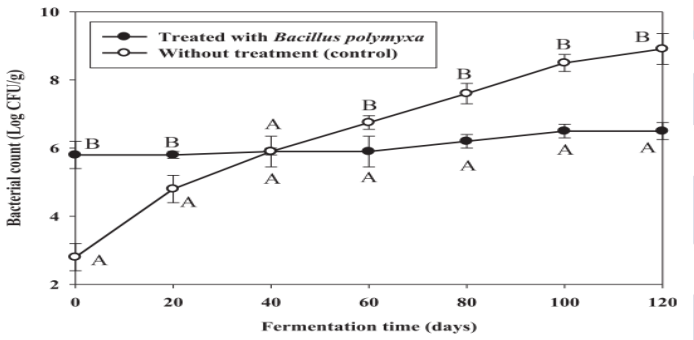


Figure 2: Bacterial Count in Fish Fermentation

Source: Lee et al., (2016)

From Lee et al., (2016), the result of the experiment presented in Figure 2, show that the number of bacterial counts of the controlled sample during the fermentation process increased while that of the inoculated sample appeared to be at the same level before starting to rise slightly in the bacteria counts. This could be associated to the fact that some sanitary measures where not taken to control the growth of bacteria in the controlled sample, hence, the increase in bacteria counts.

Other studies conducted showed an increase in bacterial or microbial counts during the fermentation process. For instance, Paludan-Muller, Madsen, Sophanodora, Gram, and Møller (2002) reported that a range of bacteria, including halotolerant bacteria, lactic acid bacteria and yeast, began to develop and spread which led to a rise in the number of microbiological counts in the process of Thai fermentation fish. Likewise, Kuda et al., (2012) showed that there was rapid growth of the Tetragenococcus halophilus and the histamine-forming bacteria in a salted fermentation of sardine samples as a result of competition, since the nutrients in the sardine was depleting. In this regard, one may perceive the fermentation of any other fermented food nutrient or fish to follow similar pattern and realise constant growth in bacterial or microbial counts. Notwithstanding, in inoculated fermentation process, the rate of increment in the number of bacterial or microbial counts may be slightly lower than the traditional salt fermentation of fish. Even though fermented fish is consumed by most Ghanaians, it appears a limited number of studies have been conducted in relation to the number of microbial or bacterial counts in them. It is important to encourage more investigations that could unveil the microbial counts in fermented fish taking into account the number of days of fermentation.

Sensory Properties of Food

Sensory properties of fish form part of the quality attributes of fish; being it fresh or processed. These properties usually include the texture, taste, appearance and colour that can be assessed easily with the sense organ of individuals (nose, eyes, mouth, skin, etc.) Assessing the sensory properties of fish is a subjective way of evaluating the quality attributes of fish. This is because, the assessment is based on the senses of individuals who will accept or

reject the food product. Also, in the evaluation of the sensory properties, when majority of the individuals assessing the food product say the food product is not good, it is assumed that particular food product is truly not good. On the other hand, when majority of the panellists say it is good, it is said that the food product is good. In evaluation of fish, freshness is one of the most significant aspects of fish quality as it is directly associated to texture, appearance and taste. Additionally, freshness is a multidimensional quality characteristic of fish that particularly influences the consumption quality and affects the acceptability and rejection by consumers (Sharifan, et al., 2014).

Usually, in the fish processing industry, fresh fish is preserved or processed to increase its palatability and shelf life. This also helps to conserve their freshness for various cooking purchases, which in turn is very important to the economy as fish will be available throughout the year (Campus et al., 2010). Conversely, there have been some challenges faced by consumers as in whether these fishes are still fresh and of good quality even after they have gone through the various methods to preserve them. Therefore some measures such as proper handling of food must be taken into consideration to ensure that the freshness and other sensory properties possessed by food are not questionable at the end of the production process chains (Damez & Clerjon 2008).

Generally, the sensory properties that contribute to the quality of fresh, processed and preserved fish include texture, appearance, taste, flavour/aroma and colour. These sensory properties must be assessed well in order to produce food products that are safe and wholesome. All food commodities including fish must have fresh smell and must possess distinguished properties such as the natural colour and uniform shape and denseness. For instance, when one uses

the finger to press fresh fish or preserved fish of any kind, the fish should have some properties such as flaky, soft, firm, or hard so that the individual can judge its texture. Usually, aroma or flavour and taste of food are used simultaneously or interchangeably (Bayarri, Calvo, Costell, & Duran, 2001). The human tongue is made up of about 10,000 taste buds which play what is probably the most important role in food selection. Apart from taste being important, other sensory attributes such as appearance, texture, smell and sound have a vital impact on what individuals select to consume. These sensory properties are important in selecting food to eat; because irrespective of how delicious food may taste, it should have good texture, appearance, smell and flavour to make the eating experience better. How these sensory properties of food affect the quality of food is explained below.

Appearance

Appearance is one of the major characteristics of food products, including fish, which plays a vital role in determining the reaction of consumers upon seeing a food product. Determining the appearance characteristic of food involves physically looking at food products in terms of its colour, dryness, wetness, etc. This characteristic is assessed with the human eye. Lonchampt and Hartel (2004) explained that in most situations, the appearance of food is determined by how the food was preserved and stored. They also added that when storage temperature is controlled, the appearance of food products becomes better.

Colour is important in assessing the appearance of fish product because it adds to the appealing nature of the food product (McClement, 2002). When the natural colour of food appears to be dull than the normal, quality is reduced.

This is due to the fact that consumers may think the food is spoilt or in the process of spoiling and may feel reluctant to purchase such food product (Singh-Ackbarali & Maharaj, 2014). Furthermore, the colour of a food product determines its attractiveness. Usually, the eye gets attracted to beautiful things. Therefore when food products are colourful and in their natural colour, consumers tend to purchase those food products. Spence (2015) also added that food colour plays an essential function in determining consumer acceptability of variety of food products. Appearance and colour are therefore able to arouse or inhibit consumers' appetite.

Flavour/Aroma and taste

All food products, including fish have distinctive flavour and taste sensations. The term flavour and aroma are used synonymously. Flavour is another major attribute of food. When food products have good flavour, consumers tend to like them. This is because, consumers believe such foods are easy to taste. McClement (2004) opined that flavour of food is mostly determined by the content and type of fat, and the vitality and polarity of the food product. This means that the presence of fat in food products has major role to play since the fat helps in determining its flavour. In addition, the type of fat in food, whether saturated or unsaturated, can also influence its flavour. Additionally, in assessing the flavour of food, the nose is used. The nose determines the aroma from the food, to ascertain if it is cooked or uncooked. In most instances, when food is uncooked, the flavour it exudes is different from the flavour it exudes when it has been cooked. This therefore makes it necessary to evaluate food in both cooked and uncooked state. Also, the studies of Nargi (2018) and Wither (2018) indicated that flavour and taste are different attributes

of food, even though, both sensory attributes are needed to make the meal experience better. The authors also revealed in their studies that taste is one of the characteristics of the flavour of food. Nonetheless, the study of Small (2008) revealed that the flavour of food impacts its taste and vice versa.

Similarly, the taste of food is vital in determining the sensory properties of food. Food taste comprises complex incorporation of impressions from the taste buds on the tongue, the olfactory centre in the nasal cavity, perceptible receptors in the mouth, and the observation of causticness, warmth and cooling anytime food is put in the mouth (Weel et al., 2006). Tasting of food is necessary to help consumers assess the actual taste a food product possesses. The taste of food can be sweet, sour, bitter, umami or salty. Food can also have pleasant taste depending on the particular type of food. Studies also reveal that the tongue has many taste buds which make it possible to detect specific taste of food products (Belitz, Grosch, & Scchieberle, 2009). That is why the tongue is able to detect whether food products taste sour, salty, sweet, etc.

Texture

Texture is another important attribute of food. The texture of food can be determined by chewing, touching or feeling. When a consumer chews the food to be assessed, he or she will be able to assess the food's crunchiness, crispiness, softness, stickiness, brittleness, flakiness and hardness. In some cases, the texture of food can be perceived by using the eyes. This will tell the panellist whether the food product is rough, grainy or smooth in texture by just looking at the food product. According to Pszczola (2000), the texture of food can also be determined by the amount of oil in the food. He explained further that fat plays a vital role in texture of food and how food feels in the mouth and

hand. It can also be said that the texture of food may be dependent on the amount of fat the specific food product contains; the more the fat content, the better the texture of the food product. Nonetheless, Marangoni and Narine (2002) opined that though fat has an influence on texture of food products, it cannot solely determine the texture. Marangoni and Narine (2002) added that food is made up of chemical compositions and these compositions can also influence the texture of food products. Some chemical compositions mentioned by the authors that can affect the texture of food were proteins, enzymes and amount of water in the food. Since the texture of food is used to define the attributes of finished food products, the way in which the food is prepared, processed or preserved and stored can contribute to its texture attribute. In addition, the ingredients used, and how these ingredients were mixed may also have an effect on the texture of finished food products.

Sensory evaluation of fermented fish

Sensory evaluation may be termed as the methods used to evaluate or analyse food with the sense organs. In the case of fish, it could be said that the sensory evaluation involves the use of the sense organs to analyse fish products. According to Stone and Sidel (2010), sensory evaluation is defined as a scientific process that evokes, measures, analyses and interprets reactions towards products, as perceived through the sense organs of sight, smell, touch, taste and sound. Meiselman (1993) indicated that this definition is accepted to a large extent and used by various professionals in the field of food processing including the Institute of Food Technologists and the American Society for Testing and Materials. Therefore, sensory evaluation can be noted as the use of the sense organs to distinguish between the various characteristics of food.

Typically, one of the best techniques used in evaluating freshness and sensory properties by fishing sectors is sensory evaluation (Hyldig et al., 2007). This technique is usually performed in a manner which provides accurate and effective information and response on foods. The individuals involved might or should be familiar with all the sensory properties (including the taste, appearance, texture, colour and flavour) of the particular food product to be evaluated in order to provide accurate results or information.

In a study conducted to determine the physic-chemical and sensory properties of fermentation of fish mixed with other food ingredients, it was realised that no significant differences were observed among the seven groups of samples used with varying levels of salt concentration (Jittrepotch, Rojsuntornkitti, & Kongbangkerd, 2015). Even though salt has been used as one of the fermentation catalysts since ancient times, it may occur that the taste, colour or texture of fermented fish could be affected due to the length of fermentation. The study of Jittrepotch et al., (2015) revealed that the more the salt is used in the fermentation period, the more the liking or acceptance of the fermented fish decreased.

However, when the salt was replaced with 25% and 50% potassium chloride (Formulation II and III as presented in Table 2), the panel in charge of the testing accorded significantly high values for colour, flavour, texture and general acceptance (Jettrepotch et al., 2015). Meanwhile, the panel significantly reduced the acceptance levels in all aspects of the sensory evaluation when sodium chloride was replaced by calcium chloride. (See Table 5).

Table 5: *Acceptance Levels of Fermented Mixture of Fish with Partial Replacement of Sodium Chloride*

Attributes

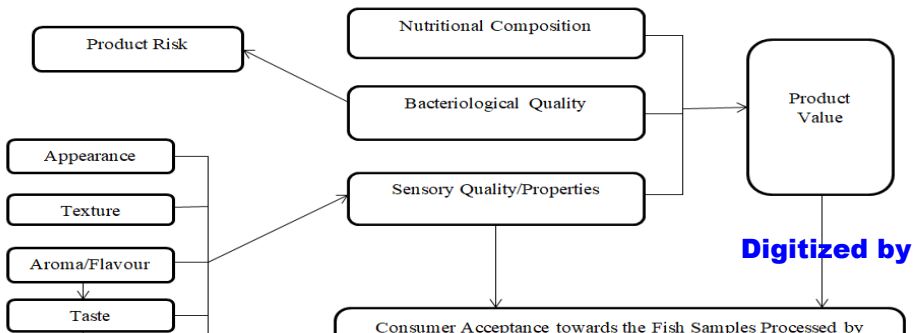
Omulation	Colour	Flavour	Texture	Saltiness	Sourness	Overall liking
I	8.50±0.54^{a}	8.60±0.54^{a}	8.50±0.89^{a}	8.00±0.36^{a}	8.40±0.71^{a}	8.50±0.63^{a}
II	8.80±0.65^{a}	8.70±0.47^{a}	8.60±0.65^{a}	8.30±0.72^{a}	8.50±0.72^{a}	8.50±0.53^{a}
III	8.70±0.39^{a}	8.70±0.32^{a}	8.60±0.25^{a}	8.30±0.72^{a}	8.30±0.79^{a}	8.60±0.47^{a}
IV	7.20±0.91^{b}	7.30±0.89^{ab}	7.30±0.45^{b}	6.90±0.89^{b}	7.00±0.58^{b}	6.80±0.72^{b}
V	6.60±0.81^{b}	6.90±0.12^{b}	6.70±0.25^{b}	6.10±0.24^{b}	6.70±0.36^{b}	6.20±0.89^{b}
VI	5.30±0.25^{c}	5.30±0.35^{c}	4.50±0.48^{c}	4.70±0.28^{c}	6.70±0.89^{b}	4.30±0.25^{c}
VII	3.00±0.45^{d}	3.20±0.47^{d}	3.20±0.98^{d}	3.60±0.15^{d}	4.70±0.15^{c}	3.00±0.22^{d}

Source: Jittrepotch et al., (2015)

A closer look at Table 5 indicates that the overall acceptance levels of the fermented mixture of fish continue to decrease with each formulation (formulation I, 100% NaCl; formulation II, NaCl 75% KCl 25%; formulation III, NaCl 50% KCl 50%; formulation IV, NaCl 25% KCl 75%; formulation V, NaCl 75% $CaCl_2$ 25%; formulation VI, NaCl 50% $CaCl_2$ 50%; formulation VII, NaCl 25% $CaCl_2$ 75%). Other researchers also indicated that the use of salt with more than 50% of potassium chloride in the fermentation process produces bitter tastes in the fermented product (Desmond, 2006; Gelabert, Gou, Guerrero, & Arnau, 2003). It could be deduced that the use of salt gives better taste, colour, or texture to the fermented fish, hence increased acceptance of the product. However, it should be noted that people might prefer and like different colours or textures though their preferred taste of food might be relatively general.

Theoretical Framework for Consumer Acceptability

The theoretical framework supporting the consumer acceptability and factors that are likely to cause difference in individual differences in the



acceptability of the fish samples processed by different fermentation periods is below;

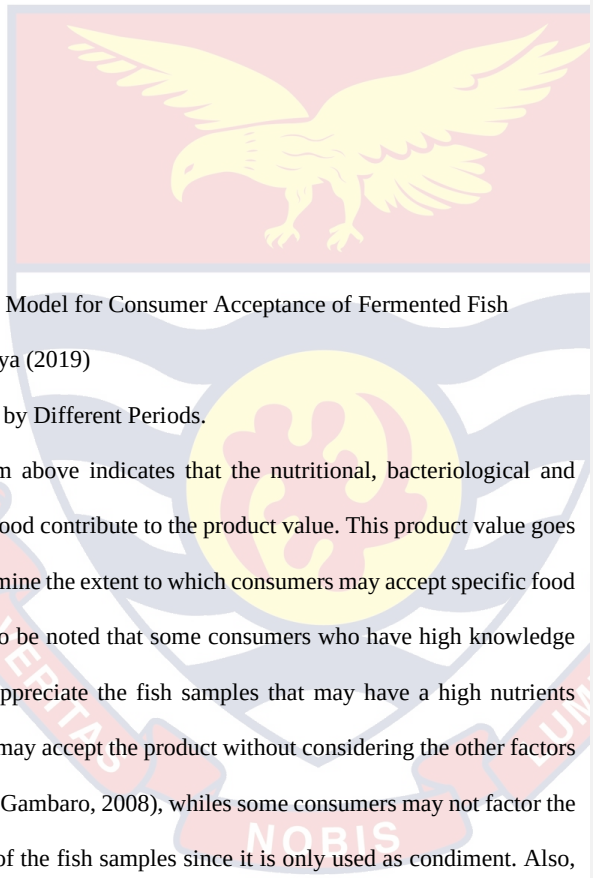


Figure 3: Proposed Model for Consumer Acceptance of Fermented Fish

Source: Amedekanya (2019)

Samples Processed by Different Periods.

The diagram above indicates that the nutritional, bacteriological and sensory quality of food contribute to the product value. This product value goes a long way to determine the extent to which consumers may accept specific food product. It may also be noted that some consumers who have high knowledge on nutrition may appreciate the fish samples that may have a high nutrients content, thus, they may accept the product without considering the other factors (Ares, Giménez, & Gambaro, 2008), whiles some consumers may not factor the nutritional quality of the fish samples since it is only used as condiment. Also, the product risk determines the amount of bacteria in the food, and whether the bacteria are harmful or safe. Some consumers are likely to accept the fish samples with minimum counts of bacteria due to the fact that they may want to enjoy safe foods and prevent foodborne illnesses (WHO, 2015).

However, it is most likely that some consumers may not take into consideration of the nutritional and bacteriology quality of food and consider the sensory properties as paramount factor to accept or reject certain type of foods. Study shows that the acceptance of food by consumers is largely impacted by the sensory properties possessed by the particular food (Nargi, 2018; Wither, 2018). The diagram in figure 3 depicted that the appearance, texture, aroma, taste and aftertaste contribute to the sensory quality of food. It was shown that the aroma or flavour of food influences the taste and aftertaste of the food (Bayarri et al., 2001). These properties are crucial in the determination of the quality of food, and also play a major role in consumers' acceptability (Caracciolo et al., 2020). Therefore, since consumers are used to the sensory properties of the local fermented fish, any sensory properties perceived from the fermented fish samples processed by different periods that do not match the local fish sample may not be accepted. Nonetheless, when consumers perceive sensory properties that are better preferred than the local fish sample, consumers are likely to accept the fish samples.

In conclusion, even though, sensory properties of food play a major role in consumers' acceptability, consumers' positive or negative reactions to food may not be solely on the sensory qualities of food, but other factors such as nutritional value and bacteriological quality of food.

Summary

The quality attributes of fermented fish include the nutritional composition, microbial load and sensory properties. According to existing literature, when fish is fresh its nutritional composition is high and stable. Other studies asserted that when fish is preserved, the preservative methods used must

maintain the nutrients in the fish or, in most cases, increase its nutritional composition. Nonetheless, in some cases the nutrients were rather reduced due to the method of preservation used, thus reducing the quality of food.

Additionally, some microorganisms are found in the fishes before and after processing. These microorganisms come in different types and counts. Studies showed that the types and counts of microorganisms are dependent on the number of days used to process the fish, and how the fish samples were handled. Also, the presence of microorganisms may be attributed to the unhygienic nature of the equipment and tools used in the fermentation process and the state of the fish before fermentation.

The sensory properties comprise the appearance, colour, flavour, taste and texture. All these properties of food aforementioned work together to make the eating experience better for the consumer. This is not to say that the nutritional and microbial counts of food are not important to consumers. However, all things been equal, when food products have great amount nutrients and free from microorganisms, but are not appealing in terms of taste, texture, flavour and appearance, consumers may not be motivated to eat and enjoy that particular food product. On the other hand, when food products are evaluated at all sides (nutritional composition, microbial load and sensory properties), the quality attributes of the food products are enhanced and made wholesome, therefore making the eating experience of consumers more satisfying.

CHAPTER THREE

RESEARCH METHODS

The focus of the study was to assess the chemical composition, microbial load and sensory properties of fish samples fermented by different periods. This chapter covers the research design, population, sampling procedure and size, data collection instrument, study area, sample preparation, laboratory analysis of the chemical and microbiological characteristics of the fermented fish, sensory evaluation, data collection, data processing and analysis.

Research Design

A research design comprises the organisations and the approaches for conducting a study (Jones & Bartlett, 2006; Kerlinger & Lee, 2000). It basically describes the variables to be studied, how the variables are going to be studied, and the projected association to other variables in the study (Spector, 1981).

In this study, a true experimental design was used to answer the research questions and test the research hypothesis to determine the quality attributes of fermented fish processed by different fermentation periods (Martyn, 2008). The researcher used factorial design, and for that matter pre-test and post-test design in this study. This type of design allowed the researcher to investigate the effects of each fermentation period on the quality attributes of the fermented fish (Box, Hunter, & Hunter, 2005). The factorial design was also suitable in this study because it deals with two or more factors. Following the conditions of using true experimental design, the study was carried out using two main groups. One group became the control group which went through the standard way of fermenting fish locally, while the other group (comprising of three sub group)

became the treatment group, which were treated using different durations (1 Day, 3 Days and 5 Days) of fermentation to evaluate the effects of the intervention given on the dependent variables (Amedahe, 2004). Likewise, factorial design was deemed fit because the design helped the researcher to collect more data that was analysed statistically to produce results that were accurate and reliable (Thompson & Panacek, 2006). The factorial design also allowed effects of the intervention to be projected at several levels of other interventions, and thus, yielded conclusions that were valid and reliable.

The fishes that were fermented were assigned randomly to the various fermentation periods (one day into fermentation, three days into fermentation and five days into fermentation). After each period of fermentation, salt was added to the fish and bottled to mature. The total number of days for maturing was seven. This process took place in three repeated sessions so that the researcher could compile accurate and adequate data from the chemical and microbiological analysis. The repetition of the fermentation process also helped the researcher generalize the results obtained from the study. In addition, the researcher tested one variable at a time so that the experiment and statistical analysis were not cumbersome and difficult, to meet the conditions stipulated by Cresswell (2005).

