UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

MICROBIAL QUALITY OF FISH ALONG THE TILAPIA, AFRICAN CATFISH AND SARDINELLA ARTISANAL VALUE CHAINS IN KPONG AND JAMES TOWN, GHANA

BY

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(ID. NO. 10244800)

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILMENT OF THE AWARD OF DEGREE OF MASTER OF PHILOSOPHY IN FOOD SCIENCE

DEPARTMENT OF NUTRITION AND FOOD SCIENCE

JULY 2016
DECLARATION

I declare that this work was conducted by me under supervision in the department of Nutrition and Food Science, University of Ghana, Legon.

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DEDICATION

This is to my wonderful parents, Edward and Esther Aboagye, for giving me an excellent childhood, for always believing in me, and most importantly for teaching me about the God, without whom I am nothing.
ACKNOWLEDGEMENTS

I would like to express my warmest gratitude and appreciation to the persons below who in their own way made this research possible and this milestone in my life a reality:

My supervisor, Prof. Kwaku Tano-Debrah for allowing me to always express myself and for all your guidance and support throughout my research period.

My co-supervisor, Dr. Angela Parry- Hanson Kunadu for inspiring me to believe that I could be more, and that I could achieve more than I could ever imagine.

Prof F.K. Saalia for always having the right words to lift me up in my lowest moments.

Prof. Kennedy Kwasi Addo and Prof Dorothy Yeboah Manu of the Noguchi Memorial Institute for Medical Research, Department of Bacteriology, for allowing me access to your facilities and resources on short notice. This would not have been possible without your cooperation and support.

Lorenzo (Moses Akyen), Christain Bonsu, Samuel Ofori Addo, Emelia Konadu Danso, Evans and Isaac Prah for all your technical support, words of encouragement, and the late nights you stayed with me in the laboratory so I could finish on time. God bless you.

Vida Adjei and all the staff at Noguchi who welcomed me so warmly and made me feel right at home. God bless you all.

My dearest Aunt Cherub, Uncle James Neequaye, Uncle Odartey, Auntie Aafio, Auntie Emelia (of blessed memory) and my whole family in Mamprobi who made all the contacts necessary to complete my survey in James Town. I love you all.

My amazing little sister Cherub Aboagye and Zachary Bielack, my dearest brother who were my unwilling but most helpful research minions. I adore you.

Finally, I wish to thank the Office of Research in Development, ORID for providing the funds needed to carry out this research.
ABSTRACT

Fish from artisanal sources constitute the most important animal protein in the Ghanaian diet. The availability and safety of fish on the Ghanaian market is however now unpredictable owing to potential rapid microbial growth which results from high ambient temperatures and poor handling along the artisanal value chains. Little is known about the artisanal fish value chains as well as the food safety knowledge and handling practices of key stakeholders involved. This study aimed at mapping out the artisanal fish value chains of Tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*) and sardinellas (*Sardinella aurita*), and assessing the food safety knowledge and handling practices of key stakeholders along the selected value chains. A survey using semi-structured questionnaires and involving 93 fishermen, 40 retailers, 40 processors and 120 consumers was carried out to investigate stakeholders’ knowledge and practices of food safety along the value chain. Samples of the selected fish species were taken along their respective value chains to test for the presence of safety indicators (*Salmonella*, *Vibrio* and *Listeria* species), hygiene indicators (*Staphylococcus aureus* and *Escherichia coli*), and spoilage organisms (*Pseudomonas* spp. and *Proteus* spp.). The mean scores for food safety of retailers, processors and consumers were found to be generally insufficient at 55%, 43% and 67.3% respectively. The stakeholders also scored poorly in their handling practices with mean scores of 41.2%, 63.0% and 58.6% for fishermen, processors and consumers respectively. Estimated fish losses were highest at the retailer and consumer stages of the value chain with reported losses as high as 35 to 100%. Pathogens such as *Clostridium perfringens*, enteropathogenic *Escherichia coli*, *Staphylococcus aureus*, *Listeria* spp. and *Aeromonas sobria* were isolated from fresh and on processed ready-to-eat fish samples. *Salmonella* spp and *Vibrio* spp were not detected on any of the samples tested. Mesophilic counts in the range of 7.96 ± 0.68 to 2.95 ± 0.23 log cfu/g were reported from fresh fish samples, with
similarly high faecal coliform counts averaging 3.11 log cfu/g. Processed fish samples had average total counts, faecal coliform counts, and yeasts and mould counts of 3.11, 2.27 and 2.45 log cfu/g respectively. *Proteus vulgaris* and *Proteus mirabilis* were the predominant spoilage organisms present on almost all the fresh fish samples. This study provided much needed insight into the unsatisfactory safety and quality of artisanal fish on the Ghanaian market and the specific microorganisms associated with them along the value chain. It also established the link between the food safety knowledge and handling practices of stakeholders within the value chain, and the actual quality and safety of fish on the market.
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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Fish contributes about 40-60% of the animal protein supply in the Ghanaian diet and is recognized as the most important source of animal protein in every part of the country (Bank of Ghana, 2011). The cost of fish constitutes 22.4% of the food expenditure in all Ghanaian households and 25.7% in poor households (BOG, 2008). Fishing communities, often some of the poorest in the country depend heavily on fish and related activities for their livelihoods (FAO, 2013). Fish, as an agricultural commodity, is therefore essential in ensuring food security especially among the poorest in the country.

The importance of fish as a food security commodity in Ghana is however affected by high postharvest losses. In the high tropical temperatures of Ghana, fresh fish spoilage can be very rapid after capture. Fish perishability is aggravated by its intrinsic properties such as high water activity, near neutral pH, and a high digestible protein content, all of which provide conducive conditions for microbial proliferation (Ghaly, 2010). Microbial activity alone accounts for the spoilage of 30% of landed fish worldwide (Bataringaya, 2007) and in Ghana, 10-30% of artisanal catch is sold for less than its true worth due to quality deterioration (Akande and Diei-Ouadi, 2010).

In terms of safety, fish has been implicated in several outbreaks of food-borne infections. It is a potential vehicle for food-borne infections such as cholera, listeriosis, salmonellosis and many more (Popovic et al., 2010; Costa, 2013; Akoachere et al., 2009). Many spoilage microorganisms which are also known to be opportunistic pathogens including Pseudomonas spp. and Proteus spp. have also been associated with fish (Ikutegbe and Sikoki, 2014; Popovic et al., 2010; Tryfinopoulou et al., 2007; Viji et al., 2014).
Poor fish quality therefore has very serious potential consequences, which transcend the loss of an important protein source. Huge economic losses are incurred annually because of losses in production volume, monies spent in treating food borne infections, and also human resources lost during the course of the illness and the incidence of death (Akande and Dei-Ouadi, 2010). With an already existing annual deficit of 320,000 Mt in Ghana’s fish requirements, fish quality loss is a problem which requires urgent attention (BOG, 2008).

Artisanal fishery in Ghana contributes 70 to 80% of the total marine fish production and is the principal supplier of fish on the local market (Amador et al., 2006: FAO, 2013). There is however, scanty literature on the structure of the artisanal marine and fresh water fish value chains. The few reported studies do not clearly depict who the key players in these value chains are and also how their knowledge and practices concerning food safety impact on the final quality of the fish that reaches the consumer. The occurrence of key pathogens associated with fish and how they are affected by processing and handling along the value chain is also sparsely documented. Again, the specific spoilage organisms associated with fish sourced from Ghanaian waters and their occurrence along the value chain is unknown. These gaps in knowledge are of great concern given the severity of the consequences associated with fish spoilage especially with regards to food security.

Also of concern is the poor and unsanitary conditions prevailing in most fish landing sites in Ghana. It becomes even more necessary for key actors or stakeholders within the fish value chain to be aware of and consistently implement proper handling and storage of fish prior to processing and distribution to consumers. It is therefore vital to investigate the association between the food safety knowledge and practices of artisanal fish stakeholders, and the actual microbiological quality of their fish. This would provide evidence and insight into how these stakeholders through their cultural and food safety related practices, impact the extent of fish losses and the microbiological quality of artisanal fish on the local market.
This study thus set out to explore the safety of frequently consumed fish species harvested by artisanal fishermen, by testing for the presence of certain pathogenic, opportunistic and spoilage organisms as the selected fish species (Tilapia, catfish and sardinellas) progressed along their respective value chains.

1.2 Rationale

A scientific understanding of the locally processed and fresh fish value chain, as well as the growth and activity of spoilage and pathogenic microbes on raw and processed fish is critical for the development of fish preservation technologies suitable for use in our local communities. These preservation methods could be tailored to promote fish accessibility by reducing losses due to spoilage; and improving fish safety, by targeting contamination points, inhibiting multiplication of pathogens and removal of fish associated with microbiological hazards.

The study is also an opportunity to map out and document the local fish value chain which is important in identifying critical contamination points on the value chain. Information on the food safety knowledge and practices of stakeholders in the fish value chain could also influence future policies and interventions to mitigate fish spoilage and tackle food safety issues related to artisanal fish.

1.3 Research Hypotheses

- There is no difference in the levels of food safety knowledge and handling practices between stakeholders in the fish value chain.
- Stakeholder food safety knowledge and practices have no effect on fish losses and microbial fish quality
- There is no difference between microbial counts and physicochemical properties of fish at different stages of the value chain.
1.4 **Overall Objective**

To investigate the fish value chains in the artisanal fishing industry in Ghana, evaluating the food safety knowledge and handling practices of stakeholders and also the microbial quality of fish along the value chain.

1.5 **Specific Objectives:**

- To map out and document the artisanal value chains of Tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*) and sardinellas (*Sardinella aurita*) in Kpong and James Town.
- To test fish samples along the artisanal fish value chain for the presence of safety indicators (*Salmonella* spp, *Vibrio* spp and *Listeria* spp), hygiene indicators (*Staphylococcus aureus* and *Escherichia coli*), and spoilage organisms (*Pseudomonas* spp. and *Proteus* spp.)
- To establish the link between food safety knowledge and practices of stakeholders in the artisanal fish value chain and the microbiological quality and safety of fish.
- To determine the potential implications of poor fish microbiology on the availability and safety components of food security.
CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Fisheries in Ghana

The Ghanaian fishing industry is based on resources from the marine and inland (freshwater) sectors, coastal lagoons and aquaculture and accounts for 5% of the country’s agricultural Gross Domestic Product (FAO, 2007).

Inland fishery in Ghana is predominantly carried out on the Volta Lake (FAO, 2007). The marine subsector on the other hand comprises four subsectors including: small scale (artisanal) fisheries, semi-industrial (inshore) fisheries, industrial fisheries and the tuna fisheries subsector.

With respect to landed weight of fish, artisanal fisheries accounts for approximately 70 to 80% of the national marine fish production and is thus the most important fisheries subsector in Ghana (FAO, 2007; FAO, 2013).

2.2 Fish production in Ghana

Marine fisheries in Ghana are affected by two upwellings in the coastal waters each year. This seasonal phenomenon brings cool, nutrient rich water to the surface, resulting in increased biomass of organisms and a consequent abundance of most marine fish species not seen in other areas of the ocean (Gordon et al., 2011).

The largest (major) upwelling occurs from the months of June to September while the minor upwelling is between February and March. There are bumper fish harvests, especially of small pelagic species during these seasons but the rest of the year is characterized by little or no catch at all (Gordon et al., 2011). In most parts of Ghana fishing is done on a daily basis, with a traditionally mandatory observed day of rest, which in most places is the Tuesday of every week.
In 2013, up to 314,848 Mt and 86,741 Mt of marine and fresh water fish respectively was produced in Ghana (SRID, 2014). The Ministry of fisheries and Aqua-culture Development (MoFAD) however estimated the amount of fish required by the Ghanaian population to be 810,000 tons, leaving a deficit of over 400,000 tons. A 2011 report by MoFAD argued that because fisheries in Ghana were already over exploited, it would be unlikely that domestic fish production alone will be sufficient to meet fish food security requirements for the foreseeable future. Fish imports to cater for the deficit is also complicated by import tariffs, and high prices caused by imposing international prices of fish on Ghanaians.

2.3 Fresh water Fishery in Ghana
Aquaculture in Ghana is dominated by tilapia and catfish production (Antwi-Asare and Abbey, 2011). Although actual production volumes are poorly documented, tilapia constitutes up to 80% of total production while the catfish species, *Clarias* spp, *Heterobranchus* spp and *Heterotis niloticus* account for the remaining 20% (Antwi-Asare and Abbey, 2011). There is high internal demand for both fishes, thus there are virtually no exports of fresh tilapia or catfish in Ghana (Antwi-Asare and Abbey, 2011).

Tilapia is the generic name of a group of cichlids widespread in Africa, and consists of three important genera in aquaculture: *Oreochromis*, *Sarotherodon* and *Tilapia* (Popma and Masser, 1999). According to a report by Younis et al (2015), the Nile tilapia (*Oreochromis niloticus*) had a composition of 79.86 to 82.43 % moisture, 15.68 to 17.24 % protein (fresh weight), and 0.71 to 0.37% lipids (fresh weight). Al-Souti and Claereboudt (2014) reported similar moisture values and a dry weight percentage of 28.1% of total lipids.

The African catfish, *Clarias gariepinus* much like tilapia has high moisture contents of up to 78% and fat as well as protein contents of 5.5% and 17% (fresh weight) respectively. High levels of moisture, proteins and fats in these fishes make them highly susceptible to microbial attack after harvest.
2.4 Marine Fishery in Ghana

Ghana’s marine waters are located within the Guinea Current Large Marine Ecosystem, and form part of the Central West African Upwelling system. Fishery resources include over 300 species of finfish, 17 species of cephalopods, 25 species of crustaceans, and three species of turtles (Perry and Sumaila, 2007).

The most important small pelagic species include the sardinellas, anchovy and the club mackerel (Akrofi, 2002). According to Boachie-Yiadom (2013), the sardinella fishery in Ghana is near collapse. This is of particular concern given the fact that the majority of fish landed during the major fishing season in Ghana, mostly comprises sardinella and club mackerel (Akrofi, 2002).

Two species of sardinella, *Maderensis* and *Aurita* were assessed for their lipid content by Njinkoué *et al.* (2002). It was found that, the total lipid content (fresh weight) was 26%, 12% and 21% in the skin, liver, and red muscle respectively. The study classified the two species of sardinellas as fatty fish because they had at least 5% of fresh weight as lipids. The study also reported a moisture content of 73% in the sardinella species tested.
2.5 Artisanal Fisheries

Artisanal fishery in Ghana is very dynamic, with fisher folk who may be sedentary or migrant, or may carry out their activities on a full time or part-time basis. Fishery at the artisanal level may also be non-differentiated or specialized, in which case only certain fish species are targeted (Aho, 2013). It is however considered small-scale fishing because it is dependent solely on local resources (BOG, 2008). The artisanal fishery system utilises very basic fishing methods such as dug out boats or canoes. These canoes are wooden dug-outs which are motorized with 40HP outboard engines and the smaller canoes use sail power (FAO, 2007). A wide range of fishing gear which include purse seines ("poli/watsa"), beach seines, drift gill nets and surface set nets are employed. They also utilise bottom set nets as well as hook and line (Bank of Ghana, 2008; Aho, 2013).

The artisanal sub-sector in Ghana is the most important in terms of fish outputs in the marine sector. It contributes 70 to 80% of the total marine fish production and is the principal supplier of fish on the local market (Amador et al., 2006). Artisanal fishery also supports an estimated 80,000 fishers and a similar number of people in related post-harvest activities such as the sale and processing of fish (MoFAD, 2011). Akrofi (2002), reported the artisanal fleet in Ghana comprising 8700 traditional wooden dug-out canoes, half of them motorised,
operating out of 82 fishing villages and 296 landing sites. A more recent report by MoFAD (2011) however quotes the number of “active” canoes at 12000 with many more that are used occasionally or re-activated for use under ideal circumstances.

The artisanal sub-sector is challenged by inadequate infrastructure at landing sites, inefficient and out-dated fishing vessels and gear, and inadequate storage facilities at the market centres (BOG, 2008). Icing fish species like the sardinella can be logistically difficult and uneconomical for the artisanal fisherman, because the low cost of the fish species does not justify the cost of icing (Akrofi, 2002). There are however those artisanal fishers that operate beyond the 50 meter depth zone known as “Lagas”. Their primary fishing gear is the hook and line but they are also equipped with ice, insulated containers, food and fishing aids like fish finders and Geographical Positioning System (GPS) (Bank of Ghana 2008; FAO, 2007). Some “Lagas” fishers use electronic fish finding devices such as echo-sounders (FAO, 2007). These fishers are however primarily concerned with high value fish which rarely reaches the local markets.

