Food safety management practices in the traditional fish processing sector in Ghana and the microbiological safety of selected processed fish products from Ghana

By

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Declaration

I certify that this work has not been accepted in substance for any degree, and is not concurrently being submitted for any degree other than that of M.Phil being studied at the University of Greenwich. I also declare that this work is the result of my own investigations except where otherwise identified by references and that I have not plagiarised the work of others.

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ABSTRACT

Fish products contribute significantly to protein nutriture, food security, livelihoods and the economy in West Africa. Food safety of processed fish products however remains an important concern. The purpose of this study was to investigate the safety of traditionally processed fish from Ghana. Microbiological analysis of selected traditionally processed fish products was conducted. Challenge tests were employed to determine the effects of storage temperature on survival of *Salmonella* Typhimurium and *Staphylococcus aureus*. The effects of salting, temperature, pH and inoculum size on the survival and enterotoxin production of *S. aureus* was also determined. Food safety surveys were conducted. Self-reported and observed food safety practices and the role of food safety inspectors were assessed. The pH levels observed in all samples were not at optimum levels to inhibit microbial growth. Water activity (a_w) levels were: fried bonga (0.82 – 0.95), koobi (0.53 – 0.75), kako (0.55 – 0.70, smoked catfish (0.72 – 0.95), smoked herrings (0.54 – 0.94) and smoked mackerel (0.84 – 0.99). *Salmonella* and *Clostridium perfringens* were not detected in 25g and 1g, respectively, of any of the samples. Varying levels of *Bacillus cereus*, *S. aureus* and yeast and mould were detected in fried bonga and smoked fish samples. Aerobic bacteria and coliforms were present in 50% and 44.4%, of fried bonga. Only yeast and moulds were detected in kako and koobi at levels of <2 log to 4 log cfu/g in koobi and from <2 log to 5 log cfu/g in kako. High levels of between 5 $\log_{10}$ CFU/g and 6 $\log_{10}$ CFU/g aerobic bacteria were recorded in smoked mackerel. On the basis of a_w levels and microbial quality, smoked mackerel and fried bonga were classified as high risk fish products requiring time-temperature control, and salted koobi, kako, smoked herrings and catfish as low risk products. Challenge tests with *S. aureus* in salted smoked mackerel and catfish showed no growth and no enterotoxin A and B at 4°C. *S. aureus* numbers increased in smoked catfish and mackerel samples stored at 30^{o}C but decreased with increasing NaCl concentration ($p<0.001$; $r^2=0.0507$). At 30^{o}C, SEA and SEB were detected in samples formulated with 5% (w/w) NaCl with high inoculum. Samples formulated with higher than 5% (w/w) NaCl suppressed growth and enterotoxin production. Food safety knowledge among respondents was good and consumers were concerned with some aspects of food safety in Ghana although not fish in particular. Very few food handlers had received adequate food safety training, the majority of whom overestimated their food safety compliance, evidenced by observed poor hygiene practices. Only 43.8% of inspectors had higher professional qualifications and 29.2% were trained in HACCP. Inspectors identified lack of information (41.7%), support (41.7%) and operational costs (39.6%) among the barriers to food safety compliance. These findings suggest a need for education at all levels including food safety enforcement professionals. A framework model which integrates all aspects of the findings in developing a national regulatory and policy framework for fish food safety has been proposed. Some of the skills that are missing are identified and suggestions put forward that will benefit traditional fish processing.

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Chapter 1

1.0 Introduction

1.1 Background and context of the study

Fish is a highly nutritious, protein-rich food commodity with wide consumer acceptance. It contains essential amino acids, minerals, vitamins and polyunsaturated essential fatty acids (PUFAs), especially omega-3 PUFAs and is low in saturated fat, and constitutes an important component of a healthy human diet (Kolanowski and Laufenberg, 2006). Scientific evidence indicates that fish consumption reduces the risk of coronary heart diseases, strokes, decreases mild hypertension, prevents certain cardiac arrhythmias, and also aids in the neurological development of foetuses (Kris-Etherton *et al.,* 2002; McMichael and Butler 2005). Its consumption is therefore highly encouraged. Worldwide, fish provides more than 1.5 billion people with almost 20 per cent of their average per capita intake of animal protein, and 3.0 billion people with at least 15 per cent of such protein (FAO, 2010). The fish industry in many sub-Saharan African countries plays a vital role in contributing directly to food and livelihood security, poverty alleviation, employment generation, wealth creation, rural development, export diversification and foreign exchange revenue (Ponte *et al.*, 2007; Lokuruka, 2009; FAO, 2010).

Many sub-Saharan African countries depend heavily on fish as an important protein source to alleviate protein-energy malnutrition (PEM) and as a source of essential micronutrients, including various vitamins and minerals (Seaman, 1999; Gopalan, 2000; FAO, 2010). Fish also generates significant employment and livelihood for whole communities. In fact, it is estimated that around 60 per cent of the population in many developing countries derive over 30 per cent of their animal protein supplies from fish, while almost 80 per cent of the population in most developed countries obtains less than 20 per cent of their animal protein supplies from fish (Ababouch, 2003). Traditional fish processing constitutes an enormous informal micro- or small-scale cottage-type sector which supplies much of the fish consumed in Ghana.

1.2 Food safety concerns of traditionally processed fish

Naturally, fish is highly perishable and has a short shelf-life under ambient conditions unless preservation methods are used. Its high moisture and nutrient content makes it a good substrate for both pathogenic and spoilage microorganisms, which are widely distributed in nature and are able to survive and proliferate under various environmental conditions. Consequently, fish safety and quality remain a dynamic situation heavily influenced by multiple factors along the food chain from farm to fork, including the harvest environment, sanitary conditions, processing and post-processing procedures and practices associated with equipment and personnel in the processing environment (FDA, 2001a; Huss, 2003). Governments and industry in developing countries, however, still face major challenges of producing safe fish products for their local markets and for export to markets in developed countries (Bagumire *et al.,* 2009) as fish can be a dietary source of hazards including chemical contaminants and foodborne pathogenic bacteria. Conditions in fish processing environments in Ghana and other parts of the continent have been generally described as rudimentary, unhygienic and good hygienic practices are said to be rarely practiced (Igene and Mohammed, 1983; Ababouch, 1990; Essuman, 1992a; Plahar *et al.,* 1999; Akinola *et al*., 2006; Anihouvi *et al.,* 2006). In Ghana, Plahar *et al.* (1999) have observed that quality assurance systems are not in place in the whole raw material procurement, processing, storage and distribution chain to facilitate prevention of consumer hazards or to produce high quality fish products. Recent investigations by Nyarko *et al.* (2011) have also reported the widespread use of old news prints, cement papers and polyethylene bags as packaging for smoked fish during storage, retail and handling of fish. There is also a serious gap and a paucity of data in respect of the food safety knowledge, attitudes and practices as well as production, processing and post-processing handling conditions, chemical and microbial contamination and the whole issue of food safety in the traditional food processing system in Ghana.

Good hygiene and manufacturing practices, appropriate cleaning, sanitation programmes, and temperature control are important requirements for the prevention and inhibition of microbial

growth (Sofos and Geornaras, 2010). Unhygienic fish processing environments and inappropriate practices can potentially contribute to contamination of fish along the fish chain from catch to fork. Concern has also been raised about the safety of West African traditionally processed fish products exported to the EU (Ward, 2003) due to heavy deposition of smoke. Of particular concern are pathogenic bacteria such as *Salmonella* spp, *Escherichia coli*, *Shigella* spp, *Vibrio* spp., and *Clostridium botulinum, Staphylococcus aureus* and *Clostridium perfringens* in tropical fish (Plahar *et al.*, 1999; Feldhusen, 2000) which may survive and grow and eventually reach infectious levels (Medvedova *et al.,* 2009). Under abusive storage and handling conditions, background flora of foodborne pathogens which may already be present in the fish products may grow and increase in numbers and/or produce toxins. Indeed, Plahar *et al.* (1999) in their study of smoked anchovies and *Sardinella* sp., reported that even though the initial microbial types and numbers decreased during smoking, they were not completely eliminated and microbial loads, including *S. aureus* and *Bacillus* spp., increased under traditional post-processing handling and storage conditions. Plahar *et al.* (1999) also observed that inadequate sunshine or inadequate thermal treatment, inadequate drying and storage of smoked fish may result in spoilage due to growth of filamentous fungi which may present a potential risk of mycotoxin production, and insect infestation. Nketsia-Tabiri (2004) has reported Total Viable Count (TVC) between 4.11 - 6.78 log cfu/g, counts of *S. aureus* between 2.85 - 4.15 log cfu/g and mould and yeast count of between 1.38-3.38 log cfu/g in market samples of salted and dried tilapia (koobi). The total viable count in this product increased to 7.5 ± 2.5 log cfu/g after 4 weeks storage under ambient conditions. Anihouvi *et al.* (2006) also reported *S. aureus* in 17.7 per cent of salted and fermented traditional fish products as well as histamine, moulds and *Clostridium* spp., but did not report the presence of *Salmonella*. In view of these facts, there is the need for an investigation into the safety of traditionally processed fish products in Ghana. It is also important to investigate food safety knowledge and how this knowledge is applied in traditional fish processing settings with the aim of developing appropriate recommendations and training for the improvement of hygiene in artisanal fish processing. Furthermore it would be useful to verify the

effectiveness of current government oversight functions in terms of food safety control, enforcement strategies and compliance in the Ghanaian fish industry.

1.3 Rationale and justification

The development of the fish industry is primarily one way to mitigate food insecurity and PEM in developing countries. For many developing countries, the development and production of value-added fish products also offers an opportunity to expand exports. The promotion of fish consumption also has potential health benefits in a country with relatively high levels of childhood protein-energy malnutrition associated with consumption of mainly starchy foods with little added protein. However, the benefits of fish consumption must be weighed against the potential health risks associated with fish consumption. The threat of food-borne disease from contaminated fish is real and of major concern to developing countries like Ghana, where fish production, marketing and distribution contributes significantly to the country's agricultural GDP. These facts make the fishing industry in Ghana an important area to examine with respect to their operations and their overall contribution to health and well being in the country.

1.4 Aims and objectives of the study

The study presented here was conducted to determine the safety of traditionally processed fish products manufactured in Ghana. The effects of a combination of hurdles on microbial growth and shelf-life extension would be investigated. The aim of this study is to contribute to the reduction of foodborne diseases in the traditional fish value chain through the development of effective food safety management system and standard food safety practices that are acceptable to micro and small-scale fish enterprises in Ghana. The primary objectives of the study were therefore:

1. To identify potential hazards in selected traditionally processed fish products (smoked fish and salted and dried fish) and to ascertain their suitability relative to food safety and risk to public health.

2. To compare bacterial survival and changes that occur in traditional fish products formulated with sodium chloride, contaminated with pre-selected levels of inocula of named foodborne pathogens under various post-processing storage temperatures.
3. To evaluate fish handlers' practical implementation and compliance with standard food safety and hygiene guidelines (CAC, 2009) as well as the food safety knowledge, attitudes and practices (KAPs) and concerns of various stakeholders involved in catch, handling, processing, storage, sale and consumption of fish in Ghana and how this contributes to food safety standards along the fish value chain.
4. To assess the effectiveness of current government oversight functions in terms of food safety control, enforcement strategies and compliance in the Ghanaian fish industry.

Addressing these issues would help risk managers to take regulatory and practical actions and would be of benefit to industry, local consumers and importing countries. It can be envisaged that empirical evidence gathered at the end of this study would be useful for implementing reliable food safety standards along the chain as well as contribute to implementing in-plant risk-based food safety management tools like the Hazard Analysis and Critical Control Point (HACCP) safety control systems in developing countries like Ghana. The key stages of this study will include microbial analysis of selected traditionally processed fish products from Ghana, challenge-testing selected fish products and toxin analysis to determine the risk they may pose to consumers, observation of food handling practices along the fish chain and a survey of fish handlers and consumers. This approach will identify any risk pathways that may lead to contamination and subsequent spread of fish-related food-borne disease. Necessary recommendations to strengthen the weak links along the food supply chain would be made.

1.5 Structure of thesis

This thesis is divided into nine chapters. Chapter 1 provides an introduction and background to the research. Chapter 2, a literature review of the research area defines the research issue and identifies food hazards in the context of traditional food processing in developing countries. Chapter 3

describes microbiological analysis of selected traditionally processed fish products. Chapter 4 describes the effects of storage temperature on the survival of *Salmonella* and *S. aureus*, and sensory and shelf-life studies. Chapter 5 is a survey of food safety knowledge, practices, attitudes and concerns. Consumer risk perception, as well as the strategies of risk reduction adopted by consumers, are also reviewed and discussed. Chapter 6 describes the growth and enterotoxin production of *S. aureus* in selected traditionally processed fish products. Chapter 7 is a survey of fish handlers' food safety compliance, self-reported and observed practices and a survey of food safety inspectors in Ghana. Chapter 8 is a general discussion of the results and findings of this study, the implications for food safety, together with recommendations, future research and conclusion.

Chapter 2

2.0 Literature Review

2.1 General background

In Ghana fish resources are from the marine and inland (freshwater) sectors, coastal lagoons and aquaculture (Quaatey, 1997; NAFAG, 2007). Average per capita fish consumption in Ghana is estimated at 27 kg, higher than Africa's per capita consumption of 8.5 kg and the world's average of 17 kg per annum (FAO, 2010). However, FAO and World Fish Centre (2008) estimates suggest that freshwater fish landings from Lake Volta may be much higher than previously thought, implying that average per capita fish consumption may exceed 40 kg per annum. Fish may therefore constitute over 70 per cent of the total animal protein intake in Ghana (FAO, 2004a; Gordon *et al.*, 2011; Nyarko *et al.,* 2011), with marine fish accounting for nearly 80% of fish production (Nyarko *et al.,* 2011). Individual and micro-enterprises represent a large proportion of the food enterprises responsible for fish capture, handling, processing and retailing a large share of the fish consumed in the region (Diei-Ouadi and Mensah, 2005). Fish capture, processing, transport, storage, marketing and associated services contribute an estimated 4 per cent of GDP and employs directly or indirectly about 10 per cent of Ghana's economically active population (World Bank, 2007). Large quantities of different species of fish such as sardines and anchovies are landed during the season of glut between July and October each year, which are preserved by one of several traditional processing techniques to avoid excessive wastage (Okraku, 1999; Kegan, 2001). Fishing is a highly gender-segregated occupation in Ghana (Odotei, 2003). Whereas men are engaged in the main fishing activity, women are involved with the on-shore post-harvest activities which involve processing, storage and trading. The latter is largely based on traditional processing methods which involve low capital investments and low technological requirements (Palmer, 2007) including direct drying, salting and drying, smoking and frying. Women's role is significant because they add value to fresh fish, by transforming, preserving and distributing fish to ensure its availability long after the peak season. In short, women are at the heart of the domestic fish market, without whose input, the sector would shrink significantly. The main sources of fish for processing plants in Ghana are

landing sites on the beaches along the Gulf of Guinea or banks of the Volta Lake. However, during periods of low domestic production (lean seasons), fish processors buy imported frozen fish species such as herrings (*Sardinella aurita*), bonga (*Ethmalosa fimbriata*) and mackerel (*Trachurus trachurus*) from cold stores to offset shortfalls. These imports help maintain price stability as well as satisfy consumer demand. Inadequate facilities, poor practices coupled with the hot and humid tropical conditions contribute to reduce shelf life and quality of fish.