Chemical and microbiological analyses were conducted to assess the quality attributes of fermented fishes that underwent different periods of fermentation on one hand and the fermented fish processed by the local producers on the other hand, to ascertain whether differences exist within and between groups in their chemical composition and microbial load. To obtain reliable data regarding the microbiological analysis, the researcher sterilized all

equipment (bowls, knives, bottles for storage, plates, among others.) for the fermentation of samples to prevent samples from getting into contact with infective equipment to avoid cross contamination. Relatedly, sensory properties of fish (fresh or processed) form part of the quality attributes of fish to make the fish commodity wholesome (Sen, 2005). Therefore, the researcher assessed the sensory properties of the samples of fermented fishes that had gone through different fermentation periods (treatment) through sensory evaluation.

To control interference of extraneous variables, raw materials (such as fresh fish, salt and clean water for washing the fishes) and tools (such as clean knife, bowls and storage jars) that are free from any contamination were used throughout the fermentation process to ensure that the end product was free from recontamination (Cresswell, 2009).

Population

A population involves all the subjects or objects the researcher will want to use for the study (Ary, Jacobs, & Razavieh, 2010). The target population for the assessment of nutritional composition and bacteria counts comprised freshly caught cassava croaker and fermented fish samples produced locally at Elmina. Fermented fish from Elmina was used because the town is well known for the production of fermented fish. The target population for the sensory evaluation on the other hand, comprised food vendors, chop bar operators and individuals who prepare meals at home. The other criteria adopted for selecting the population for the sensory evaluation was age (from 18 to 55 years). This age limit was considered since age eighteen to fifty-five, individuals can make their own decision on their likes and dislikes. The study was also limited to age fifty-five because, it is assumed that some individuals at this age may not be able to

be very active due to illness. Both literate and illiterate were used since they all use fermented fish in food preparation. All tribes of people with the exception of the people from the Northern, Upper East and Upper West regions were used. This was because, the people from these tribes were not very familiar with *momone*.

Sample and Sampling Procedure

Freshly caught cassava croakers (cassava fish) were sampled at the Elmina fishing outlet randomly and fermented by different fermentation periods (Amedahe, 2000). This variety of fish was selected because it is readily available and can be processed as fermented fish. In addition, locally fermented fish was randomly selected at the Elmina fermented fish outlet (because Elmina is a fishing town and the people are noted of producing fermented fish in large quantities) for the purpose of comparing it with the fish fermented by different fermentation periods. The locally fermented fish was collected in sterilised plain polythene, sealed and properly coded for easy identification.

Relatedly, for the chemical and microbiological analyses, two pieces of fermented fish samples from each fermentation period and locally produced fermented fish (control) were used. They were then transported immediately in an insulated ice chest to the laboratory of the School of Agriculture and the laboratory of the Department of Biological Science, both at the University of Cape Coast for microbiological and chemical analyses.

The purposive sampling technique was employed to select the cassava croakers to be processed by different fermentation periods. Also, convenient sampling technique was used to select subjects to take part in the sensory evaluation. Convenient sampling technique was deemed ideal because it offered

the researcher the opportunity to select subjects who are familiar with fermented fish. Such people have ever used fermented fish in meal preparation and are therefore in a position to select and buy quality fermented fish. It was hoped that a panel with these characteristics will be able to evaluate the sensory qualities of fermented fish samples processed by different fermentation periods, by discerning the difference in their attributes.

The sensory evaluation test method that was used to assess the sensory properties of the different fermented fish is the Discrimination or Simple Different Test method (Stone, Bleibaum, & Thomas, 2012). This test method is used to determine the difference in products that have undergone different processes. It is also suitable for assessing a new and enhanced version of a previously existing product such as the case in this study. Irfan (2007) posited that in using Discrimination Test methods, panellists must have considerable knowledge on the food sample to be evaluated. In this study, because the panellists had considerable knowledge of fermented fish, they provided the researcher with practical information needed on the product after evaluation. The panellists comprised thirty (30) people as proposed by Irfan (2007), when using the discrimination test method.

Data Collection Instrument

The data for the study was generated from chemical, microbial and sensory analyses of fish samples. The data collection on the chemical and bacterial analyses was done in triplicate (three sessions). The data collection instrument that was used to generate data on consumer acceptability of the fermented fish was questionnaire. The questionnaire was developed by the researcher and was subjected to scrutiny by the researcher's supervisors who

were familiar with sensory evaluation methods. It was then revised based on their comments. The questionnaire was then administered to the sensory panel to gather relevant information on the sensory properties of samples. In developing the questionnaire for the sensory evaluation, the researcher used Paired Difference Test instrument (Lawless & Heymann, 2013). This was because, the goal of the researcher was to determine whether the fermented fish processed by different fermentation periods possess different sensory properties. Another reason for the Paired Difference Test instrument was to ascertain which samples were similar and most preferred.

Material and Method

Source of raw materials

Freshly caught cassava croakers (cassava fish) were used for this study. The freshness of the cassava croakers was determine using physical parameters and sensory test (such as the firmness, odour, appearance and the colour of the gills of the fish) as indicated some researchers (Abbas, Mohamed, Jamilah, & Ebrahimian, 2008). The fishes were purchased at Elmina fishing outlet because of its proximity to the researcher. This afforded the opportunity of having optimum freshness of the fish. Again, Elmina is the main fishing community where consumers purchase fresh fish and is noted for processing fermented fish. The freshly caught fishes purchased were transported in an insulated container with ice to the researcher's apartment for cleaning and fermentation. The use of ice on the fresh fishes was to reduce enzymatic activity and to prevent deterioration of the fish before reaching the site for fermentation. The fermentation process was supposed to take place at the School of Agriculture Teaching and Research Laboratory, University of Cape Coast. However, it took

place at the researcher's apartment due to the stench emitted by the fish in the course of fermentation and the distraction it was likely to cause students who used the laboratory.

Figure 4: Samples of fresh cassava croaker ready for fermentation.

Source: Amedekanya (2019)

Fermenting the fish

Treatment

After purchasing the freshly caught cassava fish, the researcher cleaned the fish by removing the scales and entrails. After cleaning, the fishes were thoroughly washed with clean water twice. The removal of scale and entrails, and washing were done to ensure that the fish was free from microorganism before fermentation starts. The cleaned fishes were placed in the labelled bottles (Day 1, Day 3 and Day 5) and tightly covered to commence fermentation. After each fermentation period (Day 1, Day 3 and Day 5), salt was added and closed again tightly to continue the fermentation process. All through the fermentation period (and process), the bottles used for fermenting the fishes were carefully coded for proper and easy identification.

Figure 5: Samples of bottled fishes to go through the different fermentation periods

Source: Amedekanya (2019)

Sample Preparation

Samples of fermented fishes processed by the different fermentation periods and samples of the locally produced were coded by the researcher and transported in an air tight container to the School of Agriculture Teaching and Research Laboratory, and the Research Laboratory of the Department of Biological Science, both at the University of Cape Coast for the chemical and microbiological analyses. The samples were transported in airtight containers to the various laboratories to prevent further microbial activities. This contributed to the reliability of the chemical and microbiological results. At the respective laboratories, the fermented fish samples were blended individually and dried for the chemical and microbiological analyses.

Figure 6: Packaged fermented fish samples sent to the various laboratories for analysis

Source: Amedekanya (2019)

Methods

Chemical analysis (Proximate and mineral determination) of sample

Chemical compositions of fermented fish samples processed by different fermentation periods and that of the locally processed sample were determined according to the methods described by AOAC (2000). The chemical analysis included proximate analysis and mineral determination. The proximate analysis comprised the determination of moisture, protein, ash, fat and crude fibre content of all samples. The minerals that were determined were potassium, sodium, calcium and phosphorus. The chemical analysis was conducted at the Teaching and Research laboratory of School of Agriculture Science, University of Cape Coast.

Moisture content determination

Porcelain crucibles were washed, dried and weighed. 10 grams of the fish samples were placed in the crucible and weighed. The crucibles containing the fish samples were placed in the oven at a temperature of 105ºC for 48 hours. At the end of the period, the crucibles were removed, cooled in a desiccator and weighed (Rowell, 1994).

The moisture content was then calculated as a percentage of moisture lost by the sample using the formula:

$$\% \text{ moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where: W_1= Weight of crucible

W_2=Weight of crucible + fresh grated sample

W_3 = Weight of crucible + Dry sample

Dry matter determination

After calculating for the moisture lost, the dry fish sample weight was noted and expressed as a percentage of the fish weight (Rowell, 1994).

Ash determination

Ash content of material represents inorganic residue left behind after burning of organic matter or the mineral content present in the sample. Also, it is considered very essential as it gives a measure of the mineral elements that can be obtained from food sample (Shovon, Abida, Muhammad, Muhammed, & Ahtashom, 2013). The dried samples in the crucibles were transferred to the hot plate and charred over a period till it produced no smoke (Rowell, 1994). The charred samples were then transferred into a muffle furnace and ignited at 550ºC for 5 hours. The crucibles containing the samples were then cooled in desiccators and weighed. The percentage ash was then computed as:

$$\% \text{ Ash} = \frac{W_3 - W1}{W2 - W1} \times 100$$

Where:

W1 = Weight of crucible

W2= Weight of crucible + fresh grated sample

W3=Weight of crucible + Ash

Crude protein determination

Protein was determined by weighting 0.2g each of the milled samples into a numbered kjedahl digestion flask. About 4.5ml of digestion mixture was added and the fish samples of different fermentation periods were digested at 360ºC for two hours (AOAC, 1995). The digests were allowed to cool and were diluted to 100ml with distilled water. Twenty millilitres (20ml) of each digest was immediately distilled after adding 10ml of alkali mixture using 5ml of boric acid as indicator. 50ml of each distillate was collected and titrated against 0.00712M HCl until it turned to a pink colour - an indication of the endpoint. The remaining diluted digest were reserved for the mineral determination as recommended by Food and Agriculture Organisation [FAO] (2008).

Percentage protein was calculated using the formula:

%N=((Sample Titre-Blank Titre) x Molarity of HCL)/(Sample weight (mg)) [×14.007 x100]

% Protein= %Nx6.25

Fat/Oil determination

Twenty grams of the milled sample was weighted into a 50 x 10mm soxhlet extraction thimble. This was transferred into a 50ml capacity soxhlet extractor. A dried clean 250ml round bottom flask was weighed. About 150ml of petroleum spirit of boiling point 40-60ºC was added and connected to the soxhlet extractor and extraction commenced for 5-6 hours. After the 6 hours, the flask was removed, cooled in a desiccator and weighed. The percentage fat/oil was calculated as follows, based on FAO (2008).

$$\text{Fat} = \frac{W_2 - W_1}{W_3} \times \mathbf{100}$$

Where:

W_1 = Weight of empty flask

W_2 = Weight of flask +fat

W_3 = Weight of samples taken

Calcium determination

An aliquot of 10ml of the reserved digest was pipetted into a 250ml conical flask and 150ml of distilled water was added. 1ml each of potassium cyanide, hydroxyl-amine hydrochloride, potassium ferro–cyanide and tri-ethanol amine were added. 20ml of 10% sodium hydroxide was added to raise the pH and then 10 drops of calcon indicator were added to the solution and titrated against 0.005M EDTA solution (AOAC, 1995).

Magnesium determination

An aliquot of 10ml of the reserved digest solution was pipetted with a 250ml conical flask. One hundred and fifty millilitres (150ml) of distilled water was added. Fifteen millilitres (15ml) of buffer solution was then added and allowed to stand for few minutes. One millilitre (1ml) of each of potassium, cyanide, hydroxylamine hydrochloride, potassium ferrocyanide and triethanolamine were added. Ten (10) drops of erichrome Black T indicator were added and titrated against 0.005m EDTA solution (Page, Miller, & Keeney, 1982).

Phosphorus determination

Two millilitres of aliquot of the digested sample solutions was pipette into a 25ml volumetric flask. 2ml of the blank digest was also added to the 2ml of standard phosphorus solution to give it the same background as the digest. Ten millilitres of distilled water was added to the standards as well as the sample solutions. Four millilitres of reagent B made up of ascorbic acid and reagent

was added to the standard and sample solutions (Page, Miller, & Keeney, 1982). . Distilled water was added to the volumetric flask to make up to the volume of 25ml and allowed to stand for about 15 minutes for the colour to develop. After colour development, the absorbance of the standard and sample solutions was determined using a spectrophotometer at a wavelength of 882mm. A standard calibration curve was plotted using their concentration against absorbance.

Calculations

If C= ugP/ml obtained from the graph then

ugP/g = (C x diluted factor)/(Sample wt (g))

Sodium and potassium determination

Potassium and sodium concentrations in the digested samples were determined using the flame photometer. The following standard concentrations of both potassium and sodium were prepared 0, 2,4,6,8 and 10ug/ml (Page, Miller, & Keeney, 1982). Both the working standards and the sample solutions were aspirated individually into the flame photometer and their emissions recorded. A calibration curve was plotted using the concentration and missions of the working standards. The concentration of potassium and sodium in the sample solution were extrapolated from the curve using their emissions:

ug K/g or Na = (C x solution volume)/(Sample weight g)

Microbiological analysis

The fermented fish samples processed by different fermentation periods and that of the locally processed samples were microbiologically analysed to determine the populations and types of microorganisms present in them. The microbiological analysis was conducted at the Research Laboratory of the Department of Biological Science, University of Cape Coast.

Test media and indicators

Heterotrophic bacteria, total coliforms, faecal coliforms, anaerobic bacteria, *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella spp*, were determined using horizontal method for the enumeration of microorganism (Chouhan, 2015). By ISO standards (ISO, 2006; 2015), fish samples were analysed for heterotrophic bacteria, total coliforms, faecal coliforms, anaerobic bacteria, *Escherichia coli*, *Staphylococcus aureus* and *Salmonella spp*, using pour plate method technique. Culture media consisting of plate count agar (Oxoid, Hampshire, England), peptone water (Oxoid) and eosin methylene blue agar (Oxoid), nutrient agar (Oxoid), salmonella/shigella agar (Oxoid), reinforced clostridia agar (Oxoid) and mannitol salt agar (Oxoid) were prepared according to the manufacturer's instructions (Feldsine, Abeyta, & Andrews, 2002).

xHeterotrophic bacteria

Using peptone water (Oxoid) as recovery diluent, 180ml of the peptone water was prepared in triplicate and sterilized by means of autoclaving along with all prepared media and petri dishes at 121°C, 15psi for 15 minutes.

The fermented fish sample was adequately homogenized. 20g of the test sample was weighed aseptically into the recovery diluent and incubated in a water bath at 37ºC for 30 minutes. The test sample was serially diluted to 1 in 1000 in a sterile peptone water. Duplicate dilutions of 0.1 ml and 1 ml of 1 in 1000 dilution of the sample were plated on plate count agar and incubated at 37°C for 48 hours. All colonies were counted and an average of duplicate samples was recorded as heterotrophic bacteria (CFU/ml) for the sample.

Total coliform

Likewise, 2 duplicate dilutions of 0.1 ml and 1 ml of 1 in 100 dilution of each sample were plated on Eosin Methylene Blue agar. One each of the duplicate dilutions was incubated at 37°C for 48 hours to observe for total coliform counts (CFU/ml) for the sample.

Faecal coliform

Similarly, 2 duplicate dilutions of 0.1 ml and 1 ml of 1 in 100 dilution of each sample were plated on Eosin Methylene Blue agar. One each of the duplicate dilutions was incubated at 44°C for 48 hours to observe for faecal coliform counts (CFU/ml) for the sample.

Staphylococcus aureus

For *staphylococcus aureus*, triplicate dilutions of 0.1 ml and 1 ml of 1 in 100 dilution of each sample were plated on mannitol salt agar. One each of the duplicate dilutions was incubated at 37°C for 48 hours to observe for for yellow colonies with yellow halo's as *staphylococcus aureus* counts (CFU/ml).

Salmonella spp.

For *salmonella spp*, triplicate dilutions of 0.1 ml and 1 ml of 1 in 100 dilution of each sample were plated on salmonella/shigella agar. One each of the duplicate dilutions was incubated at 37°C for 48 hours to observe for Salmonella counts (CFU/ml) for the sample.

Anaerobic bacteria

With regard to anaerobic bacteria, triplicate dilutions of 0.1 ml and 1 ml of 1 in 100 dilution each sample were plated on reinforced clostridia agar under

anaerobic condition using oxoid anaerogen gas generator with indicator strips and incubated at 37°C for 48hrs and colonies counted (CFU/ml) for the sample.

Escherichia coli

E. coli was identified morphologically on eosin methylene blue agar as colonies with purple coloured colonies with green metallic sheen. These colonies were aseptically transferred into sterile peptone water, and the inoculum incubated overnight at 37°C. Exactly 0.5ml of the Kovác's reagent was aseptically added to the incubated broth and shaken gently. The sample was examined after 1 minute for red colour formation at the upper layer of the broth indicative of the presence of E. *coli* (Prince & Prince, 2009).

Preparation of Fermented Fish for Sensory Evaluation

In relation to sensory properties and acceptability of fermented fish by different fermentation periods, tomato sauce was prepared using the different fermented fish samples to assess their flavour and taste. This enabled the panelists to critically determine the taste and flavour of samples. Also, raw fermented fish samples by different fermentation periods were assessed in terms of their apperance, colour and texture.

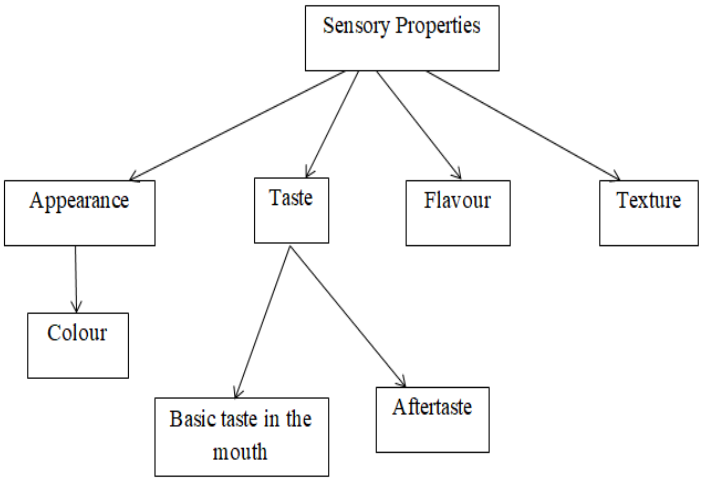


Figure 7: A diagram showing the various sensory properties used in assessing the raw fermented fish and sauces

Source: Balazs (2012)

Figure 8: Raw fermented fish samples and sauces ready to be assessed by the respondents

Source: Amedekanya (2019)

Figure 9: Evaluation of fermented fish samples and sauces in session

Source: Amedekanya (2019)

Pretesting of Equipment and Instruments

The equipment and instruments that were used for the chemical and microbiological analysis were pretested to ensure that they were potent and not faulty. The bottles for fermenting the fish were checked to ensure they were right sizes for fermenting the fish. The bottles' covers were also fitted to ensure they fitted the bottles' openings well. On the other hand, the questionnaire for the sensory evaluation was pretested at the Food Laboratory of Department of Vocational and Technical Education using 25 panellists (male and female cooks, 18 years and above). This number of panellists was used because the researcher wanted to use the required number of panellists close to the number for the main study as indicated by Irfan (2007). The pretesting of the questionnaire helped the researcher to correct all typographical errors and ambiguities. Also, some words used in the questionnaire that the panellists were not familiar with were changed to prevent any confusion during the sensory evaluation. All rules governing sensory evaluation were observed by both the researcher and the panellists that were involved in the pretesting exercise. These rules include wash the mouth with the water provided by the researcher before tasting the food samples, evaluating the food samples in the order they have been presented to the panellists, not taking alcoholic beverages a night before the pretesting, as well as not using perfumes on the body just before the evaluation.

Data Processing and Analysis

For each chemical and microbiological test, three readings were obtained and the averages were calculated. To answer the research questions,

descriptive statistics which include means, percentages, and standard deviations were employed. The Statistical Product for Service Solutions (SPSS) version 21was used. The data analyses were done by comparing the percentages, means, and standard deviations of the chemical compositions of fishes processed by different fermentation periods. Also, means of microbial load of fishes processed by different fermentation period were presented. In addition, results of the sensory properties and consumer acceptability of the different fermentation periods of fish were cross tabulated and compared. The One-way Analysis of Variance (ANOVA) was used to test for differences in the nutritional composition and microbial counts between the fishes processed by different fermentation periods and the locally processed fermented fish. ANOVA was used for the hypotheses one and two because it gave the researcher the opportunity to investigate whether the differences in means between the fish samples are significant. In addition, chi square was used to test for difference in sensory properties of the different fish samples. The use of chi square test was also appropriate to compare each sensory characteristics possessed by the fish samples (since the sensory properties had several groups described by categorical variables).

Ethical Issue Considered in the Study

For this study, official permission was obtained from the Department of Vocational and Technical Education (VOTEC). This was to ensure that ethical issues that have to do with the confidentiality of information provided by respondents, informed consent of respondents and voluntary participation were ensured. In conducting the chemical and microbiological analyses, all necessary precautions were observed. Protective clothing such as overalls, gloves,

goggles, and boots were worn to protect the researcher and the laboratory technicians. The researcher and laboratory technicians observed every rule in the laboratory to make the chemical and microbiological analysis successful.

Also the researcher prepared the sauces for sensory evaluation with quality food ingredients in a hygienic environment – the Food Laboratory of the Department of VOTEC – to prevent any contamination that may adversely affect panellists during the evaluation. The food laboratory was thoroughly cleaned and dusted to prevent dust and actions of microorganisms. The sensory evaluation exercise was also conducted at the food laboratory of the department of VOTEC. This helped panellists to comfortably assess the sauces since good sitting posture, good ventilation and good lightening in the food laboratory were ensured.

CHAPTER FOUR

RESULTS AND DISCUSSION

This study sought to assess the quality attributes of fish fermented by different fermentation periods. This chapter presents the results obtained from the chemical analysis, microbiological analysis and sensory evaluation of the fermented fish (*momone*). The findings are also discussed.