2.6 Importance of Fish to Food Security

The World Food Summit of 1996 defined food security as attained “when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life”. The concept of food security as explained by the WHO in 2014, is built on three pillars:

1. Food availability: sufficient quantities of food available on a consistent basis
2. Food access: having sufficient resources to obtain appropriate foods for a nutritious diet.
3. Food use: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.
The fishery sector contributes significantly to national economic development objectives relating not only to food security but to employment, poverty reduction and foreign exchange earnings (Aho, 2013).

Fish contributes about 40-60% of the animal protein supply in the Ghanaian diet and is recognized as the most important source of animal protein in every part of the country (BOG, 2008). The average per capita fish consumption is estimated at 20-25kg which is higher than the world average of 13kg (Bank of Ghana, 2008). It is consumed as a fresh product in the coastal areas and near landing sites and as smoked and dried fish in the more distant markets. (Gordon et al., 2011).

Various species of marine and inland fish are available in a variety of product forms which can be bought in variable quantities to suit the buying power of the consumer. Fish makes up 22.4% of the food expenditure in all households and 25.7% in poor households, and is thus a very significant part of the Ghanaian diet (Bank of Ghana, 2008).

In 2009, fish exports contributed around $87 million in revenue (Ghana Statistical Service, 2014), and contributed 4.4% of the Gross Domestic Product in 2007 (BOG, 2008) and 1.4% GDP in 2013 (Ghana Statistical Service, 2014). The fishery industry supports 135,000 fishers in the marine sub-sector alone and indirectly supports the livelihoods of 2.2 million people, representing 10% of the total Ghanaian population (MoFAD, 2011). The FAO is of the view that, revenue generated from international fish trade, can contribute to ensuring food security at an aggregate level.

It can be easily inferred that the importance of fish for food security in Ghana has far reaching implications. Fish supplies naturally enhance food availability; ensuring good nutritional outcomes particularly for the poor and rural populations; and, the vast number of
people engaged in the fishing industry can earn income that will improve their access to food (Aho, 2013).

2.7 Gender Distributions in Fishing Communities in Ghana

Fresh water or inland fisheries in Ghana is predominantly centred on the Volta Lake, in communities in the Eastern and Volta region of Ghana (BOG, 2008). Marine fisheries on the other hand can be found all along the coastal belt of Ghana which spans the Volta, Greater Accra, Central and Western regions of Ghana.

In a recent publication, FAO reported that a total workforce of 372,000 constituting fishermen, processors, marketers and boat builders are involved in artisanal fisheries in Ghana. Women constituted 40% of this work force and were employed mainly in processing and marketing. The men were often assisted by adolescent boys in fishing expeditions (FAO, 2103).

2.8 Artisanal Fish Processing in Ghana

Well-known artisanal fish preservation and processing methods include frying, salting, hot smoking, fermentation, and sun drying, or a combination of these methods. General conditions of traditional fish processing, storage and distribution are, however known to be unsatisfactory due to frequent insect infestation, microbial decomposition and rodent attack (Plahar et al., 1999).

Frying of fish is very popular in the southern part of Ghana where it is consumed with stable maize diets like Kenkey or banku (Cofie, 2003). Frying dehydrates and sterilizes the fish, achieving an extension of the shelf life by a couple of days.

Hot smoking is one of the most widely employed traditional fish processing method in Ghana. It is often used to preserve the large quantities of fish landed in the bumper harvest seasons (Plahar et al., 1999). Smoke, is produced when wood undergoes a process of
incomplete combustion. The smoke comprises numerous individual components including, aldehydes, ketones, alcohols, acids, hydrocarbons, esters, phenols, ethers etc. Smoking also imparts a characteristic flavor and colour to the fish (Goulas and Kontominas, 2005).

In Ghana, salting is normally done in conjunction with other processes like drying and fermentation. The popular “momoni” and “koobi” are examples of salted fermented fish and salted-dried fish respectively (Cofie, 2003).

Fermentation is often done spontaneously and much of the drying is done on the beaches or on the bare ground, which brings the microbial safety of these fishes under question (Bomfeh et al, 2015).

2.9 Postharvest Fish Losses in Ghana

A study conducted in Ghana, Kenya, Mali, Uganda and the United Republic of Tanzania by the FAO reported that, postharvest fish losses in artisanal fisheries occurs at all stages on the fish value chain. The losses found were principally quality losses, that is, fish that had undergone changes due to spoilage or physical damage. Such fishes were sold at a lower price than if no or minimum deterioration in quality had taken place (Akande and Dei-Ouadi, 2010). This accounts for 70% of all types of losses. In Ghana, it was found that, quality loss after landing averaged around 63.3% (Akande and Dei-Ouadi, 2010).

During the bumper harvest season, fishermen report that 10-30% of their catch is downgraded due to poor on-board icing and handling (Gordon et al., 2011). This Spoilt fish is fermented into “momone” or “Lonshala” by airing it until it begins to rot. It is then placed in brine, allowed to settle for a few days before being left out in the sun to dry. Although “momone” is still useful as food, it fetches about half the price of fish in good condition (Gordon et al, 2011). A review of African fermented fish products by El Sheikha et al (2014), emphasized the usefulness of fermentation as a means of salvaging losses and the importance
of fermented fish as a source of animal protein. Their review however warned that, in countries like Ghana where *momone* is popularly used in very small quantities as a condiment for preparing sauces, its protein contribution to the diet becomes of minor importance. It is therefore justifiable to argue that, there is considerable nutritional loss, ergo quality loss of fish even after processing by fermentation.

There are also quality losses incurred by fish smokers, after purchasing but prior to smoking, which has been attributed to long bargaining/auctioning of poorly iced or non-iced fish. The processor’s loss ranged between 11 and 17% (Akande and Dei-Ouadi, 2010).

Physical losses defined as fish thrown away accidentally, voluntarily or as authorized or eaten by birds/animals; were also recorded (Akande and Dei-Ouadi, 2010). The physical losses of fish recorded were reportedly caused by: severe spoilage of the fish, over smoking leading to severe burning and discards of juveniles or by-catch. These physical losses however rarely exceeded 5% in most of the countries included in the study (Akande and Dei-Ouadi, 2010).

Ghanaian fishermen in the FAO study in 2010 perceived that, fish spoilage leads to a loss of income, followed by food insecurity and indebtedness, then poverty and domestic tension caused by inability to adequately cater for the household. The study explained that, for these reasons, the fishermen were unable to educate their children to higher levels in order for them to obtain alternate livelihoods (Akande and Dei-Ouadi, 2010). This may well be true given the current rising cost of secondary and tertiary education in the county.

### 2.10 Fish Spoilage

Food spoilage is defined as the changes in the sensory properties of a food that render it unsuitable for human consumption (Gram and Dalgaard, 2002). Fish undergoing spoilage may possess one or more of the following signs: slime formation; discoloration; changes in
texture; off-odours; off-flavours and gas production (Bataringaya, 2007). Several studies have attributed the cause of fish spoilage to autolysis, bacterial growth and metabolism, and the chemical oxidation of lipids (Tryfinopoulou et al., 2001; Broekaert et al., 2011).

Autolysis, which is due to degradation by native enzymes, commonly occurs first, followed by microbial spoilage and finally, rancidity. Autolytic fish spoilage occurs because of continued enzymatic activity even after death (Bataringaya, 2007). Adenosine triphosphate (ATP) is broken down to adenosine diphosphate (ADP), inosine monophosphate (IMP), inosine (I) and hypoxanthine (HX), in the following reaction:

\[
\text{ATP} \rightarrow \text{ADP} + \text{Energy} \rightarrow \text{IMP} + \text{I} \rightarrow \text{HX}
\]

These compounds are broadly accepted to be responsible for the loss of fresh fish flavour (Bataringaya, 2007).

Rancidity is caused by lipid oxidation and is common in fatty fish species like mackerel, herrings, sardinellas and salmon (Quang, 2005). Lipids are oxidized to peroxides, aldehydes, ketones and lower aliphatic acids. The hydro-peroxides are tasteless but can cause brown and yellow discoloration of the fish tissue. Aldehydes and ketones formed during degradation of hydro-peroxides are chiefly responsible for the rancid off-flavours (Bataringaya, 2007).

Microbiological activity, among all the above stated reasons has been identified as the most important factor influencing fish quality and spoilage (Tryfinopoulou, et al., 2001; Quang, 2005; Amos, 2007).

Fresh seafood undergoes spoilage faster than other food commodities because the concentrations of compounds such as free amino acids, low molecular weight extractives, lipids, glycogen, glucose, and lactate are all sufficient to support massive microbial growth
(Koutsoumanis and Nychas, 1999; Viji et al., 2014). These compounds appear to be the principal precursors of those microbial metabolites that are perceived as spoilage by humans. They also have an influence on whether the type of spoilage is proteolytic or saccharolytic, and also determine the rate of spoilage (Koutsoumanis and Nychas, 1999).

The flesh of live and healthy fish is sterile. The principal contamination of fish after death is attributed to the microflora present on the skin, gills and inside the gut. Contamination is also related to conditions of the water where the fish lived prior to capture, especially the temperature and microbial quality of the water, fish feeding habits, geographical location, season and storage conditions including temperature, and condition of packaging atmosphere (Tryfinopoulou et al., 2001; Lopez-Caballero, 2002).

Lopez-Caballero (2002), reported a 100 to 1000 fold increase in the bacterial count within the mucus of the fish skin surface, immediately after direct contact with decks, equipment and boxes. This suggests that without proper checks, microbial numbers could increase further and at a much faster rate as temperature and unhygienic handling increase further down the value chain.

Viji et al. (2014) also explained that, postharvest handling practices such as gutting or evisceration considerably reduces the gut microbial load which would otherwise increase the rate of autolysis and consequent development of off- flavours and belly bursting. The researchers however cautioned that, evisceration may or may not be advantageous depending on factors such as the age of the fish, species, amount of lipids, harvesting environment and the method of harvesting. For example, the study revealed that, gutted fish samples had a higher degree of primary oxidation compared to fish samples that were not gutted. This was explained by the fact that gutting exposes the belly area to air consequently rendering lipids more susceptible to oxidation.
2.10.1 Microbial Fish Spoilage

Microbial spoilage of fish accounts for the loss of one-fourth of the world’s food supply and 30% of landed fish (Ghaly et al., 2010). Microbial growth and metabolism produces biogenic amines such as putrecine, histamine and cadaverine, organic acids, sulphides, alcohols, aldehydes and ketones with unpleasant and unacceptable off-flavours (Ghaly et al., 2010).

The composition of the microflora of freshly harvested fish is greatly varied but the specific spoilage organisms that are responsible for spoilage represent only a fraction of the microflora present. This suggests that not all the microflora present on the fish are involved in the spoilage process. Gram and Dalgaard (2002) explained this concept as the specific spoilage organism (SSO) concept. *Shewanella putrefaciens* and *Photobacterium phosphoreum* have for example been identified as the specific spoilage organisms in chilled gutted cod and packaged cod fillets respectively (Quang, 2005).

To identify an SSO, it is essential for the organism to qualitatively produce off-odours (spoilage potential) and quantitatively produce spoilage metabolites (spoilage activity) (Gram and Dalgaard, 2002).

The specific spoilage organisms of marine fish produce ammonia, biogenic amines, organic acids and sulphur compounds from amino acids, hypoxanthine from ATP degradation products and acetate from lactate. The ammonia like and “fishy” off-flavours is due to the presence of trimethylamine (TMA) produced by microorganisms during anaerobic respiration. Organisms capable of producing TMA include: *Aeromonas* spp., psychrotolerant *Enterobacteriaceae*, *P. phosphoreum*, *Shewanella putrefaciens* and *Vibrio* Spp. (Gram and Dalgaard, 2002).

Fish sourced from temperate waters have psychrotrophic bacteria of the genera *Pseudomonas*, *Moraxella*, *Acinobacter*, *Shewanella*, *Flavobacterium*, *Vibrio*,
Photobacterium and Aeromonas as part of their natural flora whereas tropical fish normally have non-psychrotrophic (mesophilic) spoilage bacteria that make tropical fish spoil much faster than temperate water fish in the absence of cold storage (Bataringaya, 2007).

Mesophilic bacteria on or in fish mostly originates from direct contact with warm-blooded animals such as human beings or are transferred by coastal waters contaminated with untreated sewage (Van den Broek et al., 1984). Mesophilic bacteria will however not proliferate during cold storage.

2.10.1.1 Pseudomonas spp. and Shewanella spp.

Gram negative psychrophilic non-fermenting rods have been implicated in spoilage observed in aerobically stored fish. Thus, under aerobic ice storage, the flora is composed almost exclusively of Shewanella putrefaciens and Pseudomonas spp. (Popovic et al., 2010). These two organisms have been found to be members of the microbial association found in fish from temperate waters and are reportedly the specific spoilage organisms in fish from temperate waters stored aerobically on ice (Tryfinopoulou et al., 2007).

Viji et al, (2014), also reported isolates of Pseudomonas spp. and Aeromonas spp. as the predominant microflora on catfish stored on ice. These organisms were also found to be the specific spoilage organisms of catfish stored on ice.

Other Gram-negative bacteria which have also been implicated in salt water fish include: Achromobacter, Acinetobacter, Flavobacterium, and Alteromonas (Chytiri et al., 2004). Shewanella putrefaciens acts biochemically on fish muscle by reducing trimethylamine oxide (TMAO) to trimethylamine (TMA). It also produces hydrogen sulphide, methylmercaptane (CH₃SH) and dimethylsulphide (CH₃)₂S from methionine, all of which are characteristic compounds responsible for perceived spoilage (Gram and Melchiorsen,
On the other hand *Pseudomonas* is unable to utilize TMAO as a terminal electron acceptor and therefore produces no TMA on spoiling fish.

TMA levels are however universally used to determine microbial deterioration leading to fish spoilage. They may however be misleading in situations where organisms like *Pseudomonas* which do not produce TMA, are the Specific Spoilage Organisms (Gram and Melchior, 1996).

### 2.11 Pathogens and Zoonotic Agents in Fish

Viruses, bacteria, fungi and parasites in fish may cause disease or food-borne infections in humans. Generally, such true zoonotic agents associated with fish are very rare because their temperature growth limits in most cases hinder their growth in humans (Hastein *et al.*, 2006). Under certain conditions however, microorganisms that are pathogenic to fishes may also infect humans. Infections in such cases are caused by handling infected fish or by ingestion of raw or inadequately processed infected fish or contaminated fish products (Hastein *et al.*, 2006).

#### 2.11.1 *Vibrio spp.*

The most important bacterial species associated with disease problems in humans include members of the *Vibrio* family, particularly *V. cholera*, *V. parahaemolyticus* and *V. vulnificus* which are generally recognized as the leading cause of human gastroenteritis associated with seafood consumption globally. Consumption of raw or undercooked seafood contaminated especially with *V. parahaemolyticus* may lead to the development of acute gastroenteritis characterized by diarrhoea, vomiting, headache, nausea, abdominal cramps and low fever (Popovic *et al.*, 2010).

The first cholera epidemic in Ghana was recorded in 1971 and had since been a major epidemic which strikes periodically often with devastating effects for large sections of the
population. A recent outbreak, saw 26,286 reported cases with 211 deaths as of November 2014 (WHO, 2014). The outbreaks were predominant in coastal regions of Ghana and have been associated with the consumption of contaminated water and street vended foods (Robalo et al., 2014; Dzotsi et al, 2014). It is however known that fish or fish products that have been in contact with contaminated water or faeces from infected persons, also frequently serve as a source of infection (Novotny et al., 2004).

2.11.2 *Listeria monocytogenes*

*Listeria monocytogenes* is a pathogenic bacterium which tolerates salt and nitrite and can grow under low oxygen conditions and low refrigeration temperatures (Lakicevic et al., 2015). *Listeria monocytogenes* is often associated with seafood products, whether they are fresh, frozen, fermented, salted or hot or cold smoked, and can occur at every stage of the value chain (Lakicevic et al., 2015). The organism has been reported to cause meningitis and abortions in sheep and listeriosis (characterized by gastro-intestinal symptoms) in humans. It is thus regarded as a zoonotic agent.

Tano-Debrah et al. 2011, detected *Listeria monocytogenes* in 53 to 80% of traditionally processed fish sampled from local informal markets in Ghana. The authors noted that the risk of listeriosis, as assessed by the codex alimentarius microbial risk assessment protocol was generally low. The report also explained that immuno-compromised individuals as well as pregnant women and children were at greater risk of infection.

2.11.3 *Escherichia coli*

*Escherichia coli* is a commensal microorganism which forms a major component of the intestinal microbiota of humans and other mammals (Costa, 2013). This facultative anaerobic bacteria, while confined to the intestinal lumen is often non-pathogenic but even some non-pathogenic strains can cause infection when gastrointestinal barriers are compromised or in immunosuppressed individuals (Teophilo et al., 2002). Pathogenic *E.coli*
strains have been implicated in a number of diseases including diarrhoea, bloody stools, haemolytic uremic syndrome as well as kidney infections (Teophilo et al., 2002; Costa 2013).