2.2 Fresh fish

2.2.1 Fresh fish spoilage, quality changes and post-harvest losses

Fresh fish is subject to rapid quality deterioration and prone to contamination by both spoilage and pathogenic microorganisms if it is not handled correctly after capture. This is because of the high moisture content, high water activity (0.98), moderate pH levels (5.5– 6.5) and readily available energy sources, carbon, nutrients, protein and soluble nitrogen compounds, vitamins and minerals (Varnam and Sutherland, 1985; Mossel *et al.*, 1995; Ray, 1996; Jay, 2000). Annual fish losses in developing countries are estimated at 10 to 12 million tonnes and this amounts to about 10% of global capture and cultured fish (FAO, 2008). In West Africa alone, fish post-harvest losses are estimated to be about 20% (Horemans, 1998). These include various forms of physical loss of material, quality loss and nutritional loss. Post-harvest fish loss may involve fish spoilage which include deteriorative changes in the sensory characteristics of a product such as appearance, flavour, odour and texture, attributes which can also be used to indicate nutritional value, and safety (Bremner, 2002). These spoilages are usually caused by microbial growth, metabolism and biochemical changes (involving enzymatic and oxidative reactions) resulting in the formation of amines, sulphides, alcohols, aldehydes, ketones and organic acids with unpleasant and unacceptable off-flavours, odour, texture, and colour (Dalgaard, 1995; Gram and Dalgaard, 2002).

2.2.1.1 Fresh fish spoilage microorganisms

The microbial status of freshly caught fish is diverse and depends among other things on the environment, water temperature, area of catch and handling and processing procedures (Jay, 2000). Only a part of these flora, known as the specific spoilage organisms (SSO), contribute to spoilage (Dalgaard, 1995). Typically fish from temperate waters with temperatures <10°C, have psychrophilic (cold-tolerant) bacteria of the genera *Pseudomonas, Moraxella, Acinetobacter, Shewanella, Flavobacterium, Vibrio, Photobacterium* and *Aeromonas* as part of their natural flora, and depending on where they are captured yield counts of 10^2-10^4 CFU/cm^2 of skin and gill surface (Gram and Huss 1996). However, fish from tropical waters normally have mesophilic spoilage bacteria including *Bacillus, Micrococcus* and *Corynebacterium*, at levels of 10^3-10^6 CFU/cm^2 (ICMSF 1998). When fish is held at temperatures between 35-37°C, fish from the tropics decays much faster (within 24 hours) than fish from temperate waters by virtue of the high mesophilic microbial load of tropical fish and the fact that mesophilic bacteria are not inhibited under these conditions. As a consequence, if chilling is delayed after harvest, fish from tropical waters may spoil faster than fish from temperate waters (Smulders and Collins, 2002). There is usually an extended lag phase while numbers increase so icing, rapid chilling and sustained low temperature storage immediately after capture can result in long shelf-life for tropical fish species (Gram *et al.*, 1989) as chilling tends to inhibit mesophiles (Shewan and Murray 1979, Liston 1980, ICMSF 1998; Smulders and Collins, 2002). This is due to temperature shock of the intrinsic mesophilic microflora. In contrast, rapid chilling or low temperature storage tend to promote better survival and the proliferation of psychrotrophs and psychrophiles on fish, which in turn enhance spoilage at chilled condition, shortens the shelf life and ultimately causes severe losses of fish (Karungi *et al.*, 2004).

Several studies have shown that under chilled storage conditions (0-5°C), *Shewanella putrefaciens*, *Photobacterium phosphoreum*, *Aeromonas* spp. and *Pseudomonas* spp. are the predominant bacteria most commonly associated with spoilage, whereas at high temperature (15-30°C), different species

including, Vibrionaceae, Enterobacteriaceae and Gram-positive organisms are found to be responsible for spoilage (Liston, 1992; Gram *et al.,* 1990; Gram *et al.,* 1987).The natural incidence of psychrotrophic bacteria on tropical fish is low. The bacteria most commonly identified with spoilage are species of *Shewanella putrefaciens* and *Pseudomonas* group 3 (Huss *et al.* 1997). The latter has been found to be dominant in spoiling tropical marine or fresh water fish (Huss 1994a). Gram and Huss (1996) attributed the importance of *Pseudomonas* in fish spoilage, to their wide distribution in the environment, their ability to utilise a wide range of materials as substrates for growth and the ability to contaminate a product from many sources. Quality control and potential shelf-life of fish is currently still often estimated based on the total aerobic psychrotrophic count (APC). A microbial load of $>10^6$/g in the fish muscle may be indicative of advanced stages of spoilage or the upper limit of microbiological acceptability (Liston 1980, Howgate 1982, Connell 1990). However, according to Gram *et al.* (1989) the total counts of bacteria on/in fish rarely indicate the sensoric quality or expected shelf-life of the fish as high counts may prevail for a long time before rejection. During storage, the microflora changes, owing to different abilities of the microorganisms to tolerate the preservation conditions (Gram and Dalgaard, 2002) and the origin of fish (fast or slow flowing river, deep water or brackish water fish).

2.2.1.2 Fresh fish autolytic spoilage

Autolytic changes lead to decomposition of proteins, and other vital compounds that consequently eventually result in the softening of the fish flesh and unpleasant loose/mushy substances in the gut cavity (Bremner, 2002). According to Huss (1994b) autolytic changes are responsible for the early quality loss in fresh fish but contribute very little to spoilage of chilled fish and fish products. Factors, including species, size, temperature, physical condition, and methods of catching and handling fish determine the onset and end of rigor mortis and shelf-life during storage (Huss, 1995; 1988). Although the onset and duration of rigor mortis are more rapid at high temperatures, observations on tropical fish show the opposite effect of temperature with regard to the onset of rigor. In these species the onset of rigor is accelerated at 0°C compared to 10°C (Poulter *et al.,* 1982; Iwamoto *et al.,* 1987). Abe and Okuma (1991) attribute this to the difference in water

temperature and storage temperature. When the difference is large the time from death to onset of rigor is short and *vice versa.* Stunning and killing by hypothermia (the fish is killed in iced water) give the fastest onset of rigor, while a blow on the head gives a delay of up to 18 hours (Azam *et al.*, 1990; Proctor *et al.*, 1992). Low molecular weight components, such as, trimethylamine-oxide (TMAO) and free amino-acids produced by the autolysis of proteins not only lower the commercial acceptability of fish, but have been shown to accelerate the growth of spoilage bacteria by providing a superior growth environment for such organisms (Aksnes and Brekken, 1988; Huss, 1988; Huss, 1994b). The microbial activity and especially the formation of volatiles such as trimethylamine (TMA), ammonium and H_2S of SSOs such as *Shewanella putrefaciens* and *Pseudomonas* spp. (Dalgaard, 1995; Koutsoumanis and Nychas, 1999; Tryfinopoulou *et al.*, 2002; Vogel *et al.*, 2005), contribute to the characteristic "fishy" smell of spoiled fish, off-flavours and taste associated with spoilt seafood. The fish viscera contain proteolytic enzymes responsible for food digestion but when fish die, they attack the organs and the surrounding tissues culminating into a condition known as belly-burst. They are also capable of penetrating the flesh and causing additional damage (Connell 1990). The bacteria in the gut also contribute to this. Autolytic tissue degradation tends to be more pronounced in heavily feeding fish than petite feeders (Gildberg and Raa, 1980). Fish is also highly susceptible to oxidative rancidity because of their high degree of unsaturated lipids (Connell 1990; Huss 1994b). The main reactants in these processes involve atmospheric oxygen and fish lipid but the reactions are initiated and accelerated by heat, light (especially UV-light) and several organic and inorganic substances like copper and iron ions. The end products are aldehydes and ketones, which impart the strong rancid flavour of spoilt fish (Huss 1994b).

2.2.2 Fresh fish chemical hazards – histamine

Naturally occurring chemicals such as histamine, putrescine and cadaverine are considered likely causes of scombrotoxicosis and can pose health hazards in fish if elevated levels are consumed (Taylor, 1990; Lehane and Olley, 2000). Scombroid fish poisoning results from the consumption of spoiling scombroid or other marine fish, that contain hazardous levels of toxigenic biogenic amines,

which may form on exposure of fish to abuse temperature (Klausen and Lund, 1986). Many cases of histamine (or scombroid) fish poisoning (HFP) have been reported (Dalgaard *et al.,* 2008). HFP foodborne intoxication occurs when people ingest fish in which bacteria have decarboxylated histidine to histamine. Two fish families, scombroideae (tuna, mackerel and bonito) and scombrososcideae (herring and marlins) which contain very large amounts of histidine in their muscle tissues are commonly implicated in incidents of histamine poisoning (Lokuruka, 2009). A considerable number of scombroid fish are found in the marine catches of the major African fishing nations. Tropical fish that have been confirmed to be potentially scombrotoxic include herring (Mackie *et al.,* 1997), yellow fin tuna (Du *et al.,* 2002), mackerel (Chakrabarti, 1991, 1993,1998; Kim *et al.,* 2001; Shakila *et al.* 2002), tuna (*Thunnus thynnus*) (Lopez-Sabater *et al.,* 1996), the grouper (*Plecteropomus maculates*) (Surti *et al.,* 2001), sailfish (Hwang *et al.,* 1995), sardines (Ababouch *et al*. 1991; Plahar *et al.* 1999) and anchovies (FDA, 2001). Dried sardine has been implicated in histamine poisoning in Japan (Kanaki *et al.,* 2004). Salted and fermented anchovy have also been found to contain high levels of histamine of 15.5–57.9 mg/100g (Mah *et al.,* 2002). In a study of stored sardine and anchovy samples in Ghana, Plahar *et al.* (1999) reported 1.1mg/100g, 1.8mg/100g and 1.5mg/100g levels of histamine in raw, smoked and 6 months stored sardine samples respectively, but no histamine was found in anchovy samples. Histamine levels ranging between 17.4 - 25.4mg/100g in cassava fish (*Pseudotolithus* sp.) and 26.5 - 39.7mg/100g in king fish (*Scomberomorus tritor*) have been reported in the Republic of Benin (Anihouvi *et al.,* 2006). Seventy-five percent of the cassava fish and the entire king fish (100%) sampled in this study showed histamine contents higher than the maximum allowable level of 20mg/100g. Histamine >50 ppm in fish flesh is legally regarded as hazardous in the U.S. (FDA, 1998), whereas in the EU levels must be greater than 100 ppm to be regarded as hazardous (Veciana-Noguez *et al.,* 1997). Due to lack of reporting or ignorance about histamine poisoning in developing countries, estimates of its consequences are not known. In the U.S.A. according to the CDC, scombrotoxicosis is the most frequently reported chemical foodborne illness (CDC, 1996).

Histamine poisoning is more commonly the result of high temperature spoilage than of long term, relatively low temperature spoilage (FDA, 2001a). Histamine-forming bacteria are capable of growing and producing histamine over a wide temperature range. Mesophilic histamine producing bacteria such as *Morganella morganii*, *Raoultella planticola*, *Klebsiella pneumoniae* and *Hafnia alvei* can grow to high levels and form histamine in toxic concentrations above 500–1000 ppm when exposed to elevated temperatures, above 7–10°C (Lehane and Olley, 2000). Other studies show that the psychro-tolerant bacteria *Morganella psychrotolerans* and *Photobacterium phosphoreum* can produce toxic concentrations of histamine in seafood even when products are stored chilled (Dalgaard *et al.,* 2008). However, growth and the rate of accumulation of histamine are more rapid at high-abuse temperatures (20–45^{o}C) than at moderate-abuse temperatures (e.g. 7.2°C). Growth is particularly rapid at temperatures near 32.2°C (FDA, 2001a). In a study by Mitchell (1993) the level of histamine in mackerel stored at 0^{o}C for 18 days was low whereas, the level observed in mackerel stored at 10^{o}C for only 5 days was high. Freezing may inactivate the enzyme-forming bacteria and cooking can inactivate both the enzyme and the bacteria. However, if histamine is present before freezing it will remain in fish and histamine is not inactivated by hot smoking, cooking and retorting or freezing (FDA, 2001b). Thus, to prevent histamine formation fish should be chilled rapidly after capture and maintained at chill or freezing temperatures. The time of storage and distribution (the safe shelf-life) must be limited depending on storage conditions and product characteristics (Emborg and Dalgaard, 2008). A temperature range of 0-2^{o}C is recommended for fresh fish storage and any storage temperature above 4^{o}C is regarded as abuse temperature (FDA, 1998). Rapid chilling in ice or iced seawater and/or freezing are very important methods of preserving fish in international seafood trade in order to avoid losses and disruptions arising from potential scombrotoxicity (Lokuruka, 2009). Freezing in particular is a more effective procedure to arrest scombrotoxin formation in stored fish and fish products than ice storage (Lokuruka, 2009). Connell (1975) has reported that icing is more effective in suppressing bacterial growth in tropical than in temperate fish. Lokuruka and Regenstein (2004) have also reported that

iced tropical fish had much lower potential for scombrotoxicity under comparable handling conditions as temperate Atlantic mackerel.

2.2.3 Environmental contaminants in fish

Fish are constantly exposed to many potentially dangerous chemicals (e.g. heavy metals, pesticides and algal toxins) from polluted and contaminated waters including industrial and domestic waste water, mining, fuel combustion, natural runoff and tributary rivers (Tariq *et al.*, 1991; Rashed, 2001; Mendil *et al.*, 2010). Estuarine and coastal environments are often most seriously affected by contamination because of agricultural and urban runoff, industrial effluents and domestic discharges (Mendil *et al.*, 2010). Pesticide residues (Osafo, 1997; Ntow, 2001; Ntow *et al*., 2008), chemical contaminants and biotoxins (WHO, 2006) have been detected in fish in Ghana. Adimado and Baah (2002) and Babut *et al.* (2003) reported the presence of mercury contamination in fish in Ghana at levels exceeding EU threshold levels. EU legislation EC 466/2001 establishes maximum permissible levels of mercury in fish at 0.5 mg of mercury per kg of fresh weight of fish, except for a maximum level of 1.0mg/kg for fish on a certain list (e.g. eel, halibut, swordfish and tuna). In Nigeria elevated levels of arsenic have been reported in smoked fish (Adekunle and Akinyemi, 2004).

2.2.4 Fresh fish pathogenic microorganisms

Microbiological health hazards in fresh fish need to be controlled to prevent or reduce outbreaks of foodborne diseases and reduce losses of this important commodity. The presence of foodborne pathogens depends on the harvest environment, sanitary conditions, and practices associated with equipment and personnel in the fish processing environment (FDA, 2001; Huss, 2003). Contamination of food is influenced by multiple factors and may occur before harvest or anywhere in the food production, processing, storage, handling and distribution process (Huss *et al*., 2000; Newell *et al.*, 2010; Amagliani *et al.*, 2012). Pathogenic bacteria, including *Clostridium botulinum* type E, pathogenic *Vibrio* spp., *Aeromonas*, *C. botulinum* type A and B; and *Listeria*

monocytogenes are naturally present in aquatic environments (Huss *et al*. 2000). *Vibrio* sp. including *V. parahaemolyticus* (Vuddhakul *et al.,* 2006; Yano *et al.,* 2006) and *V. cholerae* (Alam *et al.,* 2006) are examples of indigenous pathogenic bacteria that inhabit tropical coastal and aquatic environments. They are frequently implicated in foodborne outbreaks (Lee *et al.,* 1996). Certain *Salmonella* types may also be part of the indigenous microflora in tropical aquaculture (Huss *et al*. 2000). Other non-indigenous pathogenic bacteria come from the disposal of sewage, land run-off (Reilly and Twiddy, 1992), contaminated feeds and animal faeces (Bhaskar *et al.,* 1998) and may include *Escherichia coli*, *Staphylococcus aureus, Salmonella* Typhimurium, *Bacillus cereus, Shigella* spp.*,* and *C. botulinum.*

Pre-harvest contamination with pathogens from animal or human reservoir (*Salmonella*, *Shigella*, *E.coli*, enteric viruses) may pose a risk since in some cases a very low infective dose is required to cause illness (Huss *et al*., 2000). Bacteria may be found in high numbers on the skin (10^2-10^7 cm^{-2}), gills (10^3-10^9 g-1) and intestines (10^3-10^9 g-1) (Hielm *et al.,* 2002). Accidental contamination can also occur during catch, processing, manufacturing, distribution and sale resulting in heavy losses and public health problems (Farkas, 1990; 1999; Roca and Incze, 1990). Lack of temperature control in the hot tropics will permit the growth of pathogenic microorganisms, including *Salmonella* spp., *E. coli*, *Shigella* spp, *Campylobacter* spp., *Vibrio* spp., and *C. botulinum, S. aureus* and *C. perfringens* in tropical fish (Feldhusen, 2000; WHO, 1999a) with consequent risk to consumer health. In addition, outbreaks of foodborne infection or intoxication can occur if there is failure of food safety practices at any stage along the fish chain. Identifying points in the fish food chain where these microorganisms either singly or in combination may flourish or pose a risk to human health is important for the fisheries industry in West Africa, including Ghana.