Objective One: The nutritional compositions of fresh fish, fish samples processed by different fermentation periods, locally processed fermented fish (control) and salted bottled fish

Fish samples including fresh fish, fishes that were fermented by different periods (1 day, 3 days, and 5 days), locally produced fermented fish, and salted bottled fish were sent to laboratories for chemical and microbial analyses. The individual fermented fish samples were analysed at the School of Agriculture Teaching and Research Science Laboratory and the Research Laboratory of the Department of Biological Science University of Cape Coast. The proximate composition (moisture, ash, protein and fat) were determined. In addition, some minerals in fish (phosphorus, potassium, sodium, calcium and magnesium) were also determined using the individual fish samples. The proximate composition of the fresh harvested fish (FHF), the day 1 fermented fish (D1F), day 3 fermented fish (D3F), day 5 fermented fish (D5F), locally fermented fish (LFF) and the salted bottled fish (SBF) are presented in Table 6.

Table 6: *Proximate composition of fresh cassava fish, fish samples processed by different fermentation periods, salted bottled fish and locally fermented fish*

Fish sample	Moisture %	Ash %	Protein %	Fat %
FHF	76.63±0.00	2.63±0.60	72.66±0.56	2.85±0.41
D1F	77.09±0.80	3.46±0.87	72.59±0.01	2.47±0.17
D3F	78.38±0.81	2.81±0.21	52.70±0.56	2.31±0.13
D5F	77.49±1.47	3.87±0.76	42.95±0.11	1.98±0.16
LFF (control)	79.04±0.80	1.44±0.02	71.21±0.18	2.29±0.02
SBF	59.77±0.61	16.13±0.08	55.26±0.73	2.82±0.42

Source: Laboratory data (2019)
- FHF: Fresh harvested fish
- D1F: Day 1 fermented fish
- D3F: Day 3 fermented fish
- D5F: Day 5 fermented fish
- LFF: Local fermented fish
- SBF: Salted bottled fish
-Values are averages of triplicate determinations
-Data is represented as mean ± standard deviation

The results presented in Table 6 show some variations in the proximate composition of FHF and the rest of the samples (D1F, D3F, D5F, LFF, SBF). The results from the study showed that FHF had the highest protein value of 72.66%. This sample (FHF) was used to compare with the other samples (D1F, D3F, D5F, LFF, SBF) since they were all processed from the fresh fish (FHF). This score was expected since there has been a report on high protein content in fresh fish (Uauy & Valenzuela, 2000). On the contrary, the Nigerian Institute for Oceanography and Marine Research (2016) results on nutrient composition

of cassava croaker indicated that the protein value in a 100g of the fish was 21.21%; substantially lower than result obtained in this study. Similarly, the high score of protein value of FHF may be as a result of the fact that the fish was freshly caught and had not gone through any decomposition or spoilage, hence having the protein content intact (Burt, 2003).

It was observed that there was slight reduction of protein value in D1F (0.1%) and LFF (2.0%). This reduction may be attributed to the effect of fermentation on the fish samples. However, the effect was not marked compared to the reduction of protein in D3F (27.47%) and D5F (40.88%). This percentage decrease of protein value was also expected because both samples were allowed to ferment for three (D3F) and five days (D5F) resulting in the samples losing high amounts of their protein value. According to Gopakumar (2000) and Gupta (2017), when fishes spoil they tend to lose some vital nutrients such as proteins, thus making the fermented fish decrease in the amount of nutrients that were present in them before the fermentation process. Also, the protein value of SBF showed a reduction level of 23.94%. This result was not expected since SBF was not allowed any duration in terms of time to ferment. Rather, salt was immediately added to the fresh fish and bottled, which supports the conclusion of a study that the early addition of salt caused the protein reduction in the fish (Thorarinsdottir, 2004). The study of Armenteros et al., (2009) indicated that the use of sodium chloride in food preservation influences the protease enzyme (an enzyme responsible for breaking down proteins into amino acids), while controlling the action of bacteria that are responsible for deteriorating food. This also confirms the results of Oranusi, Abah, and Anosike (2019) where fish

samples investigated showed a decrease in protein value after the fish samples have undergone salt treatment.

LFF recorded the highest percentage of moisture content (79.04%), followed by D3F (78.38%), D5F (77.49%), D1F (77.09%), and FHF (76.63), with SBF recording the least (59.77%). The slight decrease in moisture of FHF could be attributed to the freshness of the fresh fish, and probably because no decomposition had been initiated. The high percentage moisture of samples LFF, D3F, D5F and D1F was expected as the fish sampled had gone through decomposition (fermentation). However, the differences in the percentage moisture may be attributed to the number of days each sample was allowed to ferment (Abbas, Saleh, Mohamed, & Lasekan, 2009). It could therefore be said that within the first three days of fermentation, the fish gained some amount of moisture and depreciated as the fermentation process progressed. Also, the high decrease of moisture in SBF was expected as a result of the salt added to the fish. Studies have shown that when salt is added to food to preserve it, water in the food is drawn out, thereby reducing the moisture content of the food and increasing its shelf life (Thorarinsdottir, 2004).

Results from the ash content in the samples revealed that SBF had the highest ash content of 16.13%, followed by D5F (3.87%), D1F (3.46%), D3F (2.81%), FHF (2.63%), and LFF (1.44%). According to Shovon, Abida, Muhammad, Muhammed, and Ahtashom (2013), ash content is considered very significant as it provides information on the amount of mineral elements that can be obtained from food. In this study, though the ash content recorded was generally low, SBF exhibited the highest ash content and therefore it can be concluded that SBF may contain more mineral elements than the other samples

(Shovon et al., 2013). In the study of El-Bassir et al., (2015) the percentage ash in the fish samples treated by salt (17.85%) was higher than the fresh harvested fish. Also, samples D1F and D5F had increased ash content as compared to D3F and FHF, even after the samples had gone through fermentation. LFF recorded the least ash content of 1.44% signifying that it may contain less mineral elements. Sample FHF was also expected to exhibit high ash content but it happened to be the second lowest (2.63%) even though it was fresh.

From the table presented above, there was a little variation of the fat content in all the samples. Sample FHF recorded the highest fat content of 2.85%, followed by SBF (2.82%), D1F (2.47%), D3F (2.31%) and LFF (2.29%). The sample recording the least fat content was D5F (1.98%). The FHF recording the highest fat content was an indication that the nutrients in the sample was intact due to it freshness. This supports the studies of Kris-Etherton et al., (2002); Uauy and Valenzuela (2000) which indicated that fresh fishes are rich in nutrients (including healthy fats). Also, sample D1F, D3F and LFF reduced in fat content slightly. This may be because of the number of days the fish was left to decompose. According to Secci and Parisi (2016), fat in fish is one of the main nutrients that are vulnerable to decomposition (especially by oxidation). This therefore explains the slight decrease in sample LFF because it was not processed in a bottle; nonetheless, the samples that were processed in bottles with tight covers also exhibited some decrease. However, sample SBF did not go through any fermentation period and was processed in a bottle, but still reduced slightly in fat content. Also, sample D5F exhibited the least fat content and this may be attributed to the longest period (5 days) of decomposition it went through (Berkel et al., 2004; Burt, 2003).

Generally, the different fermentation periods played a role in the amount of proximate composition of the samples. While longer duration of fermentation resulted in the loss of some amounts of the nutrient components as revealed in the protein and fat content, the trend was different for moisture and ash content where no definite pattern was observed. This was also observed in the proximate composition of matured fermented fish samples, which is presented in Table 7.

Table 7: *Proximate composition of matured fermented cassava fish samples (After salt was added)*

Fish sample	Moisture %	Ash %	Protein %	Fat %
FHF	76.63±0.00	2.63±0.60	72.66±0.56	2.85±0.41
MD1F	59.11±0.31	21.78±0.34	42.75±0.47	1.77±0.22
MD3F	63.06±0.82	20.13±0.41	41.76±0.35	1.82±0.25
MD5F	63.23±0.62	19.80±0.33	36.49±0.79	1.64±0.17
MLFF (control)	62.09±0.62	14.36±0.54	57.38±0.15	2.17±0.07

Source: Laboratory data (2019)
- FHF: Fresh harvested fish
- MD1F: Matured day 1 fermented fish
- MD3F: Matured day 3 fermented fish
- MD5F: Matured day 5 fermented fish
- MLFF: Matured local fermented fish
-Values are averages of triplicate determinations
-Data is represented as mean ± standard deviation

The results in Table 7 show the proximate composition of matured fermented fish samples. The prefix 'M' added to the codes thus denotes matured (MD1F, MD3F, MD5F and MLFF) after salt was added. The first figures in the presentation refer to the values obtained during fermentation (before the addition of salt). These figures are being compared to the levels of the proximate composition after salt was added (matured)

From the results presented in Table 7, it may be observed that much of the proximate composition of the matured fermented fish samples had decreased except for the ash content. Results in Table 7 shows that there was a decrease in the protein value of all the samples of different fermentation periods and that of the locally fermented fish after salt was added. Even though the samples lost some proteins during fermentation, the protein depreciated further after the fish samples had matured (salted). Sample MD1F which was initially 72.59% reduced to 42.75%, followed by MLFF (71.21% to 57.38%), MD3F (52.70% to 41.76%), and MD5F (42.96% to 36.49%). Even though there was a reduction of protein content in all the fish samples after the samples have matured (salted), it was an evident that sample MLFF (control) had the highest protein content as compared to the other samples processed by different fermentation period (MD1F, MD3D and MD5F). The reduction of protein after salt was added to the samples supports the study of El-Bassir et al., (2015). Even though the authors used a different fish (cat fish), their results revealed that the fresh cat fish which contained protein value of 72.34% reduced to 66.82% after the fish was treated (salted).

The decrease in the protein value of the samples can also be attributed to the addition of salt to the fish after the fermentation period. It was observed that though the protein content decreased after the fermentation period, it further decreased after the fermented fish samples had matured (salted), and this could be associated with the salt added to the fish. This supports the assertions by Thorarinsdottir (2004) that whilst using high amount of salt to preserve fish, simultaneously, it reduces the protein content of the commodity. This is because in the study of Armenteros et al., (2009), it was indicated that the use

of sodium chloride in food preservation influences the protease enzyme (an enzyme responsible for breaking down proteins into amino acids), while controlling the action of bacteria that are responsible for deteriorating food. This also confirms the results of Oranusi, Abah, and Anosike (2019) where fish samples investigated showed a decrease in protein value after the fish samples had undergone salt treatment.

Some authors also established that unhygienic procedures of handling and processing fish and high storage temperature may result to the denaturation of protein in fermented fish, and this may be associated with sample MLFF since it was not processed in a bottle (Gandotra et al., 2015; Karrar, 2007). Unhygienic procedures of handling fishes can affect protein reduction because the procedure may introduce bacteria to the fish which may aid in rapid decomposition of the fish, therefore reducing the protein content. Nonetheless, since the other fish samples (MD1F, MD3F, and MD5F) were handled and processed under strict hygienic conditions, the denaturation of the protein may be associated with the number of days the samples were fermented and the salt added to them.

From Table 7, the percentage moisture in all the samples decreased. It was observed that sample MD3F which was initially 78.38% decreased to 63.06%. This was followed by MD1F (77.09% to 59.11%), MD5F (77.49% to 63.23%) and MLFF (79.04% to 62.09%). This decrease exhibited by the samples shows that salt is effective in drawing water in food during preservation as the study of Lawrence et al., (2003) indicated. Also, a decrease in percentage moisture of fish samples was observed in the findings of El-Bassir et al., (2015) where the result highlighted a decrease in moisture content of Clarias Lazera

(Catfish) from 70.75% to 23.14% after salt was added. Though the reduction in moisture in their study was high, it may be attributed to the type of fish used. According to Table 6 and 7, a Critical observation of the moisture content revealed that fermented fish first attracted more moisture for some period of time (during decomposition) before starting to lose moisture after adding salt.

From the results, the ash content in all the samples experienced high increment. The findings showed that MD3F which was initially 3.46% increased to 21.78%, MD3F increased from 2.81% to 20.13%, and MD5F increased from 3.87% to 19.80%. MLFF which recorded a low ash content during fermentation period increased from 1.44% to 14.36%. This increment in the ash content of the samples may be as result of the salt that was added to the samples after the fermentation period. Likewise, results from El-Bassir et al., (2015) on the proximate composition of fresh harvested fish and salted fish indicated an increase in ash content of fresh fish from 9.9% to 17. 85% (treated fish). Therefore it could be expected that the mineral elements in the matured samples will be more than the samples during fermentation.

The fat content of the samples also decreased after the salt treatment. It was revealed that sample MD1F which recorded 2.47% fat decreased to 1.77%, followed by MD3F (2.31% to 1.82%), MD5F (1.98% to 1.64%), and MLFF (2.29 to 2.17). It was observed that even though the fat content reduced during the fermentation process, the addition of salt to the samples after fermentation caused further decrease. This showed that, decomposition of samples alone was not enough to reduce the fat content (Berkel et al., 2004; Burt, 2003), but the addition of salt to the samples also affected the fat content as revealed by the findings of Thorarinsdottir (2004). Mostly, fish contains essential fats and oils

that provide the body with its supplies of vitamins and omega 3 and 6 fatty acids; therefore when it decreases due to fish processing and handling in the quest to preserve fish, it must be replaced by adding foods that are rich in healthy fats and oil such as fresh fish, olive oil, palm oil, and coconut oil so as to protect the body and improve upon healthy living (Kris-Etherton et al., 2002; Uauy & Valenzuela, 2000).

From the results presented, it is noteworthy that the nutritional composition of the matured fermented fishes decreased more than those presented during the fermentation period. It could be said that the absence of a preservative such as salt in the fermented fish samples from the beginning of the treatment also contributed to the general nutrient loss (Baird 2000). Hence, the study highlighted the proximate composition of matured fermented fish where the ash content increased greatly, with the protein and fat content showing low levels. This supported the study of Koffi-Nevry and Koussémon (2012) which indicated that fishes, meats and other types of food substances that are high in protein must be preserved immediately after they have been obtained to prevent spoilage or decomposition.

Okonta and Ekelemu (2005) explained preservation as an essential procedure to ensure an increase in the shelf-life of fish, by making conscious effort to maintain its nutritional value and wholesomeness. From the results obtained from the proximate composition of fermented fish samples, it is evident that in the quest to preserve fish using the fermentation method, some vital nutrients (protein and fat) are likely to reduce.

The mineral composition of fresh fish and fermented fish samples was also determined and the results are presented in Table 8

Table 8: *Mineral composition of fresh cassava fish, fish samples processed by different fermentation periods, salted bottled fish and locally fermented fish*

Fish sample	Phosphorus Mg	Potassium Mg	Sodium Mg	Calcium Mg	Magnesium Mg
FHF	15.76 ±0.54	15.01 ±0.59	5.43 ±0.47	0.03 ±0.00	0.004 ±0.00
D1F	14.89 ±0.70	14.53 ±0.70	4.96 ±0.41	0.02 ±0.00	0.003 ±0.00
D3F	13.64 ±0.64	11.75 ±0.85	5.28 ±0.36	0.04 ±0.00	0.005 ±0.00
D5F	12.89 ±0.91	11.20 ±0.77	5.76 ±0.04	0.03 ±0.00	0.003 ±0.00
LFF (control)	16.00 ±0.05	14.43 ±0.94	6.34 ±0.01	0.03 ±0.00	0.002 ±0.00
SBF	13.41 ±0.21	9.24 ±0.04	10.85 ±0.15	0.04 ±0.00	0.004 ±0.00

Source: Laboratory data (2019)
-Values are averages of triplicate determinations
-Data is represented as mean ± standard deviation
-Mineral elements are measured in milligram (mg)

As portrayed in Table 8, the mineral elements determined included phosphorus, potassium, sodium, calcium and magnesium. LFF recorded the highest phosphorus (16.00mg) content.

It was followed by FHF (15.76mg), D1F (14.89mg), D3F (13.64mg) and SBF (13.41mg), with D5F (12.89) recording the least. Sample LFF recording higher phosphorus than FHF was unexpected because unlike FHF which was fresh, LFF went through some decomposition (fermentation). The decrease exhibited by other samples (D1F, D3F and D5F) was expected, as the phosphorus continued to decrease by each period of fermentation. Gupta (2015) established that when fish spoil it tends to lose some nutrients and this may have caused the decreased in the samples fermented, since each sample went through some decomposition thus making the fermented fish decreased in the amount of

nutrients that were present in them before the fermentation process. Sample SBF decreasing in phosphorus content was also not expected as the fish was not allowed to decompose before the addition of salt. In the study by the Nigerian Institute for Oceanography and Marine Research (2006), freshly harvested cassava croaker recorded 27.80mg of phosphorus. On the contrary, sample FHF (fresh fish) recorded a phosphorus content of 15.76mg, which was below the quantity recorded by the authors. This difference in phosphorus content may be associated with the size of cassava croaker used by both researchers and possibly the geographical location of the fish (Jabeen & Chaudhry, 2011)

The Potassium content in FHF was the highest (15.01mg). It was followed by D1F (14.53mg), LFF (14.43mg), D3F (11.75mg), D5F (11.20mg) with SBF (9.24mg) recording the least potassium content. It was expected that FHF to shows a high content of Potassium as compared to the other samples due to the freshness of the fish. On the contrary, another study showed a high content of potassium (125.60mg) in cassava croaker (Nigerian Institute for Oceanography and Marine Research, 2006). This difference in potassium content in the fish supports the study of Jabeen and Chaudhry (2011) which revealed that nutritional composition may differ in levels, even with fishes of similar species. The findings of El-Bassir, et al., (2015) on catfish recorded a high amount of potassium. The high score of potassium recorded may be associated with the kind of fish used (cat fish). Sample D1F and LFF reduced slightly and this was due to the number of days the fish was fermented. Compared to the other samples (FHF, D1F and LFF), D3F, D5F and SBF decreased drastically in potassium content. This was also expected as the D3F and D5F were allowed to decompose for some days. Some authors established

that mineral elements may be reduced in food due to the invasion of microorganisms, since these microorganisms depend on mineral elements for their growth and metabolic processes (Bello & Akinyele, 2007; Rainbault, 1998). However, sample SBF exhibiting a high decrease in potassium may be associated to the addition of salt to it at an early stage (Thorarinsdottir, 2004).

From the results, the sodium content of SBF was the highest (10.00mg). It was followed by LFF (6.34mg), D5F (5.76mg), FHF (5.43mg) and FFD3 (5.28mg), with D1F (4.96mg) recording the least. The high content of sodium recorded in SBF was expected because salt was added to the fish while it was still fresh, thus the increment. The other samples (LFF, D5F, FHF and D3F) experienced a slight decrease, with D1F experiencing the highest decrease. Considering the level of sodium in FHF (5.43mg), an author recorded a higher level (111.20mg) even though the same species of fish (cassava croaker) was investigated (Nigerian Institute for Oceanography and Marine Research, 2006).

Calcium content in D3F (0.04mg) and SBF (0.04mg) registered the highest. It was followed by FHF (0.03mg), D5F (0.03mg), LFF (0.03mg), while the least score was recorded in D1F (0.02mg). The results showed that all the samples had traces of calcium. Though the calcium content was relatively low in all the samples, D1F experienced the highest decrease. Again, contrary to the results observed in Table 8, the study of Nigerian Institute for Oceanography and Marine Research (2006) showed a very high content of calcium (220.40mg). This huge difference could be attributed to the size of the fish the two researchers used.

The highest of magnesium was recorded in D3F (0.005mg). It was followed by FHF (0.004mg) and SBF (0.004mg). Sample D1F (0.003mg) and

D5F (0.003mg) recorded the same score, with sample LFF (0.002mg) recording the least. The results on magnesium content were rather low in all the samples, with LFF exhibiting the least level. On the contrary, the Nigerian Institute for Oceanography and Marine Research (2006) revealed a higher level of magnesium (18.40mg) in the cassava fish they investigated.

Likewise, the mineral composition of the matured fermented cassava fish samples was determined and the results are shown in Table 9.

Table 9: *Mineral composition of matured fermented cassava fish samples*

Fish sample	Phosphorus Mg	Potassium Mg	Sodium Mg	Calcium Mg	Magnesium Mg
FHF	15.76 ±0.54	15.01 ±0.59	5.42 ±0.47	0.03 ±0.00	0.004 ±0.02
MD1F	11.61 ±0.43	7.45 ±0.11	14.42 ±0.40	0.03 ±0.00	0.004 ±0.00
MD3F	10.06 ±0.75	10.94 ±0.67	14.58 ±0.22	0.03 ±0.00	0.004 ±0.00
MD5F	14.13 ±0.16	13.07 ±0.53	14.43 ±0.15	0.03 ±0.00	0.003 ±0.00
MLFF	12.85 ±0.15	10.89 ±0.10	13.70 ±0.09	0.03 ±0.00	0.003 ±0.00

Source: Laboratory data (2019)
-Values are averages of triplicate determinations
-Data is represented as mean ± standard deviation
-Mineral elements are measured in milligram (mg)

The results in Table 9 show the mineral content of matured fermented fish samples. The prefix 'M' added to the codes thus denotes matured (MD1F, MD3F, MD5F and MLFF) after salt was added. The first figures in the presentation refer to the values obtained during fermentation (before the addition of salt). These figures are being compared to the levels of the minerals after salt was added (matured)

The phosphorus content in MLFF (16.00mg to 12.85mg), MD1F (14.89mg to 11.61 mg) and MFFD3 (13.64mg to 10.06mg) decreased while MD5F (12.89mg to 14.13mg) exhibited an increase in phosphorus content. This result shows that the addition of salt increased the level of phosphorus in only MDF5, which is five days after fermentation and rather decreased the levels in MLFF, MD1F, and MD3F where the fish was fermented for few days (1 – 3 days).