The occurrence of *E.coli* in foods is directly related to faecal contamination and has over the years been linked to seafood contamination especially in the tropics. *E. coli* type 1 was for instance, isolated from fish sourced from the beaches of Cameroon. This strain of *E. coli* is a uropathogen possessing the fimA gene for type1 fimbriae (short pili) and heteropolymeric mannose binding fibres. Type 1 fimbriae enable the bacteria to attach to various host cells, thus facilitating bacterial growth and persistence within the adverse settings of the host urinary tract. *E. coli* type 1 is thus one of the leading causes of urinary tract infections and it additionally produces many toxins (Akoachere et al., 2009).

### 2.11.4 *Salmonella*

Although fish and shell fish are known to be major carriers of *Salmonella*, they rarely show any clinical symptoms of salmonellosis themselves. They are passive carriers of the organism and are often contaminated via terrestrial sources (Novotny et al., 2004).

Salmonellosis is one of the most important food borne diseases and causes substantial medical and economic burdens worldwide. *Salmonella* can enter the fish value chain at every stage and the consequences for humans after consumption of the contaminate end product depend on the adequacy of the food processing conditions. The organism is also known to persist in processing environments for long periods to cause multiple recontaminations of foods (Malorny et al., 2008).

In Ghana, *Salmonella typhi* and *paratyphi* are common infections as evidenced in a report by Appiah-Korang et al (2014). The study documented the epidemiology of invasive salmonellosis in a tertiary hospital setting which serves as a referral centre for most
healthcare facilities in the southern part of Ghana. The study described *Salmonella* bacteraemia as endemic although it only reported 6.5% prevalence at the case study hospital. This may very well be the case, given unconfirmed reports of up to 50% prevalence of salmonellosis.

2.11.5 *Staphylococcus aureus*:

*Staphylococcus aureus* is one of the key bacterial agents responsible for human foodborne intoxications in humans worldwide. It has been reported as the third major causative agent of foodborne illnesses by fish and fish products in the European Union (Vasquez-Sanchez *et al.*).

Staphylococcal food poisoning is caused by staphylococcal enterotoxins (SE’s) which are resistant to proteolysis and are also heat stable. They therefore pose a significant health risk although staphylococcal food poisoning is usually self-limiting and resolves within 24-48 hours after onset (Schoeller and Ingham, 2001).

The initial load of *S. aureus* cells on fish samples may be low because common heat treatments are often sufficient to destroy the cells. The organism’s presence may therefore be indicative of insufficient heating or post-processing contamination (Schoeller and Ingham, 2001).

2.12 The Role of Value Chains in Fisheries Management:

A *value chain* describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use (Hempel, 2010). In its most basic form, a value chain may be condensed into three main vertically linked activities:

Production ➔ Marketing ➔ Consumption
Factors such as infrastructure, financial services and government policies, create an environment that influence the efficiency of the chain and are referred to as horizontal linkages (Gordon et al., 2011).

Management of fisheries in any nation is vital to both the economic and physical well-being of its inhabitants and an integral part of any development strategy (De Silva, 2011). Many developing countries including Ghana have taken fisheries management as an integral part of both their economic development plan and poverty reduction programmes. This is evident in the public-private partnership (PPP) sustainable fisheries project carried out between 2006 and 2009. The project aimed at strengthening the local fishing industry and consequently alleviating poverty along the coastal areas of Ghana.

Value chain analysis has become increasingly relevant in the analysis of fisheries management. Although it was originally intended to help economists in understanding how demand drives supply and vice-versa, it has found applications in many fields including sociology and agriculture where fish value chains have been used to identify inequalities between stakeholders and to enhance sustainability (Aho, 2013). For the microbiologists and food scientists, a value chain analysis affords an opportunity to study the growth and activity of spoilage and pathogenic microorganisms at each stage of the value chain. (Popovic et al., 2010). This would enhance better traceability and allow design and implementation of better quality control and fish safety methods (Popovic et al., 2010).

Each country has different value chains based on the number of actors involved in the process. While some chains are based entirely on local markets, others have both local and foreign market interventions, making the market function a lot more complicated (De Silva, 2011). Presented in Figure 2. 12.1 are the different types of global fishery value chains.
2.13 The Fish Value Chain in Ghana

Value chain studies have been uncommon in developing countries because it is difficult to ascertain the outcomes of different interactions when certain steps in the chain are missing (Hempel, 2010). This is often the case in Ghana where data is only collected at certain levels of the chain. For example, the Volta lake research and development project in 1969 only recorded data at the major fish selling markets and at the fish landing sites.

According to Gordon et al. (2011), the marine fish value chain begins with supply of inputs to fishermen, example nets, cork, fuel outboard motors etc. The chain continues in respective order as follows: Fishers, fish traders and middlemen, fish processors, fish traders or retailers, before finally reaching the consumer.
Figure 2.12 1 Global fishery value chains (adapted from De Silva, 2011)
CHAPTER THREE

3.0 METHODOLOGY

3.1 Study design

The study was in two parts. The first part was an initial cross-sectional survey which traced the local artisanal fish value chain. It also assessed the food safety knowledge and practices of key players or stakeholders within the identified value chain through questionnaire surveys. Participation in the survey was on a voluntary basis and anonymity and confidentiality of the response was ensured. Ethical clearance was obtained from the Noguchi Memorial Institute for Medical Research Institutional Review Board (NMIMR-IRB), University of Ghana.

The second phase was microbiological analyses in the laboratory. The study examined the microbiological quality of three locally consumed fishes at different stages of their respective value chains. The sardinella was used as a case study for marine fishes while Tilapia and the African catfish were used as case studies for fresh water fishes. These fishes were selected based on their availability and popularity among different socio-economic groups within Ghana.

3.2 Sampling and Data Analysis for Cross-sectional Survey

To trace the individual fish value chains, the fishermen were the first point of contact. They were asked who supplied resources necessary for their expeditions and which groups of people they handed their catch to. The trail was then followed to identify the next group of stakeholders until the fish reached the final consumer. All the different kinds of processing the fish were subjected to, as well as the major fish markets, where fish were either retailed or wholesaled were also identified in the process. Consumers were recruited on condition
that they had purchased raw, unprocessed fish from local informal markets at any time within the past six months.

Tilapia and the African catfish, were traced from stakeholders in Kpong, Senchi and Ayikpala, all of which were artisanal fishing communities located around the Volta Lake in the Eastern region of Ghana. Stakeholders in the sardinella value chain were interviewed along the coastlines of James Town and Chokor in Accra and also in the major fish markets, Salaga, Madina market and Kaneshie in Accra and Tuesday market in Mamprobi, a suburb of Accra. Figure 3.2.1 depicts a map of the study sites.

![A map of towns and markets from which samples were obtained](image)

**Figure 3.2.1** A map of towns and markets from which samples were obtained

A total of 293 stakeholders in the value chain were interviewed with four semi-structured questionnaires. These included 93 fishermen, 40 retailers, 40 processors and 120 consumers. All questionnaires were administered in the local language and responses given were entered
by the interviewer. All questionnaires were pre-tested prior to use. The questionnaire designed for fishermen assessed food safety practices based on 4 questions while retailers/wholesalers, processors and consumers were assessed based on 8 items on the questionnaire. Knowledge about food safety was also assessed based on up to seven items on the wholesaler, retailer, processor and the consumer questionnaire.

In both the knowledge and practice sections of the questionnaire, categorical responses (yes/no/don’t know) as well as open and more detailed responses were used. Each correct answer within the categorical responses carried a score of 1 while correct responses in the open ended questionnaires carried a score of 2. ‘Wrong’ or ‘don’t know’ answers were given a score of zero. For each respondent, the score of questions were summed up and converted into percentages (0 to 100). A representative score of 70% and above was considered “sufficient knowledge/practice” while a score of <70% was considered “insufficient knowledge/practice”. The scoring system applied here was adapted from similar studies by Osaili et al., (2013) and Zanin et al., (2015).

3.3 Sampling for microbiological analyses

Sampling was done at different stages of the value chain for each type of fish. The samples were collected on at least two separate occasions and from different individuals provided they sourced their fish from areas in and around Kpong in the case of Tilapia and catfish, and James Town in the case of the sardinellas.
Table 3.3.1: Study design for microbiological analyses:

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Product</th>
<th>Fish type (N)</th>
<th>Fish type (N)</th>
<th>Fish type (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RAW FISH</strong></td>
<td></td>
<td>Tilapia</td>
<td>African Catfish</td>
<td>Sardinella</td>
</tr>
<tr>
<td>Fishermen</td>
<td>Freshly landed fish</td>
<td>1x2</td>
<td>1x2</td>
<td>1x2</td>
</tr>
<tr>
<td>Wholesalers</td>
<td>Fresh fish</td>
<td>1x2</td>
<td>1x2</td>
<td>1x2</td>
</tr>
<tr>
<td>Retailers</td>
<td>Fresh fish</td>
<td>1x2</td>
<td>N/A</td>
<td>1x2</td>
</tr>
<tr>
<td>Processors (fermented/salted)</td>
<td>Raw fish</td>
<td>1x2</td>
<td>1x2</td>
<td>N/A</td>
</tr>
<tr>
<td>Processors (Salted/dried)</td>
<td>Raw fish</td>
<td>1x2</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Processors (Grilled)</td>
<td>Raw fish</td>
<td>1x2</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Processors (Smoked)</td>
<td>Raw fish</td>
<td>1x2</td>
<td>1x2</td>
<td>1x2</td>
</tr>
</tbody>
</table>

| **PROCESSED FISH** | | | | |
| Processors | Fermented/dried | 1x2 | 1x2 | N/A |
| Salted/dried | 1x2 | N/A | N/A |
| Smoked | 1x2 | 1x2 | 1x2 |
| Grilled | 1x2 | N/A | N/A |
| Fried | 1x2 | 1x2 | N/A |
| Smoked | 1x2 | 1x2 | 1x2 |
| Salted | 1x2 | N/A | N/A |
| Sun-dried | N/A | N/A | 1x2 |

N/A: Not applicable (samples were not typically found at that stage of the value chain)

Samples were collected into sterile stomacher bags, appropriately labelled and transported in thermos ice chests disinfected with 70% alcohol. All fresh and raw samples were transported on ice and analysed in the laboratory within 4 hours of sampling. Processed fish samples were analysed within 24 hours of collection. To prevent cross contamination, processed fish were not sampled on the same day as the raw and fresh fishes.

Figure 3.3.1 Collected fish samples in ice chest transported to the laboratory
3.3.1 Sampling of fish from Fishermen

Sampling was done by convenience. Sampling of the landed fish was done by asking the fishermen to randomly select the fish of interest from their catch. Sampled fish was then transferred into a sterile stomacher bag handled by the gloved hands of the researcher. The bag was sealed and put into the thermos ice chest.

3.3.2 Sampling of fish from wholesalers and retailers

Fresh fish samples were purchased from wholesalers at the fish landing site and from retailers at the informal fish markets in Salaga and Madina. The fishes were purchased from individuals far removed from each other in the market. The wholesaler or retailer was asked to randomly select the fishes in the same manner she would handle them when selling to a consumer or customer.

3.3.3 Sampling of fish from Processors:

Sampling here was done at the processing site. Where it was available, samples of the raw fish intended for processing were also collected, and their storage temperature measured with a thermocouple (Thermoscientific). Such samples were however, collected and transported in a container separate from the processed fish samples. Processed fish in storage or ready to be served to consumers were randomly selected by the processor and sealed in sterile stomacher bags for transport on ice to the laboratory. The samples were stored in a cold room at 4°C for no longer than 24 hours when they could not be worked on immediately.

3.4 Microbiological analyses

Samples were analysed for the total count or concentration of aerobic mesophiles, coliforms, staphylococci, yeasts and moulds and Clostridium perfringens. The fish samples were also analysed for the presence of Escherichia coli, Salmonella spp., Vibrio cholera, Vibrio parahaemolyticus, Staphylococcus aureus, Pseudomonas spp., and Listeria spp.
3.4.1 Sample preparation

Ten grams of each sample was aseptically weighed into sterile stomacher bags with the addition of 90 mls peptone water. Because of their smaller sizes, juvenile sardinellas were weighed whole. In the case of tilapia and catfish, bits of the surface tissues, gills, gut and muscle from the loin (thickest part of fish muscle) were taken with sterile scissors and aseptically weighed to obtain the final mass. The weighed samples were then homogenised for up to 2 minutes in a Seward stomacher blender. Serial dilutions for the various microbial counts earlier mentioned were then carried out according to methods described by the International Commission for Microbiological Specifications for Foods (ICMSF, 1985).

![Figure 3.4.1 Aseptically weighed fish (juvenile sardinellas) in Peptone water](Image)

3.4.2 Aerobic Mesophilic Count

In a method described by the (ICMSF, 1985), homogenates of fish samples were serially diluted and 0.1ml of three dilutions was pipetted into sterile disposable petri-dishes. Twenty millilitre portions of Plate Count Agar (PCA) (Biolab-Merck) were then poured on the inoculum using the pour plate technique. The set PCA dishes were incubated inverted at 20-25 °C for 48±2 hours to account for psychrophiles which may be present. Two replicates of at least two dilutions with 25-250 discrete colonies were enumerated following incubation. All counts were reported as the logarithm to base 10 of colony forming units per gram (log cfu/g).
3.4.3 Enumeration of Total Staphylococci and Detection of S. aureus

Three serial decimal dilutions of the samples were plated using the pour plate technique on Baird-Parker agar (Oxoid CM275) supplemented with egg yolk tellurite emulsion (Oxoid). After incubation at 35-37°C for up to 48 hours, plates containing 20-200 typical staphylococcal colonies (black, circular) were counted. Up to 5 colonies on each plate were subcultured on nutrient agar (Oxoid CM003), gram stained and tested for catalase activity. All typical staphylococci were catalase positive and were gram positive stacked cocci. *Staphylococcus aureus* colonies were circular, convex, grey-black to jet-black with an off-white margin. They were also gram positive cocci, catalase positive and coagulase positive (APHA, 2001).

![Coagulase Reaction of Staphylococcus aureus using Pastorex coagulase test kit (Bio-Rad)](image)

**Figure 3.4.** 2 Coagulase Reaction of *Staphylococcus aureus* using Pastorex coagulase test kit (Bio-Rad)

3.4.4 Enumeration and Detection of faecal coliforms and *E.coli*

Three serial decimal dilutions of the fish-peptone water homogenate were pour plated on Levine Eosin Methylene Blue (EMB) agar (Oxoid CM0069) and incubated at 35 °C for 24 hours. Plates with 20-200 Purple colonies were counted and subcultured on MacConkey agar (Oxoid). Faecal coliforms fermented lactose (pale pink colour on MacConkey) and were gram negative rods. *Escherichia coli* colonies appeared circular, dry and flat with a metallic sheen. Five of such colonies were subcultured on Sorbitol MacConkey (SMAC) agar (Merck), where they appeared as pin point, pale pink colonies. These suspect colonies were then purified on
nutrient agar and then transferred unto Triple sugar iron agar (TSI) slants, Simon’s citrate slants and Sulphur-Indole-Motility (SIM) agar. *E.coli* colonies were indole positive, gas positive, H₂S negative, citrate negative and could ferment glucose and sucrose.

All presumptively identified *Escherichia coli* colonies were confirmed with API 20E and serotyped using a serotyping kit. *Klebsiella spp.* often mimicked *E.coli* on EMB plates but had a moist appearance, with or without a metallic sheen and was also slimy when touched with an inoculating loop. Suspect colonies were purified on nutrient agar and confirmed with API 20E (APHA, 2001).

### 3.4.5 *Clostridium perfringens* Count

Spread plates of serial dilutions were made using 0.1ml aliquots on TSC (tryptose-sulfite-cycloserine) agar (Oxoid CM0587) supplemented with egg-yolk and TSC supplement (Oxoid). After the agar had dried slightly, the surface was overlaid with 5ml of TSC agar and incubated upright in an anaerobic jar containing an aerobic gas generating kit (Oxoid anaerogen) and incubated at 35-37°C for 24 hours. Plates containing 20-200 black colonies with opaque halos were selected and counted.

To confirm presumptive positive *Clostridium perfringens* colonies, 5 black colonies were selected and tested for motility in SIM agar and for nitrate reduction in nitrate broth (Fluka 72548). *Clostridium perfringens* reduced nitrate and was non motile (APHA, 2001).