2.2.5 Prevention of fresh fish contamination and handling challenges in developing countries

Preventing pre-harvest contamination can be very difficult, as naturally occurring disease agents will always be present. Chemical pollution and faecal pollution can be prevented at a cost (Huss *et*

al., 2000). The method of catch and the subsequent on-board handling greatly affect the number and types of bacteria on the raw material (Hielm *et al.,* 2002). Poor handling practices such as using dirty canoes, equipment, fish boxes and baskets; not washing fish; washing fish in dirty water; placing fish on dirty surfaces; and physically damaging fish by throwing or standing on them lead to sustained and increased microbial contamination, hastening the spoilage rate of fish (Diei-Ouadi and Mgawe, 2011). High ambient temperatures influence the rate of spoilage and deterioration of fresh fish (Diei-Ouadi and Mgawe, 2011) and will result in autolysis and subsequent quality loss during long fishing trips.

Sustainable and reliable fish supply systems are needed to ensure availability, access at the household level, and more opportunities for improved livelihood. Knowledge about the microbiological status of the different fishing grounds is of utmost importance when deciding on risk management strategies. Immediate preventive measures include monitoring of fishing areas for the presence of toxic algae and faecal pollution (Huss *et al*., 2000). Fish also requires proper handling, processing and distribution for cost effective and efficient utilisation (FAO, 2010). Appropriate post-harvest technologies and handling facilities are also necessary. Adequate infrastructure, including hygienic landing centres, electric power supply, potable water, roads, ice plants, cold rooms, refrigerated transport, and standard processing and packaging facilities are lacking in many developing countries (Buckle *et al*., 1998; Abila, 2003; FAO, 2010). In Ghana, with improvement in electricity supply a number cold storage facilities and ice production facilities are now being built. Consequently, ice packing or top icing is increasingly used for fresh fish during transport, distribution and storage. Other fish handlers use domestic refrigerators or freezers to store fish or site their processing plants near the landing sites so as to shorten the supply chain.

Where refrigerators or freezers are used, they may run at inadequate temperatures, either because they lack maintenance or irregular power supply. These factors, linked with the high ambient temperature and humidity of the tropics cause a high percentage of post-harvest losses through

various forms of biochemical, physical, microbial and quality deterioration at various stages along the distribution chain from capture to consumption (FAO, 2010). To improve food security better use can be made of fish produced by reducing post-harvest losses and increasing the percentage of fish available for direct household consumption. Provision of essential infrastructure will add value to fish caught in the country.

2.3 Processed fish

Utilisation of fish and processing methods vary according to local tradition and geographic preferences. In Ghana, about 80 percent of the total fish supply is cured before consumption (Essuman, 1992a) and fish products not consumed immediately are converted into a variety of traditional products primarily as a means of preservation for longer storage at ambient temperature. Traditional fish products are usually heavily salted and dried, fermented, heat-treated or smoked over open fires to cook and dehydrate them, fried or pickled or processed by various combinations of these methods (Essuman, 1992a; Plahar *et al.,* 1999; Nti *et al.,* 2002; Nyarko *et al.,* 2011). Fish processed using these methods are often considered to be shelf-stable without the need for refrigeration and may be eaten directly with or without re-hydration and cooking (Egbunike and Okubanjo, 1999). A process flow diagram for various traditional fish product preservation and processing is shown on Figure 2.1.

Traditional processing techniques involve manipulation of a range of factors which can impact on microbial growth. These include moisture content, water activity (a_w) and pH value, which when combined with heat treatment and/or chemical preservatives like sodium chloride, result in shelf-stable intermediate moisture fish (IMF) or dried fish products. These intermediate or dried fish products partially or totally inhibit the development of pathogenic and spoilage microorganisms and offer food security and economic advantages for local populations in developing countries. Several authors (Van Garde and Woodburn, 1994; Wang *et al.,* 1995; Canovas and Mercado, 1996) have noted advantages of IMFs including their shelf stability, convenience and safety.

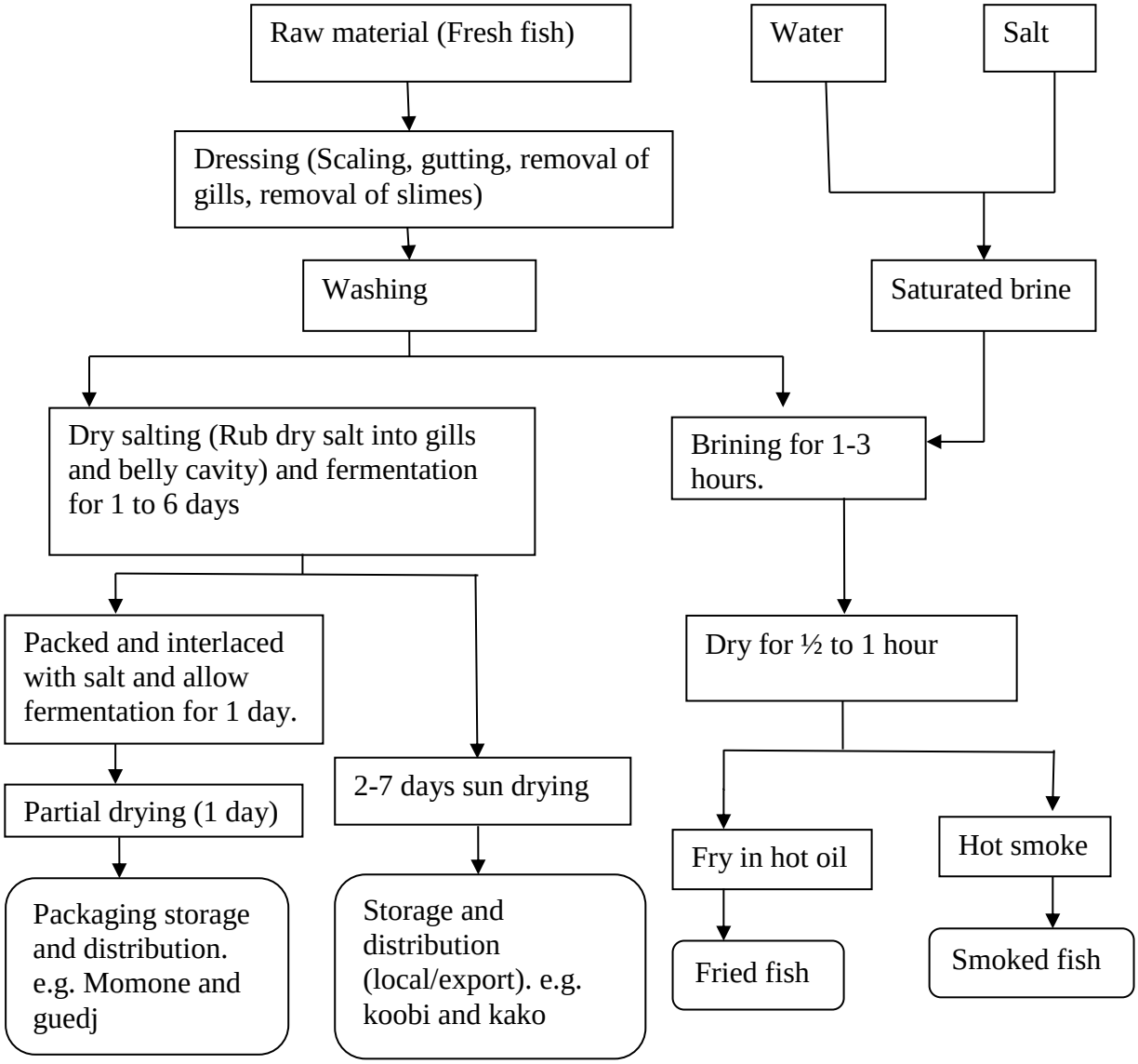

Fig 2.1. Process flow diagram for the traditional production of various fish products from Ghana/West Africa

The processes applied are based on principles similar to the concept of hurdle technology, a centuries' old technology that has been known and used in many developing countries to produce shelf-stable traditional foods (Leistner and Goris 1995). Hurdle technology involves the intelligent use of combinations of different preservation factors or techniques ('hurdles') that cannot be overcome by microorganisms present in the food (Leistner, 1995, 2000; Leistner and Gorris, 1995).The 'higher" the hurdle, the greater the effort needed to overcome it. The growth retarding and lethal effect of various combinations of preservative factors applied during traditional preservation and processing are well established (Leistner, 1995).

2.3.1 Fish smoking in West Africa

Most (70%) of the total fish caught in Ghana's marine waters is preserved by smoking, a process through which volatile compounds from thermal combustion of wood penetrate fish flesh (Essuman, 1992a; Ward, 1995). The most widely used smoking process, hot smoking, is undertaken over smouldering wood, sawdust or other local sources of energy (Ako and Salihu, 2004). This is usually done using traditional kilns or round mud ovens with a single platform above the combustion chamber, onto which a single layer of fish is loaded ready for smoking (Ako and Salihu, 2004) or the '*Chorkor smoker*' (Plahar *et al.,* 1999). The *Chorkor smoker* oven consists of a 65-cm-high rectangular combustion chamber made of burnt bricks with stock holes leading to fire pits and a set of framed wire mesh trays (usually 10). The rectangular trays make up the smoking unit when stacked up on the oven, each loaded with one layer of fish (Nti *et al.,* 2002). Smoking is often undertaken in conjunction with salting, cooking and drying, important to the products' shelf-life and safety. Depending on the type of fish to be smoked, its uses and the length of time for storage, the smoking process in Ghana can take the form of wet hot smoking or dry hot smoking (Hall, 2011). Both processes are carried out at temperatures above 80°C, high enough to cook the flesh of the fish and de-activate enzymes present (Berkel *et al.,* 2004).

Marine fish like mackerel are usually wet hot-smoked. Wet hot smoking usually takes about 1-2 hours and yields a moist, versatile product with about 40-55 per cent moisture content but a limited shelf life of 1-3 days under ambient conditions (UNDP 2001; Hall, 2011). Dry hot smoking, which is usually preceded by the former process, takes about 10-18 hours, sometimes, days, yielding fish with 10-15 per cent moisture content or even below 10 per cent (UNDP 2001; Hall, 2011). Freshwater fish and marine species are usually dry hot smoked. Fish species that are commonly smoked in Ghana include catfish (*Clarias* spp.), sardinella (herring) (*Sardinella aurita*, *S. maderensis*), mackerel (*Scomber* spp.) and tuna (*Thunnus albacores*, *Katsuwonus pelamis*). The shelf-life of a dry hot smoked fish can be 6-9 months (UNDP, 2001) or last as long as one year (Britwum, 1993). When packaged and stored properly this product can be transported long

distances within Ghana and beyond (UNDP, 2001). The longer shelf-life allows women some measure of control over the distribution process and fish prices.

The preservation effect of smoking is generally attributed to several antimicrobial and antioxidant substances which can effectively inhibit microorganisms, limit harmful enzymic and oxidative reactions, especially in combination with high temperature application (FAO 1992; Horner 1997; Muratore *et al.*, 2007). Contact and embedding of phenolic compounds generated from burning wood, combined with the temperature and conditions of smoking can reduce microbiological development and oxidation and provide longer shelf-life (Efiuvwevwere and Ajiboye, 1996; Ravishankar and Juneja, 2000; Varlet *et al.*, 2007). Effective heat treatment can reduce water activity (a_w) sufficiently to inhibit survival and growth of spoilage and pathogenic bacteria (Knøchel, 1983; Vandenbergh, 1993). Moreover, heat generated during hot smoking accelerates the drying process by reducing moisture content, lowering the pH and destroying microbes thus ensuring shelf-stable intermediate moisture products (Horner, 1997; Nickelson *et al.*, 2001; Berkel *et al.*, 2004; Sengor *et al.*, 2004; Abolagba and Melle, 2008). This growth retarding and lethal effect of smoking on spoilage and pathogenic microflora is influenced by salt content in the water phase of the product, time and temperature of heating, humidity, density and duration of smoking, and concentration of active components including antimicrobials in smoke (Kolodziejska *et al.*, 2002). Efiuvwevwere and Ajiboye (1996) evaluated microbial characteristics of smoked catfish subjected to different concentrations of sodium benzoate or potassium sorbate and stored at tropical ambient temperature. They found that smoking reduced the total viable count significantly in all samples, but samples treated with 0.4% (w/v) potassium sorbate showed the greatest microbial reduction. However there was significant increase in the total bacteria counts and staphylococci population within 4 days of storage. This may be due to post-processing contamination. Smoking is also responsible for significant modifications of the organoleptic properties of fish (Kjallstrand and Petersson, 2001), including taste, odour, colouration and flavour (Horner, 1997; Sengor *et al*., 2004; Abolagba and Melle, 2008).

2.3.2 Salting and sun-drying of fish products

Salted fish products are widely consumed in Ghana and other African countries. Salting and fish drying is carried out in coastal areas and along lakes and rivers in rural communities in Ghana where modern preservation facilities and infrastructure for transportation are relatively lacking. Salting is often used to enhance the quality and acceptability of naturally dried fish. Freshwater fish, tilapia (*Oreochromis niloticus*), is widely supplied to the market in the salted and dried form, called koobi in Ghana. Larger demersal species such as sharks, skates and rays are often dry-salted and dried in the sun to produce a product called kako. Other salt-cured fish products in Ghana include εwule, a salted fermented and dried triggerfish (*Balistes* spp.) product and mɔmɔne, a semi-dried fermented fish product characterised by a strong pungent odour often used in small quantities as a condiment. Fresh fish for frying is often brined for about three hours before frying (Figure 2.1). Some of the most commonly fermented fish products widely consumed in Africa are listed in Table 2.1.

Table 2.1. Selected fish products and the fermentation process

Country	Local/Common Name of Product	Fermentation Period	Drying Period	Packaging
Burundi	Ndagala	2-5 days (normally during drying, no salting)	2-5 days on ground or rack	Sacks, polythene bags
Chad	Salanga	Overnight (3-6 hours), no salting	3-7 days	Baskets, sacks
Côte d'Ivoire	Gyagawere, adjonfa	6 hours to 3 days with salting	3-5 days on grass, nets, mats or raised platforms	Baskets, sacks
The Gambia	Guedj	Overnight to 2 days with salting	3-5 days on raised platforms	Sacks
Ghana	Momone, koobi, kako, ewule	Overnight to3 days with salting	3-5 days on straw, nets, stones	Sacks, baskets
Mali	Djegue, jalan	Overnight, no salting	3-7 days on grass, mats or ground	Sacks, mats and ropes
Senegal	Guedj, tambadiang, yeet	Overnight to 2 days with salting	3-7 days	Sacks, baskets
The Sudan	Fessiekh, kejeick, terkeen, mindeshi	10-20 days with salting	No drying (fessiekh) 3-7 days (kejeick)	Cartons, cans, polythene bags
Uganda	Dagaa	3-6 hours without salting	2-5 days	Sacks, baskets

Adapted from Essuman (1992a).