From Table 9, the results of Potassium content in MD1F (14.53mg to 7.45mg) and MLFF (14.43mg to 10.85mg) reduced about 50% and 24% decrease, while in MD3F (11.75mg to 10.94mg) recorded a marginable decreased after salt was added. Unexpectedly, sample MD5F (11.20mg to 13.07mg) experienced an increase in potassium content. This may be attributed to the number of days it was allowed to ferment, even though it was the sample that experienced the greatest amount of protein reduction. The addition of salt also contributed to the increase in potassium content from 76.57mg to 82.92mg as observed by El-Bassir et al., (2015) in their study on the mineral composition of cat fish.

From the results, sodium content in MD1F (4.96mg – 14.42mg), MD3F (5.28mg – 14.58), MD5F (5.76mg – 14.43mg), and MLFF (6.34mg – 13.70mg) showed a high increase. This was expected as salt was added to the samples after they had gone through the different fermentation periods. In the findings of El-Bassir et al., (2015), though a different fish (cat fish) was used in the study, when salt was added to the fresh fish the sodium content increased from 92.75mg to 403.81mg.

The Calcium content in MD1F (0.02mg – 0.03mg) increased slightly, whilst MD3F (0.04mg – 0.03mg) decreased slightly. Sample MD5F (0.003mg) and MLFF (0.03mg) maintained the calcium level even after salt was added. This indicated that the addition of salt had no effect on them (MD5F and MLFF) even though the samples were processed by different fermentation periods.

Though the magnesium content appeared to be minute, it was observed that some of the samples experienced marginable increase. It was observed that MD3F (0.005mg – 0.004mg) also decreased slightly. Also, it was recorded that samples MLFF (0.002mg – 0.003mg) and MFFD1 (0.003mg – 0.004mg) increased in magnesium content, whilst sample FFD5 (0.003mg) maintained its level of magnesium.

Generally, it was observed that the decomposition of the fish samples contributed to the loss of some mineral elements, which continued to reduce even after salt had been added (Lawrence et al., 2003). On the other hand, other samples increased in mineral elements after decomposition and the addition of salt. It is therefore necessary to handle fish appropriately by observing all conditions during preservation so that all nutrients, including mineral elements, are maintained or increased to make meals nutritious and promote healthy living (Okonta & Ekelemu, 2005).

Objective Two: The microbial counts of fresh fish, fish samples processed by different fermentation periods and the control.

In this section, the results of the microbial counts in the freshly caught fish, fermented fish samples processed by different fermentation periods and the locally processed sample are presented. Table 10 highlights the bacterial counts that were present in the fish samples as well as the locally fermented fish. The

types of bacterial counted included the Total Heterotrophic bacteria (TH), Total coliform (TC), Faecal coliform (FC), *Staphylococcus aureus* (S. au), *Salmonella spp* (S. spp), Anaerobic bacteria (AB) and *Escherichia coli* (E. coli).

From the result presented in Table 10, it is evident that there was no bacterial count in the fresh fish, as none of the samples tested positive for any of the organisms determined. This may imply that freshly harvested fish may be free from microbes. Literature, however show that the microbial count of the water body from which fish is harvested contributes to the microbial counts present in fresh fish (Gram & Huss, 2000). This implies that FHF is likely to bacteria have bacteria load if the water where the fish was harvested is contaminated and the opposite is the counts for microbial case, if otherwise. FHF showing no counts of bacteria supports the findings of Pal et al., (2016) and Topic-Popovic et al., (2010) and suggests that the freshly harvested fish was free from S*taphylococcus aureus* and other bacteria because it was handled properly. As expected, the bacterial counts increased considerably in the other samples during the fermentation period but later reduced after salt was added.

Table 10: *Bacterial counts in the fresh fish, fish samples processed by different fermentation periods, salted bottled fish and locally processed fermented fish*

Sample	Bacteria counts						
	T.H	T.C	F.C	S. au	S. spp	A.B	E. coli
FHF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D1F	510.00±0.0	623.33±0.55	34.67 ±0.53	573.33±0.16	15.33±0.93	176.67±0.59	100.00±1.65
MD1F	653.33±0.55	0.00	0.00	46.67±0.55	0.00	393.33±0.33	0.00
D3F	703.33±0.77	360.00±0.24	28.67 ±0.51	389.00±0.0	7.00±0.24	80.00±0.32	0.00
MD3F	186.67±0.63	0.00	0.00	36.67 ±0.78	0.00	35.33 ±0.03	0.00
D5F	206.67±0.78	40.00±0.20	9.00±0.00	10.33 ±0.58	0.00	103.33±1.81	0.00
MD5F	86.67±0.17	0.00	0.00	0.00	0.00	123.33±0.78	0.00
LFF	21239.00±0.17	2170±1.32	144±0.60	616.67±0.32	1719.67±0.59	2306.67±2.17	0.00
MLFF	493.33±0.55	0.00	0.00	513.67±0.51	0.00	0.00	0.00
SBF	226.67± 0.82	0.00	0.00	528.00±0.28	0.00	0.00	0.00

Source: Laboratory data (2019)

-Values are averages of triplicate determinations

For the D1F, the results showed a high count of bacteria as compared to the MD1F. The results showed mean values of microbial counts for heterotrophic bacteria (510.00), coliform (623.33), faecal coliform (34.67), S*taphylococcus aureus* (573.33), *Salmonella spp*. (15.33), anaerobic bacteria (176.67), and *E. coli* (100.00). For the MD1F, apart from the increase of heterotrophic bacteria (510.00 - 653.33) and anaerobic bacteria (176.67 - 393.33), there was a decrease in the count of S*taphylococcus aureus* (46.67), whilst all other bacteria counts recorded in D1F reduced to zero. These microbial counts give indications that the bacterial content began to increase rapidly when fermentation started and later decreased when salt was added to the samples. The rapid increase in bacteria in D1F could be due to fish spoilage since the fish was left for more than 12 hours without the application of any preservative method and environmental conditions (temperature, moisture and nutrients) provided by the fish itself (Burt, 2003). Also, the salt added to the fish served as a preservative thereby reducing the bacteria load (S*taphylococcus aureus*) and even killing some bacteria (total coliform, faecal coliform, S*almonella spp* and E. coli) entirely.

This supports Ray (2004) who found out that under a normal circumstance, individuals would preserve fish or food commodities through various techniques such as salting to keep commodities free from bacteria contamination, and reduce the growth and survival of bacteria and untimely spoilage due to the antimicrobial nature of salt. However, some bacteria (total heterotrophic bacteria and anaerobic bacteria) experienced increase even in the presence of salt. This may mean that there were some types of bacteria

(halophiles- they are bacteria that can survive and multiply very well in salty environments) in the two groups which survived well in MD1F even after the addition of salt (Slonczewski et al., 2008). It could also be inferred that the presence of multiple bacteria in the MD1F was due to the absence of oxygen. This was in agreement with the study of Begum, Roy and Yusuf (2015). Their study revealed that anaerobic bacteria tend to multiply and survive well in environments without oxygen. Some authors argue that the growth of microbes in the presence of salt may be due to the use of contaminated salt in the quest to preserve the fish as was the case of MD1F (Koffi-Nevry & Koussemon, 2012).

For sample D3F, the findings showed a higher increase in bacterial counts than that of the parallel matured fermented fish (MD3F). *E. coli* however did not record any load fermented fish and the matured fermented fish day 3. The bacterial counts for D3F registered lower load than those recorded for D1F, with the exception of heterotrophic bacteria which was 703.33. Likewise, MD3F recorded a decrease in the microbial counts for heterotrophic bacteria (703.33 - 186.6667), *Staphylococcus aureus* (389.00 - 36.6667), and anaerobic bacteria (80 - 35.3333). It was also observed that MD3F reduced in microbial count more than sample MD1F. This reduction may be attributed to the fact that bacteria attack fish rapidly at the onset of spoilage.

Scientifically, it has been argued that microbial growth and survival vary greatly and manifest in different ways. For instance, *Pseudomonas*, *Bacillus*, Coranebacterium, Acinetobacter, Shewanella, Moraxella, Flavobacterium, and Lactobacillus are found to survive well in cold environments (as low as 0^{o}C) while others survive well around 25^{o}C (Gram & Dalgaard, 2002). Gram and

Dalgaard also submitted that some bacteria such as Lactobacillus, yeast and moulds adapt to acid to survive and multiply. Again, the findings of Slonczewski et al., (2008) showed that some microbes grow and multiply well in concentrated salted fishes and other food items. This shows that, the variations in the microbial counts may be due to the environments in which the fish samples were kept.

Consequently, the fermented fish day 5 (D5F) experienced more reduction in the bacterial counts. The bacterial count in the D5F decreased more than that of D1F and D3F. Similarly, D5F and did not record for *E. coli* as observed in D3F. For *Salmonella spp* in D5F and MD5F, 0.00 was recorded. Also for MD5F, it was observed that all the bacteria tested recorded zero, except the bacteria counts for heterotrophic (86.6667) which reduced drastically and anaerobic bacteria (123.3333) which increased slightly.

This could imply that the bacteria replication in the MD5F was better controlled than the other samples, even though there was a drastic reduction in protein content (Table 6).

Additionally, the local fermented fish (LFF) recorded the highest counts of heterotrophic bacteria (21239.00), total coliform (2170), *Staphylococcus aureus* (616.67) and anaerobic bacteria (2306.67). The matured local fermented fish (MLFF) also recorded 0.00 for all bacteria except total heterotrophic bacteria (493.33) and *Staphylococcus aureus* (513.67) exhibited drastic reductions due to the addition of salt. The high bacteria counts in the LFF may be attributed to how the local producers handled the fish during the fermentation process. This also supports the study of Abbas and Saleh (2009). Their study

revealed that when fish is not handled hygienically, it may be contaminated with microorganisms and deteriorate.

SBF also recorded some bacteria counts even though salt was added immediately without allowing the fish to spoil. According to the results, most of the bacteria count was 0.00 except the total heterotrophic (226.67) and *Staphylococcus aureus* (528.00). The absence of bacteria were expected due to the fact that salt was added immediately to the sample and bottled without allowing it to go through decomposition (fermentation). This result also supports the study of some authors who indicated that salt has the potency of preserving food and making it free form bacteria by enhancing water absorption (Jay et al., 2005; Lawrence et al., 2003). On the contrary, the presence of bacteria (total heterotrophic and staphylococcus aureus) in the SBF may be attributed to the fact that the bacteria are salt-tolerant and thus can survive in salt concentrated environment (Slonczewski et al., 2008).

Generally, the findings of this study support the result of other authors who assert that, it is possible to obtain different results in bacterial counts even where the samples used in the fermentation process receive similar treatment (Lee et al., 2015; Lopetcharat & Park, 2002; Pombo et al., 2009). The nutritional composition, microbial counts and sensory properties of fermented fish products may also vary greatly according to the number of periods used as indicated by Mahulette et al., (2018). According to the results in Table 10, the microbial counts in the fermented fish samples varied greatly from day to day even though all the samples did not record any count their fresh state. Possibly, the difference in the microbial counts could be related to the number of days

used for the fermentation process. Additionally, the method of fermentation may have contributed to the growth and survival of microbes in the fish samples as the microbial count in the matured fermented fishes (salted) exhibited lower counts than that of fermented fishes (without salt) for the same number of days used for the fermentation (Mahulette et al., 2018).

Furthermore, studies have shown inadequate cooking of food as a common cause for foodborne illness (Feng & Bruhn, 2019). The presence of microorganisms such as *Staphylococcus aureus* and *Salmonella spp* in the fermented fish therefore makes it unsafe when the fish is not cooked thoroughly before consumption (Soriano, Blesa, Rico, Molto, & Manens, 2002). Also, fermented fish producers must strive to produce bacteria-free fermented fish to improve its quality (Anihouvi, Ayernor, Hounhouigan, & Sakyi-Dawson, 2006). The results also revealed that fermented fish can be invaded with bacteria as and when the environment is conducive for them. For instance harmful bacteria such as *E. coli* and *Salmonella spp*, when found in undercooked fermented fish could be a major contribution to the outbreak of foodborne illnesses (Hillers et al., 2003). It is therefore crucial for food vendors, cooks, and consumers of fermented fish to ensure that fermented fish is adequately cooked before it is used in the preparation of meals, especially '*Abom*' (a local vegetable sauce delicacy prepared in an earthenware bowl where the fermented fish in just grilled in an open fire for few seconds and added to the sauce and consumed). Aside this, it is argued that sauces, stews, soups, and pottages prepared with fermented fish must be heated thoroughly at the right temperature

in order to destroy any harmful bacteria that could be present to ensure food is safe for consumption (Slonczewski et al., 2008).

According to Medeiros et al., (2004), cross contamination could occur through the transfer of harmful bacteria from one source to the other. This could be from food commodities, kitchen equipment, food providers and consumers, where proper hygienic practices are not adhered, particularly when handling fermented fish. The findings of this study support this stance in view of the traces of bacteria of different counts found in fermented fish and this also makes it important to thoroughly wash kitchen equipment and tools used to cook food in order to prevent the transfer of bacteria from kitchen tools and equipment to food commodities and surfaces.

Generally, microorganisms have the potency of multiplying very quickly if the food, and for that matter, fermented fish is stored at room temperature. The findings of Elyass et al., (2015) and Johnson (1991) revealed that some bacteria such as *E. coli*, *Staphylococcus*, *Bacillus subtilis* and *Salmonella spp* were present in some selected fermented foods investigated and even caused food poisoning. Therefore, in order to prevent food contamination and further deterioration of fermented fish, adequate facilities should be available for heating, cooling, refrigerating, and freezing the fish (FAO, 2009). It is also essential to freeze fermented fish below 30°C and heat it above 60°C to prevent the growth of microorganisms and further decay. On the contrary, some types of microorganisms are able to withstand extreme temperatures and thereby grow and multiply below 5°C (Gram & Dalgaard, 2002), nonetheless, adequate heating is likely to kill most of them.

Objective Three: The sensory properties and consumer acceptability of fish samples processed by different fermentation periods, locally processed fermented fish (control) and salted bottled fish

Thirty panelists were used to evaluate the sensory properties of the matured fermented fish samples. The third research objective sought to evaluate the sensory properties as well as consumer acceptability of the fermented fish products processed by different fermentation periods and the control. In order to achieve this objective, the researcher collected data from a panel that evaluated the sensory properties and indicated their preferences for the matured fermented fish samples (MLFF, SBF, MD1F, MD3F, MD5F).

With regard to the raw matured fish samples, the panel assessed the appearance, colour and texture. However, in the case of the tomato sauce made from the same samples, flavour, taste and aftertaste were evaluated. Results obtained for the appearance of the matured fermented fish samples are presented in Table 11.

The raw fermented fish samples were evaluated to determine the differences in appearance of the samples. From the results presented in Table 11, it is evident majority (60%) of the respondents reported salted bottled fish (SBF) to have a dry appearance, followed by the matured local fermented fish (MLFF) with 50%. The matured fermented fish day 1 (MFFD1) and matured fermented fish day 3 (MD3F) recorded 30% each while matured fermented fish day 5 (MD5F) recording 3.3%.

Table 11: *The appearance of matured fermented cassava fish samples (N = 30)*

Sample	Appearance								Total	
	Dry		Moist		Fresh		Rotten			
	N	%	N	%	N	%	N	%	N	%
MLFF (control)	15	50.0	10	33.3	5	16.7	0	0.0	30	100.0
SBF	18	60.0	3	10.0	9	30.0	0	0.0	30	100.0
MD1F	9	30.0	7	23.3	14	46.7	0	0.0	30	100.0
MD3F	9	30.0	15	50.0	3	10.0	3	10.0	30	100.0
MD5F	1	3.3	9	30.0	1	3.3	19	63.3	30	100.0
Total	52	34.7	44	29.3	32	21.3	22	14.7	30	100

Source: Field data (2019)

Hence, most of the respondents indicated that the SBF (60%) and MLFF (50%) looked more 'dry' than the other samples. On the other hand, it was observed that majority (63.3%) of the respondents recorded MD5F as rotten with MD1F scoring the least (10%), while the other samples (SBF, MD1F and MLFF) recorded zero for that attribute. In relation to the 'fresh' appearance, none of the samples scored 50%.

The rational for assessing the appearance of the fermented fish samples is because, appearance plays a vital role in the acceptability of food (McClement, 2002). The assessment of this attribute was therefore deemed necessary due to the fact that appearance adds to the appealing nature of food product. From the table, it was observed that all the samples scored differently for appearance, even though some registered similar scores. The differences in scores may be associated with how the samples were processed and the number

of days the samples went through fermentation as observed by Martinsdottir (2002). Under normal circumstances, sample SBF and MLFF should have had 'dry' appearance due to how it was processed. In processing SBF, salt was added to the fresh fish sample soon after harvesting and bottled without going through any fermentation. This supports the study by El-Bassir et al., (2015) who found that the addition of salt can influence the moisture content of fish by reducing the water activity. Also, apart from the salt which played a role in making MLFF 'dry', the sample was wrapped in a brown paper after adding salt to continue the fermentation process. The paper could have aided in the absorption of the moisture, hence making the sample dry, although it went through 2 days of fermentation.

The fresh appearance of MD1F may be attributed to the number of days (1) the fish was fermented before adding salt. This record (46.7%) disagrees with the authors who stated that fish begins to deteriorate after 12 hours (Baird, 2000; Burt, 2003). It was observed that MD1F still remained fresh even after a day (24 hours) into fermentation. It can also be inferred that since the fish was bottled, it did not go through poor handling to accelerate spoilage (Bate & Bendall, 2010), therefore accounts for the loss of less proteins when the proximate composition was determined (Table 6). Similarly, 'moist' appearance was also expected in samples MD1F, MD3F and MD5F since they were bottled throughout the fermentation process. According to study, fresh fish usually begins to spoil when it is stored in unfavourable conditions after they have been harvested (Baird, 2000).

Conversely, sample MD5F recorded the highest score (63.3%) for 'rotten' appearance. This high score was expected because the fish was allowed to deteriorate for 5 days before adding salt. The deterioration of the fish turned the sample into a paste which made it impossible for the salt that was added to reduce the water capacity in the fish as stated by Lawrence et al. (2003) and El-Bassir et al., (2015). The finding was not surprising since it also recorded a very low protein as compared to the other samples (Tables 6 and 7).

Most importantly, it can be deduced from the results that samples MLFF and MD3F had similar appearance. This similarity in appearance is attributed to the number of days the fish samples were fermented (2 and 3 days respectively), since the difference in the days was just a day. Again, these samples (MLFF and MD3F) are likely to appeal to consumers who enjoy food with fermented fish since the fish samples do not appear rotten or dry and therefore meet consumers' perception of quality and wholesomeness (Alasalvar et al., 2011). However, the samples with 'dry' appearance can be used to prepare meal to serve as a main meal, and not necessarily a condiment.

The appearance of fish may not necessarily denote the colour and this study took a step further to evaluate the colour of the samples. Results obtained for colour of the fermented fish samples are presented in Table 12.

Table 12: *The colour of matured fermented cassava fish samples (N = 30)*

Sample	Colour				Total
	Brown	Dark-brown	Off-white	Grey	

	N	%	N	%	N	%	N	%	N	%
MLFF (control)	9	30.0	1	3.3	15	50.0	5	16.7	30	100.0
SBF	10	33.3	6	20.0	6	20.0	8	26.7	30	100.0
MD1F	2	6.7	1	3.3	22	73.3	5	16.7	30	100.0
MD3F	3	10.0	3	10.0	14	46.7	10	33.3	30	100.0
MD5F	1	3.3	3	10.0	10	33.3	16	53.3	30	100.0
Total	25	16.7	14	9.3	67	44.7	44	29.3	150	100.0

Source: Field data (2019)

The colour of all the fermented fish samples was assessed in their raw state. Assessing the fermented fish samples in their raw state was crucial since fermented fish is bought in its raw state before cooking it. From the results presented in Table 12, it can be deduced that all the samples recorded different scores for specific colour due to the different processes and fermentation periods used. The colour with the highest score is 'off-white'. Samples that scored 50% and above are MD1F (73.3%), MLFF (50%), while MD3F (46.7%), MD5F (33.3%) and SBF (20%) registered below 50% scores. The samples possessing an 'off-white' colour were expected because cassava croaker is a white fish and is therefore very important to maintain its original colour or possess a colour close to that after it has been preserved. Assessing the colour of fermented fish is subjective since most individuals may have different ways of perceiving colours. However, in sensory evaluation, conclusion is based on what majority of the respondents' reported. In view of that, it is accepted that most of the fermented fish samples possessed off- white colour.

According to the table, the sample MD1F reported the highest score (73.3%) of 'off white' colour. This evidence may be attributed to the fact that the fish was allowed to ferment for a day before adding the salt, therefore maintaining its original colour. Likewise, sample MLFF registering the second highest (50%) for colour was not expected as the local producers used brown paper to wrap it in order to remove the moisture during the fermentation process, however, it turned out to have an 'off- white' colour. Sample MD3F also recorded 46.7% 'off white' even though the fish was fermented for several days (3 days), but maintained its original colour of the fish. Sample SBF should have had an off- white colour but about one-third (33.3%) of the respondents indicated that it had a 'brown' colour. The brown colour possessed by SBF may be attributed to the herbs (bay leaves, rosemary and cloves) added to the fish during processing. Also sample MD5F exhibiting a 'grey' colour as indicated by 53.3% of respondents was expected since the fish was left to decompose for five days before adding salt (Baird, 2000). In most cases, food loses its original colour as a result of spoilage, therefore food must be handled well to maintain its original colour.