### 3.4.6 Detection and Enumeration and of Yeasts and Moulds

Serial decimal dilutions of the homogenate were pour plated in Malt Extract Agar (MEA)-Oxoid CM0059, supplemented with 10% lactic acid and incubated at 25°C for up to 5days. Plates containing 20-200 colonies were counted.
3.4.7 Detection of *Pseudomonas* species:

In a method described by Tryfinopoulou *et al.*, (2001), dilutions of the homogenate were pour plated in *Pseudomonas* agar (Oxoid CM0559) with 5ml of glycerol and a vial of pseudomonas CFC (Cephaloridine-fucidine-centrimide) supplement (Oxoid), and incubated at 25°C for 24 hours and 48 hours. *Pseudomonas aeruginosa* appeared as straw-coloured colonies with green pigmentation. Presumptive positive colonies were subcultured on nutrient agar and tested for oxidase activity. *Pseudomonas* spp were gram stained (gram negative rods) and confirmed with API 20E.

3.4.8 Detection of *Vibrio* species

Twenty-five grams of fish samples were weighed and homogenised in 225ml of alkaline peptone water. The homogenate was aseptically dispensed as 10ml aliquots in lightly capped test tubes and incubated for 18-24 hours at 35°C. The pre-enriched samples were vortexed after which a 3mm loop (about 0.1ml) was aseptically taken and streaked unto well-dried Oxoid CM0333 Thiosulphate Citrate and Bile salts Sucrose (TCBS) agar plates. The plates were incubated (inverted) at 35-37°C for 18 to 24 hours or until growth was satisfactory.

Suspect *Vibrio cholerae* colonies on TCBS agar were large, smooth, flat and yellow while *Vibrio parahaemolyticus* were smaller, green and round. *Aeromonas* spp. could mimic both appearances on the TCBS agar. All suspect colonies were purified on nutrient agar and tested for oxidase activity. Colonies that were found to be oxidase positive were purified further on nutrient agar and confirmed with API 20E (APHA, 2001).

3.4.9 Detection of *Salmonella* species

Twenty-five grams of fish samples were homogenised in 225ml of selenite broth, dispensed into loosely capped sterile test tubes as 10ml aliquots, and incubated for 18-24 hours at 35°C to recover injured cells. Three drops of the pre-enriched culture were evenly inoculated on plates of Modified Semi-solid Rappaport Vassiliadis medium (MSRV, Oxoid CM1112). A
loop full of the pre-enriched culture was also streaked on dried plates of Salmonella-Shigella agar (SSA, Park scientific M0240). Growth on both media was examined after 18-24 hours at incubation temperature of 35°C.

Presumptive positive *Salmonella* colonies appeared on SSA as straw coloured with or without black centres. *Proteus* spp often swarmed the SSA plates, appeared as black colonies and had a very foul smell. Suspect *Salmonella* colonies were isolated and purified on nutrient agar for biochemical testing.

Suspect *Salmonella* growing on the MSRV were greyish and appeared motile. A sample of the growth was streaked unto a dried SSA plate with a sterile loop and incubated overnight. *Salmonella*-like colonies observed were streaked unto Nutrient agar for purification. All purified colonies were tested for urease reactions on Urea agar slants and on TSI agar.

Gram negative rods with negative urea reaction were confirmed using the API 20E kit (APHA, 2001). All identified *Proteus* species were tested for indole reaction to differentiate *P. mirabilis* or *P. penneri* from *P. vulgaris*.

### 3.4.10 Detection of *Listeria* species

Twenty-five gram samples of fish homogenised in 225ml of Merck Listeria Enrichment Broth (LEB) were distributed into loosely caped test tubes as 10 ml aliquots. After 24 hour incubation at 35°C, 1ml of the LEB-fish homogenate was aseptically transferred into 9ml of Fraser broth (Oxoid CM0895). This was incubated at 35±2°C for another 24 hours. A loop full of the enriched homogenate was then streaked unto well-dried plates of Chromogenic Listeria agar (LCA, Oxoid CM1017), which was incubated at 35±2°C for 24 hours or until growth was satisfactory. Suspect *Listeria* colonies appeared as blue-green colonies surrounded by an opaque halo.
Selected colonies on the LCA plates were purified on 5% sheep blood agar (Oxoid). Presumptive *Listeria* colonies appeared whitish on blood agar and displayed β-haemolytic activity. Discrete colonies from the blood agar were also tested for motility on SIM agar, for catalase activity and for Gram’s reaction. Presumptive positive *Listeria* were catalase positive, gram positive short rods, and displayed umbrella motility in SIM agar (APHA, 2001).

### 3.5 Physical and Chemical Analysis of Intrinsic properties of Fish

#### 3.5.1 Temperature

The fish (both fresh and processed) temperature was measured with a thermocouple (Hanna Instruments) calibrated in hot water at 100°C and ice water at 0°C on each sampling day. The probe of the thermocouple was first disinfected with 70% ethanol before being used to measure the temperature at the head, mid-section and tail regions of the fish. The average of the three readings were recorded and reported as Mean± Standard deviation.

#### 3.5.2 pH

Moisture content of the fish sample was first determined using the standard method described in I.S 14950: 2001 fish dry and dry salted. If the fish was for example found to contain 20% moisture, it implied that every 10g of the sample weighed had 8g of dry matter. To obtain 10g of fish dry matter, 12.5g of the sample was weighed and homogenized in 87.5g of deionized water. The pH of the homogenate was then measured with a glass electrode pH meter. The average of three readings were recorded and corrected for temperature differences (I.S 14950: 2001).

#### 3.6 Determination of Risk Factors along the Fish Value chain

To establish the link between the food safety knowledge and practices of stakeholders and the actual quality and safety of the fish, a flow chart was designed based on evidence from the survey and from the laboratory microbiological analyses.
The risk of poor handling was determined from the food safety knowledge scores and handling practices determined from the survey. Also, the risk of fish spoilage and pathogenic contamination was determined by the presence of spoilage organisms and pathogens respectively from fish sampled at the various stages of the value chain. Finally, temperature abuse and poor hygiene were determined by recorded temperatures of fish and counts of hygiene indicator microbes respectively.

3.7 Statistical Analysis

A binary logistic regression was used to determine the possible predictors of food safety knowledge and handling practices of stakeholders using their demographic characteristics as covariates. Descriptive statistics such as means, standard deviations and frequencies were used to analyse microbial counts. The means were data from three independent experiments for microbial counts of fresh and processed fish. Analyses of variance, ANOVA (one-way) was used to assess the significance of differences between counts of microbes obtained from different stakeholders, and also between the counts sourced from the different value chains (marine and fresh water).

The percentage prevalence of isolated microorganisms was determined using Cross tabulations. Pearson’s chi-square was used to test the association between the level of food safety knowledge and practices, and the estimated fish losses. All statistical analyses were done using IBM SPSS version 21, Minitab version 14 and Microsoft Excel (2010).

3.8 Assumptions and Limitations

Fishermen were generally harder to track and interview because they often landed at different times of the day and were often busy negotiating, sorting or selling their catch at the time of the interviews. In order to reduce the time required in interviewing them, fishermen were not assessed on their food safety knowledge. It was instead assumed that
their practices were more important given that, they typically handed over their catch immediately after landing.

The study also assumed that the reported practices of the stakeholders were their actual practices.
CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Demographic Characteristics of Stakeholders in the Kpong and James Town Artisanal Fish Value Chain.

Every stage in the artisanal fish value chain was dominated by women with the exception being the fishermen who were all male. Wholesalers and retailers of fresh and processed fish were predominantly female (87.5%). Processors were also mostly female, recording 97.5% in all areas surveyed in this study. The demographic characteristics of the stakeholders are depicted in Table 4.1.1.

It was of interest to note that majority of the stakeholders with the exception of consumers were above 40 years in age. This as explained by the stakeholders, was primarily because a significant amount of capital and social connections are required to enter the fish business. As many as 32% of fishermen had never received formal education. Similarly, 17% of wholesalers and retailers as well as 27% of processors also had no formal education.

Fishermen in James Town were predominantly ethnic “Ga” while those in Kpong were mostly of “Ewe” and “Ga-Dangbe” descent.
Table 4.1. 1: Demographic Characteristics and Profile of Stakeholders within the Fish Value chain

<table>
<thead>
<tr>
<th>Biodata</th>
<th>% Stakeholder (N)</th>
<th>F’man (N=93)</th>
<th>Whol/Ret (N=40)</th>
<th>Procs (N=40)</th>
<th>Cons (120)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-24 yrs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-39 yrs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;40 yrs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ada</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krobo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ewe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ga</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northerner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Religion</td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Christian</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Muslim</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional African</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pri/Midsch/ SHS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertiary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longevity in fisheries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-5yrs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-10yrs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-15yrs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-20yrs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;20yrs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: N/A = not applicable; F’man= fishermen; Whol/Ret= wholesaler/retailer; Procs= processor; Cons= consumer
4.2 Mapping out the Artisanal Fish Value Chains in Kpong and James Town

The value chains of tilapia and the African catfish, traced from the artisanal fishermen in Kpong are depicted in Figure 4.2.1 and Figure 4.2.2 respectively.

![Fisherman](http://ugspace.ug.edu.gh)

**Figure 4.2.1** Artisanal value chain for Tilapia sourced from Kpong, Eastern region, Ghana

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**Figure 4.2.1** Artisanal value chain for Tilapia sourced from Kpong, Eastern region, Ghana
Figure 4.2 The value chain of the African catfish sourced from Artisanal fishermen in Kpong, Eastern region, Ghana
The value chain began with fishermen, the majority of whom owned their own canoes and a few who rented the canoe on a daily or weekly bases. Tilapia and the African catfish (fresh water fishes) were often sold at landing by fishermen to women who in turn sold the fish either on wholesale or retail to consumers, processors and other small-scale retailers. Many of these small scale retailers sold the fresh fish in vehicular traffic to travellers on the Kpong –Tema road, while some also sold the fresh fish in distant markets like the Madina and the Makola markets in Accra, and also in markets in Tema. Also at retail, there was a secondary group of stakeholders, depicted in Figure 4.2.1 and Figure 4.2.2 as “Fish cleaners”. This group of people, who included both men and women, would often hang around the landing site and render the service of gutting, scaling and sizing of the tilapia and catfish bought by consumers. This is important to note because, these individuals increased the number of handlers along the value chain and were a potential source of recontamination.

Tilapia was typically processed by smoking, salting (“Koobi”), grilling, frying, and fermenting (“Momone”). The African catfish was also mainly processed by smoking, frying and fermenting. Fried tilapia and catfish were retailed directly by processors who hawked in traffic on the Kpong-Tema Highway. Grilling of Tilapia was mostly carried out at night time and retailed directly by the processors as street food. Smoked and salted tilapia was often sold on wholesale to retailers who in turn sold the fish to consumers in the previously mentioned local markets. It was however still possible to purchase salted and smoked tilapia directly from the processors. This also applied to smoked and fermented catfish. To keep smoked tilapia or catfish from rapid deterioration, processors and retailers reported that, they re-smoked or reheated the fish daily until it was sold to consumers. Nonetheless, the majority of tilapia and catfish were reportedly bought by consumers in their raw or unprocessed state. Most consumers however reported buying sardinellas already processed. The absence of a frozen fish value chain in the Tilapia value chain and in the value chain of the African catfish was of significance. Cold store operators in and around the study sites all reported having
obtained their fish from inland fish farms rather than from artisanal fishermen. Very little, if any of the artisanal catch therefore ended up in frozen storage or in cold stores prior to reaching the consumer.

The value chain of the sardinella, which was sourced from marine habitat, was markedly more complicated than the fresh water fishes. This value chain is depicted in Figure 4.2.3. This value chain also began with the fishermen, but had a unique and very interesting group of stakeholders, the fish queens known locally as “Lonye”. These women appeared to wield great influence throughout the sardinella value chain and in fact, the value chains of most fishes landed at the James Town fishing harbour.

The Fish Queens were typically the wives of the Captains of the fishing canoes and in many cases, these women also owned the canoes. They also reportedly pre-financed some of the fishing expeditions by providing fishing gears and pre-mix fuel for the outboard motors. In situations where the fish queen owned the canoe or pre-financed the operation, she was handed the largest percentage of the catch or the entire catch. The fish queens reportedly had such arrangements with several fishermen on different canoes and were therefore able to offer for sale large quantities of fish pooled from different fishermen. A similar system has been reported in the Lake Victoria fisheries bordering Uganda (FAO, 2013). Many fishermen also owned their own canoes or worked for other men who also financed their expedition much like the fish queen did. They however also sold their fish to the fish queens and scarcely engaged themselves in selling the fish directly to consumers or to other stakeholders. The roles of these women have also been described by Akrofi (2002) who referred to them as “fish mummies”.

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Figure 4.2 3 The value chain of the sardinella sourced from artisanal fishermen in James Town, Accra, Ghana.
Sardinellas were typically hot smoked, sun-dried, and occasionally fried. Smoking was however the primary mode of processing and smoked sardinellas were retailed on local markets like Madina, Kaneshi, and Makola, all in Accra but also in distant markets such as Kumasi in the middle belt of the country, and in the Northern regions as well.

Fish smokers, who often processed their fish in large quantities to make efficient use of fuel and labour, typically purchased their raw fish from the fish queens. With the order placed, the fish was carried in cane baskets on the heads of young boys to the processing site or by public transport if the site was too far off. The sardinellas were thus ready to be smoked within a few hours after landing. It should be noted that, very little smoking was carried out on the beach of James Town. Majority of the sardinellas landed in James Town were smoked on the beach of “Chorkor”, a fishing settlement about 50 minutes’ walk (4km) from James Town. A good number of the fishermen in James Town were also reportedly resident in “Chorkor”. Chorkor was thus the primary hub of fish smoking and many wholesalers and retailers from different parts of the country were reported to purchase smoked fish in this town for resale in local and international markets.

During lean seasons, when sufficient quantities could not be obtained from artisanal sources, fish smokers especially reported that they bought frozen sardinellas from cold stores. Much like tilapia and catfish, sardinellas in frozen storage were not obtained from artisanal sources. Cold store operators bought their sardinellas from industrial fishing trawlers at the Tema port.

Contrary to the practice in most developed countries, wholesale and retail of fresh artisanal sardinella, tilapia or catfish was rarely measured out in costs per weights of fish. At the wholesale level, fish was sold per basket or crate (appendix 2C). The baskets were filled at the discretion of the fishermen or wholesalers and were not weighed. Retail was done by counts or number in the case of tilapia and catfish, while sardinellas were retailed in
handfuls. This practice invariably led to frequent handling of the fish by both retailers and consumers, thus introducing opportunities for contamination. It also led to variations in prices between different retailers, resulting in longer bargaining times.

In the case of Tilapia and the African catfish, the price could vary considerably depending on the size of the fishes in the crate. The fishes were therefore sorted by size and species prior to sale. Sorting was also a practice used by stakeholders in the marine fish value chain. Smaller sized fish species in the marine fish value chain were however often sold without sorting. This was particularly true for sardinellas which were mixed with Anchovies at landing and at the wholesale level, mainly because Anchovies were similar in size and could be utilised in place of sardinellas in most recipes. Processors therefore smoked these two species together but separated them after smoking. Once smoked the sardinellas and anchovies were then sorted out and sold separately to consumers and other retailers, especially because sardinellas fetched a higher price. This sorting step after processing, however increases handling and could therefore introduce post-processing contamination.

4.3 Food Safety Knowledge and Practices among Stakeholders

The mean knowledge score for all stakeholders was found to be 6.0±2.3 (60%) while the mean practice score was 5.64 ±2.8 (56%), generally suggesting insufficient levels of food safety knowledge and practice. The exception was with the retailers who had a mean practice score of 7.85±1.64 (79%), which suggested sufficient levels of food safety practices.