Salting techniques are simple and involve covering the fish with dry salt crystals or immersion in saturated brine solution or a combination of both. The raw fish are dressed, thoroughly washed and

dry-salted by rubbing salt into the gills and belly cavity and on the surface. The fish are then arranged in alternate layers with salt before being allowed to ferment for two to three days and then dried for several more days on mats, raised platforms, racks/poles, or spread on the floor by the roadside until the fish is almost completely dehydrated. This practice exposes fish to insect infestation including, blow flies (*Chrysomya* spp.) and their larvae (maggot) and beetles. Loss of dried products due to pests e.g. rats, cats, dogs and birds are relatively common. A number of improved solar-drying techniques have been developed to reduce drying time, insect and microorganism infestation; and prevent bird, cat and rodent attacks and protect the fish from wind-borne dust (Curran and Trim, 1982; Osei-Opare and Kukah, 1989; Ampratwum and Dorvlo 1997; Sablani *et al.,* 2003).

Salt and water transfer in fish muscle during the salting process is complicated and depends on various transfer mechanisms (Andrés *et al.,* 2002), including diffusion (Wang *et al.,* 2000; Barat *et al.,* 2003), osmotic pressures between the muscle and the salting agent (Raoult-Wack, 1994) and the concentration gradients within the muscle (Erikson *et al.,* 2004). Brine concentration and temperature are the main factors affecting the rate of water and salt diffusion (Bellagha *et al.,* 2007; Boudhrioua *et al.,* 2009). Salt-dried fish have low water activity resulting from rapid dehydration and only halophilic microorganisms are able to develop in them (Rodrigues *et al.,* 2003; Andrés *et al.,* 2005; Brás and Costa, 2010) thus improving their shelf-life. According to Poulter *et al.* (1982), a good quality salted and sun dried fish with a_w of 0.65 and moisture content of below 20 % could have a predicted mould-free shelf-life between 100 and 450 days. Foods with a_w above 0.85 require refrigeration or another barrier to prevent growth of pathogens and spoilage microorganisms including moulds and yeast. Foods with medium a_w i.e. between 0.65 and 0.85 on the other hand do not often require refrigeration to control pathogens, but have a limited shelf-life because of spoilage, primarily by yeasts and moulds. For the most part, foods with a water activity below 0.60 are shelf-stable at ambient temperature and are not considered to be potentially hazardous (Poulter *et al.,* 1982). Salted fish products have a long shelf-life and are considered low risk foods because

of their low moisture and low water activity levels (Rodrigues *et al.,* 2003; Andrés *et al.,* 2005). Nevertheless potentially pathogenic micro-organisms have been found in these products (Huss and Valdimarsson, 1990). The low a_w environment represses any bacteria present and their virulence capabilities might be reduced in salted dried fish. For dried or cured products stored under normal conditions in a tropical climate, a_w can be considered the best index to determine product stability and how quickly microorganisms will grow in them (Chiralt *et. al.,* 2001; Jeyasekaran and Shakila, 2003). Salting, by increasing rapid dehydration from fish, inhibits microbial growth by lowering a_w, thereby restricting the amount of water available to support microbial growth. Salt also forms a membranous surface which inhibits growth of microorganisms in food (Leroi and Joffraud, 2000; Rorvik, 2000) and chloride ions in salt are toxic for some microorganisms (Leroi *et al.,* 2000).

Salted and dried fish are themselves generally considered safe and acceptable but unhygienic food production processing and unsanitary fermentation practices, contaminated environments as well as improper personal hygiene of food handlers and the presence of vermin (e.g. house flies) could pose a significant threat to consumers (Steinkraus, 1997). Halo-tolerant and moderately halophilic psychrotrophs that have survived salting and / or drying could still grow during soaking (desalting) and pose risk to consumer health (Rodrigues *et al.,* 2003). The drying behaviour, preservative effect and characteristics of the final product depends on the length of the salting period, the salt or brine concentration applied, the rate of penetration, the degree of contamination with salt tolerant organisms and storage temperature (Berhimpon *et al.,* 1990; Bellagha *et al.,* 2007; Boudhrioua *et al.,* 2009). Salt and water transfer in fish muscle during the salting process is complicated and depends on various transfer mechanisms (Andrés *et al.,* 2002), including diffusion (Wang *et al.,* 2000; Barat *et al.,* 2003), osmotic pressures between the muscle and the salting agent (Raoult-Wack, 1994) and concentration gradients within the muscle (Erikson *et al.,* 2004). Jittinandana *et al.* (2002) have reported that brine concentration and time of salting affect the pH, protein solubility, water-holding capacity, water activity and textural properties of brine-salted rainbow trout fillets.

In Ghana, salting and sun-drying are sometimes combined with fermentation. Traditional applications of fermentation are based on experience gained through trial and error by generations of food producers and households who use the technology for domestic preparation and preservation of foods (Motarjemi, 2002). The use of starter cultures is virtually unknown in these communities and microorganisms including yeast and lactic acid bacteria present in the raw materials or introduced through salt or recycled brine usually bring about fermentation. Consequently, a mixture of bacteria, yeast, and moulds all contribute to traditional fermentation resulting in distinct change or a series of changes in the product. Production of dry-salted tilapia (koobi) and dry-salted demersal fish (kako) does not include steps such as cooking or pasteurisation, which kill pathogenic bacteria. The preservative effect of salting and drying is due to a combination of factors which have been variously described (Mensah *et al.,* 1988; Simange and Rukure, 1991; Vandenbergh, 1993; Lee *et al.,* 1994; Østergaard *et al.,* 1998; Riebroy *et al.,* 2004).

The pH range at which microorganisms grow on food is quite wide (pH 4.0-9.5), with most of them surviving and growing well within the range 6.5 to 7.0 (Rodrick and Schmidt, 2003). Generally, pH should be below 4.5-5 in order to inhibit pathogenic and spoilage bacteria (Owens and Mendoza, 1985). However, some microorganisms including yeasts and moulds, survive below pH 4.0 and a few grow at very low pH. Lactic acid fermentation using high levels of culture of log $\geq$ 8.0 cfu/g inhibit *Salmonella, Staphylococcus* and coliform bacteria (Raccach, 1992). Studies also reveal that fermentation to a pH level below pH 4 significantly inhibits proliferation of diarrhoea-causing pathogens including *Campylobacter jejuni, Salmonella* Typhimurium, enterotoxigenic *E. coli, Shigella sonnei, S. aureus, L. monocytogenes* and *B. cereus* (Adams, 1990; Mensah *et al.,* 1988; Svanberg *et al.,* 1992). However, failure of fermentation processes can result in spoilage and / or survival of pathogens, thereby creating unsafe and undesirable end products with inherent health risks to consumers (Holzapfel, 2002). A number of biological hazards, including Enterohaemorrhagic *E. coli, Clostridium botulinum* and *S. aureus* have shown patterns of acid

resistance and salt tolerance and may survive certain fermentation processes. Fermentation should thus not be relied upon for the elimination or reduction of these hazards (Motarjemi, 2000).

The main problems associated with dried fish are the variable but often low quality final product, high salt content, microbial contamination, and mould and fungal growth resulting from inadequate drying. The latter makes sun-dried fish susceptible to rapid deterioration and spoilage (Bellagha *et al.*, 2007). Excess sodium consumption has been cited as a primary cause of hypertension and cardiovascular diseases (AFSSA, 2002; Matthews and Strong, 2005; WHO, 2006; Havas *et al.*, 2007; Taormina, 2010). Excess salt in the diet therefore constitutes an important potential public health hazard. Efforts to reduce salt content of fish products must take into consideration microbiological food safety and quality implications of NaCl reduction in foods. Flegel and Magner (2009) have argued that "refrigeration has largely replaced the need for sodium salts as food preservatives". However, refrigeration alone would not prevent the growth of psychrotrophic food borne pathogens like *Listeria monocytogenes*, *Yersinia enterocolitica*, and *Aeromonas hydrophila* (Taormina, 2010). Such generalizations are rather unhelpful and need to be contextualized. Whereas refrigeration has become fairly routine and affordable in middle and high income countries, it is still very expensive, nor is the power supply system efficient enough for them to work well in low income countries likes Ghana. Diminished food safety and increased risk of microbial hazards could be an unintended consequence of salt and sodium reduction in processed foods due to the lowering of a key hurdle against food borne pathogens (Taormina, 2010). Moreover, heavily salted fish is not usually consumed in the salted-dried state but soaked in water to desalt prior to cooking.

2.4 Food safety and quality issues associated with traditional fish processing

The safety of fish and seafood products vary considerably and is influenced by a number of factors, therefore it is important to determine whether the hazard is significant for a particular product, and how it should be controlled (Amagliani *et al.*, 2012). Identifying points in the fish food chain where microorganisms may flourish or pose a risk to human health is important for the fisheries industry in West Africa, including Ghana.

2.4.1 Microbial hazards in processed fish products

Hot-smoked fish may contain relatively heat-stable organisms such as *Bacillus*, *Micrococcus*, and yeasts (Nickelson *et al.,* 2001). The microbial quality and storage stability of the smoked product are determined by fish type, the quality of fish at smoking, salt content, smoking temperature, drying time and post-smoking storage conditions (Nickelson *et al.*, 2001; Antonia da Silva *et al.*, 2008). Eyabi *et al.* (2001) have described traditional smoked fish as generally of variable quality and sometimes of poor quality, essentially manifested by mould growth after a few days of storage. In Ghana, 17 genera of bacteria including food pathogens have been isolated from smoked and sun-dried anchovies obtained from markets and feed-mills (Osei-Somuah and Nartey, 1999). Nketsia-Tabiri *et al.* (2003) reported the presence of *Staphylococcus* spp., *Enterobacter sakazakii, Klebsiella pneumonia ozaenae, Bacillus* spp., and mycotoxin-producing *Aspergillus* spp. and *Penicillium* spp. in smoked sardines. Other studies have reported the presence of various spoilage and pathogenic bacteria in smoked fish (Plahar *et al.,* 1999; Adu-Gyamfi, 2006; Nyarko *et al.,* 2011). *Salmonella* species are transmitted through the human/animal reservoir (Shabarinath *et al.,* 2007) and have been isolated from smoked fish in Ghana (Nyarko *et al.,* 2011). However, *Salmonella* spp., are unable to grow under desiccated conditions (Norhana *et al.,* 2010). Microbial pathogens such as *Listeria monocytogenes*, and the non-proteolytic or saccharolytic strain of *C. botulinum* type E may also be present high risks in fishery products (Heinitz and Johnson, 1998; Kolodziejska *et al.,* 2002). However, Fuchs and Surendran (1989) have observed that *Listeria* spp. other than *L. monocytogenes* appear to be common in tropical areas. *C. botulinum* type E is able to grow and produce toxins at low temperatures (Sikorski *et al.,* 1990) and mild thermal treatment may be insufficient to inactivate the spores. Experiments with naturally contaminated hot-smoked fish produced from fish with high levels of *C. botulinum* show that toxin may be formed under conditions of temperature abuse (Ward, 2001). There are no reports of *Campylobacter jejuni* in smoked fish. Lightly salted, mildly heated or cold-smoked, hot-smoked or fermented fish may contain spoilage and pathogenic bacteria including Gram-negative organisms such as *Pseudomonas*

and *Moraxella–Acinetobacter* that may have re-contaminated the final product during handling (Nickelson *et al.,* 2001).

2.4.1.1 *Staphylococcus aureus*

S. aureus is a major cause of gastroenteritis worldwide (Soriano *et al.,* 2002) and a known hazard in fish products, particularly if unsalted and if adequate hygienic measures have not been employed (Embarek, 1994; Plahar *et al.,* 1999; Huss, *et al.,* 2003; Simon and Sanjeev, 2007). Staphylococci thrive in environments relatively free of competition from other bacteria, such as foods with high concentrations of salt and sugar that impede the growth of other organisms (Aycicek *et al.,* 2005). It has been recognized as an indicator of deficient food hygiene and processing (Soriano *et al.,* 2002). Food poisoning caused by staphylococcal intoxication follows ingestion of foods containing preformed thermotolerant staphylococcal enterotoxins (SE) (Scherrer *et al.,* 2004; Bergdoll and Lee Wong, 2006). An enterotoxin dose of $\leq$ 1.0 µg in contaminated food produces symptoms of staphylococcal intoxication, but this toxin level is typically reached only when *S. aureus* populations exceed 10^5 cfu/g (Notermans and Heuvelman, 1983; Jablonski and Bohach, 1997; U.S. FDA, 2007). Environmental conditions during food storage and preparation conducive to growth of *S. aureus* (i.e. time and temperature abuse) result in production of staphylococcal enterotoxins, which are potentially harmful for consumers (Todd *et al.,* 2008). Several outbreaks have been reported in the United States of America and European countries (EFSA, 2006). There are however no reports of outbreaks in Ghana and other West African states, probably due to lack of reporting or poor record keeping. Humans are thought to be the primary source of strains associated with food matrix staphylococcal intoxication (Rosec *et al.,* 1997). *S. aureus* are usually present in the nasal passages, throat, hair, and skin of healthy people, and are abundant in cuts, pustules, and abscesses (Bergdoll, 1990; Dillon *et al.,* 1992). The organism is also widely present on work surfaces and utensils in food services (Sneed *et al.,* 2004; DeVita *et al.,* 2007) and on worker hands (Sattar *et al.,* 2001).

Staphylococci, micrococci and non-faecal coliforms have been detected in smoked and dried king salmon strips in Alaska but these have not been linked to food-borne illness (Himelbloom *et al.*, 1996). Smoked and charred Baltic herrings have however been implicated in staphylococcal outbreaks in Finland (Korkeala and Pakkala, 1988). *S. aureus* is known for its tolerance of lower a_w levels, but will not grow at $a_w \leq 0.83$ under aerobic conditions or at $a_w \leq 0.88$ under anaerobic conditions (Troller and Stinson, 1975; ICMSF, 1996; Baird-Parker, 2000). *S. aureus* can grow at a_w 0.83 and produce toxin at a_w 0.85, survive in sodium chloride concentration of up to 25% (w/w) (ICMSF, 1996), grow in a wide range of temperatures ranging from 7° to 48.5°C with an optimum of 30 to 37°C (Schmitt *et al.,* 1990) and pH between 4.0 and 10.0, with an optimum of 6.0–7.0; (ICMSF, 1996). This organism should therefore be considered a target pathogen for drying (Huss *et al.*, 2003). Water activities of less than 0.85 could also arrest the growth of organisms such as *C. sporogenes* and reduce viability of *B. cereus* spores during storage (Kanatt *et al.,* 2002). Whereas under anaerobic conditions, *S. aureus* toxin production is inhibited at temperatures below 8°C, water activity below 0.92, and pH of 5.0, under aerobic conditions, toxin production is limited at water activity below 0.87, and pH of 4.5 (ICMSF, 1996). Control of the critical control points (CCPs) will ensure pathogenic bacteria such as *S. aureus* are eliminated or reduced to acceptable levels. Safe handling will enhance seafood safety while maintaining product quality attributes (Himelbloom and Crapo 1998).