Generally, when foods are in their original colour, consumers are able to assess its quality. Hence, any food that loses its original colour, becomes questionable; that is whether it is spoilt, overcooked, over processed or mishandled, as indicated by Bayarri et al., (2001). Consequently, the conservation of a food's original colour is very essential to consumers as a proof of quality and wholesomeness as indicated by Sharifian et al., (2011). Generally, in the quest of preserving food to last for a longer period of time, some food

tend to lose their original colour which may not always be a reduction in quality or wholesomeness. In this study however, despite the fact that all the fish samples were processed by different fermentation periods, the colour of most fish samples did not change, thereby maintaining their original colour (Okonta & Ekelemu, 2005).

The texture of food is another important attribute to be considered when choosing fermented fish for food preparation. This is because texture is one of the attributes that determines the quality of food to be used by consumers. Panelist was required to evaluate the texture of the fermented fish processed by different fermentation periods by pressing the raw fermented fish samples to assess the texture attribute. The result for the texture of the fermented fish samples are presented in Table 13.

From the results presented in table 13, majority of the respondents recorded that sample SBF (66.6%) and MD1F (76.7%) were hard. Also, majority of the respondents indicated that sample MLFF (67%) and MD3F (70%) had soft textures, while sample MD5F (93.3%) was reported to be very soft. The results indicate that there were some similarities in the texture of some pair of samples (MD3F and MLFF). This may be attributed to the fermentation periods used and how the fish was processed.

Table 13: *The texture of matured fermented cassava fish samples (N = 30)*

Sample	Texture								Total	
	Hard		Flaky		Soft		Very soft			
	N	%	N	%	N	%	N	%	N	%
MLFF	5	16.7	5	16.7	20	66.6	0	0.0	30	100.0

(control)										
SBF	20	66.6	5	16.7	5	16.7	0	0.0	30	100.0
MD1F	23	76.7	6	20.0	1	3.3	0	0.0	30	100.0
MD3F	3	10.0	5	16.7	21	70.0	1	3.3	30	100.0
MD5F	0	0.0	0	0.0	2	6.7	28	93.3	30	100.0
Total	51	34.0	21	14.0	49	32.7	29	19.3	150	100.0

Source: Field data (2019)

Samples SBF and MD1F exhibiting a 'hard' texture may be attributed to the early addition of salt to the fish during the fermentation process. Unlike the other fermented fish samples which were allowed some time before the addition of salt for SBF, salt was added soon after harvesting. The immediate addition of salt to that sample could have reduced the water content and therefore made it have a hard texture (Lawrence et al., 2003). Apart from the addition of salt at the early stage of fermentation, the 'hard' texture of MD1F may also be associated with the few hours (1 day) the fish was allowed to decompose. Hence, the fish was still hard when salt was added. This may also account for the reason why it exhibited 'fresh' appearance.

Furthermore, sample MLFF and MD3F were reported to have a soft texture. This similarity may be attributed to their fermentation periods (2 days and 3 days respectively), even though they were processed in differently; on the other hand, while sample MLFF was wrapped in brown paper after the addition of salt, sample MD3F was bottled throughout the fermentation process.

Sample MD5F had the highest score (93.3%) of possessing a 'very soft' texture. This explains the result obtained for appearance (Table 11). The 'rotten'

appearance and 'very soft' texture of sample MD5F may be associated with the fermentation period adopted. The fish sample was allowed to deteriorate for 5 days, after which the salt was added. Studies have shown that when food becomes rotten, it gives a very soft texture and makes it unwholesome for consumption (FAO, 2009). It is assumed that if the salt was added early as done in the other samples (SBF and MD1F), it would have reduced the water capacity, and made MD5F a bit hard (El-Bassir et al., 2015). On the contrary, the salt's potency of reducing the water capacity of sample MD5F was not achieved also because after the fifth day, the fish sample turned into a paste making it very difficult for the salt to reduce its water capacity. It may be assumed that the 'rotten' and 'very soft' nature of MD5F may be a breeding environment for bacteria as indicated by Pal (2010). However, it turned out to have less bacteria counts as compared to the other samples (Table 10).

Even though some fermented fish samples had similar texture, the change in texture was linked to the different fermentation periods of the samples which is in concord with the studies conducted by Lee et al., (2015) and Pombo et al., (2009). Moreover, the changes in texture of the various fermented fish sample may also be associated with the amount of fat the fish lost during the fermentation process, which support the study by Pszczola (2000). In the study conducted by Marangoni and Narine (2002), the authors revealed that chemical composition such as proteins, moisture and minerals play vital roles in determining the texture of fish. Since most of the samples lost some of the aforementioned nutritional composition, the difference in texture was expected.

Generally, the fermented fish sold on the market (MLFF) has a soft texture due to the number of days it is fermented. This explains why sample MD3F was similar to the MLFF in terms of texture. It also implicate that when sample MD3F is placed on the market, it will be patronized by consumers since it has a similar texture as MLFF. Additionally, this may make the patronage of sample SBF and MD1F very difficult when placed on the market, since the texture of the samples is far from the MLFF (control). Consequently, it may be difficult for consumers to accept and use as condiment. Nonetheless, with the 'hard' texture of MD1F and SBF, they could be used in the preparation of food to create variety in their dishes because it may not break or melt in the soup or stew. Also, due to the texture of MD5F, when placed on the market, it will be very difficult for consumers to patronize since the sample turned into paste and thus may appear unwholesome, unsafe and less appealing to consumers as stated by FAO (2009).

Sample	Flavour/Aroma								Total	
	Mild		Moderate		Moderate strong		Very strong			
	N	%	N	%	N	%	N	%	N	%
MLFF (control)	3	10.0	10	33.3	16	53.4	1	3.3	30	100.0
SBF	20	66.7	9	30.0	1	3.3	0	0.0	30	100.0

MD1F	9	30.0	19	63.3	2	6.7	0	0.0	30	100.0
MD3F	1	3.3	8	26.7	18	60.0	3	10.0	30	100.0
MD5F	0	0.0	1	3.3	5	16.7	24	80.0	30	100.0
Total	33	22.0	47	31.3	42	28.0	28	18.7	150	100.0

Table 14: *The flavour of matured fermented cassava fish samples (N = 30)*

Source: Field data (2019)

After evaluating the raw matured fermented fish samples, the panel was made to assess the flavour, taste and aftertaste of tomato sauce prepared from the same matured fermented fish samples. Table 14 presents the result obtained for the flavour of tomato sauces made from the fish samples. With regards to the flavour of sauces, MLFF (53.4%) and MD3F (60%) recorded high scores for moderate strong flavour. Sauce SBF (66.7%) was recorded to have a mild flavour while sauce MD1F (63.3%) and MD5F (80%) recorded a moderate flavour and very strong flavour respectively. From the results presented in Table 14, it can be deduced that the change in flavour in the different fermented fish samples may be specifically associated with the different fermentation periods that were used to process them. This supports the study of Jittrepotch et al., (2015) which revealed that fish samples processed by different fermentation periods possessed different flavours.

The strong flavour of sauce MLFF and MD3F may be associated with the fermentation periods. The samples were allowed to ferment for two (MLFF) and three (MD3F) days respectively. During fermentation, the fish decomposed and biogenic amines were released by food spoilage bacteria, giving off undesirable smell which, generated the strong flavour the sauce possessed (Dalgaard, Madsen, Samieian, & Emborg, 2006). The results also support the

study of Abbey, Hondari-Okae, and Osei-Yaw (1994) who indicated that fermented fish with strong flavour are ideal for use as condiments to induce the appetite-stimulating aroma of food. On the contrary, Al-Jufisome and Opara (2006); Gram and Dalgaard (2002) debunked that the stinking aroma of fermented fish attracts bacteria and therefore makes the wholesomeness of such fish questionable. Even though sample MLFF and MD3F generated a very unpleasant smell in their raw state, they developed strong stimulating flavour when they were used in a sauce.

Additionally, the mild flavour reported for the sauce SBF was expected due to how the sample was processed as salt was added soon after the fish was harvested and bottled, unlike the other fish samples which were allowed to ferment before adding the salt. Usually, the number of days used in fermentation makes the fish stinks (due to spoilage) which results in the characteristic flavour in a condiment.

The sauce MD1F (63.3%) also recorded a moderate flavour and this may be as a result of the fish being fermented for one day before adding salt. This also support the study by Baird (2000) that if a fish sample is allowed for 24 hours without freezing or smoking, it goes through some sort of decomposition, thus making the sample have a moderate stinking property and producing a moderate flavour when used in cooking as was in the case of MD1F.

Furthermore, the very 'strong flavour' recorded for sauce MD5F (80%) was associated with the number of days (5) the fish was fermented before salt was added. It was observed after the fifth day that the fish had greatly deteriorated and appeared rotten. The sample also possessed an extremely

stinking smell. Therefore, the addition of salt to the sample at that point could not reduce the stench after the fish had matured. This resulted in the high score (80%) of a 'very strong' flavour produced by the tomato sauce prepared from the sample.

Usually, fermented fish should possesses a flavour that can impact stimulating-appetite to foods prepared from it, since it is used as condiment for stews, soups and sauces. Nonetheless, the flavour must be acceptable to consumers. In this regard, samples MLFF and MD3F could be suggested as ideal fermented fish (condiment) since their flavour is strong. The other samples however are not likely to receive patronage since SBF and MD1F may produce a flavour that is too mild for a condiment while MD5F may produce a very strong flavour. Even though, consumers desire a strong flavour of a condiment, they are not likely to accept those that have 'a very strong' flavour to avoid the food smelling all over the hands after eating.

Table 15: *The taste of matured fermented cassava fish samples (N = 30)*

Sample	Taste								Total	
	Normal		Savoury		Pungent		Sharp pungent			
	N	%	N	%	N	%	N	%	N	%
MLFF (control)	4	13.3	8	26.7	16	53.3	2	6.7	30	100.0
SBF	21	70.0	7	23.3	2	6.7	0	0.0	30	100.0

MD1F	8	26.7	17	56.6	5	16.7	0	0.0	30	100.0
MD3F	2	6.7	7	23.3	18	60.0	3	10.0	30	100.0
MD5F	0	0.0	1	3.3	5	16.7	24	80.0	30	100.0
Total	35	23.3	40	26.7	46	30.7	29	19.3	150	100.0

Source: Field data (2019)

According to the Table 15, it is an evident majority of respondents reported sauce MD3F (60%) and MLFF (53.3%) to have a 'pungent' taste. In relation to sauce SBF (70%), majority of the respondents reported that it had a 'normal' taste, while sauce MD1F (56.6%) recorded a 'umami' (savoury) taste with the greatest proportion (80%) of respondents reporting a 'sharp pungent' taste for sauce MD5F

From the results presented in Table 15, it can be deduced that sauce MLFF and MD3F had similar taste as almost close to equal proportions of the respondents indicated that both sauces had a 'pungent' taste. Both sauces having a 'pungent' taste may be linked to the flavour each sauce possessed. The pungent taste was expected because in the evaluation of the flavour of the sauces of matured fermented fish samples, majority of the respondents reported the two sauces had similar flavour (Table 14). This confirms the study of Small (2008) which indicated that the flavour of food influences its taste and vice versa

Moreover, sauce SBF tasted 'normal' because the fish sample did not go through any form of fermentation (deterioration) to have developed the characteristic stinking flavour. Also, sauce MD1F recording a 'umami' (savoury) taste may be associated with the 24 hour fermentation processing period. Though the fish did not ferment for long there was some amount of

deterioration within the 24 hours (Baird, 2000) and therefore produced a 'moderate flavour' and impacted a 'savoury taste' to sauce. Furthermore, sauce MD5F producing a 'sharp pungent' taste may be associated with the long number of days used in fermenting the fish. The fish was fermented for five days before it was salted, and after the maturation date, the sample appeared rotten with extremely stinking flavour, which may account for the 'sharp pungent' taste possessed by the sauce prepared from the fish sample.

Normally, fermented fish used as condiment must possess an appetite-stimulating aroma and taste to make eating food prepared from it enjoyable (Abbey et al., 1994). This means that preparing food with samples MLFF and MD3F may produce the stimulating aroma and taste a condiment must possess since the sauces prepared from the two samples had almost the same taste and flavour.

Table 16: *The aftertaste of matured fermented cassava fish samples (N = 30)*

Sample	Aftertaste								Total	
	No aftertaste		Mild pungent		Moderate pungent		Strong pungent			
	N	%	N	%	N	%	N	%	N	%
MLFF (control)	0	0.0	5	16.7	23	76.6	2	6.7	30	100.0
SBF	22	73.3	8	26.7	0	0.0	0	0.0	30	100.0
MD1F	7	23.3	18	60.0	5	16.7	0	0.0	30	100.0
MD3F	2	6.7	4	13.3	21	70.0	3	10.0	30	100.0
MD5F	0	0.0	2	6.7	5	16.7	23	76.6	30	100.0
Total	31	20.7	37	24.7	54	36.0	28	18.7	150	100.0

Source: Field data (2019)

The aftertaste of the sauces of matured fermented fish processed by different periods was assessed. Aftertaste is explained as the taste intensity of a food perceived after food has been swallowed.

From the results presented in Table 16, majority of the respondents reported sauce MLFF (76.6%) and MD3F (70%) to have a moderate pungent aftertaste. This result may be associated with the taste of the sauces and may be concluded that since the sauces (MLFF and MD3F) had pungent taste, they left an aftertaste that was moderate pungent. The similarity in the aftertaste of the sauces may also be related to the number of days of fermentation (2 and 3 days respectively). The number of days used to process the two samples could have influenced a similar flavour in the two sauces resulting in the samples also exhibiting similar aftertaste.

From the result presented for sauce MD1F, majority of the respondents recorded a 'mild pungent' aftertaste. This revelation may also be associated with the fact that the fish was fermented a day before salt was added, hence, the fish underwent some sort of decomposition (Burt, 2003), therefore impacting a 'mild pungent' aftertaste after swallowing. In relation to sauce SBF, it was reported to have 'no aftertaste'. This could also be linked to the way the sample was processed. The sample was not allowed to undergo any form of fermentation. Salt was added to the fish and bottled immediately with bay leave and cloves. Thus, there was no decomposition of any sort to have influenced the aftertaste.

Furthermore, in evaluating the aftertaste of sauce MD5F, majority of the respondents recorded the sauce to have a strong pungent aftertaste.

This strong aftertaste was expected and also may be said to be associated with the long fermentation period (5 days) which allow the fish to deteriorate greatly and stink. This resulted in the sauce made from sample MD5F to exhibit a 'very strong' flavour, 'sharp pungent taste' and a 'strong pungent aftertaste'.

Table 17: *The overall acceptability of matured fermented cassava fish sauces (N = 30).*

Sample	Overall Acceptability								Total	
	Not good		Good		Very good		Excellent			
	N	%	N	%	N	%	N	%	N	%
MLFF (control)	0	0.0	3	10.0	20	66.7	7	23.3	30	100.0
SBF	22	73.4	7	23.3	1	3.3	0	0.0	30	100.0
MD1F	6	20.0	15	50.0	7	23.3	2	6.7	30	100.0
MD3F	0	0.0	2	6.7	23	76.6	5	16.7	30	100.0
MD5F	18	60.0	9	30.0	3	10.0	0	0.0	30	100.
Total	46	30.7	36	24.0	54	36.0	14	9.3	150	100.0

Source: Field data (2019)

After evaluating the sensory properties of the fermented fish samples processed by different periods, their overall acceptability was also evaluated. This overall acceptability determined the extent to which these matured fermented fish samples were accepted by consumers. With regard to the overall acceptability of samples, majority (66.7%) of the respondents reported that sauce MLFF was 'very good' with slightly below one-third (23.3%) reporting it to be 'excellent'. Similarly, it is evident from the table that majority (76.6%) of respondents reported sample MD3F as 'very good' with few of them (16.7%) recording that it was 'excellent'. The results presented in the table also indicates that majority (73.4%) of the respondents reported that sample SBF was 'not

good' to be used as fermented fish (condiment), while 50% of them also recorded 'good' for sample MD1F. Also, with regards to sample MD5F, majority (60%) reported it to be 'not good'.

The results presented in Table 17 indicates that the fermented fish sample MD3F was the most accepted fermented fish sample probably because it had the sensory attributes most preferred by respondents (consumers). Moreover, it can be concluded that MD3F was the most preferred sample because it had attributes similar to the MLFF, which consumers are used to. Even though sample SBF and MD1F were not accepted as fermented fish, consumers may use those fish samples for stews, sauces and soups as the main protein sauce and not as condiment due to their mild flavour and hard texture. Sample MD5F was not accepted by respondents due to its extreme 'strong pungent flavour', 'sharp taste' and 'strong pungent aftertaste' it possessed.

Hypothesis

H_0: There is no statistically significant difference in the nutritional composition of fresh fish, fish samples processed by different fermentation periods and the control

Hypotheses were tested to ascertain whether there were significant differences in the quality attributes of fermented fish samples processed by different fermentation periods. The ANOVA results on the nutritional composition of samples are presented in Table 18.

According to the results presented in the table, there were statistically significant differences ($p<.05$) in the nutritional composition of all samples with the exception of calcium (2 tailed), as values were lower than the α-value of

0.05, suggesting that there is significant differences in the nutritional composition (dry matter, moisture, ash, protein, fats and oils, phosphorus, potassium, sodium and magnesium content) of both the fermented fish and matured samples processed by different fermentation periods and that of the matured samples (*FHF, LFF, SBF, D1F, D3F, D5F and MLFF, MD1F, MD3F, MD5F*). As a result, the null hypothesis was rejected.

The mean square for calcium was 0.582 with a df of 9 and a significance of 0.871. The null hypothesis failed to be rejected on the basis that the p-value of 0.871 was more than the α-value of 0.05, implying that there was no statistically significant difference in the calcium content among samples processed by different fermentation periods.

Table 18: *Result of ANOVA on the nutritional composition of samples*

NUTRITIONAL COMPOSITION OF FISH SAMPLES		Sum of Squares	DF	Mean Square	F	Sig.
	Between Groups	464.042	2	51.160	16.166	.000
DM	Within Groups	19.065	20	.308		
	Total	483.109	23			
	Between Groups	464.042	3	51.160	16.166	.000
MOISTURE	Within Groups	19.065	20	.308		
	Total	483.109	23			
	Between Groups	507.126	3	56.084	34.040	.000
ASH	Within Groups	10.179	20	.164		
	Total	517.132	23			
	Between Groups	1344.487	3	149.088	5.143	.000
PROTEIN	Within Groups	167.087	20	2.695		
	Total	1511.174	23			
	Between Groups	1.191	3	.132	2.197	.000
FAT/OIL	Within Groups	.374	20	.006		
	Total	1.165	23			
	Between Groups	2282.306	3	2535.583	2.973	.005
Phosphorus	Within Groups	5287.185	20	8528.127		
	Total	7570.344	23			
	Between Groups	3957.168	3	4397.140	5.297	.000
Potassium	Within Groups	5147.110	20	8302.486		
	Total	9105.178	23			
	Between Groups	1378.160	3	1531.173	301.914	.000
Sodium	Within Groups	3144.098	20	5072.093		
	Total	1409.160	23			
	Between Groups	.0052	3	.0058	.497	.871
Calcium	Within Groups	.762	20	.117		
	Total	.786	23			
	Between Groups	.0023	3	.002	3.020	.005
Magnesium	Within Groups	.0053	20	.009		
	Total	.0076	23			

Source: Laboratory data (2019)

H_0: There is no statistically significant difference among the microbial counts of the fresh fish, fish samples processed by different fermentation periods and the control

The ANOVA results obtained in testing hypothesis 2 on the bacterial count of fermented fish samples are presented in Table 19.

Table 19 presents the results of ANOVA test on samples (*FHF, LFF, SBF, D1F, D3F, D5F and MLFF, MD1F, MD3F, MD5F*) in terms of their bacterial count. From the table, there were statistically significant differences ($p<.05$) in the bacterial count of all samples with exception of E. coli (2 tailed) as values were lower than the α-value of 0.05. Thus, the null hypothesis that there is no statistically significant difference in the bacterial count of samples is rejected. The alternate hypothesis that there is statistically significant differences among the count of bacteria (that total Heterotrophic bacteria, total Coliform, Fecal coliform, *Staphylococcus aureus*, *Salmonella spp*. and Anaerobic bacteria) in the fish samples processed by different fermentation periods (*FHF, LFF, SBF, D1F, D3F, D5F and MLFF, MD1F, MD3F, MD5F*) failed to be rejected. The mean square for E. coli was 0.136 with a df of 2 and a significance of 0.873. In view of that the null hypothesis failed to be rejected on the basis that the p-value of 0.873 was more than α-value of 0.05. This implies that there was no statistically significant difference in the loads of E. coli of the fish samples processed by different fermentation periods.

Table 19: *Result of ANOVA on the bacterial count of samples*

Microorganisms	Samples	Df	Mean	F	Sig.
Total Heterotrophic Bacteria	FHF	2	.00	9.950	.000
	MD1F		653.33		
	MD3F		186.67		
	MD5F		86.67		
	MLFF		493.33		
	SBF		226.67		
Total Coliform	FHF	2	.00	20.587	.873
	MD1F		.00		
	MD3F		.00		
	MD5F		.00		
	MLFF		.00		
	SBF		.00		
Faecal Coliform	FHF	2	.00	14.515	.873
	MD1F		.00		
	MD3F		.00		
	MD5F		.00		
	MLFF		.00		
	SBF		.00		
Staphylococcus aureus	FHF	2	.00	39.184	.000
	MD1F		46.67		
	MD3F		36.67		
	MD5F		.00		
	MLFF		.00		
	SBF		.00		
Salmonella sp	FHF	2	.00	30.177	.873
	MD1F		.00		
	MD3F		.00		
	MD5F		.00		
	MLFF		.00		
	SBF		.00		
Aerobic Bacteria	FHF	2	.00	17.044	.000
	MD1F		393.33		
	MD3F		35.33		
	MD5F		123.33		
	MLFF		.00		
	SBF		.00		
E. coli	FHF	2	.00	0.136	.873
	MD1F		.00		
	MD3F		.00		
	MD5F		.00		
	MLFF		.00		
	SBF		.00		

Source: Laboratory data (2019)

H_0: There is no statistically significant difference among the sensory properties and acceptability of fish samples processed by different fermentation periods and the control

The results of Chi- Square test on the appearance of fish samples are presented in Table 20.