Fishermen, processors and consumers had mean practice scores of 4.12±2.99 (41%), 6.30±2.04 (63%) and 5.86±2.42 (59%) respectively. Mean knowledge scores of retailers, processors and consumers were found to be 5.50±1.99 (55%), 4.30±2.05 (43%), and 6.73±2.02 (67%) respectively. Table 4.3.1 displays the responses on the food safety knowledge of stakeholders along the value chains of the fishes used in this study.
Table 4.3.1: Responses to questions on food safety knowledge

<table>
<thead>
<tr>
<th>Questions</th>
<th>Ret/Whole (40)</th>
<th>Processors (40)</th>
<th>Consumers (120)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>correct</td>
<td>wrong</td>
<td>correct</td>
</tr>
<tr>
<td>Are you able to identify spoilt fish?</td>
<td>87.5</td>
<td>12.5</td>
<td>100.0</td>
</tr>
<tr>
<td>What are the indications of fish spoilage?</td>
<td>69.7</td>
<td>30.3</td>
<td>82.5</td>
</tr>
<tr>
<td>What causes fish spoilage?</td>
<td>67.5</td>
<td>32.5</td>
<td>40.0</td>
</tr>
<tr>
<td>Could handling contribute to spoilage?</td>
<td>77.5</td>
<td>22.5</td>
<td>87.5</td>
</tr>
<tr>
<td>What are some of the bad handling practices?</td>
<td>77.5</td>
<td>22.5</td>
<td>60.0</td>
</tr>
<tr>
<td>Describe the condition of infected fishes</td>
<td>32.5</td>
<td>67.5</td>
<td>17.5</td>
</tr>
<tr>
<td>Can eating a diseased fish cause illness</td>
<td>22.5</td>
<td>77.5</td>
<td>20</td>
</tr>
<tr>
<td>What illnesses are caused by eating spoilt fish?</td>
<td>2.5</td>
<td>97.5</td>
<td>20</td>
</tr>
<tr>
<td>How is fish spoilage prevented?</td>
<td>95.0</td>
<td>5.0</td>
<td>77.5</td>
</tr>
<tr>
<td><strong>Average Scores</strong></td>
<td><strong>5.50±1.99</strong></td>
<td><strong>4.30±2.05</strong></td>
<td><strong>6.73±2.02</strong></td>
</tr>
</tbody>
</table>

Table 4.3.1 revealed that there was generally good knowledge among all stakeholders with regards to indications of fish spoilage, proper ways of handling fish and ways of preventing fish spoilage. Table 4.3.2 also displays the questions which assessed fish handling practices and shows that, the stakeholders reported practices which supported this knowledge.
Table 4.3. 2: Responses to questions on food safety practices

<table>
<thead>
<tr>
<th>Questions</th>
<th>% Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fishermen (93)</td>
</tr>
<tr>
<td></td>
<td>correct</td>
</tr>
<tr>
<td>Do you inspect raw fish before purchasing/selling?</td>
<td>N/A</td>
</tr>
<tr>
<td>What indications of spoilage do you look out for?</td>
<td>N/A</td>
</tr>
<tr>
<td>How do you transport raw fish?</td>
<td>52.7</td>
</tr>
<tr>
<td>How do you prevent spoilage?</td>
<td>52.5</td>
</tr>
<tr>
<td>How do you store your fish?</td>
<td>48.0</td>
</tr>
<tr>
<td>What do you do with spoilt fish?</td>
<td>N/A</td>
</tr>
<tr>
<td>Average scores</td>
<td>4.12±2.99</td>
</tr>
</tbody>
</table>

It can however be argued that this knowledge is basic to their trade and essential to prevent economic losses. It is traditional knowledge that has been passed down through generations, as evidenced by the fact that 87% of processors and retailers reported that their skills were acquired through family traditions. It can be deduced therefore that, they had no genuine knowledge of the actual causes of fish spoilage. That is, they practiced what they had been taught to do traditionally without truly understanding the basis of their actions. Table 4.3.3 displays the actual responses given by the stakeholders when asked about the cause of fish spoilage.
<table>
<thead>
<tr>
<th>What causes fish spoilage (Responses)</th>
<th>% Stakeholder (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole/Ret</td>
</tr>
<tr>
<td><strong>Microorganisms</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5 (1)</td>
</tr>
<tr>
<td><strong>Lack of cold storage</strong></td>
<td>65.0 (26)</td>
</tr>
<tr>
<td><strong>Flies and other insects</strong></td>
<td>15.0 (6)</td>
</tr>
<tr>
<td><strong>Prolonged storage</strong></td>
<td>2.5 (1)</td>
</tr>
<tr>
<td><strong>Under-processing</strong></td>
<td>5.0 (2)</td>
</tr>
<tr>
<td><strong>Chemical treatment of fish</strong></td>
<td>0 (0)</td>
</tr>
<tr>
<td><strong>Unhygienic handling</strong></td>
<td>0 (0)</td>
</tr>
<tr>
<td><strong>Don’t know</strong></td>
<td>10.0 (4)</td>
</tr>
</tbody>
</table>

Majority of wholesalers, retailers and consumers pointed to the lack of cold storage as the cause of fish spoilage, while processors attributed spoilage to insufficient processing and high moisture after processing. These and other responses such as insect infestation were scored as correct responses because they pointed to conditions that favoured microbial growth. Only six out of the total number of respondents pointed correctly at microorganisms while none mentioned autolysis. It should also be noted that, with regards to fish handling and food safety practices, respondents were assessed based on their responses in the questionnaire survey and not their actual observed practices.

The gender, age, ethnicity, longevity in the fish business, religion, level of education and the type of stakeholder within the value chain were used to predict the probability that a stakeholder within the fish value chain would have sufficient levels of food safety knowledge and practices. The results of the binary logistic regression to assess this association is displayed in Table 4.3.4.
Table 4.3. 4: Logistic regression predicting level of Knowledge and self-reported food safety practices from stakeholders’ demographic characteristics

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>Wald chi-square</th>
<th>p-value</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Know</td>
<td>Prac</td>
<td>Know</td>
<td>Prac</td>
</tr>
<tr>
<td>Gender</td>
<td>-1.36</td>
<td>-2.42</td>
<td>1.12</td>
<td>7.55</td>
</tr>
<tr>
<td>Age</td>
<td>0.682</td>
<td>0.00</td>
<td>1.61</td>
<td>0.00</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>-1.90</td>
<td>-3.48</td>
<td>1.74</td>
<td>19.05</td>
</tr>
<tr>
<td>(Ada)</td>
<td>-</td>
<td>-</td>
<td>4.76</td>
<td>27.5</td>
</tr>
<tr>
<td>(Krobo)</td>
<td>17.68</td>
<td>-3.14</td>
<td>0.00</td>
<td>6.42</td>
</tr>
<tr>
<td>(Ewe)</td>
<td>-2.57</td>
<td>-3.60</td>
<td>3.95</td>
<td>24.71</td>
</tr>
<tr>
<td>Longevity</td>
<td>-1.79</td>
<td>0.33</td>
<td>0.45</td>
<td>3.02</td>
</tr>
<tr>
<td>Religion</td>
<td>-1.04</td>
<td>-1.12</td>
<td>4.03</td>
<td>0.28</td>
</tr>
<tr>
<td>Education</td>
<td>-1.29</td>
<td>0.35</td>
<td>0.03</td>
<td>0.84</td>
</tr>
<tr>
<td>Stakeholder</td>
<td>-1.65</td>
<td>-2.74</td>
<td>3.18</td>
<td>10.34</td>
</tr>
<tr>
<td>(Retailer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*significant at p-value <0.05; Know= food safety knowledge; Prac= fish handling practices

Based on responses from the questionnaire survey, the model predicted that, retailers were more likely to have sufficient food safety practices compared to other stakeholders within the value chain. Individuals who were Ewe’s, Krobo’s and Ga Dangbe (predominantly within the fresh water value chain) were also more likely to engage in good fish handling and food safety practices. This suggests therefore that, stakeholders within the freshwater value chain were significantly more likely to engage in good fish handling practices compared to those in the marine fish value chain. The odds of this likelihood was however, notably very small (Odds ratio = 0.03, on average).

Figure 4.3.1 below compares the percentage of stakeholders who were found to have sufficient levels of knowledge on food safety and fish handling practices in order to establish a relationship between reported knowledge and practices.

50
Figure 4.3.1 Relationship between the knowledge and practices of Some Stakeholders in the fish value chain

It can be observed from Figure 4.3.1 that, while almost 90% of retailers in the value chain sufficiently practiced food safety rules concerning fish handling, only 30% of these individuals had sufficient knowledge about food safety. A similar trend was apparent among the processors. An insignificant correlation (rho=0.008, p-value= 0.856 at 95% CI) between knowledge and practices lends even more support to the argument that many of the stakeholders practiced good handling practices without necessarily understanding the basis or importance of their actions.

Most other studies assessing food safety knowledge and practices however reported a different trend, where good knowledge did not always translate to good practices. This is exemplified by the findings of Omemu and Aderoju (2008), whose study on the food safety knowledge and practices of street food vendors in Nigeria, revealed that a good knowledge in the importance of hand washing did not translate into improved handling practices. The
situation among stakeholders in the Ghanaian fish value is however not of less concern, as the lack of understanding of the bases of their good food safety practices may lead them to use those practices nonchalantly.

4.4 Fish Losses due to Spoilage in the Artisanal Fish Value Chain

Stakeholders in both the marine and fresh water value chains reported that they never really considered fish as spoilt, especially with regards to tilapia, catfish and sardinellas. According to most of them, fish only loses its freshness and is useful as food even when it looks rotten. Tilapia and catfish were for example salted, and sun dried into “momone” or “lonshala”. *Lonshala* however fetches a much lower price than in the fresh state. Again, *lonshala* is primarily intended for flavouring and used in very small quantities during cooking. The fish therefore ceased to be a primary source of protein in the diet once it lost its freshness prior to processing. Stakeholders thus estimated their losses based on fish they had to devalue because they were no longer considered fresh by consumers and customers.

Figure 4.4.1 depicts the levels of fish losses due to spoilage experienced by the different stakeholders along the value chain.

![Figure 4.4.1 Estimated fish losses along the fish value chain](http://ugspace.ug.edu.gh)

Figure 4.4. 1 Estimated fish losses along the fish value chain

52
Spoilage was classified in this study as low when the losses ranged between zero and 34%. The losses were considered high when as much as 35 to 100% of the fish were lost. Consumers understandably suffered the greatest amounts of losses, sometimes losing up to 100% of all fish bought, owing to the fact that they were at the very end of the value chain. They also attributed these high levels of losses to the less than reliable electrical power supply currently the situation in Ghana. For consumers, the cause of action for fish that had lost its freshness was to discard or use the spoilt fish as animal feed (refer to Table 4.4.1). Fish therefore intended for use as the primary protein in meals were lost and significant economic losses had to be incurred to replace the spoilt fish.

Table 4.4.1: Stakeholders’ Responses to Use of fish no longer considered fresh

<table>
<thead>
<tr>
<th>Use of “Spoilt” Fish</th>
<th>Number of Stakeholders (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wholesaler/Retailer</td>
</tr>
<tr>
<td>1 Discarded</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>2 Modified to “lonshala/momone”</td>
<td>18 (66.7)</td>
</tr>
<tr>
<td>3 Animal feed</td>
<td>1 (14.3)</td>
</tr>
<tr>
<td>4 Sold to consumers as “fresh”</td>
<td>1 (100)</td>
</tr>
<tr>
<td>5 Processed as originally intended</td>
<td>0 (0)</td>
</tr>
<tr>
<td>6 Returned to purchase point</td>
<td>0 (0)</td>
</tr>
<tr>
<td>7 Consumed Regardless</td>
<td>0 (0)</td>
</tr>
<tr>
<td>8 Never experience spoilage</td>
<td>19 (23.8)</td>
</tr>
</tbody>
</table>

Processors, wholesalers and retailers rarely experienced high levels of losses due to their ability to transform and add value to fish that had lost its freshness. Processors for example
reported that they could still process spoilt fish as originally intended (without downgrading it to *momone*), because they believed their processing methods could render the spoilt fish safe for consumption. Fishermen experienced minimal losses comparatively, most likely because they reported that they always had a ready market at landing.

Akande and Dei-Ouadi (2010) reported that, between ten and thirty percent of artisanal catch in Ghana is downgraded due to quality deterioration. Similar findings from this study, displayed in Figure 4.4.2, showed up to 34% losses among 37% of all stakeholders and between 68 to 100% losses among 13% of stakeholders.

![Figure 4.4.2 Stakeholder estimates of fish downgraded, devalued or discarded due to spoilage](image)

The food safety knowledge and practices of the stakeholders within the fish value chain also appeared to play a role in the reported extent of fish losses. A strong association (Pearson chi-square = 16.137, p-value 0.00) was found between level of knowledge and the estimated
fish losses. This suggested that the level of food safety knowledge of a stakeholder can reliably predict the extent of their fish losses.

Presented in Figure 4.4.3 is a graph illustrating the relationship between extent of fish losses and food safety practices.

![Figure 4.4.3 Relationship between insufficient food safety practices and fish losses among stakeholders](image)

**Figure 4.4.3 Relationship between insufficient food safety practices and fish losses among stakeholders**

### 4.5 Microbiological Quality and Safety of Fish at different stages of the Artisanal Fish Value Chain

*Salmonella* spp, *Vibrio parahaemolyticus*, and *Vibrio cholerae* were not detected on any of the samples tested. Ikutegbe and Sikoki (2014) also reported the absence of these organisms although their study focused only on dried-smoked fish samples. All the suspect *Vibrio* colonies were confirmed as *Aeromonas sobria* by API 20E, with a prevalence rate of 4.8%.
Table 4.5.1 lists the incidence of some of the pathogenic and spoilage organisms detected in raw and processed fish samples.

The absence of *Salmonella* spp, *Vibrio parahaemolyticus*, and *Vibrio cholerae* on the tested fish samples is of key importance given the significant public health threats they are capable of. The presence of *Aeromonas sobria* on both raw and processed fish samples is however very troubling. This organism is a pathogen that can cause foodborne gastroenteritis in humans and extraintestinal symptoms such as septicaemia, meningitis and endocarditis and osteomyelitis. It is especially dangerous in immuno-compromised individuals. This organism had been previously isolated from fish by Boari *et al.*, (2008) and by Ashiru *et al.* (2011) who also isolated the organism on catfish and tilapia even at refrigerated temperatures. *Aeromonas* spp. have also been implicated in the spoilage of fish (Tryfinopolou *et al.*, 2002; Gram and Dalgaard, 2002) because of their ability to produce enzymes such as lipases and proteases.
### Table 4.5. 1: Prevalence of some pathogenic and spoilage organisms on raw and processed Tilapia, catfish and sardinella

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>% Prevalence (n/N)</th>
<th>Raw (0/27)</th>
<th>Smoked (0/17)</th>
<th>Salted (0/6)</th>
<th>Fried (0/5)</th>
<th>Dried (0/3)</th>
<th>Grilled (0/3)</th>
<th>Fermented (0/3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salmonella spp.</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Vibrio spp.</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Listeria spp.</em></td>
<td>11</td>
<td>23.5</td>
<td>33.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>66.7</td>
<td>(3/27)</td>
</tr>
<tr>
<td><em>Proteus spp.</em></td>
<td>55.5</td>
<td>52.9</td>
<td>33.3</td>
<td>40</td>
<td>66.7</td>
<td>0</td>
<td>66.7</td>
<td>(15/27)</td>
</tr>
<tr>
<td><em>Staph. aureus</em></td>
<td>29.6</td>
<td>17.6</td>
<td>16.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(8/27)</td>
</tr>
<tr>
<td><em>Klebsiella spp.</em></td>
<td>48.1</td>
<td>11.8</td>
<td>16.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(13/27)</td>
</tr>
<tr>
<td><em>Aeromonas spp.</em></td>
<td>7.4</td>
<td>5.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(2/27)</td>
</tr>
<tr>
<td><em>Pseudomonas spp.</em></td>
<td>11.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(3/27)</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>7.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>33.3</td>
<td>0</td>
<td>33.3</td>
<td>(2/27)</td>
</tr>
<tr>
<td><em>Clostridium perf.</em></td>
<td>77.8</td>
<td>0</td>
<td>33.3</td>
<td>50.0</td>
<td>100.0</td>
<td>0</td>
<td>0</td>
<td>(21/27)</td>
</tr>
</tbody>
</table>

*Proteus spp.* was detected at a prevalence of 55% in all the raw samples and up to 66.7% in the processed samples. This organism is capable of decarboxylating histidine into histamine, produces H$_2$S and is therefore capable of causing fish spoilage. It is also an opportunistic pathogen which can infect immune-compromised individuals. *Pseudomonas* species have been implicated by a number of studies as the dominant bacterium in the spoilage of fish (Tryfinopoulou *et al.*, 2007; Popovic *et al.*, 2010; Ikutegbe and Sikoki, 2014; Viji *et al.*, 2014). In this study however, the dominant spoilage organisms detected in all fishes at different stages of the value chain appeared to be *Proteus mirabilis* and *Proteus vulgaris*.
(Table 4.5.2 and Table 4.5.3). Akoachere et al. (2009) also isolated *Proteus vulgaris* and *Proteus penneri* in fish sourced from the coastal waters of Cameroun, a country with similar climatic and socio-economic conditions as Ghana.