2.4.1.2 *Salmonella*

Salmonella spp., one of the important bacterial pathogens associated with gastrointestinal diseases worldwide, can be found both in water, especially of contaminated coastal regions or ponds, and in fresh fish from these areas, although incidence is low (Feldhusen, 2000; Panisello *et al.*, 2000; Vieira *et al.*, 2004). *Salmonella* can survive over long periods, months or even years in soil and aquatic environments (Winfield and Groisman, 2003). *Salmonella* prevalence is influenced by rainfall, storm water (Bienfang *et al.,* 2011) and intense sunlight (Setti *et al.*, 2009). *Salmonella* has been isolated from fish and seafood (Heinitz *et al.* 2000; Novotny *et al.,* 2004) and can contaminate fish during storage and processing (Panisello *et al.,* 2000). It has been found in fish boxes and on

the hands of fishermen (Cox, 2000). *Salmonella* has also been found in the gastrointestinal tract, internal organs and muscle tissue in several fish species, e.g. rainbow trout (*Salmo gairdneri*), Israeli mirror carp (*Cyprinus carpio*) and tilapia (*Tilapia aurea*), and Atlantic salmon (*Salmo salar*) (Nesse *et al.,* 2005; Gaertner *et al.,* 2008). The microorganism has been identified as the cause of seafood related outbreaks in the European Union (EFSA, 2010), the United States (CSPI, 2009) and other countries worldwide. Huss *et al.* (2000) reported that about 12% of the foodborne outbreaks related to consumption of fish are caused by bacteria including *Salmonella*.

Salmonella is a facultatively anaerobic, non-sporulating, Gram negative bacterium; most strains are motile by means of flagella (Amagliani *et al.,* 2012). The genus *Salmonella* belongs to the family of Enterobacteriacea*e*. *Salmonella* bacteria are believed to cause two distinct disease syndromes, described simply as systemic disease and gastroenteritis. Gastroenteric disease is most frequently associated with food-borne transmission (Bremer *et al.,* 2003). The non-typhoid *Salmonella* serotypes most often encountered in human infections are Enteritidis followed by Typhimurium (Greig and Ravel, 2009). An amount as low as 10^0 -10^1 *Salmonella* cells may cause human infection in a high fat substrate such as chocolate (D'Aoust 1994). The elderly, infants, and the immunocompromised are the most vulnerable to developing illness (Hohmann 2001; CDC 2004). The optimum growth a_w of *Salmonella* is 0.99 (Mattick *et al.,* 2000) and the minimum is 0.92–0.93 (Bremer *et al.,* 2003). However, *Salmonella* can tolerate many stressful conditions and some serovars may survive at low a_w of 0.43 foods for long periods (Juven *et al.* 1984; Jung and Beuchat, 1999; Arkoudelos *et al.,* 2003; Ristori *et al.,* 2007). Therefore, knowledge of the behaviour of *Salmonella* in salted and/or dried products is important from a food safety point of view. *Salmonella* are mesophilic, with optimum growth temperature between 35 and 37°C and a growth range of 5 to 46°C. The growth of *Salmonella* is very slow below 10°C, although it can withstand freezing conditions. Refrigeration retards salmonellae growth, but is not an effective means of killing the organism. Cells survive under frozen and dried states for a long time and to multiply in many foods without affecting the acceptance qualities (Murray, 1999). The optimum pH is neutral,

in the range from 6.6 to 8.2, but the bacteria are able to grow between pH 4.05 and 9.0 (Jay *et al.* 2005) and survive relatively high salt conditions (Jay *et al.,* 2003). They are killed by pasteurization temperature and time, are sensitive to low pH (≤4.5) and do not multiply at a_w 0.94, especially in combination with a pH of 5.5 and less (Bibek, 2001). EC regulation (Regulation EC No 2073/2005) sets microbiological criteria defining the acceptability of a product, a batch of foodstuffs or a process, based on the absence, presence or number of micro-organisms, and/or on the quantity of their toxins/metabolites, per unit(s) of mass, volume, area or batch.

2.4.2 Mould growth and mycotoxin contamination in processed fish

Fish is frequently infected with fungi that produce mycotoxins pre or post processing (Bagy *et al.*, 1993; Efiuvwevwere and Ajiboye 1996). Spores of moulds often present in air and soil contaminate fish during processing. Insects and mites are also known to cause mould contamination by carrying the spores on their bodies. Mould growth on processed fish products is therefore an important issue, as it may present economic, food safety and aesthetic problems for the producer. The xerophilic moulds (*Wallemia sebi* and *Eurotium* spp.) tolerate diverse conditions of moisture, pH, water activity and temperature and are able to grow under much dryer conditions compared to bacteria (Abarca *et al.,* 2001; APHA 2001; Gock *et al.* 2003; Magan and Olsen, 2004). Their water activity requirements for growth may be 0.75 or less (Kinderlerer, 1984; Fafioye *et al.,* 2002) and their moisture requirements are relatively low (Pitt and Christian, 1968). The optimum temperature for mould growth under tropical conditions is 30°C and the maximum ranges from 40° to 55°C depending on species (Christensen and Kaufmann, 1974). Extensive mould growth in food can result in marked deterioration in quality and may lead to off-flavour development and outright destruction. The dun mould (*Wallemia sebi*), which is a defect associated with cured fish, results from mould growth on fish with a_w of 0.75 and salt concentration of 10-15 percent. Although it does not produce any objectionable flavour or change in texture in the fishery products, its visible growth and discoloration of the products is undesirable. A more compelling reason for preventing the growth of moulds in food is production of mycotoxins, a group of toxic secondary metabolites which can cause serious long-term diseases (Smith and Moss, 1985; Bauerand and Gareis, 1987;

Essono *et al.,* 2007). The most widespread and most important xerophilic moulds belong to the genera *Aspergillus* and *Penicillium*. *Aspergillus* spp., are major producers of aflatoxins and include *Aspergillus flavus*, *A. parasiticus* and *A. nomius*. Other species that produce aflatoxin in minute quantities include *A. pseudotamarii*, *A.bonbysis* and *A. ochraceoroseus*. The four main naturally produced aflatoxins are B_1, B_2, G_1 and G_2; with B_1, usually the aflatoxin found at the highest concentration in contaminated food and feed (Sweeney and Dobson, 1998). These aflatoxins cause chronic liver damage, are potentially carcinogenic, suppress the immune system and retard growth and therefore occupy a prominent position as a food safety risk (Efiuvwevwere and Ajiboye, 1996; Dutton *et al.,* 2001). One of the most extensively studied compounds, ochratoxin A (OTA), has been shown to be a nephrotoxic, immunosuppressive, teratogenic and carcinogenic agent (Battilani *et al.,* 2003).

Moulds commonly associated with dried cured fish in storage are *Aspergillus halophillus*; *A. restrictus*; *Wallemia sebi*; *Eurotium* spp.; *A. candidus*; *A. ochraceus*; *A. flavus* and *Penicillum* spp. (Christensen and Kaufmann, 1974). Several studies have reported moulds as problems in traditionally processed fish products in Ghana (Plahar *et al*., 1999; Nketsia-Tabiri *et al.,* 2003; Adu-Gyamfi, 2006; Oduor-Odote *et al.,* 2010) and in Nigeria (Nwokolo and Okonkwo, 1978; Adebayo-Tayo *et al.,* 2008). The xerophilic moulds, *Aspergillus* spp. and *Penicillium* spp., have been reported in fresh fish (Bagy *et al.* 1993; Efiuvwevwere and Ajiboye 1996), smoked dried salted fish (Atapattu and Samarajeewa 1990; Fafioye *et al.* 2002) and in salted dried fish products (Atapattu and Samarajeewa 1990; Jonsyn and Lahai 1992; Ahmed *et al.,* 2005). Various researchers have also reported dangerous levels of aflatoxin in dried fish (Okonkwo *et al.,* 1977). The most important sources of mould contamination of fish include the natural environment (Sallenave-Namont *et al.* 2000), raw fish (Bagy *et al.* 1993; Delcourt *et al.* 1994), fish skin (Yanong, 2000), internal organs (Bagy *et al.* 1993), additives, especially salt (Delcourt *et al.* 1994) and fish handling or processing. High humidity and temperatures favour fungal proliferation resulting in contamination of food and feed (Wagacha and Muthomi, 2008). Mycotoxin contamination and spoilage of fish can also occur

during transport and in storage (FAO, WHO, UNEP, 1987). The acceptable limit for mould in salted fish is $<10^4$ cfu/g at the point of sale (FSAI, 2001; Ghana Standard Boards, 1998). Pre-processing handling practices, handling during processing, moisture levels during transportation, marketing and processing; and insect damage can increase the risk of mycotoxin contamination. Possible intervention strategies include good food handling practices, discarding contaminated and deteriorating fish, proper drying, and use of clean containers, sanitation, proper storage and insect management among others. When moisture is reduced to 25% wet basis, contaminating agents cannot survive and autolytic activity is greatly reduced (Bala and Mondol, 2001). To prevent mould growth during storage, moisture must be reduced to below 15% (Bala and Mondol, 2001). For smoked fish to survive mould attack during storage after, moisture should be below 12% (Daramola *et al.,* 2007). Reported incidents of aflatoxin poisoning in Africa are rare, probably due to the long period of heating during food preparations or lack of records. Also, aflatoxin poisoning is long-term and cumulative (chronic rather than acute), hence attribution is difficult.

2.4.3 Insect pest infestation

In Ghana traditionally smoke-dried fish are stored in round smoking ovens and covered in polyethylene and jute sacks. Occasional re-smoking is undertaken to maintain dryness and drive off insect pests and control mould attack. For salted and sun-dried fish, the traditional method of drying is to lay them out in the sun on a sandy beach or raised platforms for a few days, then to gather them into heaps and pack them, along with adhering sand, and small stones, into jute bags or baskets for transport and storage. Fish dried in this way often become mouldy very quickly. Storage under such conditions also results in frequent insect infestation, microbial decomposition and rodent attack (Fialor *et al.,* 2002; Directorate of Fisheries, 2003). Insect infestation can cause losses ranging from 30 to 50 percent of fish meat (Eyo and Mdaihi, 2001; Khan and Khan, 2001; 2002). Blowfly infestation has been identified as the major cause of losses during processing and the early stages of storage in cured fish. The flies lay their eggs in the flesh of wet fish before and during processing. The larvae eat the fish until moisture inhibits their development. The flies are deterred from laying eggs during smoking, but larvae already present penetrate the deeper regions of the fish

and may survive in smoked fish that is not properly heat-treated. Humidity level above 25% (Oduor-Odote *et al.,* 2010), moisture content above 20% and salt level below 3% do not completely halt the activity of maggots. Blowflies are also notorious carriers of diseases particularly cholera, diarrhoea and dysentery in developing countries (Yu, 1994). Optimal temperatures for insect development in such cured fish are between 25 to 35°C (Haines and Rees, 1989; Oduor-Odote *et al.,* 2010). Attempts have been made to use extracts from neem (*Azadirachta indica*) and neem powder as insect deterrent during storage (Oduor-Odote *et al.,* 2010) with limited success. As the fish dries it becomes less attractive to flies, but becomes more appealing to beetles which can eat up the entire flesh (Waterman, 1976). Plahar *et al.* (1999) reported the presence of *Dermestes maculatus* Deg in smoke-dried fish during storage and marketing in Ghana. According to Waterman (1976) the dermestes beetle can lay up to 300 eggs in cracks and fissures in the fish during drying; the larvae hatch in 1-2 days and eat through the dried fish, leaving tunnels for further egg laying and pupation. The fish is already highly infested by the time the journey begins, and uncontrolled infestation increases rapidly during the long journey and the fish may be completely hollowed out by the end resulting in loss of as much as half the weight of the product. This is a major problem of inland fishing where drying is the main form of preservation, and some processors store fish for up to six months to await better prices during the lean season. Moisture content of 15–20% in smoked or sun-dried fish is conducive for infestation by *Dermestes* species. Where wood is available, periodic re-smoking is practised. Some processors prevent insect attack by applying insecticides. There are also reports of the illegal use of chemical insecticides such as deltametluin, a pyrethroid insecticide, Lindane, Baygon, Shelltox (Dichlorvos aerosol) and Gamallin 20, Gardona and DDT to prevent insect infestation of cured fish (Azeza, 1986; Akande and Asuquo-King 2001). Unfortunately, these chemicals are used without strict control over the safe dosage levels, hence the product though protected from insects could be harmful to consumers. In Ghana, the use of camphor to control insects in fish has been reported.

2.4.4 Polycyclic aromatic hydrocarbons in smoked fish

A major drawback of fish smoking is that wood smoke also contains a large number of polycyclic aromatic hydrocarbons (PAH) (Stołyhwo and Sikorski, 2005) and their alkylated derivatives such as nitro-PAH or oxygenated PAH, N-nitroso compounds and heterocyclic aromatic amines. Many PAH compounds, including benzopyrenes are carcinogenic (Bartoszek, 2002; Scientific Committee on Food, 2002; Stołyhwo and Sikorski, 2005). In a study of traditionally smoked fish from Ghana, benzopyrene levels of up to 83.928ug/kg were detected (Palm *et al.,* 2011) and in Nigeria, benzopyrene levels ranged from 8.7 to 34.8ug/kg (Ogbadu and Ogbadu, 1989). A maximum benzopyrene residue limit of 5ug/kg has been fixed by the European Commission (208/2005/EC) for smoked seafood products (European Commission, 2005). Research has shown that the formation of benzopyrene can be influenced by the smoking conditions. In Ghana, Plahar *et al.* (1999) have reported excessive deposition of wood smoke chemicals on smoked fish. Modern smoking ovens allow for the control of these conditions, for example by controlling the level of smoke present in the oven (Karl and Leinemann, 1996). Whilst the role of smoking techniques in preservation and fish safety is not in doubt, the levels of metabolites such as benzopyrenes need to be checked and regulated, and consumers educated, in the interests of consumer health. The difficulty is how such regulation should be formulated and how it can be enforced, given the fact that most traditional fish processing is currently done by small independent family fishmongers. One way of addressing this issue would be to design and test different models of traditional kiln developed to reduce the amounts of these toxic by-products and where they do not currently exist, encourage the formation of fish processing cooperatives. These cooperatives can serve as a basis for health screening, education, training and eventually, the introduction of newer, safer ways of treating fish for the market. The formation of such recognised self-help groups would also allow the implementation of a traceability framework and regulation of the fish processing trade and lead to improved standards of practice, quality of products, consumer safety and export potential of fishery products. The design of a framework that incorporates the fish traders' needs and interests with that of consumers and the fish market is a subject of particular interest in this project.

2.5 Prerequisite programmes

Food safety is mainly ensured by preventive approaches, such as the implementation of good hygiene practices or application of procedures based on the Hazard Analysis and Critical Control Point (HACCP) system (Vilar *et al.,* 2012). However, before HACCP or a similar food safety management system can properly be applied to a process, it is important that a solid foundation of good prerequisite programmes (PRPs) is in place to underpin the HACCP system. PRPs describe the measures that provide the basic environmental and operating conditions that are necessary for the production of safe and wholesome food (Seward, 2000; McSwane *et al.,* 2003). Mortimore and Wallace (1998) view PRPs as the HACCP Support Network, which shows the inter-relationship of management systems and procedures in any food business for the production of safe, high quality products. Well-designed prerequisite programmes provide a solid foundation on which an effective HACCP system can be based. They are "universal steps or procedures that control the operational conditions within a food establishment allowing for environmental conditions that are favourable for the production of safe food" (UK Expert HACCP Steering Group, 1999). The US National Advisory Committee on Microbiological Criteria for Foods (NACMCF, 1997) defines PRPs as 'Procedures, including GMPs that address operational conditions providing the foundation for the HACCP system.' The World Health Organisation defines PRPs as 'practices and conditions needed prior to and during the implementation of HACCP and which are essential for food safety' (WHO, 1999a). These practices and conditions are described in the Codex Alimentarius Commission's General Principles of Food Hygiene and other Codes of Practice (CAC, 2009).