Table 20: *Result of Chi- Square test on the appearance of fish samples processed by different fermentation periods and the control*

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	106.319[a]	12	.000
Likelihood Ratio	103.708	12	.000
Linear-by-Linear Association	38.521	1	.000
N of Valid Cases	150		

Source: Field data (2019)

As shown in the table, there were significant differences ($p<.05$) in the appearance of all samples (2 tailed). This is because values were lower than the α-value of 0.05, which led to the rejection of the null hypothesis. The implication is that there is statistically significant difference between the appearance of fish samples processed by different fermentation periods (SBF, MD1F, MD3F, MD5F) and the control (MLFF).

Table 21 presents the result of Chi- Square test on the colour samples (SBF, MLFF, MD1F, MD3F and MD5F). From the table, there were significant differences ($p<.05$) in the colour of all samples (2 tailed), because values were lower than the α-value of 0.05, and for that reason, the null hypothesis that there was no statistically significant difference in the colour of the fish samples processed by different fermentation periods and the control was rejected.

Table 21: *Result of Chi- Square test on the colour of fish samples processed by different fermentation periods and the control*

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	34.993[a]	12	.000
Likelihood Ratio	35.873	12	.000
Linear-by-Linear Association	13.014	1	.000
N of Valid Cases	150		

Source: Field data (2019)

The alternate hypothesis that there is statistically significant difference between the colour of fish samples processed by different fermentation period (SBF, MD1F, MD3F, MD5F) and the control (MLFF) failed to be rejected.

Table 22 presents the result of Chi- Square test on samples in terms of their texture. As can be gathered from the table above, there were statistically significant difference ($p<.05$) in the texture of all samples (2 tailed).

Table 22: *Result of Chi- Square test on the texture of fish samples processed by different fermentation periods and the control*

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	80.730[a]	12	.000
Likelihood Ratio	95.990	12	.000
Linear-by-Linear Association	36.334	1	.000
N of Valid Cases	150		

Source: Field data (2019)

All values were lower than the α-value of 0.05, which lead to the rejection of the null hypothesis. Thus, the alternate hypothesis that there is statistically significant difference among the texture of fish samples processed by different fermentation period (SBF, MD1F, MD3F, MD5F) and the control (MLFF) failed to be rejected.

Table 23: *Result of Chi- Square test on the flavour of fish samples processed by different fermentation periods and the control*

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	70.739[a]	12	.000
Likelihood Ratio	73.105	12	.000
Linear-by-Linear Association	49.705	1	.000
N of Valid Cases	150		

Source: Field data (2019)

Table 23 presents the result of Chi- Square test on the flavour of fish samples (SBF, MLFF, MD1F, MD3F, MD5F). From the table above, there is statistically significant difference ($p<.05$) in the flavour of all samples (2 tailed). It can be observed that all values are lower than the α-value of 0.05, and so the null hypothesis that there is no statistically significant difference among the flavour of fish samples processed by different fermentation periods and the control was rejected, while the alternate hypothesis that there is statistically significant difference among the flavour of fish samples processed by different fermentation period (SBF, MD1F, MD3F, MD5F) and the control (MLFF) failed to be rejected.

Table 24: *Result of Chi- Square test on the taste of fish samples processed by different fermentation periods and the control*

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	78.293[a]	12	.000
Likelihood Ratio	75.487	12	.000
Linear-by-Linear Association	50.414	1	.000
N of Valid Cases	150		

Source: Field data (2019)

Table 24 presents the result of Chi- Square test of samples (SBF, MLFF, MD1F, MD3F, MD5F) in terms of their taste. As shown in the table above, there was statistically significant difference ($p<.05$) in the taste of all samples (2 tailed), as all values were lower than the α-value of 0.05, indicating that the null hypothesis that there is no statistically significant difference among the taste of the fish samples processed by different fermentation periods and the control was rejected. This implies that there is statistically significant difference between the taste of fish samples processed by different fermentation periods (SBF, MD1F, MD3F, MD5F) and the control (MLFF). The alternate hypothesis that there is statistically significant difference among the taste of the fish samples, therefore, failed to be rejected.

Table 25 presents the result of Chi- Square test on samples (SBF, MLFF, MD1F, MD3F, MD5F) in terms of their aftertaste. As portrayed in the table above, there were statistically significant difference ($p<.05$) in the aftertaste of all samples (2 tailed).

Table 25: *Result of Chi- Square test on the aftertaste of fish samples processed by different fermentation periods and the control*

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	50.807[a]	12	.000
Likelihood Ratio	51.232	12	.000
Linear-by-Linear Association	31.452	1	.000
N of Valid Cases	150		

Source: Field data (2019)

As may be observed from the table, all values were lower than the α-value of 0.05, implying that the null hypothesis was rejected. As a result, the alternate hypothesis that there is statistically significant difference among the aftertaste of fish samples processed by different fermentation periods (SBF, MD1F, MD3F, MD5F) and the control (MLFF), failed to be rejected.

Table 26 presents the result of Chi- Square test on samples (SBF, MLFF, MD1F, MD3F, MD5F) with regards to their overall acceptability. According to the results presented in the table, there were significant differences ($p<.05$) in the overall acceptability of all samples (2 tailed).

Table 26: *Result of Chi- Square test on the overall acceptability of fish samples processed by different fermentation periods and the control*

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	45.915[a]	12	.000
Likelihood Ratio	41.635	12	.000
Linear-by-Linear Association	6.602	1	.000
N of Valid Cases	150		

Source: Field data (2019)

The values obtained were lower than the α-value of 0.05. In view of that the null hypothesis that there is no statistically significant difference among the overall acceptability of fish samples processed by different fermentation periods and the control was rejected. The alternate hypothesis that there is statistically significant difference among the overall acceptability of fish samples processed by different fermentation periods (SBF, MD1F, MD3F, MD5F) and the control (MLFF) failed to be rejected.

Chapter Summary

In this chapter, the researcher presented and discussed the results on the fresh fish, fish samples processed by different fermentation periods and the control from the chemical and microbiological analyses conducted. The results helped in determining the nutritional composition and assess the bacterial count of the fish samples. The chapter also presented and discussed the results on the sensory properties and consumer acceptability of the fish samples. The findings were supported by the work of other researchers who have investigated on the quality attributes of fresh fish and fermented fish products.

The major key finding of the results was that the period of fermentation has effect on the quality attributes of fermented fish. Generally, it was observed that the decomposition of the fish samples contributed to the loss of some vital nutrients (proteins; from 76.63% to 42.95% and fat; from 2.85% to 1.98%) in the fish, which continued to reduce even after salt was added to the samples. On the other hand, other samples increased in nutrient (mineral elements) after

decomposition and the addition of salt. From the results obtained on the nutritional composition of fermented fish samples, it is evident that in the quest to preserve fish using the fermentation method, some vital nutrients (protein and fat) are likely to reduce.

According to the results discussed, the bacterial count in the fermented fish samples varied greatly from day to day even though all the samples did not record any count in their fresh state. It was also indicated that sample LFF/MLFF recorded the highest bacteria count, while sample D5F/MD5F recorded the least. Possibly, the difference in the microbial counts could be related to the number of days used for the fermentation process. It was also observed that the bacterial count in the matured fermented fish samples (salted) exhibited lower counts than that of the fermented samples (without salt). This observation may be associated with the salt added to the fish samples after they have been fermented.

The study similarly indicated the sensory properties and the acceptability of the fish samples processed by different fermentation periods and the control. It was shown that the sample of fish fermented for three days (MD3F) had a comparable sensory attributes and consumer acceptability with the control (MLFF).

Hypotheses were also tested in this study to find out if there are statistically significant differences in the quality attributes of fish samples processed by different fermentation periods and the control. The results showed

that there are statistically significant difference in the quality attributes of fish samples processed by different fermentation periods and the control, thus, the alternate hypothesis failed to be rejected. This therefore led the null hypothesis that there are no statistically significant differences in the fish samples processed by different fermentation periods and the control to be rejected.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In this chapter, the summary, key findings, conclusions, and recommendations as well as suggestions for further studies are presented. The purpose of the study was to conduct chemical and microbiological analyses on fishes processed by different fermentation periods to determine their nutritional composition and assess the microbial quality. The study also assessed their sensory properties and consumer acceptability.

Summary

Freshly harvested fish (Cassava croakers) were fermented by different fermentation periods (D1F, D3F and D5F), with an additional sample that did not receive any treatment (SBF). The fish samples were compared with locally fermented fish (LFF) which were collected at the Elmina fermented fish outlet. The quality attributes of the fish samples were assessed with respect to their nutritional composition, bacterial counts and sensory properties.

The main purpose of this study was to determine the nutritional composition and bacteriological quality of fish samples processed by different fermentation periods and also assesses their sensory properties.

Factorial design (Pre-test – Post-test) was the research design used to allow the researcher to investigate the effect of each fermentation period on the quality attributes of the fish samples. The fish fermented by different periods were subjected to chemical analysis in order to provide nutritional information to

consumers. The analysis showed reduced nutrients, especially protein in the fermented fish samples. Microbiological analysis was also conducted to provide information on the varying bacterial counts in the different fermented fish samples. Additionally, sensory evaluation was done to evaluate the sensory properties and acceptability of fish samples in terms of appearance, colour, texture, flavour, taste, and aftertaste. Hypotheses were formulated to test whether there were any significant differences that existed among SBF, the fish process by the different fermentation periods (D1F, D3F & D5F) and the control (LFF). SPSS version 20 for Windows was used to analyse the data collected. Frequencies, percentage, mean, standard deviation, chi- square and ANOVA were the statistical tools used to analyse the data.

Key Findings

1. The fish samples were allowed to ferment for varied number of days before salt was added to continue the fermentation process. Due to decomposition of the fish, most nutrients depreciated. It was also observed that the longer the fermentation period, the more the nutrients reduced (proteins; from 76.63% to 42.95% and fat; from 2.85% to 1.98%).
2. All the fermented fish samples processed by different fermentation periods and that of local fermented fish had varied levels of nutrients (protein and fat). It became evident that the MLFF had more proteins than the samples fermented by different fermentation periods and its moisture content was

also lower than MD3F and MD5F, while SBF and MD1F had the least moisture content.

3. Generally, it was observed that the decomposition of the fish samples contributed to the loss of some mineral elements, which continued to reduce even after salt was added. On the other hand, other samples increased in mineral elements after decomposition and the addition of salt.
4. Even though salt played a role in reducing the water capacity of the samples, it depreciated the protein content in the fish samples (refer to p73 and 77; Table 6 and 7).
5. Bacteria were found in the different samples of fermented fish before and after salt were added, during the process of fermentation (preservation).
6. All the fermented fish samples by different fermentation periods and that of local fermented fish had varied counts of bacteria. It became evident that LFF recorded the highest bacteria count, while D5F recorded the least.
7. Fish fermented by the researcher even though were kept in sterilized bottles with fitted covers, they were found to be loaded with varied counts of bacteria.
8. It was also found that the sensory properties (appearance, colour, texture, flavour and taste) of fermented fish sample MD3F was similar to the local fermented fish sample (MLFF), even though they both had different proximate composition and bacterial loads. Also sample SBF, MD1F and MD5F had their sensory properties far from the control (MLFF).

Conclusion

The fish samples after being allowed to ferment for a varied number of days before salt was added revealed that the longer the fermentation period, the more the nutrients are reduced (proteins; from 76.63% to 42.95% and fat; from 2.85% to 1.98%). This explained why sample D5F which was allowed to ferment for 5 days recorded a tremendous reduction in its protein content even after the salt was added. On the other hand, sample D1F (1 day) and MLFF (2 days) which were initially fermented for few days recorded high protein content than the other samples which were allowed to initially ferment for relatively longer periods. Also, salt was observed to play a role in reducing the protein content in the fish samples as observed in sample SBF and all the other samples after they have matured (MD1F, MD3F, MD5F and MLFF). This is because even though the protein content of the fish samples reduced after each fermentation period, the protein further depreciated after the fermented fish samples matured. However, it was observed that the salt added to the fish samples aided in the reduction of the moisture content. Consequently, this could explain why it is important to add protein (such as eggs, meat, poultry, fish) to meals prepared from fermented fish. This will ensure that individuals meet their recommended daily protein intake to promote growth, repair body tissue and sustain life.

Also, samples MLFF and LFF recorded the highest bacteria infestation as compared to the other samples (D1F, D3F, D5F, SBF). The low count

recorded for fish samples processed by different fermentation periods may be attributed to the fact that the fermentation process took place in a bottle with well covered lid, while sample LFF/MLFF was wrapped in paper. From the observation made before, during and after the fermentation process, it may be concluded that the bacteria started to increase in count as the fermentation days were extended and dropped on the fifth day. This was mainly observed in sample D5F because it had the least bacterial counts, while the other sample recorded a high bacterial count by each the day (D1F and D3F). It was also observed that the addition of salt aided in reducing the bacterial counts that were present in the fish samples. This makes it necessary to thoroughly cook and heat food prepared from fermented fish in order to kill those bacteria. Also kitchen tools and equipment must be washed thoroughly to prevent transferring these bacteria to other food commodities and working surfaces in the kitchen.

Interestingly, sample MD3F had attributes similar to sample MLFF (the normal fermented fish consumers are used to). This could explain why it was the most preferred by the respondents. Also sample MD5F was not accepted by respondents due to extremely strong pungent flavour, sharp taste and strong pungent aftertaste which may stay in the mouth and on the hand for hours. Finally, samples SBF and MD1F were rejected as fermented fish due to their hard texture, mild flavour and taste.

Recommendations

Based on the key findings of this study, the following recommendations were made:

1. It is recommended that the local fermented fish producers adopt standard procedures in processing fermented fish to reduce bacteria load.
2. The researcher also recommends MD3F to consumers since it had a reduced bacteria load compared to the local fermented fish and comparable sensory attributes and acceptability with the control. Even though MD3F possessed a protein value lower than MLFF, it is used as a condiment and not the protein part of meals, therefore, does not raise any serious nutritional concern. Additionally, the method employed to ferment sample MD3F can be used by consumers to produce their own fermented fish, if possible.
3. Fermented fish must be washed thoroughly before it is used in food preparation (soups, sauces and '*abom*'). In preparation of '*abom*' (a type of sauce enjoyed by Ashantis and Akans), fermented fish must be thoroughly boiled or fried to kill all microorganisms to make it safe for consumption.
4. Due to the loss of nutrients, especially protein, in fermented fish, the protein content of a meal with fermented fish should be fortified with additional protein foods (such as smoked or fresh fish, meat, eggs, beans, *agushie*, mushroom etc.) to make up the recommended daily intake of protein.

Suggestions for Further Research

1. In this study, it was observed that salt has a direct effect on the chemical composition of fish (protein, moisture, ash and fat contents). Therefore there is the need to conduct a study to learn more about the chemicals in salt that make this effect possible.
2. There is a need to conduct a study on other fleshy fish to find out if those fishes will lose their quality attributes through fermentation.
3. There is also a need to conduct a study on the quality attributes of dried salted fishes (such as salted tilapia, herrings, shrimps etc.) since they serve as a main source of protein for some consumers.

REFERENCES

A.O.A.C. (2005). *Official methods of analysis*. Association of Official Analytical Chemists. (18th ed.). New York: AACC International Press.

A.O.A.C. (2000). *Official methods of analysis.* Association of Official Analytical Chemists. (13th ed.). New York: AACC International Press.

A.O.A.C (1995). *Official method of analysis*. Association of Official Analytical Chemists. (8th ed.). New York: AACC International Press.

Ababouch, L. (2005). *Preservation techniques of fish utilization and marketing service*, *Food and Agriculture Organization (FAO), AFisheries Techincal Paper, 1*.

Abbas, K. A., Saleh, A. M., Mohamed, A., & Lasekan, O. (2009). The relationship between water activity and fish spoilage during cold storage: A review. *J. Food Agric. Environ, 7*, 86-90.

Abbey, L. D., Hodari-Okae, M., & Osei-Yaw, A. (1994). *Studies on traditional processing and quality of fermented fish (momone).* Artisanal Fish Processing and Applied Research Report. (Ed.) Food Research Institute. Ghana: Accra.

Achinewhu, S. C., Amadi, E. N., Barimalaa, I. S., & Eke, J. (2004). Microbiology of naturally fermented fish (Sardinella sp.). *Journal of Aquatic Food Product Technology*, *13*(1), 47-53.

Adebayo-Tayo, B. C., Odu, N. N., Anyamele, L. M., Igwiloh, N. J. P. N., & Okonko, I. O. (2012). Microbial quality of frozen fish sold in Uyo Metropolis. *Nature and Science*, *10*(3), 71-77.

Akpambang, V. O. E. (2015). Proximate composition of some tropical fish species. *Der Chemica Sinica*, *6*(4), 125-129. Nigeria: Ondo State.

Alasalvar, C., Miyashita, K., Shahidi, F., & Wanasundara, U. (Eds.). (2011). *Handbook of seafood quality, safety and health applications.* United State*:* New York. John Wiley & Sons.

Al-Jufaili, M. S., & Opara L. U. (2006). Status of fisheries postharvest industriy in the Sultanate of Oman: Part 1 handling and marketing system of fresh fish. *Journal of Fisheries International 1*(2-4), 144-149.

Amedahe, F. K. (2004). *Notes on educational research*. A paper presented during lecture. Cape Coast, Ghana, 18th June, 2004.

Amedahe, F. K. (2000). *Notes on educational research*. A paper presented during lecture, Cape Coast, Ghana, 12th May, 2000.

Anggo, A. D., Ma'ruf, W. F., Swastawati, F., & Rianingsih, L. (2014). Changes of amino and fatty acids in anchovy (*Stolephorus sp*) fermented fish paste with different fermentation periods. *Procedia Environmental Sciences, 23,* 58 – 63.

Anihouvi, V. B., Ayernor, G. S., Hounhouigan, J. D. & Sakyi-Dawson, E. (2006). *Quality characteristics of lanhouin*: A traditionally processed fermented fish product in the Republic of Benin. Benin: Cotonou.

Arias, C. (2009). Chilled and frozen raw fish. In R. Fernandes, (Ed.), *Microbiology handbook fish and seafood*. United Kingdom (UK): Leatherhead Food International Ltd.

Ares, G., Gemenez, A., & Gambaro, A. (2008). Influence of nutritional knowledge on perceived healthiness and willingness to try functional foods. *Appetite, 51*(3), 663-668.

Armenteros, M., Aristoy, M., & Toldra, F. (2009). *Effects of sodium, potassium, calcium, and magnesium chloride salts on porcine muscle proteases*. European Food Research andTechnology, 229, 93-98.

Ary, D., Jacobs, L. C., & Razavieh, A. (2010). *Introduction to research in education 8th edition, Wardswoth Cengage Learning.* Canada: Nelson Education Ltd. Exotic Classic.

Baird-Parker, T. C. (2000). The Production of microbiologically safe and stable foods. In B.M. Lund, & T.C. Baird-Parker, (Eds.). *The microbiological safety and quality of food.* USA: Gaithersburg, MD. Aspen Publishers Inc.

Balazs, S. P. (2012). *Sensory evaluation in food industry*. Magyarorszag: Kormanya.

Bartram, J., Cotruvo, J., Exner, M., Fricker, C., & Glasmacher, A. (2003). *Heterotrophic plate counts and drinking-water safety*: The significance of HPCs for water quality and human health. IWA Publishing

Bate, E. C., & Bendall, J. R. (2010). Changes in fish muscle after death. *British Medical Bulletin,* (12), 2305.

Bautista, J., Arroyo, N., Duran, M., & Garrido, A. (2008). Individual effects of sodium, potassium, calcium, and magnesium chloride salts on Lactobacillus pentosus and Saccharomyces cerevisiae growth. *Journal of Food Protection, 71*, 1412-1421

Bayarri, S., Calvo, C., Costell, E., & Duran, L. (2001). Influence of colour on perception of sweetness and fruit flavour of fruit drinks. *Food Science and Technology International, 7*(5), 399.

Begum, S., Roy, S., & Yusuf, A. (2015). Anaerobic bacteria: Infection and management. *IOSR Journal of Dental Medical Sciences, 14*(12), 69-72.

Belitz, H. D., Grosch, W., & Scchieberle, P. (2009). *Food chemistry*. (4th ed.). Berlin: Springer

Bello, B. K., & Akinyele, B. J. (2007). Effect of fermentation on the microbiology and mineral composition of an edible mushroom termitomycesrobustus (Fries). *International Journal of Biological Chemistry. 1*(4), 237-243.

Berkel, B. M., Boogaard, B. V., & Heijnen, C. (2004). *Preservation of fish and meat.* Agromisa Foundation, Wageningen, The Netherlands.

Beuchat, L. R. (1996). Pathogenic microorganisms associated with fresh produce. *Journal of Food Protection, 59*, 204-216.

Blesata, E., Alina, M., Barat, J., Toldra, F., & Pagan, M. J. (2008). Microbiology and physicochemical changes of dry-cured ham during the post-salting stage as affected by partial replacement of NaCI by other salts. *Meat Science, 78*, 135-142.

Box, G. E., Hunter, W. G., & Hunter, J. S. (2005). *Statistics for experimenters: Design, innovation and discovery* (2nd ed.). New York: Wiley.