The total mesophilic counts determined for fresh catfish from fishermen and wholesalers were consistently below the maximum allowable limit of 7 Log cfu/g set by the International Commission on Microbial Specifications for Foods (ICMSF), which initially suggested good overall hygienic quality. Raw tilapia intended for grilling was however found to consistently contain unacceptable counts of 7.96±0.68 Log cfu/g. This value however did not significantly vary from other fresh tilapia and fresh sardinella samples, as presented in Table 4.5.2. Erkan and Ozden (2008) who assessed the quality of sardines stored on ice in Turkey, reported mesophilic bacteria counts of 3.8 to 4 log cfu/g on the first day of storage, and up to 6 log cfu/g after 9 days of storage. These results were consistent with findings from this study.
Table 4.5. 2: Microbial quality of raw, unprocessed fish at different stages of the artisanal fish value chain

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Fish specie</th>
<th>Product</th>
<th>n</th>
<th>Food Safety Indicators</th>
<th>Food Hygiene Indicators</th>
<th>Overall quality indicator</th>
<th>Physico-chemical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>List.</td>
<td>Kleb</td>
<td>TMC</td>
<td>Temp (°C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Log cfu/g</td>
<td>Cl Perf.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Proteus</td>
<td>E. coli</td>
<td>S. aur</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fishermen</td>
<td>Tilapia</td>
<td>Fresh fish</td>
<td>3</td>
<td>A</td>
<td>P</td>
<td>3.71 ±2.68</td>
<td>29.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>2.98 ±0.57</td>
<td></td>
</tr>
<tr>
<td>Fishermen</td>
<td>Catfish</td>
<td>Fresh fish</td>
<td>2</td>
<td>A</td>
<td>P</td>
<td>2.83 ±0.22</td>
<td>29.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>3.70 ±0.95</td>
<td></td>
</tr>
<tr>
<td>Fishermen</td>
<td>Sard</td>
<td>Fresh fish</td>
<td>3</td>
<td>A</td>
<td>P</td>
<td>2.70 ±0.11</td>
<td>26.68</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>2.12 ±0.28</td>
<td></td>
</tr>
<tr>
<td>Wholesaler</td>
<td>Tilapia</td>
<td>Fresh fish</td>
<td>3</td>
<td>A</td>
<td>A</td>
<td>2.31 ±1.28</td>
<td>19.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>2.31 ±1.28</td>
<td></td>
</tr>
<tr>
<td>Wholesaler</td>
<td>Catfish</td>
<td>Fresh fish</td>
<td>2</td>
<td>A</td>
<td>P</td>
<td>ND</td>
<td>27.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>1.99 ±0.13</td>
<td></td>
</tr>
<tr>
<td>Retailer</td>
<td>Tilapia</td>
<td>Fresh fish</td>
<td>3</td>
<td>P</td>
<td>P</td>
<td>2.83 ±0.22</td>
<td>15.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>5.54 ±2.09</td>
<td></td>
</tr>
<tr>
<td>Retailer</td>
<td>Sard</td>
<td>Fresh fish</td>
<td>3</td>
<td>A</td>
<td>P</td>
<td>2.43 ±2.02</td>
<td>26.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>2.32 ±1.19</td>
<td></td>
</tr>
<tr>
<td>Processor</td>
<td>Tilapia</td>
<td>Raw fish</td>
<td>1</td>
<td>P</td>
<td>A</td>
<td>ND</td>
<td>32.30</td>
</tr>
<tr>
<td>(Salted)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>3.43 ±0.00</td>
<td></td>
</tr>
<tr>
<td>Processor</td>
<td>Tilapia</td>
<td>Raw fish</td>
<td>2</td>
<td>A</td>
<td>A</td>
<td>2.96 ±0.39</td>
<td>30.24</td>
</tr>
<tr>
<td>(Fermented)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>3.52 ±0.27</td>
<td></td>
</tr>
<tr>
<td>Processor</td>
<td>Catfish</td>
<td>Raw fish</td>
<td>2</td>
<td>P</td>
<td>A</td>
<td>2.71 ±1.14</td>
<td>29.95</td>
</tr>
<tr>
<td>(Fermented)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P</td>
<td>2.9 ±0.68</td>
<td></td>
</tr>
<tr>
<td>Processor</td>
<td>Tilapia</td>
<td>Raw fish</td>
<td>3</td>
<td>A</td>
<td>A</td>
<td>3.36 ±0.14</td>
<td>23.03</td>
</tr>
<tr>
<td>(Grilled)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>3.38 ±0.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>7.96 ±0.68</td>
<td></td>
</tr>
</tbody>
</table>

Values in the same column with different superscripts are significantly different at α=0.05.
Abbreviations: A= absent; P=present; PM= Proteus mirabilis; Pv= Proteus vulgaris ND= not detected; Temp: temperature
Lis: Listeria spp; Kle: Klebsiella spp; Cl perf: Clostridium perfringens; F.coli: faecal coliforms; S.aur: Staphylococcus aureus; TMC: Total mesophilic count; Sard: sardinella;
Table 4.5.3: Microbiological Quality of Processed Fish at different stages of the Artisanal Fish Value Chain

<table>
<thead>
<tr>
<th>SH type</th>
<th>Fish type</th>
<th>Prod n</th>
<th>Food Safety Indicators</th>
<th>Food Spoilage indicator</th>
<th>Food Hygiene Indicators</th>
<th>Overall quality indicator</th>
<th>Physico-chemical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lis</td>
<td>Kle</td>
<td>Cl. Perf</td>
<td>Prot</td>
<td>F. coli.</td>
<td>Log E.</td>
<td>S.</td>
<td>TMC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Log cfu/g</td>
<td>cfu/g</td>
<td>col</td>
<td>au</td>
<td></td>
</tr>
<tr>
<td>Pro</td>
<td>Til</td>
<td>Ferm</td>
<td>2</td>
<td>A</td>
<td>A</td>
<td>2.08±1.14b</td>
<td>Pm</td>
</tr>
<tr>
<td>Pro</td>
<td>Cat</td>
<td>Ferm</td>
<td>2</td>
<td>P</td>
<td>A</td>
<td>1.54±0.09b</td>
<td>Pm</td>
</tr>
<tr>
<td>Pro</td>
<td>Til</td>
<td>Gril</td>
<td>3</td>
<td>A</td>
<td>A</td>
<td>1.73±0.70b</td>
<td>A</td>
</tr>
<tr>
<td>Pro</td>
<td>Til</td>
<td>Smo</td>
<td>2</td>
<td>A</td>
<td>A</td>
<td>ND</td>
<td>A</td>
</tr>
<tr>
<td>Ret</td>
<td>Til</td>
<td>Smo</td>
<td>3</td>
<td>P</td>
<td>A</td>
<td>ND</td>
<td>Pm</td>
</tr>
<tr>
<td>Pro</td>
<td>Cat</td>
<td>Smo</td>
<td>2</td>
<td>P</td>
<td>P</td>
<td>ND</td>
<td>Pm</td>
</tr>
<tr>
<td>Ret</td>
<td>Cat</td>
<td>Smo</td>
<td>3</td>
<td>P</td>
<td>A</td>
<td>ND</td>
<td>Pm</td>
</tr>
<tr>
<td>Pro</td>
<td>Sar</td>
<td>Smo</td>
<td>3</td>
<td>A</td>
<td>A</td>
<td>ND</td>
<td>Pm</td>
</tr>
<tr>
<td>Ret</td>
<td>Sar</td>
<td>Smo</td>
<td>3</td>
<td>A</td>
<td>A</td>
<td>ND</td>
<td>Pm</td>
</tr>
<tr>
<td>Pro</td>
<td>Til</td>
<td>Fried</td>
<td>2</td>
<td>A</td>
<td>A</td>
<td>ND</td>
<td>Pm</td>
</tr>
<tr>
<td>Pro</td>
<td>Cat</td>
<td>Fried</td>
<td>3</td>
<td>A</td>
<td>A</td>
<td>ND</td>
<td>Pm</td>
</tr>
<tr>
<td>Pro</td>
<td>Til</td>
<td>Salt</td>
<td>2</td>
<td>A</td>
<td>A</td>
<td>1.75±1.29b</td>
<td>A</td>
</tr>
<tr>
<td>Ret</td>
<td>Til</td>
<td>Salt</td>
<td>3</td>
<td>P</td>
<td>A</td>
<td>ND</td>
<td>A</td>
</tr>
<tr>
<td>Pro</td>
<td>Sar</td>
<td>Dry</td>
<td>3</td>
<td>A</td>
<td>A</td>
<td>3.88±2.54b</td>
<td>P</td>
</tr>
</tbody>
</table>

Values in the same column with different superscripts are significantly different at α=0.05.
Abbreviations: A= absent; P=present; ND: not detected; Prot: Proteus spp; Pm= Proteus mirabilis; Pv= Proteus vulgaris; SH: stakeholder; Pro: Processor; Ret: retailer; Temp: Temperature
Lis: Listeria spp; Kle: Klebsiella spp; Cl perf: Clostridium perfringens; F. coli: faecal coliforms; S. au: Staphylococcus aureus; TMC: Total mesophilic count; Ferm: fermented; Gril: grilled; Smok: smoked; Salt: salted; Dry: dried; Til: tilapia; Cat: catfish; Sar: sardinella; Pro: Processor; Ret: Retailer
The microbiological quality of the processed fish samples also appeared initially to be good given the generally low counts of total mesophilic bacteria as well as total counts of yeasts and moulds (Table 4.4.3). A study by Ikutegbe and Sikoki (2014) which followed the counts of heterotrophic fungi on smoked fish sourced from retail markets in Nigeria, also reported counts of up to 3.40 log cfu/g in smoked fish stored for three weeks or less. Retailers in Ghana, stored smoked fish for longer periods, up to 6months. Counts for fungi (yeasts and moulds) on smoked fish samples in this study were however generally lower in comparison.

Table 4.5.2 and Table 4.5.3 however, presents evidence to suggest issues with the safety of fish on the Ghanaian market. Key quality and safety indicator pathogens were detected at different stage of the value chain. To begin with, *Listeria* spp. was detected at a prevalence of 11% in raw tilapia and catfish and up to 66.7% in fermented fish samples. This is of great concern given the public health threat posed by this organism (Bomfeh *et al.*, 2015). The microorganism was also present in salted-dry fish (“koobi”) and in smoked-dry fish.

A study by Tano-Debrah *et al.* (2011) attributed the occurrence of Listeria on fermented fish mainly to post-process contamination. Samples in that study were also collected in James Town and in some informal fish markets in Accra and detectable levels of *Listeria monocytogenes* on salted-dry and on sun dried tilapia and herrings were reported and the evidence presented also suggested that salting and drying methods used by processors could not adequately control the organism.

The high incidence of *Listeria* on fermented fish in this study was however more likely attributable to the opportunities available for proliferation from landing until the start of fermentation. These included consistently high storage temperatures (Table 4.5.2) and poor hygienic conditions and handling practices reported from landing until the commencement of fermentation. In fact fermentation, unlike the other processing methods was typically carried out as a means to salvage fish that has lost its freshness or fish that may be considered
spoiled by consumers. A review of studies on African fermented fishes by El Sheikah et al. (2014), similarly reported safety issues related to *Clostridium, Salmonella* and aflatoxin contamination in *momone* and other fermented fish products.

It was also noteworthy that the aerobic mesophilic counts of raw tilapia sampled from grill-processors, was not significantly reduced in the final grilled tilapia samples. A similar trend was also observed between raw samples of tilapia and catfish intended for fermentation and salting, and their final processed equivalents. There was also a noticeable persistence of other pathogenic microorganisms like *Staphylococcus aureus* and *Klebsiella pneumonia* on smoked and salted fish as well as the presence of *Clostridium perfringens* on salted tilapia fried tilapia and sun-dried sardinella samples. It was more plausible to attribute this observation to post-processing contamination rather than the inadequacy of processing methods, owing to poor hygienic conditions of storage and handling reported among stakeholders within the fish value chain (Table 4.32). Questions about the adequacy of processes such as sun drying, salting and smoking in ensuring safety, could however not be completely discounted. Poor hygienic conditions prevailing at most processing sites in addition to evidence from studies reporting on the poor quality of salt, wash water and drying temperatures could very well account for the high incidence of pathogenic and spoilage organisms observed in this study (El Sheikah et al., 2014). Some of the hygiene issues observed at processing sites included open defecation close to processing areas, presence of livestock, drying of fish directly on the ground or close to the ground, and exposure of fish to the elements especially during sun drying (pictures in appendix 2B).

Also of significance was the detection of *Clostridium perfringens* in all the raw fish samples tested. *Clostridium perfringens* has been implicated as the etiological agent in many food poisoning outbreaks and its presence on food samples is indicative of sewerage contamination (Lalitha and Surendran, 2003). It was therefore not surprising that there were
also high counts of faecal coliforms on both the fresh and processed fish samples. The shores of James Town have long been a dumping site of sewerage for the city of Accra and poor fishing communities along the Volta lake have also been known to dispose off faecal matter into the Lake (Awuah and Abrokwa, 2008). The high loads of Clostridium perfringens and faecal coliforms on landed fish from these sources coupled with the poor handling practices documented in this study, may very likely ensure survival and proliferation of the microorganism even under the dehydrating conditions of processing.

In a similar study, Lalitha and Surendran (2003), reported a 22% incidence rate of C. perfringens in fish and shell fish sampled in Kerala, India. Their study reported detection of C. perfringens at every stage of the value chain from which the samples were sourced. This was especially the case of the tilapia samples in their study- The microorganism was detected in 94% of all raw unprocessed samples tested (17 out of 18), with counts significantly higher in the raw fish at landing. El-Shorbagy, Reda and Mona (2012) also reported a prevalence of 57.1% in 56 processed samples and 59% in 57 samples. These researchers also found the microbe in three types of salted sardines but found none in canned fish.

Another key fish quality and safety indicator detected in samples from this study was Escherichia coli. Two diarrheogenic E. coli (E. coli (2) 0146 and E. coli (4) 027) were isolated from fresh catfish from fishermen and fermented catfish from processors respectively. The former is an enteropathogenic (EPEC) strain while the latter is an enterotoxigenic (ETEC) strain of E. coli. Both have been implicated in acute and persistent watery diarrhoea in children especially between the ages of 6months to 3years (Warrell et al., 2003). ETEC can particularly cause diarrhoea in all ages because of its ability to mimic clinical symptoms of diarrhoea. Costa (2013) concluded that, the presence of these organisms on the fish samples could be indicative of the presence of other enteric pathogens and recommended adequate processing prior to consumption.
Escherichia coli (4) 0148 detected on all the sun dried sardinella samples, were also ETEC strains. This finding is of particular importance because more often than not, dried sardinellas are consumed without further heat processing in Ghana. They are often made into powder and used to increase the protein content of complementary feed given to children. This is of obvious concern given the public health implications of ETEC. The survival of ETEC in the otherwise unfriendly conditions of low water activity in the dry fish could be the result of the drying methods employed in processing the sardinellas as depicted in appendix 2B.

Klebsiella pneumoniae was another fish safety indicator pathogen that was detected in some samples. It is an opportunistic pathogen that can cause nosocomical infections of the respiratory tract, urinary tract and blood especially in children immuno-compromised by a diarrhoeal infection.

Also presented in Table 4.4.2 and Table 4.4.3 are the temperatures used in fish storage by the different stakeholders in all the three value chains. The temperatures were less than ideal and may very well account for the incidence of the spoilage and pathogenic organisms observed. The temperature at landing of all the fish species, ranged from 26°C to 29°C. These values did not vary significantly at the next stage of the fresh fish value chain, which involved retailers and wholesalers. The high average temperatures recorded also appeared to contradict reports by the majority (85%) of wholesalers and retailers who claimed to keep their fish on ice during the period of sale.

The disparity between the reported use of ice to reduce the temperature of the fish and the actual recorded temperatures could however be explained by the fact that, the amount of ice used was insufficient to effect cooling to desirable temperatures. Again, the Styrofoam containers used by stakeholders in the fresh fish value chain, and the wooden boxes with sack lining used in the marine fish value chain, did not provide enough insulation to maintain
cold temperatures (see appendix 2C for pictures of cold storage boxes). The recorded temperatures for the processed fish samples, especially in the fresh water fish value chain were particularly high (50 to 85°C) and significantly different from other fresh and processed fish temperatures because they were sampled a few minutes after processing.

The pH of the fish measured at landing and at different stages of the value chain however appeared to conform to trends reported in similar studies. The general pH of fresh tropical fish muscle reported by Susanto et al. (2011) ranged from 6.0 to 7.3 on the first day of capture and from 6.8 to 8.2 by the second day when kept at ambient temperature. In this study, the pH at landing (from fishermen) was found to range from 7.2 to 7.8 for the fresh water fishes and between 7.3 and 7.6 for the marine fish. These values significantly decreased at the wholesale stage in the tilapia value chain. Because the same batch of fish was not followed from fishermen to wholesalers, it was impossible to accurately assume that the observed significant increase in acidity from one stage in the value chain to the next was due to microbial or autolytic activity. High glycogen levels in the fish prior to capture may however account for the increased acidity because of the resultant accumulation of lactic acid.