In Ghana where HACCP is not a mandatory requirement for traditional fish processors, the Codex Alimentarius General Principles of Food Hygiene (CAC, 2009), the Codex Codes of Practice for fish and fishery products (CAC/RCP 52-2003) and the Food and Drugs law constitute the basis of food safety management in the fish industry. Common prerequisite programmess may include but are not limited to: proper fishing and harvesting vessel design and construction, proper facility-design practices and construction to include a product flow-through pattern that is designed to prevent potential sources of contamination, minimize process delays, prevent cross-contamination

and allow ease of cleaning and disinfection, preventative maintenance of equipment, hygiene control programme (including cleaning and disinfection schedule, cleaning and sanitation standard operating procedures (SSOPs), pest control system, supply of water, ice and steam, and waste management), good personal hygiene and health (GPH) (including the exclusion of persons with communicable diseases and the provision of appropriate clothing), appropriately designed vehicles for transportation, product tracing and recall procedures, Good Manufacturing Practices (GMPs), training, chemical control and supplier selection and specification programmes (NACMCF, 1997; CAC, 2003a; CAC, 2009). Effective environmental cleaning and disinfection, excluding infected staff, implementing hand hygiene principles, and preventing cross-contamination should be treated as integral parts of the production process (Adams and Moss, 1995; Greig and Lee, 2009). It is important that strict personal hygiene measures should be adopted during food preparation. Cruickshank (1990) has argued that proper hand washing with soap and water followed by drying is effective in removing large numbers of pathogenic bacteria. Improvement of fish handling conditions and proper sewage disposal are other intervention strategies (Pozio, 2008). Proper processing of fish is necessary to ensure the reduction or elimination of the growth of harmful microorganisms. Hygienic measures are required throughout the continuum from "catch to fork".

There are however, concerns about the level of compliance with prerequisites, including hygiene standards, handling conditions, and general food safety standards along the traditional fish processing chain in Ghana and other West African countries (Plahar *et al.,* 1999; Kleter, 2004). Extensive handling of fish during production, processing and marketing provides opportunities for foodborne pathogens to contaminate fish products if insufficient attention is given to hygienic food safety practices. As large quantities of food pass through a multitude of food handlers and middlemen, the risk of exposing food to unhygienic environments, contamination and adulteration increases. Mishandling of food can introduce and spread pathogenic microorganisms from contaminated hands of food workers to food and subsequently to other surfaces when food handlers fail to observe critical behaviours during handling and preparation (Chen *et al*. 2001, Montville *et*

al. 2001, Bloomfield 2003; McCabe-Sellers and Beattie, 2004). Surveys of food vendors in Nigeria attribute the failure to wash hands to the fact that water and hand washing or toilet facilities are not readily available in most of the vending sites surveyed (Idowu and Rowland, 2006; Omemu and Aderoju, 2008). Data on the contributory factors are of great importance for assessing risks. The pressure of time may also prevent food handlers from carrying out food safety actions (Clayton *et al.,* 2002). Further studies are therefore required to identify the food safety problems in the traditional fish chain and the reasons for lack of adherence.

2.6 Food safety management and the Hazard Analysis and Critical Control Point (HACCP) concept

The HACCP concept, a risk-based system of food safety management, has become the universally accepted method for increasing food safety and is now an important part of national governments and international strategy to reduce the prevalence of food-borne disease (Griffith, 2000; Kirby *et al.*, 2003; CAC, 2009). The four most prominent driving forces for use of HACCP are: (1) HACCP is focused on food safety, (2) is science based, (3) is a prevention-oriented approach for identifying hazards and risks rather than retrospective end-product testing, and (4) focuses control on those food safety hazards that are reasonably likely to occur (Steinkraus, 1997; Motarjemi, 2002; Walker and Jones, 2002; CAC, 2003a; McSwane *et al.,* 2003; Reij *et al*. 2004; Walls and Buchanan, 2005; Baş *et al.,* 2006; Dong and Jensen, 2008). The intent of the HACCP system is to identify potential hazards and focus control at critical control points (CCPs) at which the identified hazards may occur. Critical limits should be established that can be monitored and give a real time response, e.g. pH level, time/temperature. Criteria such as microbiological levels or absence of pathogens cannot be used as it takes too long to obtain these results. This requires product specific hazard analysis to determine the CCPs in each process. Monitoring should measure accurately the chosen parameters which have been identified as control measures specific for the identified hazard at the CCPs, and be able to detect deviations from specifications or criteria (Huss 1994a). When there is a failure, pre-determined corrective actions may be taken for the CCP that is not under control. Verification activities will confirm that the critical limit identified is appropriate for the identified hazard.

Documentation concerning all procedures and records according to the HACCP principles and their application need to be maintained (Holdsworth, 1997; McSwane *et al.*, 2003; CAC, 2009). Review of the operation should be considered if a new hazard which must be controlled is identified but no control measures have been identified or the process is changed in anyway.

Although HACCP holds great promise for minimizing the risk of foodborne disease and is now part of the legislative framework for most countries in the world, the application of the process has not yet been widely realised in small-scale operations in most developing countries because of several challenges (Ward, 2001; Holzapfel, 2002). Many of the operators in the artisanal and traditional fish processing sector are small- or micro-scale operators who may not be familiar with the hazards associated with their operations. Moreover, HACCP is still not considered feasible for small-scale subsistence operators because of the cost involved in implementation (Holzapfel, 2002). In addition, its practical roll out requires a mix of managerial, organizational and technical resources to cope with the technical barriers it presents (Panisello and Quantick, 2001). In practice, even large food firms with their resources of money and expertise face significant hurdles in developing a successful HACCP system (Taylor, 2001) and small and medium sized enterprises (SMEs) may feel that the difficulties of HACCP are potentially insurmountable (Ehiri *et al.*, 1995; Route, 2001). Small and medium-sized enterprises in particular may be lacking not only financial resources and time but also experience, information, support, technical expertise, available personnel and interest in food safety management (Jouve, 1994; Mortlock *et al.*, 1999; Taylor 2001). Micro businesses have been found to have an even poorer understanding of food safety management systems (Fielding *et al.* 2005). Karipidis *et al.* (2009) have observed that food enterprises that implement quality assurance systems may do so because they are forced, either by their customers or by public authorities to ensure food safety and to protect public health, or are driven by their own firm belief that the benefits of implementing food safety outweigh all associated costs. In Ghana, HACCP is not yet considered an obligation in small and micro-scale fish processing operations supplying fish to the local market. There is also no requirement for traditional fish handlers to be aware of or to

have any knowledge of HACCP in order to develop and implement the system. However, all food businesses supplying food to European retailers are required to implement HACCP. To achieve the successful implementation of HACCP in the industry, the concept must be understood first, by the managers of the establishments (FAO/WHO, 2006). It is also important to ascertain conditions that restrain the implementation of HACCP-based Food Safety and Quality Management. In this regard, it is important to identify the contribution of the food industry, consumers and government along with its inspection authorities and regulatory agencies. The underlying hindrances to compliance with the regulations may also include a lack of trust in food safety legislation and authorities, a lack of motivation in dealing with food safety legislation and a lack of knowledge and understanding (Yapp and Fairman 2006).

2.7 The role of fish handlers in food safety

Typically, major risks of food contamination originate from the working practices of food handlers (Gordon-Davis, 1998). Unsafe food handling practices, a lack of knowledge or incorrect application of sound hygiene practices by food handlers are potential causes of serious outbreaks of foodborne diseases (FSA, 2002; Caswell, 2003; Walker *et al.*, 2003a; Baş *et al.*, 2006; Santos *et al.*, 2008). Unclean, insufficiently or inadequately cleaned hands, processing equipment, including knives and chopping boards have been identified as sources of bacterial contamination including *Shigella* spp., *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp., *Bacillus cereus* and faecal streptococci in processed seafood (Ash, 1997; Lawrie, 1998; Snyder 1998; Jiang and Doyle, 1999; Kusumaningrum *et al.*, 2002; Shena *et al.*, 2007). In many cases, foodborne infections are transmitted from infected food handlers (FDA 2000) who may not know that they are carrying the pathogen as they may not feel unwell and may exhibit no symptoms (Adams and Motarjemi, 1999).

Poor hygiene, particularly deficient or absence of hand washing has been identified as the causative mode of transmission (Reij *et al*. 2004). Studies also show that unsound food safety behaviours or practices are more common in small- and medium-sized food businesses and these businesses constitute important locations in the transmission of foodborne illness (Walker *et al.*, 2003a).

McCabe-Sellers and Beattie (2004) listed the leading causal behaviours of food safety problems as failure to: (a) hold and cool foods appropriately, (b) practice proper personal hygiene, (c) prevent cross-contamination, (d) cook to proper internal temperatures, and (e) procure food from safe sources. Other researchers have also identified inadequate cleaning of food surfaces, inadequate handwashing, inadequate heat treatment, inappropriate storage of foods, infected food handlers and cross-contamination as causes of foodborne illness (Kassa *et al.,* 2000; Paulson, 2000; WHO, 2000a; Sagoo *et al.,* 2003; Baş *et al.,* 2006). Good agricultural practice and good manufacturing practice should be adopted to prevent introduction of pathogens into food products (Koopmans and Duizer, 2004).

2.8 Food safety training, knowledge and attitude

General good hygiene and proper food handling practices are recognized as effective measures to control the spread of pathogens especially when considered along with the restriction of ill workers (Cruickshank, 1990; Adler 1999; Montville *et al*., 2001). Some researchers are of the view that food safety knowledge and training will ensure that food handlers practice the correct way of handling food and that, knowledge and training should constitute an essential as part of their job training (Seaman, 2010; Martins *et al.,* 2012). Practical knowledge about the intrinsic properties of the products, as well as food handling practices, food safety knowledge and PRPs would constitute crucial lines of defence in the prevention of most food-borne illnesses. However, training alone is not enough, attitude change, continuous education and enforcement, are necessary to ensure positive behaviour change and the sustainability of food safety practices (Howes *et al.,* 1996; Baş *et al.,* 2006). Moreover, food handlers' knowledge of food safety is not always translated into good hygiene practices in reality (Howes *et al.,* 1996). It is therefore, crucial to gain an understanding of the interaction of prevailing food safety beliefs, knowledge and practices of food handlers (WHO, 2000b). Training and hygiene promotion programmes are therefore, more likely to be effective if they are built on local research and use locally appropriate channels of communication repeatedly and for an extended time (Pinfold and Horan, 1996; Curtis *et al.,* 2001). Further research is required to explore pathways of the foodborne illness and to determine the vehicles of the greatest

importance (Unicomb, 2009). Prevention strategies should also focus on creating awareness among consumers regarding proper refrigeration and storage of foods, prevention of cross-contamination of food, use of clean slicing boards and utensils while cooking; and washing hands often while preparing food (Linscott, 2011).

2.9 Role of governments in developing countries

Foodborne illnesses are an obstacle to global development efforts and in the achievement of the Millennium Development Goals (MDGs) (WHO, 2011). Food safety concerns, particularly microbial contamination, are the basis for the worldwide promotion of safety standards. International regulations and national legislations of developed countries require that food safety management should be based on a comprehensive and integrated approach so that all food chain participants, including food handlers, are responsible for ensuring food safety (Garayoa *et al.*, 2011). Governments have an important role in providing policy guidance on the most appropriate food safety and quality assurance systems and verifying/auditing their implementation as a means of regulatory compliance (FAO, 2003). To this end, there is no doubt that national trading standards and food safety laws should exist in countries such as Ghana. Nonetheless, studies show that governments and industry in developing countries face major challenges of producing safe fish and fishery products for domestic and international markets (Jaffee and Henson, 2004; Jaffee, 2004; Ponte *et al.*, 2007; FAO, 2004b, 2007). Of particular concern is the ability of developing countries in sub-Saharan Africa to upgrade their legislation, integrate laws and regulations in a comprehensive and user-friendly document, and harmonize the responsibilities of multiple institutions dealing with food safety issues, and reorganise inconsistent and selective enforcement (Nguz, 2007).

Other weaknesses in developing country food safety management include the non-use of risk assessment to develop standards, the non-existence or insufficient number of efficient accredited control laboratories, the confusion between quality and safety and the lack of a framework of collaboration between governmental institutions and the food industry (Nguz, 2007). These

weaknesses exist partly because of the lack of human resource capacity, the costs involved and the frequent changes in standards (Henson *et al.*, 2000; Athukorala and Jayasuriya, 2003).

The capacity of local Ghanaian processors to meet current food safety and quality standards is also severely affected by poorly developed food safety policies and plans of action, legislation, insufficient governmental oversight including, inspection, surveillance and monitoring, inadequately trained food workers and the lack of basic infrastructure. Even where international standards are implemented they are mostly driven by government regulations generally in response to importing countries' provisions to secure traditional export markets (Zaibet, 2001). Donovan *et al.* (2000) have observed that poor countries allocate their meagre resources to achievement of the requirements for the export markets with a lack of attention to the safety and quality of the locally consumed products. It is therefore important to develop food safety policies and effective strategies for implementation of food safety programmes. In order to access prime markets for their fish products, sub-Saharan countries would need to develop effective official National Food Control Systems (NFCS) in line with international guidelines. The NFCS should typically comprise the following five components: (1) Food law and regulations, (2) National food control management, (3) Inspection services, (4) Laboratory services and (5) Information, education, communication and training process aimed at imparting knowledge and skills to key players in food safety control and management (FAO/WHO, 2003; Safe Food International, 2003; Jukes, 2003; Vytelingum, 2003). National legislative bodies should develop the capacity for coordination of food safety policies with an operational arm of an appropriate authority to foresee the food safety control function.

In Ghana, the safety of food, including the hygiene of fish products, is regulated by the Ghana Food and Drugs Board (FDB), under the Ministry of Health. Ghana's fish exporters must fulfil EU requirements on health and food safety as described by the EU Council Regulations EC/852/2004 (hygiene of foodstuffs), EC/853/2004 (specific hygiene rules for food of animal origin), EC/2073/2005 (microbiological contamination), EC/396/2005 (pesticides), EC/1881/2006 (contaminants), EC/1224/2009 (minimum labelling) among others for fishery products intended for

export to the EU. Imports of fishery products into the EU are subject to official certification, which is based on the recognition of a competent authority (CA) of the non-EU country by the European Commission (EC). This formal recognition of the reliability of the CA is a pre-requisite for the country to be eligible and authorised to export to the EU. The nominated CA in Ghana is the Ghana Standards Board (GSB), under the Ministry of Trade and Industry. The GSB facilitates compliance with EU requirements and issues licences to compliant firms. Although Ghana's FDB has progressively improved its inspection, monitoring and control systems and therefore meet the minimum requirements for fish trade with the EU and the US, improved controls for fish exports has occurred mainly for products from the large EU approved fish processing plants but not the small and micro-scale artisanal processing units.

2.10 Statement of the problem and context of the present study

Considerable progress has been made to improve fish safety for local markets and to boost export-oriented supply chains that are reliant on high-value markets in developed countries. Considering that most of the fish traded and consumed in West Africa is processed using traditional methods, it is important to ensure that the traditional food processing sector is producing safe food. Smoke drying is by far the commonest method, since the distribution process of the smoked fish may take a long time and producers often want to store it for months while waiting for a more favourable market (Britwum, 1993). Smoked fish from Ghana is mainly destined for the domestic market where demand is very strong. However, small quantities of smoked fish are exported to regional countries including, Togo, Benin and Nigeria, and to Europe and the US (Ward, 2003). In the UK alone, there are about 20-30 importers, specialized in West African food products, who import air-freighted smoked fish from Ghana and other West African countries (Ward, 2003). These products are well suited to local needs, tastes and cultures. It has previously been estimated that more than 60% of fish consumers in Ghana rank smoked fish as the most preferred cured fishery product (Essuman, 1992b). The quantity of smoked fish from West Africa entering the UK is estimated to be 500 metric tonnes per year with a retail value of £5.8 to £9.35 million (Ward, 2003). Approximately 120 metric tonnes arrive in the UK by airfreight. A significant proportion of the

remainder is thought to enter as accompanied baggage or overland from mainland Europe (Ward, 2003). Major exporting countries in West Africa include Nigeria, Ghana, the Ivory Coast, the Gambia and Cameroon. Cross border trade in these products within the sub-region is also a vibrant activity.