Buchheister, A., & Latour, R. J. (2015). Diets and trophic-guild structure of a diverse fish assemblage in Chesapeake Bay, USA. *Journal of Fish Biology*, *86*(3), 967-992.

Burt, J. R. (2003). Hypoxanthine a biochemical index of fish quality. *Process Biochemistry, 11*(10), 23-25.

Cabeen, M. T., & Jacobs-Wagner, C. (2005). Bacterial cell shape. *Nature Reviews Microbiology, 3*(8), 601-610.

Campus, M., Addis, M. F., Cappuccinelli, R., Porcu, M. C., Pretti, L., Tedde, V., Secchi, N., Stara, G., & Roggio, T. (2010). Stress relaxation behaviour and structural changes of muscle tissues from gilthead sea bream (Sparus aurata) following high-pressure treatment. *Journal of Food Engineering, 96*(2), 192–198.

Caracciolo, F., El-Nakhel, C., Raimondo, M., Kyriacou, M. C., Cembalo, L., De Pascale, S., & Rouphael, Y. (2020). Sensory attributes and consumer acceptability of 12 microgreens species. *Agronomy, 10*(7), 1043.

Centers for Disease Control and Prevention (2011). *Hepatitis C information for health professionals*. Guidelines for laboratory testing and result reporting.

Chaol, L. N., & Trewavas, E. (1990). Sciaenidae. In J. C. Quero, J. C. Hureau, A. P. Karrer, & L. Saldanha, (Eds.). *Check-list of the fishes in the eastern tropical Atlantic (CLOFETA)*. JNICT, Lisbon, SEI, Paris and UNESCO. Vol. 2 Chemical and Microbiological Properties, (2nd ed.).

Chesapeake Bay Program (2011). *Atlantic croaker and spot fishery management plan.* Maryland, National Service Center for Environmental Publication (NSCEP).

Chouhan, S. (2015). Enumeration and identification of standard plate count bacteria in raw water supplies. *IOSR Journal of Environmental Science Toxicology and Food Technology Ver. II*, *9*(2), 2319–2399.

CODEX, (2013). *Code of Practice for fish and fishery products*. (CAC/RCP 52-2003, amendment 2013). Retrieved from http://www.codexalimentarius.org/download/standard/10273/Cxp-052e.pdf

Cresswell, J. W. (2005). *Educational research: Planning, conducting and evaluating quantitative and qualitative research* (2nd ed.). Upper Saddle River, NJ: Pearson Education, Inc.

Cresswell, J. W. (2009). *Research design: Quantitative, Qualitative and Mixed Methods approaches* (3rd ed.). Los Angeles: Sage Publications

Creswell, J. W. (2014*). Research design: Qualitative, quantitative and mixed Methods Approaches* (4th ed.). Thousand Oaks, CA: Sage Publications.

Dalgaard, P., Madsen, H. L., Samieian, N., & Emborg, J. (2006). Biogenic amine formation and microbial spoilage in chilled garfish (Belone-belone) effect of modified atmosphere packaging and previous frozen storage. *Journal of Applied Microbiology, 101*(1), 80-95.

Damez, J. L., & Clerjon, S. (2008). Meat quality assessment using biophysical methods related to meat structure. *Meat Science, 80*(1), 132–149.

Desmond, E. (2006). Reducing salt: A challenge for the meat industry. *Meat Science, 74*(1), 188-196.

Dissaraphong, S., Benjakul, S., Vissenbanguan, W., & Kishmura, H. (2006). The influence of storage conditions of tuna viscera before fermentation on the chemical, physical and microbiological changes in fish sauce during fermentation. *Bioresource Technology, 97*(16), 2032-2040

El-Bassir, A. R. H. A., Karar, A. M. H. M., Altayeb, H. Z., Azrag, T. A. R. & Yasir, A. M. (2015). *Effect of salting on the nutritive value of catfish*. Larsemouth Bass Aquacultulture.

Elyass, M. E., Altayar, M. A., Mahdi, A. A., Abdelrawaf, S. A., Shigidi, M. T., & Attitalla, I. H. (2015). Characterization and evaluation of antimicrobial activity of bacteriocins from Lactobacillus curvatus and Pediococcus pentosaceus. *Journal of Microbial Pathophysiology & Pathogenesis, 1*, 1-7.

Emborg, J., Laursen, B. G., & Dalgaard, P. (2005). Significant histamine formation in tuna (Thunnus albacares) at 2°C: Effect of vacuum-and modifiedatmosphere-packaging on psychrotolerant bacteria. *International Journal of Food Microbiology, 101*(3), 263-279.

Emikpe, B. O., Adebisi, T., & Adedeji, O. B. (2011). Bacteria load on the skin and stomach of Clarias gariepinus and Oreochromis niloticus from Ibadan, South West Nigeria: Public health implications. *Journal of Microbiology and Biotechnology Research, 1*(1), 52-59.

Engvang, K., & Nielsen, H .H. (2001). Proteolysis in fresh and cold-smoked salmon during cold storage: Effects of storage time and smoking process. *Journal of Food Biochemistry, 25*, 379-395.

Eves, A., & Brow, R. (1993). Effects of traditional drying process on the nutritional value of fish. *Tropical Science 33*, 183-189.

Eyo, E. E. (2002). Fish processing and utilization. *In National Workshop on Fish Processing, Preservation, Marketing and Utilistion, New Bussa, (pp.4-5)*

FAO Fisheries and Aquaculture Department, (2010). *The state of the world fisheries and aquaculture.* Rome: FAO Publishing Management Service.

FAO Fisheries and Aquaculture, (2008). *Globalisation and fisheries*. Proceedings of an OECD-FAO Workshop Organization for Economic Co-operation and Development, OECD Publishing.

FAO Fisheries and Aquaculture, (1996). *Fisheries and aquaculture in sub-Sahara Africa: Situation and outlook.* FAO Fisheries Circular. Rome

FAO Fisheries and Aquaculture, (2002). *Report of the workshop on the promotion of sustainable commercial aquaculture in Zambia and Malawi*: *Lusakaa, Zambia*. FAO Fisheries Report No. 733. Rome, Italy.

FAO Fisheries and Aquaculture, (2011). *Handling of fish and fish products fisheries and aquaculture department*. F.A.O. Communication Division. Rome.

FAO Fisheries and Aquaculture, (1971). United Nations Food and Agriculture Organization. Poisson fermenté et produits dérivés. *FAO Fish. Rep. (Fr), 100,* 62.

FAO Fisheries and Aquaculture, (2001). *The freezing time of fish.* FAO in partnership with Support unit for International Fisheries and Aquatic Research (SIFAR).

FAO Fisheries and Aquaculture, (2005). Post-harvest changes in fish. In *FAO Fisheries and Aquaculture Department, Food and Agriculture Organization, Rome, Italy*. Retrieved from http://www.fao.org/fishery/topic/12320/en

FAO Fisheries and Aquaculture, (2006). Fisheries Global Information System. FAO Rome: FAO. http://www.fao.org/figis/servlet/

FAO Fisheries and Aquaculture, (2007). The State of world fisheries and aquaculture 2006. In *trash or treasure? Low-value/trash Fish from*

Marine Fisheries in the Asia-Pacific Region. FAO Fisheries and Aquaculture Department, Rome, Italy. pp. 115-120.

FAO Fisheries and Aquaculture, (2013). *The role of aquaculture in improving nutrition.* Working Document COFI: A Q/VII/2013/7, Russia Saint: Petersburg. http://www.fao.org/cofi/30795

Farber, J. M. (2000). The present situation in Canada regarding Listeria monocytogenes and ready-to-eat seafood products. *International Journal of Food Microbiology*, *62*(3), 247-251.

Feldsine, P., Abeyta, C., & Andrews, W. H. (2002). AOAC International methods committee guidelines for validation of qualitative and quantitative food microbiological official methods of analysis. *Journal of AOAC International*, *85*(5), 1187-1200.

Feng, Y., & Bruhn, C. M. (2019). Motivators and barriers to cooking and refrigerator thermometer use among consumers and food workers: A review. *Journal of Food Protection*, *82*(1), 128-150.

Fennema, O. R. (1996). *Minerals*. In O. R. Fennema (Ed.). *Food chemistry* (3rd ed.). Marcel Dekker Inc New York.

Food and Agriculture Organisation (2011). *Global Aquaculture Production Statistics for the year*. Fisheries and Aquaculture Department. Rome: FAO.

Food and Agriculture Organisation of the United Nations (FAO) (2009). *The state of world fisheries and aquaculture 2008.* Fisheries and Aquaculture Department. Rome: FAO.

Fox, A. (2016). *Bacteriology: Nutrition, growth and energy metabolism.* Microbiology and Immunology On-line. University of South Carolina School of Medicine. South Carolina.

Fuerst, J. A. (2014). Microorganisms. *A Journal and a Unifying Concept for the Science of Microbiology*, *2*, 140-146.

Gandotra, R., Meenakshi, K., Sweta, G., & Shallini, S. (2012). Change in proximate composition and microbial count by low temperature preservation in fish muscle Of Labeo rohita (Ham-Buch). *IOSR Journal of Pharmacy and Biological Sciences*, *2*(1), 13-17.

Koul, R. G. M., Gupta, S., & Gupta V. (2015). Studies on the effect of vacuum packaging on some quality changes in Lobeorohita during the frozen storage period. *IJABPT*, *6*(2), 78-84.

Geissler, K., Manafi, M., Amoros, I., & Alonso, J. L. (2000). Quantitative determination of total coliforms and Escherichia coli in marine waters with chromogenic and fluorogenic media. *Journal of Applied Microbiology*, *88*(2), 280-285.

Gelabert, J., Gou, P., Guerrero, L., & Arnau, J. (2003). Effect of sodium chloride replacement on some characteristics of fermented sausages. *Meat Science*, *65*(2), 833-839.

Gopakumar, K. (2000). Enzymes and enzyme products as quality indices. *Food Science and Technology*. New York: Marcel Dekker.

Gram, L., & Huss, H. H. (1996). Microbiological spoilage of fish and fish products. *International Journal of Food Microbiology*, *33*(1), 121–137.

Gram, L., & Huss, H. H. (2000). Fresh and processed fish and shellfish. *In The Microbiological Safety and Quality of Food* (pp. 472-506). Aspen Publishers.

Gram, L., & Dalgaard, P. (2002). *Fish spoilage bacteria–problems and solutions. Current opinion in biotechnology*, *13*(3), 262-266.

Gram, L., Ravn, L., Rasch, M., Bruhn, J. B., Christensen, A. B., & Givskov, M. (2002). Food spoilage – Interactions between food spoilage bacteria. *International Journal of Food Microbiology*, *32*(2), 120-123.

Gupta, V. (2017). *Evaluation and enhancement of shelf life of raw fish and its products.* (Doctoral dissertation, Thesis for the award of Doctor of Philosophy in Zoology, University of Jammu).

Hancock, D., Besser, T., Lejeune, J., Davis, M., & Rice, D. (2001). The control of VTEC in the animal reservoir. *International Journal of Food Microbiology*, *66*(1-2), 71-78.

Harland, B. F., & Harland, J. (1980). Fermentative reduction of phytate in rye, white and whole wheat bread. Cereal Chem. *The American Association of Cereal Chemists*, *57*(3), 226-229.

Hillers, V. N., Medeiros, L., Kendall, P., Chen, G., & Dimascola, S. T. (2003). Consumer food-handling behaviours associated with prevention of 13 foodborne illnesses. *Journal of Food Protection*, *66*(10), 1893-1899.

Huff-Lonergan, E., & Lonergan, S. M. (2005). Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. *Meat Science, 71*, 194-204.

Huss, H. H. (1995). *Quality and quality changes in fresh fish* (Vol. 348). Rome: FAO.

Hussein, H. S. (2007). Prevalence and pathogenicity of shiga toxin producing escherichia coli in beef cattle and their products. *Journal of Animal Science, 85*, 63-72.

Hyldig, G., Bremner, A., Martinsdóttir, E., & Schelvis, R. (2007). Quality index methods. In L.M.L. Nollet, T. Boylston, & F. Chen (Eds.), *Handbook of meat, poultry and seafood quality*. Oxford: Blackwell.

Ifediora, A. C., Nkere, C. K., & Iroegbu, (2006). Weaning food preparation consumed in Umuahia, Nigeria: Evaluation of the bacteriological quality. *Journal of Food Technology, 4*, 101-105

International Commission on Microbiological Specifications for Food, [ICMSF], (1996). *Salmonella sp. in microorganism in foods: Characteristics of microbial pathogens*. London: Chapruan and Hall

Irfan, H. (2007). *Sensory evaluation techniques*. 18th Annual IAOM Conference. Oman: Muscat

Irish Sea Fisheries Board, (2008). *Nutritional Aspects of Fish Archived* 2008-11-15 at the Wayback Machine.

ISO. (2006). *Microbiology of food and animal feeding stuffs*: Horizontal method for the enumeration of coliforms— Colony-count technique (ISO 4832). Geneva, Switzaland: International Organization for Standardization, Part 1, *30*.

ISO. (2015). *Microbiology of the food chain: Horizontal method for the enumeration of microorganisms* (ISO 4833). International Organization for Standardization, - Part 1, *44*(0).

Jabeen, F., & Chaudhry, A. S. (2011). Chemical compositions and fatty acid profiles of three freshwater fish species. *Food chemistry*, *125*(3), 991-996.

Jay, J. M., Loessner, M. J., & Golden, D. A. (2005). *Modern food microbiology*. Springer Science & Business Media.

Jeyaram K., Singh T. A., Romi, W., Devi, A. R, Singh, W. M., Dayanidhi, H., Singh, W. M., & Tamag, J. P. (2009). Traditional fermented foods of Manipur. *Indian Journal of Traditional Knowledge*, *8*(1), 115–121.

Ji, C., Zhang, J., Lin, X., Han, J., Dong, X., Yang, S., Yan, X., & Zhu, B. (2017). Metaproteomic analysis of microbiota in the fermented fish, Siniperca chuatsi. *Food Science and Technology 80*, 479–484.

Jittrepotch, N., Rojsuntornkitti, K., & Kongbangkerd, T. (2015). Physico-chemical and sensory properties of Plaa-som, a Thai fermented fish

product prepared by using low sodium chloride substitutes. *International Food Research Journal, 22*(2), 721-730.

Johnson, E. A. (1991). *Microbiological safety of fermented foods.* In J. G. Zeikus & E. A. Johnson, (Eds.), Mixed cultures in biotechnology. McGraw- Hill

Jones, A. P., & Bartlett, J. F. (2006). *Experimental research design.* New York: Sage.

Kader, A. A. (2005). Increasing food availability by reducing post- harvest losses of fresh produce. *Act 9, Horticulture, 3,* 2169-2176.

Karrar, A. M. H. (2007). The Impacts of drying practices on the quality of fish products. *An unpublished Ph.D thesis in the Department of Zoology, Faculty of Science, University of Khartoum*, 1-193.

Kerlinger, F.N., & Lee, H.B. (2000). *Foundations of behavioural research* (4th ed.). Fort Worth, New York: Holt, Tex: Harcourt College Publisher.

Kleter, G. A., & Marvin, H. J. (2009). Indicators of emerging hazards and risks to food safety. *Food and Chemical Toxicology*, *47*(5), 1022-1039.

Koffi-Nevry, R., & Koussémon, M. (2012). Microbiological composition, processing and consumer's characteristics of Adjuevan, a traditional Ivorian fermented fish. *Tropicultura, 30*(1), 9-14.

Kolodziejska, I., Niecikowska, C., Januszewska, E., & Sikorski, Z. E. (2002). The microbial and sensory quality of mackerel hot smoked in mild conditions. *Food Science and Technology*, *35*(1), 87-92.

Kris-Etherton, P. M., Harris, W. S., & Appel, L. J. (2002). Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease. *Circulation. 106*(21), 2747–2757.

Kuda, T., Izawa, Y., Ishii, S., Takahashi, H., Torido, Y., & Kimura, B. (2012). Suppressive effect of Tetragenococcus halophilus, isolated from fish-nukazuke, on histamine accumulation in salted and fermented fish. *Food Chemistry, 130*, 569-574.

Lauritzsen, K., Akse, L., Johansen, A., Joensen, S., Sørensen, N. K., & Olsen, R. L. (2004). Physical and quality attributes of salted cod (Gadus morhua L.) as affected by the state of rigor and freezing prior to salting. *Food Research International, 37,* 677–688.

Lawrence, T. E., Dikeman, M. E., Stephens, J. W., Obuz, E., & Davis, J. R. (2003). 1n situational investigation of the calcium-induced proteolytic and salting-in mechanisms causing tenderization in calcium-enhanced muscle. *Meat Science, 66*, 69-75

Lee, Y. C., Kung, H. F., Huang, C. Y., Huang, T. C., & Tsai, Y. H. (2015). Reduction of histamine and biogenic amines during salted fish fermentation by Bacillus polymyxa as a starter culture. *Journal of Food and Drug Analysis*, *24*, 157-163.

Leister, L. (2000). Basic aspect of food preservation by hurdle technology. *International Journal of Food Microbiology* 55,181-186.

Lin, C. S., Liu, F. L., Lee, Y. C., Hwang, C. C., & Tsai, Y. H. (2012). Histamine contents of salted seafood products in Taiwan and isolation of halotolerant histamine-forming bacteria. *Food Chemistry, 131*, 574-579.

Lin, T. M., & Park, J. W. (1996). Protein solubility in Pacific whiting affected by proteolysis during storage. *Journal of Food Science, 61*, 536-539.

Løje, H., Jensen, K. N., Hyldig, G., Nielsen, H. H., & Nielsen, J. (2007). Changes in liquid holding capacity, water distribution and microstructure during chill storage of smoked salmon. *Journal of the Science of Food and Agriculture, 87*(14), 2684-2691.

Lonchampt, P., & Hartel, W. R. (2004). Fat bloom in chocolate and compound coatings. *European Journal of Lipids Science and Technology* 106 (4), 241-274.

Lopetcharat, K., & Park, J. W. (2002). Characteristics of fish sauce made from Pacific whiting and surimi by-products during fermentation stage. *Journal of Food Science, 67*(2), 511-516.

Mokoena, M. P., Mutanda, T., & Olaniran, A. O. (2016). Perspectives on the probiotic potential of lactic acid bacteria from African traditional fermented foods and beverages. *Food & Nutrition Research, 60*(1), 29630.

Madu, C. T., Okoye, F. E., Sado, E. K., Omorinkoba, W. S., Bankole, N. O., & Ita, E. O. (1984). *A preliminary report of induced breeding trials of mud*

fish (Clarias anguillaris). KLRI Annual Report. Kainji Lake Research Institute.

Mahalakshmi, M., Srinivasan, M., Murugan, M., Balakrishnan, S., & Devanathan, K. (2011). Isolation and identification of total heterotrophic bacteria and human pathogens in water and sediment from Cuddalore fishing harbour after the hydrographical features of Pazhakayal estuary, Tuticorin, India. Journal of *Environmental Biology*. *33*, 769-773.

Mahulette, F., Mubarik, N. R., Suwanto, A., & Widanarni. (2018). Microbiological and physicochemical characteristics of inasua-traditional fish fermented from Maluku islands. *Journal of Biology & Biology Education*, *10*(2), 298-305.

Mansur, M. A., Rahman, S., Khan, M. N. A., Reza, S., Sadia, L., & Wahab, R. (2014). Studies on the quality attributes and safety aspect of semi-fermented fish product. *Indian Journal of Geo-Marine Sciences, 43*(6), 949-954.

Maragoni, A. G., & Narine, S. S. (Eds.). (2002). *Physical properties of lipids*. Florida: CRC Press.

Mariutti, L. R., & Bragagnnolo, N. (2017). Influence of salt on lipid oxidation in meat and seafood products: A review. *Food Research International, 94*, 90-100.

Martinsdóttir, E. (2002). Quality management of stored fish. *In Safety and quality issues in fish processing* (pp. 360-378).

Martyn, S. W. (2008). *True experimental design.* Retrieved from https://explorable.com/true-experimental-design.

McClement, D. J. (2002). Theoretical prediction of emulsion color. *Adu Colloid Interface Science*, *97*, 63-89.

McClement, D. J. (2004). *Food emulsions*: *principles, practice and techniques*. CRC Press.

Medeiros, L. C., Hillers, V. N., Kendall, P. A., & Mason, A. (2001). Food safety education: what should we be teaching to consumers? *Journal of Nutrition Education*, *33*(2), 108-113.

Meiselman, H. L. (1993). Critical evaluation of sensory techniques. *Food Quality and Preference*, *4*, 33-40.

Mhango, M., Mpuchane, S. F., & Gashe, B. A. (2010). Incidence of indicator organisms, opportunistic and pathogenic bacteria in fish. *African Journal of Food, Agriculture, Nutrition and Development*, *10*(10).

Michael, S., Cai, J., Akwasi, A. Y., & Adele, A. Y. (2019). Fish smoking in ghana: a review. *Journal of Fisheries Sciencescom*, *13*.

Mohanty, B. P., Behera, B. K., & Sharma, A. P. (2011). *Nutritional significance of small indigenous fishes in human health.* (CIFRI Bulletin no. 162).

Nargi, L. (2018). *Taste and flavour are not the same*. New York: Society for Science Publisher.

Nartey-Djaba, S., Muala, D. N., Amankwaa, D., & Amo-Yeboah, J. (2018). *The significance of momone in Ghanaian delicacies.* Ghana: Cape Coast

Nendissa, S. J. (2013). Pengaruh penambahan Pediococ-cus acidilactici F11 sebagai kultur starter terhadap kualitas ikan asin (ina sua) bae (Lutjanus malabaricus). In Indonesia [Addition effect Pediococcus acidilactici as starter culture to quality salty fish (Ina sua) bae (Lutjanus malabaricus)]. *Ekosains*, *2*(1), 39-46.