A significant rise in alkalinity in raw catfish and tilapia intended for fermentation and salting was observed from samples sourced from processors. Such fish were considered no longer fresh by the stakeholders and therefore transformed into “Momone” and “Koobi”. A rise in fish muscle alkalinity with increasing storage time was also observed in a study by Erkan and Ozden (2008). These researchers attributed the pH increases to the accumulation of alkaline compounds such as ammonia mainly derived from microbial action. Viji et al. (2014) also supported this theory but warned that pH was a poor quality indicator of fish quality.
Compared to the fresh water value chain, fewer pathogens were isolated from the marine fish value chain. Sardinellas which were to be sold fresh to consumers were also potentially stored for up to two weeks by retailers. This however did not imply that, the quality of the marine fish was better than the fresh water fishes as is evidenced by the high unacceptable total mesophilic counts observed in raw tilapia samples.

### 4.6 Association between stakeholder knowledge and practices and the actual Microbial quality of artisanal fish

It is evident from Figure 4.6.1 that, pathogens and spoilage organisms could be found at almost every stage of the value chain where poor handling practices by stakeholders were reported. The exception was with wholesalers and retailers of fresh unprocessed fish, who reported generally sufficient handling practices but still had poor quality fish. This deviation from the trend was clearly as a result of insufficient cooling temperatures and temperature abuse during storage. Temperature abuse was in fact observed throughout the value chain and is without question, a major reason for the poor quality of fish observed in this study.
Figure 4.6. 1: Association between food safety practices and the actual microbial quality of Artisanal fish
Another possible contributor to the poor quality of fish observed at the retail and wholesale stage of the fresh fish value chain could be the existing traditional laws which places certain restrictions on the uninhibited flow of fish on the artisanal value chain. Fishing in James Town on Tuesdays for example, was strictly tabooed. Consequently, the women who retailed fresh or raw fish in the local fish market were also not allowed to sell their fish on Tuesdays. This cultural practice, although crucial in ensuring the sustainability of fisheries also implied that, fresh fish remained longer (up to two weeks) at the retail stage of the value chain. This represented a classic case in which a stakeholder practice which was not directly related to food safety, may have had implications on the poor quality of fish observed at the retail stage.

Figure 4.6.1 also shows likely opportunities for recontamination of processed fish in the artisanal fish value chain. Here again, poor handling practices by processors themselves and retailers of processed fish may very well be the cause of the poor quality of processed fish reaching the consumer. This is of particular concern given the fact that, fish at these stages of the value chain, (processor and retailer) led directly to the consumer who may in all likelihood consume this fish without further processing.

The high reported fish losses due to spoilage was also corroborated by the detection of various spoilage microorganisms, particularly *Proteus* spp. at various stages of the value chain. Figure 4.6.1 indicates risk of fish spoilage especially with fish reaching wholesalers and retailers from fishermen, at the actual retail and wholesale point, and also during processing. Prior to reaching the consumer, the highest incidence of spoilage were reported by wholesalers and retailers. The few processors who reported losses said that spoilage occurred mostly in the period prior to processing, that is during pre-process operations such as spicing before grilling, or sun-drying before hot-smoking. This was again confirmed
during microbiological testing as spoilage organisms were isolated at these exact points in the value chain.

The link between the food safety knowledge and practices of stakeholders and the actual microbiological quality of the fish thus becomes obvious. Poor food safety knowledge and handling practices of stakeholders have clear implications on the final microbiological quality of fishes handled by these stakeholders.

4.7 Food Security Implications
Given the findings of this study, a valid argument can be made with regards to a potential threat to food security. To begin with, the significant economic implications of high reported fish losses is undeniable. Although one may argue that much of this loss is salvaged through fermentation processing, economic losses are still incurred, owing to the fact that, fermented fish fetches a considerably lower price than fresh fish and it no longer serves its purpose as a primary protein in a meal. Fermented fish is typically consumed in very small quantities as a condiment for soups and sauces and is therefore not consumed in sufficient quantities to represent a significant source of protein. Ikutegbe and Sikoki (2014) also reported a decline in fish protein levels with increasing microbial load and storage time. Again, the high quantities of salt used in the process of fermentation renders the fish quite unhealthy when frequently used in meals. Table 4.71 displays consumer responses to questions about their food security in relation to fish.
Majority (61%) of consumers in this study reported that they used meat as an alternate source of protein when fish was unavailable. They however stated that meat was more expensive than fish and therefore had to spend more money on food when fish was unavailable. Up to 80% of consumers also chose fish as their primary source of protein because they believed it was healthier in comparison to other protein sources. Majority (76%) also trusted the safety of the fish on the local market; a matter of concern, given the probability that most of these consumers may not take the necessary precautions in processing their fish because they trust it to be safe.
With regards to safety, the poor microbiological quality of fish from artisanal sources could contribute to the high disease burden among the most vulnerable groups. Fish has been implicated in several outbreaks of food-borne infections. It is a potential vehicle for food-borne infections such as cholera, listeriosis, salmonellosis and many more (Popovic et al., 2010; Costa, 2013; Akoachere et al., 2009). In Ghana, diarrhoeal diseases are among the top three causes of death among children under five. According to a WHO/UNICEF report, 55000 children under five died from diarrhoea in 2008 alone (Wardlaw et al., 2010). Diarrhoeagenic microorganisms such as *E.coli, Aeromonas sobria* and *Clostridium perfringens* detected on ready to eat fish given as complementary feed to children may very well contribute to the high incidence of diarrhoea in Ghanaian children under five.

From the nutritional, safety and an economic point of view therefore, the food security of the many Ghanaians who depend on artisanal fish as a primary source of protein, and as a source of livelihood, may be under reasonable threat.
CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The analysis of results obtained from this study gives evidence to the unsatisfactory microbiological quality and safety of fish from the local artisanal fish value chain. Of particular concern was the occurrence of key fish safety indicator pathogens such as *Clostridium perfringens*, enteropathogenic *E. coli*, *Aeromonas sobria*, *Staphylococcus aureus* and *Listeria spp* on fresh and processed fish at different stages of the value chain. It was also of interest to note that, *Proteus vulgaris* and *Proteus mirabilis* were the most frequently isolated spoilage microorganisms on the fish samples while *Pseudomonas spp*, which is reported more frequently as the specific spoilage microorganism on fish, was only present in a few samples.

This study found a generally inadequate level of food safety knowledge and poor handling practices among stakeholders at every stage of the artisanal fish value chain. The poor handling practices of stakeholders, particularly storage temperature abuse, could be associated with the high estimated fish losses (30 to 100%) reported in this study. It was also alarming to find that, stakeholders within the value chain were not aware of the food safety implications of consuming unwholesome fish. Reports documented by this research again demonstrated how the insufficient food safety knowledge and practices of stakeholders could result in poor microbial fish quality and high fish losses. It also alludes to how poor microbial fish quality could potentially affect food security by making fish less nutritious, less available, less affordable and unsafe for human consumption.

The study finally documented three artisanal fish value chains (tilapia, African catfish and sardinella) and identified the key risk factors and the contamination hotspots along these value chains. Poor stakeholder knowledge and practices, especially regarding storage
temperature abuse occurred at all stages of the value chain. There were also potential contamination opportunities at the fresh fish retailer stage, the processor stage and also at the fish cleaner stage. Recontamination of processed fish at the retail stage was also very likely, especially because of the poor hygienic conditions prevailing throughout the value chain and especially at the processing sites.

5.2 Recommendations

There is an urgent need for government and regulatory bodies to offer training in good hygienic practices (GHP’s) for all stakeholders within the artisanal fish value chain. The training should be offered in an informal manner and given at landing sites, markets and processing sites to accommodate stakeholders with little or no formal education. Further investigations should also be made into stakeholder attitudes toward food safety in order to gain further insight into why some stakeholders may not implement good food safety practices although they may have received some food safety training.

The structure of the artisanal value chains depicted in this study showed a general lack of organization and regulation. In order to implement quality management systems, it is vital to establish some formality and better organization within the artisanal fish value chain. Wholesale of artisanal fish which is traditionally done on the open beach could be instead carried out in well-constructed fish auction markets equipped with cold storage facilities, which would allow stricter regulation by appropriate bodies to ensure proper sanitation and fish safety.

Further research should also be conducted into the stress response mechanisms of the microorganisms detected in this study so that preservation techniques can be tailored to target and properly control the microorganisms, thus ensuring the quality and safety of artisanal fish on the Ghanaian market.
Table 5.2.1 summarizes the risk factors identified in this study and offers some potential interventions that could have the best impact on their resolution.

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Potential Interventions</th>
</tr>
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</table>
| Poor food safety knowledge and handling practices | 1. Informal training on good hygienic practices (GHP’s) for all stakeholders on the artisanal fish value chain  
|                                   | 2. Stricter regulation and monitoring                                                   |
| Temperature Abuse                 | 1. Provision of good quality ice and cold storage containers                             |
|                                   | 2. Provision of well-organized fish auction markets, fitted with cold storage facilities |
|                                   | 3. Design of cost-effective cold storage containers with better insulation properties    |
| Poor initial fish quality         | Proper sewerage treatment and disposal into water bodies                                 |
| Recontamination                   | Training on proper handling and storage of processed fish (food safety training).        |
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Bataringaya, A. (2007). Analysis of Quality Deterioration at critical steps(points) in the fish handling in Uganda and Iceland and suggestions for improvement (Master’s


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Appendix 1A: Retailer Questionnaire

DEPARTMENT OF NUTRITION AND FOOD SCIENCE
UNIVERSITY OF GHANA, LEGON

MICROBIAL QUALITY AND SAFETY OF FISH ALONG THE FISH VALUE CHAIN AND THEIR IMPLICATIONS ON FOOD SECURITY:
A CASE STUDY OF THE ARTISANAL FISHING INDUSTRY IN GHANA

Dear respondent, this questionnaire is aimed at collecting information on the use, processing and handling of fish in Ghana as it moves from its source to the final consumer. It is part of an MPhil Food Science Thesis on the topic above. Your identity will be protected to the best of our ability. Your name will not appear on any record including the questionnaires and reports. Only students and academic staff involved in execution, review and examination of this project may access the research records. Thank you.

Date: _______________________

Location: ____________________

Respondent’s Code: ____________

Kindly tick (√) the responses that apply to you. Where appropriate, write out your own responses in the spaces provided.

A: BACKGROUND INFORMATION

RESPONSE

1. Sex: 1=Male 2=Female

2. Age: 1=18 to 20 years
2=20 – 29 years
3=30 – 39 years
4=40 – 49 years
5=50 years and above

3. Ethnicity, Specify …………………………………………………

4. Religion
1.=Christian
2. Muslim
3. Traditional African religion
4. Other, specify

5. Highest level of education received
   1. None
   2. Primary
   3. Middle School/JHS
   4. Secondary
   5. Tertiary
   6. Other, specify

6. How long have you been in the fish retailer business?
   1. 1-5 years
   2. 6-10 years
   3. 11-15 years
   4. 16-20 years
   5. More than 20 years

7. What types of fish(es) do you retail? Tick as many as apply to you.
   1. Sardinellas
   2. Anchovies
   3. Tilapia
   4. African Catfish
   5. All the above
   6. Other, specify

8. How will you define your retail business?
   1. Wholesale
   2. Middleman
   3. Small scale cold store
   4. Small scale retail (raw fish)
   5. Small scale retail (processed fish)
   6. Other, specify

9. Who are your key customers?
   1. Wholesalers
   2. Small scale cold store operators
   3. Processors
   4. Consumers
   5. Other, specify

B: RAW MATERIAL ACQUISITION

10. What kind of fish do you retail?
    1. Marine fish
    2. Freshwater fish

11. What form of fish do you retail?
    1. Raw fresh fish
    2. Raw frozen fish
    3. Processed fish, specify
12. Where do you obtain your raw fish from?
   1 = Fish landing port
   2 = Wholesaler
   3 = Retailer
   4 = Cold store
   5 = Processor
   6 = Other, specify.......................................................

13. Do you inspect fresh fish before purchasing?
   1=Yes   2=No

14. If yes to 11, what do you look out for?
   1=Colour of eyes
   2=Colour of gills
   3=Skin surface (smooth or slimy)
   4=Other, specify..........................................................

15. What quantity of fish do you procure at a time? Tick the appropriate answer and unit
   1= Less than 1 carton/basket
   2= 1 – 5 cartons/basket
   3= 6 – 10 cartons/basket
   4= More than 10 cartons/basket
   5=Other, specify..........................................................

C. TRANSPORTATION OF RAW FISH

16. How do you transport the fish to the market?
   1= On ice
   2= Without ice
   3= In a refrigerated van
   4= Other, specify..........................................................

17. In what containers do you transport the fish?
   1= In a basket
   2= In basin
   3= Paper cartons
   4= Plastic containers
   5= Other, specify ..........................................................

18. What is the mode of transportation of fish
   1= On foot
   2= Trotro
   3= Taxi
   4= Private vehicle
   5= Other, specify..........................................................

19. How long does it take to transport the fish
   1=Less than 2 hours
   2=2 hours to 6 hours
   3=More than 6 hours but up to 12 hours

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20. How long does it take to sell the lot purchased at a time?
   1=Less than 4 hours
   2=4 hours to 8 hours
   3=More than 8 hours but up to 16 hours
   4=More than 16 hours, but up to 24 hours
   5=More than 24 hours, specify ................................................

D. HANDLING AND STORAGE OF FISH

21. How do you store the fish during the period it takes to sell
   1=At room temperature
   2=In a fridge
   3=In a freezer
   4=Other, specify................................................................

22. In what measures do you retail?
   1=by weight (kg)
   2=by numbers
   3=in cartons…/baskets……
   4=other, specify…………………………………………

E. FOOD QUALITY AND SAFETY DURING RETAIL

23. How do you maintain the quality of fish you retail during the retail period?
   ............................................................................................

24. Are you familiar with spoilt fish?
   1=Yes  2=No

25. When do you think fish you are selling is spoilt?
   ............................................................................................

26. What do you think or know causes fish spoilage?
   ............................................................................................

27. Have you had the experience of some of the fish you are selling getting spoilt?
   1=Yes  2=No

28. If yes to Question 27, please describe the experience.
   ............................................................................................

29. Please estimate the average quantities of fish that get spoilt from the lots you buy
30. What did you do with the quantity of fish that got spoilt?

31. Do you think the ways fishes are handled could contribute to their spoilage?
   1=Yes  2=No

32. If yes to Question 31, please list some of the handling practices that could cause spoilage:

33. Have you ever found some of the fishes you have purchased looking diseased or infected?
   1=Yes  2=No

34. If Yes to Question 33, please describe the condition of the fish(es):

35. How frequently do you see fishes with such conditions?

36. What did you do to the fish you found as regards Question 33?

37. Do you think eating an infected or diseased fish can cause some illness?
   1=Yes  2=No

38. If Yes to Question 37, please indicate/describe the type of illness:
39. With your experience, indicate some of the observations that can inform a buyer that a fish is infected, diseased or unwholesome…………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

40. Apart from spoilage and infection, list other problems that may be associated with fishes
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

41. In general, what is your view about the quality of raw and processed fish on the local market?
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

42. What measures could be taken to ensure that the fishes on our local markets are wholesome and safe for human consumption?
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

THANK YOU
Appendix 1B: Processor Questionnaire

DEPARTMENT OF NUTRITION AND FOOD SCIENCE
UNIVERSITY OF GHANA, LEGON

MICROBIAL QUALITY AND SAFETY OF FISH ALONG THE FISH VALUE CHAIN AND THEIR IMPLICATIONS ON FOOD SECURITY:
A CASE STUDY OF THE ARTISANAL FISHING INDUSTRY IN GHANA

Dear respondent, this questionnaire is aimed at collecting information on the use, processing and handling of fish in Ghana as it moves from its source to the final consumer. It is part of an MPhil Food Science Thesis on the topic above. Your identity will be protected to the best of our ability. Your name will not appear on any record including the questionnaires and reports. Only students and academic staff involved in execution, review and examination of this project may access the research records. Thank you.

Date: _______________________

Location: ____________________

Respondent’s Code: __________

Kindly tick (√) the responses that apply to you. Where appropriate, write out your own responses in the spaces provided.

A: BACKGROUND INFORMATION

RESPONSE

[For interviewer use only]

1. Sex:  1=Male  2=Female

2. Age:  1=18 to 20 years  
          2=20 – 29 years  
          3=30 – 39 years  
          4=40 – 49 years  
          5=50 years and above

3. Ethnicity, Specify ……………………………………………

4. Religion  
           1.=Christian  
           2.=Muslim  
           3.=Traditional African religion  
           4.=Other, specify…………….