Despite the significant production and distribution of traditional fish products in Ghana, there is no documentation of the application of risk analysis to traditional processing of these products. Moreover, there is very little insight into the actual food safety management practices of traditional fish processors in Ghana. The traditional fish processing sector has not been well studied to understand the food safety implications of their practices and to identify areas that need improvement in order to ensure safe fish production. Moreover, many of the small and micro-scale producers who supply the bulk of their products to local markets have not received the level of support given to the large export-oriented firms. Consequently, not all companies are able to meet the stringent food safety regulations and requirements. References to the way things are done, why they are done in that way and the impact on food safety are only made in relatively few studies and there is a need to understand risks linked to specific products.

This study would evaluate the safety of traditionally processed fish in Ghana, in combination with the food safety management practices, knowledge, attitudes and concerns of various stakeholders in order to provide insight into the causes of food safety problems and solutions. Studies show that food handlers tend to overestimate the frequency with which they carry out food safety practices (Howes *et al.,* 1996; Manning and Snider, 1993; Oteri and Ekanem, 1989). Redmond and Griffith (2003a) are of the opinion that observation, although not without its limitations, represents the most accurate and reliable method of assessing consumers' implementation of hygiene practices. As part of this study visits to landing, processing and retailing sectors will be conducted to observe practices. The study seeks to identify any hazards that may pose a public health risk to consumers. This approach provides science-based data on potential hazards which can be included in a formal

risk analysis. Findings in respect of this analysis should be matched with outcomes of analysis of fish samples and help inform any scientific deductions made in this study. The influence of temperature, water activity and pH levels of a medium on the viability and growth of microorganisms have been demonstrated (Walton and Pringle, 1980; Li and Torres 1993). The pH level, temperature of storage, microbial load, salt content and a_w are factors generally considered to influence storage life and safety of cured fish products (Gopakumar, 1997).

This study would also investigate the physico-chemical properties of traditionally processed fish and evaluate how these properties affect microbial growth. The fates of these microorganisms, including *S. aureus*, during storage of processed fish and associated risk factors will be studied. An attempt will be made to identify major factors that influence food safety in the traditional fish sector and to suggest strategies to improve the food safety situation. In this context, reference will be made to the need to have up-dated food legislation, improved surveillance and monitoring programmes, health education in food safety and a number of other strategies in place. The findings from this study can form the basis for developing public health guidelines for consumers and the manufacturing and processing industry. Food safety problems are more prominent in developing countries where food production, processing, and marketing systems are highly fragmented, dominated by a large number of small producers and quality control is poorer than in industrialised countries (WHO, 2007). Tackling the problems would require that gaps in information are filled. There are opportunities for designing and implementing educational packages for handlers at different levels along the food chain as part of a package of measures to improve safety in the fish trade sector. It is one's contention that in carrying out studies of this kind, there should be an end point which provides opportunities for practical application of knowledge to benefit the wider community for example through education. It is however important to first ascertain prior knowledge, attitudes and practices before embarking upon an educational intervention. It is for those reasons that a knowledge, attitude and practice survey has been built into this study to enable data to be collected among fisher folk, traders and processors (fish mongers) and consumers in

Ghana to help understand the current system in place and set the scene for any future recommendations and interventions. Unless the context of this study as a whole is fully understood, including the environmental, socio-cultural and traditional food culture aspects, it would be difficult for people without indigenous knowledge to fully understand and appreciate both the nature and potential value of the approaches employed in this study.

Chapter 3

3.0 Assessment of the quality characteristics and microbial safety of different artisan-produced fish products of West African origin procured from retail outlets in London.

3.1 Introduction

Traditional fish products which are widely consumed in Ghana include fried bonga (*Ethmalosa* fimbriata), smoked herrings (*Sardinella aurita*), smoked catfish (*Clarias* spp.), smoked mackerel (*Trachurus trachurus*), heavy-salted and sun-dried tilapia (*Oreochromis niloticus*) called koobi and heavy-salted and sun-dried sharks, skates and rays popularly called kako. A large amount of preserved fish is produced in household or cottage-type industry for the local markets. However, there is increasing export potential of these products to Western countries such as the UK where they are widely patronised by the African community (Ward, 1995). Hygiene and food safety issues could be a major problem of traditional fish products processed in developing countries (Plahar *et al.,* 1999; Kleter, 2004) as fish can become contaminated with several pathogens along the food chain. Nketsia-Tabiri *et al.* (2003) reported the presence of *Staphylococcus* spp., *Enterobacter sakazaki, Klebsiella pneumonia ozaenae, Bacillus* spp., and mycotoxin-producing *Aspergillus* spp. and *Penicillium* spp. in smoked sardines. Annan (2008) and Nyarko *et al.* (2011) have reported higher microbial loads in smoked fish samples obtained from retail markets compared to samples collected from smoking sites.

Ready-to-eat smoked mackerel served from food service outlets in Accra have also been reported to harbour varying levels of indicator organisms, sometimes as high as 10^9 cfu/g, including coagulase-positive *S. aureus*, faecal Streptococci, faecal coliforms, notably *Escherichia coli* and *Shigella flexneri* (Adu-Gyamfi, 2000). Poor handling, packaging, transporting and storage conditions may be the probable factors for higher counts obtained in these products. The quality of smoked fish is essentially linked to processing and post-processing procedures. The practice of displaying smoked fish uncovered in open baskets and trays during storage, transportation and retail can increase the risk of contamination. Koobi or salt-cured and dried tilapia (*Oreochromis niloticus)* is produced

from thoroughly washed, split, fresh or thawed tilapia. The fish are most often heavily dry-salted and sun-dried on raised platforms or on the ground, by the roadside until very dry. They are stored and sold under ambient conditions. To prolong the shelf-life, stored koobi is occasionally sun-dried and aired. Koobi is usually eaten after washing, rehydration and cooking or boiling in the household, but the rehydration process is time consuming. Kako is processed using similar methods as koobi but from shark as the raw material. The objective of this part of the study was to assess microbial and physicochemical quality of smoked catfish, smoked mackerel, smoked herrings, salted and dried tilapia (koobi), salted and dried shark (kako) and fried bonga in order to identify the risks that traditional fish products might present. The findings can be used to make decisions on whether to accept as safe or reject the products. In the experimental analysis of microbial safety, products will be classified on the basis of high risk, medium risk and low risk.

3.2 Materials and methods

3.2.1 Sampling

Eighteen samples each of three smoked fish products prepared in and imported from Ghana (catfish, herrings and mackerel), two salted and dried fish products (koobi and kako), fried ready-to-eat fish product (bonga shad, *Ethmalosa fimbriata*), were obtained from retail outlets in London and used for this experiment. The fried bonga products were processed in London using traditional West African processing techniques. The fish products were selected on the basis of their commercial value and availability in retail outlets in London. In all 108 samples were aseptically collected into sterile plastic bags and transported to the laboratory at the University of Greenwich, Medway campus for analysis. Table 3.1 is a summary of the fish products sampled.

Table 3.1. The sample types obtained and their packaging and storage conditions when being marketed.

Product Group	Product	Packaging and storage condition
Salted/dried	Koobi (salted and dried tilapia)	Ambient storage/no packaging
	Kako (salted and dried shark)	Ambient storage/no packaging
Smoked	Adwene (smoked catfish)	Ambient storage/no packaging
	Amani (smoked herrings)	Ambient storage/no packaging
	Saman (smoked mackerel)	Ambient storage/no packaging
Fried product	Bonga (fried fish)	Ambient display in sauce pan PE* or no packaging

PE* = Polyethylene packaging

3.2.2 Microbiological methods

3.2.2.1 Microorganism and inocula preparation

Pure cultures of bacteria were obtained in freeze-dried form from the National Collection of Type Cultures (NCTC), PHLS Central Public Health Laboratory, London and used to inoculate the fish samples. The bacterial samples included *Salmonella* Typhimurium (NCTC 74), *S. aureus* (NCTC 8532), *Bacillus cereus* (NCTC 2599) and *Clostridium perfringens* (NCTC 6719). All the stock cultures were maintained in cryoprotect beads (Technical Consultant Services Ltd, Lancashire, U.K.) at -20^{o}C and subcultures of these stock cultures were prepared and used as working cultures. To prepare working cultures, one cryobead of stock culture was transferred into 10 ml of Nutrient Broth (Oxoid, CM1) in a test tube and subsequently incubated at 37 ± 1°C for 24 h, after which, cells from the broth cultures were inoculated into Nutrient Agar (NA-Oxoid, CM3) slants. The inoculated Nutrient Agar slants were incubated for an additional 24h at 37 ± 1°C and used as working cultures which were maintained at 4°C and transferred to new slants monthly. These operations were carried out in a laminar airflow cabinet to minimise the risk of contamination. To start an experiment, a colony picked from the nutrient agar slopes was transferred into a sterile universal bottle containing 10ml Maximum Recovery Diluent (MRD), incubated overnight at 37°C for 24 ± 2h, centrifuged for 2 minutes at 6000 revolutions per minute (RPM) (Mistral 3000N)

streaked on a Petri dish NA - and incubated overnight at 37°C for 24 ± 2h. From this, a colony was transferred to 10 ml MRD, and incubated overnight at 37°C for 24 ± 2h. Serial dilutions were prepared with MRD as per the requirement of the work. In every experiment, the cells employed to inoculate the test foods were obtained from an 18h old secondary culture which had undergone only one transfer beyond the working culture. The microbiological methods used were standard (CCFRA, 2003).

3.2.2.2 Detection of *Salmonella*

The presence of *Salmonella* spp. in each of the products was determined by blending 25 g of each sample in 225 ml of Buffered Peptone Water (BPW – Oxoid, CM 509) for 1 minute. The homogenate was incubated at 37°C for 18 to 24 h. Upon the completion of pre-enrichment, 10 ml was transferred to 100 ml Selenite Cysteine Broth (SCB - Oxoid, CM0699) and incubated at 37 ± 1°C for 24 ± 3 h and 0.1 ml from the broth streaked in duplicate on Xylose-Lysine-Desoxycholate Agar (XLD - Oxoid, CM0469) and Brilliant Green Agar (BGA- Oxoid, CM0263) plates. The plates were incubated at 37°C for 24 ± 3 h. Suspect colonies on either XLD or BGA were confirmed using API strips after checking for purity.

3.2.2.3 Detection of *S. aureus*

The samples (25 g) were weighed into sterile stomacher bags diluted with 225 ml MRD (Oxoid) and homogenized in a stomacher for 2 minutes. The samples were further decimally diluted with MRD and 0.1 ml portion of various dilution levels were spread on the surfaces of Baird-Parker Agar (BP, Oxoid CM275) supplemented with egg yolk–tellurite emulsion (Oxoid, SR54) and incubated at 37^{o}C for 48h. Colonies with typical *S. aureus* morphology (that is, black, convex and with or without light halo on Baird-Parker agar) were subjected to Gram staining, examined microscopically. Typical colonies were tested with the "StaphytectPlus" test (Oxoid DR850), a latex agglutination test for the detection of clumping factor, Protein A. Atypical staphylococci were identified using the API Staph System (BioMerieux, France).

3.2.2.4 Detection of *C. perfringens*

The presence of *C. perfringens* was determined with Perfringens Agar (OPSP, Oxoid CM 0543) after the addition of rehydrated Perfringens supplements A (Oxoid, SR 0076) and B (Oxoid, SR 0077). Pour plates were prepared using 1ml aliquots of a ten-fold dilution series of the homogenised test samples and the plates were incubated at 35°C for 24h with anaerobic gas generating pack (Oxoid, BR0038) in a gas-jar. All tests were done in triplicate, the results recorded and the mean values calculated. Typical black colonies were counted as presumptive *C. perfringens* colonies.

3.2.2.5 Detection of *B. cereus*

The level of *B. cereus* in the samples was determined on *B. cereus* Selective Agar (Oxoid, CM 617) after aseptically adding one vile of *B. cereus* selective supplement (Polymyxin B Supplement, OXOID, SR0099) and incubating at 35°C for 24h. 0.1 ml of the decimally diluted samples was surface-plated in duplicate on *B. cereus* Selective Agar (Oxoid, CM 617). Plates were incubated at 37°C for 24h and typical turquoise to peacock blue colonies were counted as presumptive *B. cereus.*

3.2.2.6 Aerobic plate counts

The level of aerobic bacteria was determined on Plate Count Agar (PCA- Oxoid, CM 463). PCA plates were incubated at 35°C for 48h according to the procedures of the Manual of Microbiological Methods for the Food and Drink Industry (CCFRA, 2003). Decimal dilutions up to 10^{-6} were prepared from the suspension with MRD. Using 1.1 ml pipettes, 1.0 ml aliquots of each dilution were placed in two Petri dishes. About 12 to 15 ml of tempered PCA (45°C) was poured on each plate and the plates gently swirled up/down, side to side, and round to mix the sample with the medium. After the agar in each plate had solidified, the plates were dried, inverted and incubated at 30^{o}C for 48 h after which total aerobic bacteria were counted.

3.2.2.7 Detection of coliforms

Total number of coliforms was determined with Violet Red Bile Agar (VRBA - Oxoid, CM0978) after incubation at 35°C for 24 h. Decimal dilutions of up to 10^{-6} were prepared from the suspension

with MRD. Using pipettes 1.0 ml aliquots were placed in duplicate plates and tempered VRBA added. After the agar had solidified an overlay of about 5.0 ml VRBA was added. After the agar had solidified the plates were inverted and incubated at 35^{o}C for 48 h. Red colonies surrounded by a zone of precipitate were counted as presumptive coliforms cfu/g.

3.2.2.8 Detection of yeasts and moulds

Yeasts and moulds were counted on Dichloran Rose-Bengal Chloramphenicol Agar **(**DRBC - Oxoid, CM0727) supplemented with chloramphenicol selective supplement (Oxoid, SR0078). Each plate was inoculated on the medium surface with 0.1ml of the prepared sample, spread and incubated for 5-7 days at 25°C, after which the number of colonies were counted.

3.2.3 Physico-chemical analysis

To ascertain the physico-chemical properties of the fish products, all the samples were tested for a_w, pH and moisture content.

3.2.3.1 Water activity (a_w)

The water activity (a_w) values of the samples were determined using Decagon water activity system model series CX-1(Decagon Devices Inc., Washington, USA) at room temperature. For calibration, Decagon manufactured ampoules containing verification standards were used. Samples from each batch of products were crushed in stomacher bags to produce homogenized tissues. Approximately, 5 grams of homogenized sample were spread evenly on the bottom of an Aqua Lab sample cup, fitted into the vapour chamber, and a reading was obtained after 3-5 min of equilibration. There were three replicates for each sample.

3.2.3.2 pH measurements

A Corning pH meter, model 240 (Corning Inc., Corning, NY) was used for all pH measurements. The pH meter was calibrated using standard buffer solutions (Merck) at pH 4.0 and 7.0. The pH values were determined by weighing 10 g of each sample and blending with 10 ml of distilled water

to make slurry. The pH level of the slurry was then measured with an immersed electrode according to instructions from the manufacturer's manual. Each sample was measured in triplicate.

3.2.3.3 Measurement of moisture content

Moisture content was determined by oven drying (using Gallenkamp oven 300 plus series moisture analyzer) using 5g of fish muscle at 125^{o}C for 2-4 h until a constant weight was obtained (AOAC 950.46B, 2000). Analysis of the samples was performed in triplicate. Loss in weight was reported as moisture.