Nestel, P., Clifton, P., Colquhoun, D., Noakes, M., Mori, T. A., Sullivan, D., & Thomas, B. (2015). Indications for omega-3 long chain polyunsaturated fatty acid in the prevention and treatment of cardiovascular disease. *Heart, Lung and Circulation*, *24*(8), 769-779.

New Zealand Food Safety NZFS, (2001). *Pathogen data sheets: Staphylococcus aureus*. Retrieved from http://www.foodsafety.gov.nz/elibrary/inndustry/staphylococcusaureus-Science-Research.pdf

Nigerian Institute for Oceanography and Marine Research (2016). *Food and Applied Bioscience Journal*, *4*(1), 35-40.

Nunoo, F. K. E., Boateng, J. O., Ahulu, A. M., Agyekum, K. A., & Sumaila, U. R. (2009). When trash fish is treasure: The case of Ghana in West Africa. *Fisheries Research, 96*, 167–172.

Ojokoh, A.O. (2007). Effect of fermentation on the chemical composition of mango (mangiferaindica) peels. *African Journal of Biotechnology*, *6*, 1979-1981.

Okonta, A. A., & Ekelemu, J. K. (2005). A preliminary study of micro-organisms associated with fish spoilage in Asaba, Southern Nigeria. *In Proceedings of the 20th Annual conference of fisheries society of Nigeria (FISON), Port Harcourt, 14th-18th November* (vol. 2005, pp. 557–560).

Oranusi, S., Abah, K. A., & Anosike, S. O. (2019). *Effects of salt on preservation and metabolic activities of fish and meat microflora.* Department of Biological Science. Covenant University. Nigeria: Ota

Oren, A. (2002). Diversity of halophilic microorganisms: environments, phylogeny, physiology, and applications. *Journal of Industrial Microbiology and Biotechnology*, *28*(1), 56-63.

Ovissipour, M., Abedian, A., Motamedzadegan, A., Rasco, B., Safari, R., & Shahiri, H. (2009). The effect of enzymatic hydrolysis time and temperature on the properties of protein hydrolysates from Persian sturgeon (Acipenser persicus) viscera. *Food Chemistry, 115*(1), 238-242.

Page, A. L., Miller, R. H., & Keeney, D. R. (1982). Methods of soil analysis. Part 2. Chemical and Microbiological Properties. American Society of Agronomy. *In Soil Science Society of America, 1159*.

Pal, M., Ketema, A., Anberber, M., Mulu, S., & Dutta, Y. (2016). Microbial quality of fish and fish products. *Beverage & Food World, 43*(2), 46-49.

Paludan-Muller, C., Madsen, M., Sophanodora, P., Gram, L., & Møller, P. L. (2002). Fermentation and microflora of plaa-som, a Thai fermented fish product prepared with different salt concentrations. *International Journal of Food Microbiology, 73*, 61-70.

Pandey, K., & Shukla, J. P. (2005). A textbook of f*ish and fisheries*. Rastogi Publication, Meerut.

Paugy, D., Leveque, C. & Teugels, G. G. (2003). *The fresh and brackish water fishes of West Africa.* II RID Editions. Publications Scientifiques du Museum, MRAC.

Pombo, C. R., Mársico, E. T., Franco, R. M., Guimarães, C. F. M., Da-Cruz, A. M. P., & Pardi, H. S. (2009). Salted and fermented fish processes evaluation. *International Journal of Food Science & Technology*, *44*(11), 2100-2105.

Potter, N. N., & Hotchkiss, J. H. (1995). Food safety, risks and hazards. *In Food Science*, 532-558. Springer, Boston, MA.

Prince, C., & Prince, C. (2009). Indole Test. *Practical Manual of Medical Microbiology*, 130–132.

Pszczola, D. E. (2000). Putting fat back into foods. *Food Technology*, *54*(12), 58-63.

Rahman, S. M. E., Wang, J., & Oh, D. H. (2013). Synergistic effect of low concentration electrolyzed water and calcium lactate to ensure microbial safety, shelf life and sensory quality of fresh pork. *Food control*, *30*(1), 176-183.

Raimbault, M. (1998). General and microbiological aspects of solid substrate fermentation. *Electronic Journal of Biotechnology*, *1*(3), 26-27.

Rajapakse, N., Mendis, E., Jung, W. K., Je, J. Y., & Kim, S. K. (2005). Purification of a radical scavenging peptide from fermented mussel sauce and its antioxidant properties. *Food Research International*, *38*(2), 175-182.

Ray, B., (2004). *Fundamental food microbiology*. CRC Press, Boca Raton. New York, 225-238.

Robin R. S., Vishnu Vardhan, K. V., Pradipta R., Muduli, P. R., Srinivasan, M., & Balasubramanian, T. (2012). Preponderance of enteric pathogens along the coastal waters of Southern Kerala, Southwest Coast of India. *Marine Science 2*(1), 6-11.

Rompre, A., Servais, P., Baudart, J., De-Roubin, M. R., & Laurent, P. (2001). Detection and enumeration of coliforms in drinking water: Current methods and emerging approaches. *Journal of Microbiological Methods 49*(1), 31-54.

Ross, T., & Sumner, J. (2002). A simple, spreadsheet-based, food safety risk assessment tool. *International Journal of Food Microbiology, 77*(1-2), 39-53.

Rowell, D. L. (1994). Soil science: Methods and Applications. pp. 350-366. *Harlow: Longman Group.*

Ryser, E. T., & Marth, E. H. (2007). *Listeria, listeriosis, and food safety*. Florida: CRC press.

Saladin, K. S. (2010). *Anatomy and physiology*: *The unity of form and function*. (5th ed.). New York: McGraw-Hill.

Salampessy, J., Kailasapathy, K., & Thapa, N. (2010). Fermented fish products. *Fermented Foods and Beverages of the World*, 289-307.

Sato, T., Horiuchi, T., & Nishimura, I. (2005). Simple and rapid determination of histamine in food using a new histamine dehydrogenase from Rhizobium sp. *Analytical Biochemistry, 346*, 320-326.

Secci, G., & Parisi, G. (2016). From farm to fork: Lipid oxidation in fish products. A review. *Italian Journal of Animal Science, 15*(1), 124-136.

Sen, D. P. (2005). Chemical composition and their technological significance. *Advances in Fish Processing Technology*. New Delhi: Allied Publishers, 44-64.

Sharifian, S., Alizadeh, E., Mortazavi, M. S., & Moghadam, M. S. (2014). Effects of refrigerated storage on the microstructure and quality of

grouper (Epinephelus coioides) fillets. *Journal of Food Science and Technology*, *51*(5), 929-935.

Shilklomanov, I. A. (2000). Appraisal and assessment of world water resources. *Water International*, *25*(1), 11-32.

Shovon, B., Abida, S., Muhammad, H. S., Muhammed, A. I., & Ahtashom, M. M. A. (2013). Analysis of the proximate composition and energy values of two varieties of onion (*Allium cepa* L.) bulbs of different origin: A comparative study. *International Journal of Nutrition and Food Sciences*, *2*(5), 246-253.

Silva, J. G., Morais, H. A., & Silvestre, M. P. (2003). Comparative study of the functional properties of bovine globin isolates and sodium caseinate. *Food Research International*, *36*, 73-80.

Singh-Ackbarali, D., & Maharaj, R. (2014). Sensory evaluation as a tool in determining acceptability of innovative products developed by undergraduate students in food science and technology at the University of Trinidad and Tobago. *Journal of Curriculum and Teaching*, *3*(1), 10 - 27.

Singleton, P., & Sainsbury, D. (2001). *Dictionary of microbiology and molecular biology*. (3rd ed.). West Sussex: Chichester Smith-John Wiley & Sons, Ltd.

Slonczewski, J. L., Foster, J. W., & Gillen, K. M. (2008). *Microbiology: An Evolving Science*. Boston: W. W. Norton & Company, Incorporated.

Small, D. (2008). *How does the way food looks or its smell influence taste?* Modern Diet and Physiology Research Center. United State: New Haven.

Soriano, J. M., Blesa, J., Rico, H., Molto, J. C., & Manes, J. (2002). Incidence of Staphylococcus aureus in meals from cafeterias. *Journal of food safety*, *22*(2), 135-140.

Spector, P. E. (1981). *Research designs*. Berverly Hills, CA: Sage

Spence, C. (2015). On the psychological impact of food colour. *Spence Flavour*, *4*(21), 1-6.

Stone, H., & Sidel, J. L. (2010). *Sensory evaluation practice.* Academic Press, San Diego, 1-19.

Stone, H., Bleibaum, R., & Thomas, H. A. (2012). *Sensory evaluation practices*. San Diego, CA: Academic Press.

Takagi, T., Hayashi, K., & Itabashi, Y. (1984). Toxic effect of free unsaturated fatty acid in mouse assay of diarrhetic shellfish toxin by intraperitoneal injection. *Bulletin of the Japanese Society for the Science of Fish, 50*, 1413-1418.

Tam H. L., Bao, H. N. D., & Marie, E. (2004). *Guideline for handling and preservation of black-tiger shrimp and cephalopod.* Hong Kong: Agriculture Publisher

Thomas, F. (2014). *Understanding bacterial adaptation to aerobic and anaerobic environments through experimental evolution and whole genome analysis*: *a thesis presented in fulfilment of the requirements for the degree of Doctor of Philosophy in Genetics at Massey University, New Zealand*. Unpublished Doctoral dissertation, Massey University.

Thompson, C. B., & Panacek, E. A. (2006). Research study designs: Experimental and Quasi-Experimental. *Air Medical Journal, 25*(6), 242-246.

Thorarinsdottir, K. A., Arason, S., Bogason, S. G., & Kristbergsson, K. (2004). The effects of various salt concentrations during brine curing of cod (Godusmorhuo). *International Journal of Food Science and Technology, 39*, 79-89.

Thurman, H. V., & Webber, H. H. (1984). *Marine Biology*. Charles E. Merril Publishing CA Bell and Howell co. Columbus, Ohio USA.

Topic-Popovic, N., Benussi-Skukan, A., Coz-Rakovac, I., Kozacinski, L., Jadan, M., & Brlek-Gorski, D. (2010). *Microbiological quality of*

marketed fresh and frozen seafood caught off the Adriatic Coast of Croatia. Croatia: Zagreb.

Uauy, R., & Valenzuela, A. (2000). Marine oils: The health benefits of n-3 fatty acids. *Nutrition (Burbank, Los Angeles County, Calif.)*, *16*(7-8), 680-684.

Unclesbay, N. (1992). *World food and you*. New York: Food Product Press.

Van-Tonder, I., Lues-Jan, F. R., & Theron, M. M. (2007). The personal and general hygiene practices of food handlers in the delicatessen sections of retail outlets in South Africa. *Journal of Environmental Health, 70(*4), 33-8.

Voskresensky, N. A. (1965). *Salting of herring: Fish as food, 3*, 195-217. New York*:* Academic Press.

Wafula, E. N., Franz, C. M., Rohn, S., Huch, M., Mathara, J. M., & Trierweiler, B. (2016). Fermentation of african indigenous leafy vegetables to lower post-harvest losses, maintain quality and increase product safety. *African Journal of Horticultural Science*, *9*.

Weel, K. G. C., Boelrijk, A. E. M., Burger, J. J., Gruppen, H., Voragen, A. G. J., & Smit, G. (2006). A protocol for measurement of in vivo aroma release from Beverages. *Journal of Food Science*, *68*(3), 1123-1128.

World Health Organization. (2015). *WHO estimates of the global burden of foodborne diseases: Foodborne Diseases Burden Epidemiology Reference Group 2007-2015*. Department of Food Safety and Zoonoses.

Wither, C. (2018). *Difference between taste and flavour*. Debswana Botswana: Heinemann Publishers.

Wongkhalaung, C. (2004). Industrialization of Thai fish sauce (Nam Pla). In K. H. Steinkraus (Ed.), *Industrialization of indigenous fermented food.* New York: Marcel Dekker.

Yousuf, A. H. M., Ahmed, M. K., Yeasmin, S., Ahsan, N., Rahman, M. M., & Islam, M. M. (2008). Prevalence of microbial load in shrimp, Penaeus monodon and prawn, Macrobrachium rosenbergii from Bangladesh. *World Journal of Agricultural Sciences, 4*, 852-855.

APPENDICES

APPENDIX A: SENSORY EVALUATION QUESTIONNAIRE

UNIVERSITY OF CAPE COAST

COLLEGE OF EDUCATIONAL STUDIES

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF VOCATIONAL AND TECHNICAL EDUCATION

Dear Respondent, I am Juliet Dzigbordi Amedekanya and a student at the University of Cape Coast pursuing MPhil Home Economics (Food and Nutrition major). My research topic is; **Quality Attributes of fermented fish (*momone*) processed by Different Periods**. This study seeks to assess the sensory properties of fish samples processed by different fermentation periods to determine if significant differences exist among them. The data being collected is solely for academic purposes. Therefore, honest responses to the questions will be appropriate to evaluate the sensory properties of fish samples and the most preferred by consumers. Every information provided would be used for that purpose. Your identity will not be exposed under any condition and the information provided will be treated as strictly confidential. In case you are allergic to any of the ingredients (tomatoes, onion, fresh pepper and vegetable oil) used prepare the sauce, please do not volunteer to participate in this study.

Confidentiality and anonymity is assured. Your participation in this study is voluntary and do not hesitate to withdraw at any point if you desire to do so.

Date……. Panellist ID……

Background Information of Respondent

1. Please **tick [√]** your age range and your sex
   a. 20-24 [ ]
      25-29 [ ]

      30-34 [ ]

      35-39 [ ]

      Above 40 [ ]

   b. Male [ ]
      Female [ ]

INSTRUCTION FOR THE SENSORY EVALUATION

You have been presented with five coded food samples (one of which is the reference sample). Taste the samples in the order presented (from left to right).

1. Please wash your mouth with the water provided before tasting the food samples.
2. Evaluate the food samples in the order they have been presented to you.
3. Kindly remember to wash your mouth with the water and spit out the contents into the cups provided before and after tasting each food sample.
4. Kindly taste each sample once. Do not repeat tasting of a sample more than once.
5. Please **tick [√]** the range of attributes provided based on your assessment of the food samples.
6. Kindly **tick [√]** once.

	MLFF				
	ATTRIBUTES	**A**	**B**	**C**	**D**
Raw fermented fish	Appearance	Dry [ ]	Moist [ ]	Fresh [ ]	Rotten [ ]
	Colour	Brown [ ]	Dark-brown [ ]	Off-white [ ]	Grey [ ]
	Texture	Hard [ ]	Flaky [ ]	Soft [ ]	Very soft [ ]
Sauce	Aroma/Flavour	Mild [ ]	Moderate [ ]	Moderate Strong [ ]	Very strong [ ]
	Taste	Normal [ ]	Umami [ ]	Pungent [ ]	Sharp pungent [ ]
	Aftertaste	No aftertaste [ ]	Mild pungent [ ]	Moderate pungent [ ]	Strong pungent [ ]
	Overall Acceptability	Not good [ ]	Good [ ]	Very good [ ]	Excellent [ ]

	SBF				
	ATTRIBUTES	**A**	**B**	**C**	**D**
Raw fermented fish	Appearance	Dry [ ]	Moist [ ]	Fresh [ ]	Rotten [ ]
	Colour	Brown [ ]	Dark-brown [ ]	Off-white [ ]	Grey [ ]
	Texture	Hard [ ]	Flaky [ ]	Soft [ ]	Very soft [ ]
	Aroma/Flavour	Mild [ ]	Moderate [ ]	Moderate Strong [ ]	Very strong [ ]
Sauce	Taste	Normal [ ]	Umami [ ]	Pungent [ ]	Sharp pungent [ ]
	Aftertaste	No aftertaste [ ]	Mild pungent [ ]	Moderate pungent [ ]	Strong pungent [ ]
	Overall Acceptability	Not good [ ]	Good [ ]	Very good [ ]	Excellent [ ]

	MD1F				
	ATTRIBUTES	**A**	**B**	**C**	**D**
Raw fermented fish	Appearance	Dry [ ]	Moist [ ]	Fresh [ ]	Rotten [ ]
	Colour	Brown [ ]	Dark-brown [ ]	Off-white [ ]	Grey [ ]
	Texture	Hard [ ]	Flaky [ ]	Soft [ ]	Very soft [ ]
	Aroma/Flavour	Mild [ ]	Moderate [ ]	Moderate Strong [ ]	Very strong [ ]
Sauce	Taste	Normal [ ]	Umami [ ]	Pungent [ ]	Sharp pungent [ ]

	Aftertaste	No aftertaste [ ]	Mild pungent [ ]	Moderate pungent [ ]	Strong pungent [ ]
	Overall Acceptability	Not good [ ]	Good [ ]	Very good [ ]	Excellent [ ]

	MD3F				
	ATTRIBUTES	**A**	**B**	**C**	**D**
Raw fermented fish	Appearance	Dry [ ]	Moist [ ]	Fresh [ ]	Rotten [ ]
	Colour	Brown [ ]	Dark-brown [ ]	Off-white [ ]	Grey [ ]
	Texture	Hard [ ]	Flaky [ ]	Soft [ ]	Very soft [ ]
	Aroma/Flavour	Mild [ ]	Moderate [ ]	Strong [ ]	Very strong [ ]
Sauce	Taste	Normal [ ]	Umami [ ]	Pungent [ ]	Sharp pungent [ ]
	Aftertaste	No aftertaste [ ]	Mild pungent [ ]	Moderate pungent [ ]	Strong pungent [ ]
	Overall Acceptability	Not good [ ]	Good [ ]	Very good [ ]	Excellent [ ]

	MD5F				
	ATTRIBUTES	**A**	**B**	**C**	**D**
Raw fermented fish	Appearance	Dry [ ]	Moist [ ]	Fresh [ ]	Rotten [ ]
	Colour	Brown [ ]	Dark-brown [ ]	Off-white [ ]	Grey [ ]
	Texture	Hard [ ]	Flaky [ ]	Soft [ ]	Very soft [ ]
	Aroma/Flavour	Mild [ ]	Moderate [ ]	Strong [ ]	Very strong [ ]
Sauce	Taste	Normal [ ]	Umami [ ]	Pungent [ ]	Sharp pungent [ ]

	Aftertaste	No aftertaste [ ]	Mild pungent [ ]	Moderate pungent [ ]	Strong pungent [ ]
	Overall Acceptability	Not good [ ]	Good [ ]	Very good [ ]	Excellent [ ]

Thanks for your participation

APPENDIX B: Result of ANOVA on the Nutritional Composition of Fish Samples

PROXIMATE COMPOSITION OF FISH SAMPLES		Sum of Squares	DF	Mean Square	F	Sig.
DM	Between Groups	464.042	2	51.160	16.166	.000
	Within Groups	19.065	20	.308		
	Total	483.109	23			
MOISTURE	Between Groups	464.042	3	51.160	16.166	.000
	Within Groups	19.065	20	.308		
	Total	483.109	23			
ASH	Between Groups	507.126	3	56.084	34.040	.000
	Within Groups	10.179	20	.164		
	Total	517.132	23			
PROTEIN	Between Groups	1344.487	3	149.088	5.143	.000
	Within Groups	167.087	20	2.695		
	Total	1511.174	23			
FAT/OIL	Between Groups	1.191	3	.132	2.197	.000
	Within Groups	.374	20	.006		
	Total	1.165	23			

Source: Laboratory Data (2019)

MINERAL DETERMINATION		Sum of Squares	DF	D Mean Square	F	Sig.
Phosphorus	Between Groups	2282.306	3	2535.583	2.973	.005
	Within Groups	5287.185	20	8528.127		
	Total	7570.344	23			
Potassium	Between Groups	3957.168	3	4397.140	5.297	.000
	Within Groups	5147.110	20	8302.486		
	Total	9105.178	23			
Sodium	Between Groups	1378.160	3	1531.173	301.914	.000
	Within Groups	3144.098	20	5072.093		
	Total	1409.160	23			
Calcium	Between Groups	.0052	3	.0058	.497	.871
	Within Groups	.762	20	.117		
	Total	.786	23			
Magnesium	Between Groups	.0023	3	.002	3.020	.005
	Within Groups	.0053	20	.009		
	Total	.0076	23			

Source: Laboratory data (2019)

APPENDIX C: Result of ANOVA on the Bacterial Count of Fish Samples

		Sum of Squares	Degree of Freedom (DF)	Mean Square	F	Sig.
Total_Heterotrophic_Bacteria	Between Groups	623342946.216	2	311671473.108	9.950	.000
	Within Groups	2161303109.437	69	31323233.470		
	Total	2784646055.653	71			
Total_Coliform	Between Groups	5472639.383	2	2736319.691	20.587	.000
	Within Groups	9171310.603	69	132917.545		
	Total	14643949.986	71			
Fecal_Coliform	Between Groups	13942.383	2	6971.191	14.515	.000
	Within Groups	33137.937	69	480.260		
	Total	47080.319	71			
Staphylococcus_aureus	Between Groups	1699262.883	2	849631.441	39.184	.000
	Within Groups	1496149.437	69	21683.325		
	Total	3195412.319	71			
Salmonella_sp	Between Groups	3949066.794	2	1974533.397	30.177	.000

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	Within Groups	4514783.817	69	65431.650		
	Total	8463850.611	71			
Anaerobic_Bacteria	Between Groups	5639031.183	2	2819515.591	17.044	.000
	Within Groups	11414246.317	69	165423.860		
	Total	17053277.500	71			
E._coli	Between Groups	178.571	2	89.286	.136	.873
	Within Groups	45371.429	69	657.557		
	Total	45550.000	71			

Source: Laboratory data (2019)

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