5. Highest level of education received

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6. How long have you been in the fish processing business?
1= 1-5 years
2= 6-10 years
3= 11-15 years
4= 16-20 years
5= More than 20 years

B. RAW MATERIAL ACQUISITION

7. Where do you obtain the fish you process from?
1 = Fish landing ports
2 = Wholesaler
3 = Cold Store
4 = Retailer
5 = Other, specify.................................................................

8. What species of fish do you process?
1=Sardinellas
2=Anchovies
3=Tilapia
4=Catfish
5=Other, specify.................................................................

9. Do you inspect fresh fish before purchasing?
1=Yes  2=No

10. If yes to 10, what do you look out for?
1=Colour of eyes
2=Colour of gills
3=Skin surface (smooth or slimy)
4=Other, specify.................................................................

11. Do you sometimes observe fishes with infections among your purchases?
1=Yes  2=No

12. If yes to question (12), describe the look of the fish with infections.
..................................................................................................................
..................................................................................................................
..................................................................................................................
..................................................................................................................

13. What do you think may be the cause(s) of the infection(s)?
..................................................................................................................
..................................................................................................................
..................................................................................................................
..................................................................................................................

..................
14. What do you do to the infected fishes?

........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

15. What quantities of fish do you process in a batch? Tick the appropriate answer and unit.

1= Less than 1 carton/basket
2= 1 – 5 cartons/basket
3= 6 – 10 cartons/basket
4= More than 10 cartons/basket, specify………………..

16. Are you always able to process the quantities you procure in a batch?

1=Yes    2=No

17. If no to question (17), please indicate how you handle the quantities you are not able to process.

........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

C: TRANSPORTATION OF RAW FISH

18. How do you transport the fish to the market?

1= On ice
2= Without ice
3= In a refrigerated van
4= Other, specify............................................................

19. How long does it take to transport raw fish to the processing site?

1= Less than 2 hours
2= 2 hours to 6 hours
3= More than 6 hours to 12 hours
4= More than 12 hours to 24 hours
5= More than 24 hours

20. What is the mode of transportation of fish to the processing site?

1= By foot
2= Public transport
3= Private transport
4= Refrigerated truck/van
5= Other, specify..........................................................................................

21. What containers do you use to carry the raw fish during transportation?

1= Basket
2= Basin
3= Ice chest
D: PROCESSING OF FISH

22. What type(s) of processing do you do?

……………………………………………………………………………………………

23. Please list the steps involved in the process(es) indicated in question 23.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
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24. Please provide a detailed description of the processes

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

25. What is the final form of your product? Tick as many as apply to you.

1=Smoked fish
2=Salted Fish
3=Dried fish
4=Fried fish
5=Other, specify

……………………………………………………………………………………………

26. What are your quality indices?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

27. Are there local standards for your type of product?

1=Yes  2=No

……………………………………………………………………………………………

28. How do you control the quality of your product?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

90
29. How did you acquire the skills involved?
1=Formal training
2=Apprenticeship
3=Self-taught
4=Traditional knowledge inherited from family

30. Do you know anything about food safety?
1=Yes  2=No

31. What are the food safety issues associated with processed fish?
........................................................................................................................................
........................................................................................................................................

32. Which of the steps listed in the processing method in question (25) can influence the quality and safety of the processed fish?
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

33. Do you sometimes have your fish getting spoilt?
1=Yes  2=No

34. If yes to question (34), please estimate the quantities of fish that get spoilt from the lot you process.
1= Less than 1 carton
2= 1 – 5 cartons
3= 6 – 10 cartons
4= More than 10 cartons, specify ........................................

36. What causes the spoilage you sometimes experience?
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

37. What do you do to reduce or eliminate spoilage?
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

E. HANDLING AND STORAGE OF PROCESSED FISH

38. Where do you store processed fish?
1= Regular room
2= Wooden shed
39. How are the processed fish stored?
   1 = In basket/sacks
   2 = In perforated boxes
   3 = In solid boxes (not perforated)
   4 = Arranged on wooded trays
   5 = Other, specify..........................................................

40. For how long after processing do you store fish before selling?
   1= Less than 1 day
   2= 1 – 3 days
   3= More than 3 days, less than 1 week
   4= 1 week – 1 month
   5 = More than a month

41. How do you market your products?

42. How long does it take to market a batch of processed fish?
   1= Less than 1 day
   2= 1 – 3 days
   3= More than 3 days, less than 1 week
   4= 1 week – 1 month
   5= Other, specify..........................................................

F. TRANSPORTATION OF PROCESSED FISH

43. Approximately how long does it take to transport processed fish from the
storage/processing site to the market?
   1= Less than 30 minutes
   2= 30 mins – 2 hours
   3= 2 – 6 hours
   4= 6 – 12 h
   5= More than 12 hours

44. How do you transport processed fish to the market?
   1= By foot
   2= Public transport
   3= Private transport
   4= Refrigerated truck/van
   5= Other, specify..........................................................
45. Which markets do you send your processed fish to?
..........................................................................................................................................................
..........................................................................................................................................................

46. What do you consider as the major constrains in fish processing in Ghana?
..........................................................................................................................................................
..........................................................................................................................................................
..........................................................................................................................................................

THANK YOU
Appendix 1C: Fishermen questionnaire

DEPARTMENT OF NUTRITION AND FOOD SCIENCE
UNIVERSITY OF GHANA, LEGON

MICROBIAL QUALITY AND SAFETY OF FISH ALONG THE FISH VALUE
CHAIN AND THEIR IMPLICATIONS ON FOOD SECURITY:
A CASE STUDY OF THE ARTISANAL FISHING INDUSTRY IN GHANA

Dear respondent, this questionnaire is aimed at collecting information on the use, processing
and handling of fish in Ghana as it moves from its source to the final consumer. It is part of
an MPhil Food Science Thesis on the topic above. Your identity will be protected to the best
of our ability. Your name will not appear on any record including the questionnaires and
reports. Only students and academic staff involved in execution, review and examination of
this project may access the research records. Thank you.

Date: _______________________
Location: ____________________
Respondent’s Code: ____________

Kindly tick (√) the responses that apply to you. Where appropriate, write out your own
responses in the spaces provided.

A: BACKGROUND INFORMATION

1. Sex: 1=Male  2=Female

2. Age: 1=18 to 20 years
          2=20 – 29 years
          3=30 – 39 years
          4=40 – 49 years
          5=50 years and above

3. Ethnicity, Specify ……………………………………………

4. Religion
   ii.  =Christian
   iii. =Muslim
   iv.  =Traditional African religion
   v.   =Other, specify…………….  

5. Highest level of education received
   1= None
   2= Primary
   4= Secondary
   5= Tertiary
6. How long have you been in this business?
1= 1-5 years
2= 6-10 years
3= 11-15 years
4= 16-20 years
5= More than 20 years
6= Other, specify

7. What types of fishing do you do? Tick as many as apply to you.
1= Netting
2= Bottom trawling
3= Explosives
4= Fishing light attractors
5= Cyanide fishing
6= Other, specify

8. What types of fishes do you harvest?
1= Sardinellas
2= Anchovies
3= Tilapia
4= Catfish
5= Other, specify

9. What is your average harvest in an expedition?
1= Less than 1 carton/basket
2= 1 – 5 cartons/basket
3= 6 – 10 cartons/basket
4= More than 10 cartons/basket, specify

10. How often do you go fishing?
1= Everyday
2= Every other day
3= 1 – 3 times a week
4= Every fortnight
5= Other, specify

11. Averagely, how long do you spend at each expedition?
1= Less than 2 hours
2= 2 hours to 6 hours
3= More than 6 hours to 12 hours
4= More than 12 hours to 24 hours
5= More than 24 hours

12. How long does it take you to transport caught fish from point of fishing to landing?
1= Less than 2 hours
2= 2 hours to 6 hours
3= More than 6 hours but up to 12 hours
13. What type of fishing vessels do you use?
   1=canoe
   2=boats
   3=trawlers
   4=Seiners
   5= other, specify…………………………

14. Do you have refrigerating systems on the vessel?
   1=Yes    2=No

15. If no to the preceding question, please describe how you handle your catches to avoid spoilage?
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………

16. Do you sometimes experience fish spoilage?
   1=Yes    2=No

17. On the average, what quantities of fish may spoil in an expedition?
   1= Less than 1 carton/basket
   2= 1 – 5 cartons/basket
   3= 6 – 10 cartons/basket
   4= More than 10 cartons/basket, specify…………………………

18. What do you do to minimize spoilage?
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………

19. How do you market your catches?
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………

20. Do you have any difficulty in marketing your catches?
    1=Yes    2=No

21. How long after landing are you able to market all your catches?
    1=Less than 2 hours
2=2 hours to 6 hours
3=More than 6 hours but up to 12 hours
4=More than 12 hours but up to 24 hours
5=More than 24 hours

THANK YOU

INTEGRI PROCEDAMUS
Appendix 1D: Consumer Questionnaire

DEPARTMENT OF NUTRITION AND FOOD SCIENCE
UNIVERSITY OF GHANA, LEGON

MICROBIAL QUALITY AND SAFETY OF FISH ALONG THE FISH VALUE CHAIN AND THEIR IMPLICATIONS ON FOOD SECURITY:
A CASE STUDY OF THE ARTISANAL FISHING INDUSTRY IN GHANA

Dear respondent, this questionnaire is aimed at collecting information on the safety of fish in Ghana as it moves from its source to the final consumer. It is part of an MPhil Food Science Thesis on the topic above. The information you provide in this document will only be used for academic purposes and your identity will be kept confidential. Thank you.

Date: _______________________

Location: ____________________

Respondent’s Code:____________

Kindly tick (√) the responses that apply to you. Where appropriate, write out your own responses in the spaces provided.

A:  BACKGROUND INFORMATION

[For interviewer use only]

47. Sex:  1=Male  2=Female

48. Age:  1=Less than 20 years
          2=20 – 29 years
          3=30 – 39 years
          4=40 – 49 years
          5=50 years and above

49. Ethnicity, Specify ..........................................................

50. Religion
    1.=Christian
    2.=Muslim
    3.=Traditional African religion
    4.=Other, specify.................

51. Highest level of education received
    1= None           4= Secondary
    2= Primary        5= Tertiary
    3=Middle School/JHS 6=Other, specify.........................
B: FISH ACQUISITION

52. What types of fish(es) do you usually buy for consumption? Tick as many as apply to you.
1=Tilapia
2=Herrings
3=Anchovies
4=African Catfish
5=All the above
6=Other, specify..............................................................

53. What is your reason for purchasing this species of fish?
1=Nutrition
2=Cost
3=Health
4=Other, specify

54. Are you able to afford this fish every time?
1= Yes 2= No

55. Are you able to get this fish every time you want it (all year round)?
1= yes 2= No

56. What is your perception of the cost of fish in relation to meat?
1=fish is cheaper than meat
2=fish costs the same as meat
3=fish is more expensive than meat
4= don’t know

57. What are your alternatives to fish?
1=meat
2=eggs
3=other, please specify…………………………………………..

58. In what form do you buy your fish?
1 = Raw fresh fish  2 = Raw frozen fish
3 = Processed fish, specify .............................

59. Where do you obtain your raw fish from?
1 = Fish landing port
2 = Wholesaler at market centre
3 = Retailer at market centre
4 = Cold store
5 = Hawkers
6 = Other, specify.......................................................

60. Do you inspect fresh fish before purchasing?
1=Yes 2= No
61. If yes to 11, what do you look out for?
   1=Colour of eyes
   2=Colour of gills
   3=Skin surface (smooth or slimy)
   4=Other, specify.................................................................

62. How do you perceive the quality of fish sold on our local markets? (eg. do you find maggots and insects in smoked fish?)
   ........................................................................................................
   ........................................................................................................
   ........................................................................................................
   ........................................................................................................

63. How do you transport the fish to your home?
   1=On ice
   2=Without ice
   5=Other, specify...........................................................................

64. In what containers do you transport the fish to your home?
   1=Plastic bags
   2=Paper wrappers
   3=Paper cartons
   4=Plastic containers
   5=Other, specify ...........................................................................

D. HANDLING AND STORAGE OF FISH

65. How do you store the raw fish once you get home
   1=At room temperature
   2=In a fridge
   3=In a freezer
   4=Other, specify...........................................................................

66. How do you cook raw fish in your home?
   1=fry
   2=smoke
   3=dry
   4=salt
   5=other, specify...........................................................................

67. If you chose more than one option in question 15, which processing method do you frequently use?
   1=fry
   2=smoke
   3=dry
   4=salt
   5=other, specify...........................................................................
68. How do you store processed fish once you get home
1=At room temperature
2=In a fridge
3=In a freezer
4=Other, specify.................................................................

E. FISH QUALITY AND SAFETY

69. Do you know anything about food safety?
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................

70. Do you know of any food safety issues associated with the consumption of fish?
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................

71. Have you ever found some of the fishes you purchased looking diseased or infected?
1= Yes  2= No

72. If yes to question 21, please describe the condition of the fishes?
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................

73. Are you familiar with spoiled fish?
1=Yes  2=No

74. What do you think or know causes fish spoilage?
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................
..........................................................................................................................

75. Have you had the experience of some of the fish you bought getting spoiled?
1=Yes  2=No

76. Please estimate the average quantities of fish that get spoiled from the lots you buy
..........................................................................................................................
..........................................................................................................................
.............................................................................................................................

101
77. What did you do with the quantity of fish that got spoilt?

78. Do you think the ways fishes are handled could contribute to their spoilage?
1=Yes  2=No

79. If yes to Question 31, please list some of the handling practices that could cause spoilage.
Appendix 2:

Appendix 2A: Unsanitary conditions prevailing at the James Town fish harbour

Appendix 2B: Sun-drying fish on Asphalt and in decommissioned canoes (picture on left shows fish after rains)
Appendix 2 C: Conditions of Retailing and Processing of fish in Kpong, James Town and Accra.
Appendix 3: Residual Plots for Analyses of variance

**One-way ANOVA: AMC versus reps**

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\[ S = 1.354 \quad R-Sq = 73.24\% \quad R-Sq(adj) = 55.89\% \]

Individual 95% CIs For Mean Based on Pooled StDev

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Pooled StDev = 1.354

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**One-way ANOVA: coliform count versus reps**

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\[ S = 1.017 \quad R-Sq = 58.89\% \quad R-Sq(adj) = 34.83\% \]

Individual 95% CIs For Mean Based on Pooled StDev

---
One-way ANOVA: staph versus reps

Source  DF  SS   MS  F     P
reps     22  70.84 3.22 2.24  0.016
Error    35  50.27 1.44
Total    57 121.11

S = 1.198   R-Sq = 58.49%   R-Sq(adj) = 32.40%

Individual 95% CIs For Mean Based on
Pooled StDev

Level  N  Mean  StDev  -----------------------------------
1      3  3.706  2.679  (--*-**-******)
2      3  2.312  1.280  (--*-**-******)
3      3  2.828  0.218  (--*-**-******)
4      2  1.000  0.000  (--*-**-******)
5      3  1.000  0.000  (--*-**-******)
6      3  1.000  0.000  (--*-**-******)
7      2  1.000  0.000  (--*-**-******)
8      3  1.745  1.291  (--*-**-******)
9      3  1.259  0.449  (--*-**-******)
10     2  2.956  0.388  (--*-**-******)
11     2  2.079  0.000  (--*-**-******)
12     3  3.378  0.162  (--*-**-******)
13     3  1.725  0.700  (--*-**-******)
14     2  1.854  1.207  (--*-**-******)
15     3  1.000  0.000  (--*-**-******)
16     3  1.000  0.000  (--*-**-******)
17     3  1.000  0.000  (--*-**-******)
18     2  1.000  0.000  (--*-**-******)
19     2  2.711  1.142  (--*-**-******)
20     2  1.540  0.088  (--*-**-******)
21     3  2.698  0.111  (--*-**-******)
22     2  2.429  2.020  (--*-**-******)
23     3  1.000  0.000  (--*-**-******)
24     3  1.000  0.000  (--*-**-******)
25     3  3.881  2.542  (--*-**-******)

Pooled StDev = 1.017

Individual 95% CIs For Mean Based on
Pooled StDev

Level  N  Mean  StDev  -----------------------------------
1      3  3.955  0.175  (--*-**-******)
2      3  3.815  0.571  (--*-**-******)
3      3  3.237  0.185  (--*-**-******)
4      2  1.000  0.000  (--*-**-******)
5      3  2.340  0.916  (--*-**-******)
6      3  1.000  0.000  (--*-**-******)
7      2  3.944  0.000  (--*-**-******)
8      3  2.056  1.219  (--*-**-******)
9      3  2.770  0.210  (--*-**-******)
10     2  5.073  0.955  (--*-**-******)
11     2  4.262  0.000  (--*-**-******)
12     3  3.269  0.158  (--*-**-******)
13     3  1.966  0.742  (--*-**-******)
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