3.3 Results and their interpretation

3.3.1 Physico-Chemical Analysis

The water activity, moisture content and pH levels of the fish samples are stated as mean ± SEM (standard error of mean) and ranges in Table 3.2. Dried fish products are usually considered shelf stable and are therefore often stored and distributed unrefrigerated. In the present study, the mean moisture content of fried bonga was 51.75 ± 1.14% (w/w, wet basis) ($p>0.05$). Wide variations were observed in the moisture content of all smoked products. The mean moisture contents of smoked catfish and smoked mackerel were 33.51 ± 1.09% and 53.55 ± 0.74%, respectively. Such variations are not unexpected because the products come from different manufacturers and are of different ages. There were no significant differences ($p>0.05$) in moisture levels among the various smoked fish samples. Smoked herring samples had the lowest water content with mean percent moisture level of 10.34 ± 0.54%. Plahar *et al.* (1996) have recommended initial smoked fish moisture content below 13% before storage. They reported that this condition would also not favour the development of aflatoxin-producing moulds. In the present study, only the smoked herring samples satisfied this requirement. Kaneko (1976) have also stated that at moisture levels of 15% and above, proteolytic and lipolytic deterioration occur and microbial proliferations are favoured. The mean moisture contents of the salted and dried fish, koobi and kako were 42.48 ± 0.80 and 42.45 ± 1.07, respectively. Similarly, no significant differences in moisture levels were observed among the koobi and kako samples.

Table 3.2. Percent moisture, water activity and pH values of traditional African fish products collected from retail outlets in London.

Product	Moisture (%) Mean ± SEM	Range	pH Mean ± SEM	Range	a_w Mean ± SEM	Range	Risk rating
Fried products							
Bonga	51.75 ± 1.14	44.89 - 62.26	6.45 ± 1.55	6.33 – 6.58	0.90 ± 0.01	0.82 – 0.95	high*
Salted and fermented products							
Koobi	42.48 ± 0.80	37.28 - 47.87	6.09 ± 0.01	5.94 – 6.16	0.64 ± 0.01	0.53 – 0.75	low
Kako	42.45 ± 1.07	33.19 - 51.65	6.15 ± 0.02	6.08 – 6.36	0.63 ± 0.00	0.55 – 0.70	low
Smoked products							
Catfish	33.51 ± 1.09	26.36 - 41.50	6.65 ± 0.03	6.39 – 6.79	0.83 ± 0.02	0.72–0.95	intermediate/high**
Herrings	10.34 ± 0.54	5.81 - 14.78	6.16 ± 0.04	5.90 – 6.39	0.67 ± 0.03	0.54 – 0.94	variable **
Mackerel	53.55 ± 0.74	48.27 - 57.36	6.33 ± 0.04	6.03 – 6.56	0.92 ± 0.01	0.84 – 0.99	high*

SEM = Standard error of mean

*Depending on how long and when these products are prepared before consumption or on the preparation method.

** The ranges in a_w are extremely broad in terms of microbial stability.

N = 18 for each sample

The moisture values observed in this study for koobi and kako were similar to the 39.9% (koobi) and 43.9% (kako) reported in previous studies (Eyeson and Ankrah 1975; Essuman, 1992a; Riebroy *et al.,* 2007). However, Mohamed *et al*. (2011) have recently reported moisture levels of 15.9% in salted tilapia fillets and 13.4% in salted tilapia fillets treated with a dilute mixture of citric acid and ascorbic acid (5%), dried using solar driers. Akinola *et al.* (2006) have observed that the lack of control over the drying rate, sometimes results in under-drying or over-drying of fish, exposure of fish to unexpected winds, dust, dirt, insect infestation, including flies.The mean pH level of fried bonga was 6.45 ± 1.55. Mean pH of koobi was 6.09 ± 0.01 and kako, 6.15 ± 0.02 ($p>0.05$). From these results, the koobi and kako sampled cannot be described as fermented fish products as previously described by Essuman (1992a). Changes observed in these salted and dried fish are more likely to be due to the actions of enzymes which break down proteins into simpler substances. Among the smoked products, smoked herrings had the lowest mean pH value of 6.16 ± 0.04, smoked catfish had the highest mean pH value of 6.65 ± 0.03 ranging from 6.39 to 6.79 and smoked mackerel had a mean pH of 6.33 ± 0.04. Generally, the mean pH level of salted and dried samples was lower than those of fried and smoked products with the exception of smoked herrings ($P < 0.05$).

The characteristic of dried fish that makes them shelf stable is a low aw below 0.6. In this study, the mean a_w levels observed in fried bonga (0.90 ± 0.01) and smoked mackerel (0.92 ± 0.01) were very high. Nearly 40% (38.89%) of the 18 fried bonga sampled had a_w levels above 0.92. Products with high a_w levels above 0.85 would support the growth of many microorganisms and tends to be high risks products. However, low levels of a_w were observed in koobi (0.64 ± 0.01) and the highest a_w levels recorded for these product was 0.75. Similarly, low a_w level as observed in kako (0.63 ± 0.00) with a maximum of 0.70. This level of water activity is sufficient to prevent growth and multiplication of most microorganisms in koobi and kako (Poulter *et al.,* 1982; Kanatt *et al.,* 2002; Huss *et al.,* 2003). Mohamed *et al.* (2011) have reported a_w of 0.66 in salted tilapia fillets dried with solar driers. The mean a_w levels of smoked herring (0.67 ± 0.03), and smoked catfish (0.83 ± 0.02)

were low to moderate, respectfully. Two out of 18 samples (11%) of smoked herrings had a_w values exceeding 0.92, whereas catfish had 1 (5.6%) and mackerel had 11 (61.1%) samples with a_w exceeding 0.92. High levels of a_w were recorded for all smoked mackerel samples, with a mean of 0.92 ± 0.01 and a maximum of 0.99. The low water activity observed in kako and koobi can be attributed to heavy salting and brining as well as the drying process that these products were subjected to. The low a_w and low moisture content observed in smoked herrings and catfish samples may also be attributed to the curing period, concentration of the salt solution in which the products are soaked, the smoking process and the drying time. Traditional smoking generally cooks and partially dries the fish, has both pasteurizing and inhibitory effects due to heat and wood smoke, effectively reduces the water activity and allows long-term storage of smoked fish (Kagan, 1970; Okraku-Offei, 1970; Plahar *et al.,* 1991; Neequaye-Tetteh *et al.,* 2002). Although, pathogenic bacteria would not grow in dehydrated foods, they are capable of surviving in them. Moreover, xerophilic moulds can grow in dehydrated foods at a_w as low as 0·61 (Corry 1987; Jay 1992). However, food spoilage problems are rare at a_w levels below 0·65 (Pitt and Hocking 1985; Corry 1987). Low aw level of 0.85 or below will prevent the growth and toxin production of all pathogens, including *S. aureus* and *C. botulinum*, and is necessary for a shelf-stable dried product. The FDA recommends that the a_w be reduced to 0.85 or below, if the product will be stored and distributed unrefrigerated (FDA, 2001a).

Given the high and varying physical properties observed in fried bonga and smoked mackerel, these products are more likely to be susceptible to microbial and fungal attack and bacterial pathogens may be capable of growth and survival in them (Jay, 1992; ICMSF, 1996). These products are usually stored and distributed un-refrigerated and to render them shelf-stable and safe, a_w values of 0.85 or below are required (Huss *et al.,* 2003). These will prevent the growth of both spoilage and pathogenic microorganisms including toxin producing *S. aureus* and *C. botulinum* but yeast and mould can grow at this level of a_w under ambient conditions. Based upon $a_{w,}$ only the salted and "fermented" products are relatively low risk. The smoked catfish and herrings could be classified

as medium to high risk and the smoked mackerel as a high risk product. Fried bonga is also classified as a high risk product and should be eaten immediately after preparation, refrigerated at 5 °C or below, kept hot at 63 °C or above or time controlled for 4 hours or less to control the multiplication of bacteria.

3.3.2 Microbial load on selected traditional African fish products sampled from retail outlets in London

Table 3.3 shows the results of bacterial analyses of fried fish (bonga), smoked fish (smoked catfish, smoked herrings and smoked mackerel) and salted and dried fish products (koobi and kako). *Salmonella* or *C. perfringens* were not detected in any of the fried fish, smoked fish and salted and dried fish samples tested (absent 1g and 25g respectively). This result conforms to previous studies (Plahar *et al.,* 1991; 1999; Neequaye-Tetteh *et al.,* 2002; Adu-Gyamfi, 2006) where *Salmonella* was not detected in smoked fish samples with the exception of a study by Nyarko *et al.* (2011), who reported the presence of *Salmonella typhi* in fish sample obtained from Tema Community 1 market. However, the a_w and pH level observed in this study could support the survival and growth of these pathogens. Traditionally all fried fish products including bonga are salted, sun-dried and sometimes sprinkled with corn flour to absorb excess moisture before pan-frying in hot oil. The combination of salting, drying and hot-frying should usually lead to a reduction in moisture content and water activity as demonstrated here. These should have a synergistic effect on the survival and growth of bacterial pathogens. However, the range of pH, water activity and moisture content recorded for fried bonga and in smoked mackerel would not inhibit bacterial and fungal growth. Storing fried bonga and smoked mackerel under ambient conditions and without appropriate packaging may therefore pose a food safety risk. The microbial contamination of these products could be attributed to a number of factors including, contaminated raw materials, insufficient heat processing, poor handling and unhygienic packaging, and the lack of adequate storage and display facilities in retail outlets implemented at the time of purchase of the samples.

3.3.2.1. Microbial quality of ready-to-eat fried fish (bonga)

Of the 18 fried bonga sampled, half (50%) contained aerobic bacteria, 44.4% had coliform bacteria, 22.2% had presumptive *B. cereus*, 16.7% had *S. aureus* and 44.4% contained yeasts and moulds. Aerobic bacteria levels were over 6.0 log cfu/g in 22.2% of samples. Faecal coliforms levels detected in 33.3% of fried bonga samples were also greater than the unsatisfactory level of $\geq 10^4$ cfu/g. Four fried bonga products had yeast and mould contamination up to 4 Log cfu/g. These may grow to levels that can have public health implications, especially when mycotoxins are produced in these products. The wide variability in a_w of the samples, the moderate pH levels and the ambient temperatures of the tropics are suitable for fungal growth and mycotoxin production in these fish products. High mould counts ($\geq 10^6$/g) are generally thought to indicate poor quality with the possibility of the presence of mycotoxins (Gourama and Bullerman, 1995). With the exception of one sample, *S. aureus* levels in fried bonga were under 3.0 log cfu/g. Low numbers of *S. aureus* in fishery products is not a serious problem. However, the high a_w levels observed in fried bonga may result in high multiplication of *S. aureus* ($>1 \times 10^5$ cfu g^{-1}) and consequently, food poisoning may occur when the fish products are stored at temperatures ranging from 7°C to 48.5°C (optimum of 30 to 37°C) (Schmitt et al., 1990) or handled carelessly during processing (Varnam and Evans, 1991; Vishwanath *et al.*, 1998). The ICMSF recommended limit for *S. aureus* for smoked and salted fish products is 1×10^3 cfu g^{-1} (Connell, 1995).

3.3.2.2 Microbial quality of smoked fish products

Aerobic bacteria were detected in 16.7% of samples of catfish and smoked herrings, and in more than half (55.6%) of smoked mackerel samples. The ICMSF (1986) has established an aerobic bacteria count limit of 7 log cfu/g for smoked fish that is fit for human consumption and the Ghana Standards Board (GSB) has set a limit of 1.0 x 10^6 cfu/g in smoked fish products (Nyarko *et al.*, 2011). All the smoked fish samples analysed had aerobic counts below this threshold; however, under ambient storage conditions aerobic bacteria levels could exceed the maximum limit. Aerobic bacteria count is used as an indicator of the hygienic quality of food. Coliform bacteria were

Table 3.3. Overall incidence of pathogenic bacteria, yeast and mould (cfu/g) in traditional African processed fish products

Product		Number of samples tested	Number of positive samples					
			ND*	10^2-10^3	10^3-10^4	10^4-10^5	10^5-10^6	>10^6
Fried fish								
Fried bonga	APC	18	8	10	7	-	-	4
	Total coliforms	18	10	1	1	3	2	1
	B. cereus	18	14	4	-	-	-	-
	S. aureus	18	15	2	1	-	-	-
	Yeast and mould	18	12	4	4	-	-	-
Smoked fish								
Smoked catfish	APC	18	15	3	4	1	1	-
	Total coliforms	18	15	1	1	1	-	-
	B. cereus	18	16	-	-	-	-	-
	S. aureus	18	18	1	1	-	-	-
	Yeast and mould	18	8	1	5	3	1	-
Smoked herrings	APC	18	15	1	2	-	-	-
	Total coliforms	18	15	1	2	-	-	-
	B. cereus	18	17	1	-	-	-	-
	S. aureus	18	17	1	-	-	-	-
	Yeast and mould	18	14	-	2	2	-	-
Smoked mackerel	APC	18	8	5	5	3	2	-
	Total coliforms	18	12	1	4	1	-	-
	B. cereus	18	10	7	1	-	-	-
	S. aureus	18	17	1	-	-	-	-
	Yeast and mould	18	8	5	3	1	1	-
Salted and dried fish								
Koobi	APC	18	14	2	2	-	-	-
	Yeast and mould	18	14	2	2	-	-	-
Kako	APC	18	14	2	2	-	-	-
	Yeast and mould	18	12	2	2	2	-	-

ND* = Not detected

detected in 16.7% of catfish and smoked herrings, and in 33.3 of smoked mackerel sampled. One sample each, of smoked catfish and smoked mackerel had coliform levels exceeding 10^4 cfu/g. Faecal contamination is evidenced by the presence of faecal *Streptococci*, faecal coliforms and *E. coli* (Vishwanath *et al.,* 1998). Their presence in foods possibly indicates the presence of enteric pathogens (Frazier and Westhoff, 1983) and the possibility of human and animal sources of contamination after processing (Plahar *et al.,* 1999). *S. aureus* were detected in 1 (5.6%) sample each of smoked herrings and smoked mackerel and in 2 (11.1%) samples of smoked catfish, one of which was above 10^4 cfu/g, an unacceptable level. However, *S. aureus* levels were below the 10^5 cfu/g threshold for toxin production. *B. cereus* was present in 1 (5.6%) sample of smoked herrings and 8 (44.4%) samples of smoked mackerel. *B. cereus* was not detected in any of the smoked catfish sampled.

Yeast and mould were detected in 10 (55.6%) samples of smoked catfish, 4 (22.2%) samples of smoked herrings and 10 (55.5%) samples of smoked mackerel samples. High levels of yeast and moulds (10^5–10^6 g^{-1}) were detected in smoked mackerel. This is a potential public health hazard. Contamination with yeast and mould is possible if the fish is handled improperly during and after processing. Observations at the retail outlets where these products are sold also showed poor post-processing handling of some products particularly regarding time-temperature control. Smoked mackerel can therefore be classified as potentially hazardous, requiring better time-temperature control. However, traditionally smoked mackerel are not classified as ready to eat products and are usually subjected to further heat treatment during soup and sauce preparations. The real risks may therefore come from any preformed toxins in these fish products.

3.3.2.3 Microbial quality of salted and dried fish products

The salted fish products were the most stable of all the fish products in this study. Bacterial and fungal counts of koobi and kako are shown in Table 3.3. No coliforms, *S. aureus, B. cereus*, *Salmonella* or *C. perfringens* were detected in any of the salted and dried fish products. However

yeast and mould were detected in the two salted and dried fish products. Previous studies reported the presence of strains of mould including Aspergillus flavus, A. tereus, A. fumigatus, A. niger, Absidia sp., Rhizopus sp., Mucor sp. *Fusarium* sp. and *Penicillium* sp. in smoke-dried fish in Nigeria (Doe, 1983; Fafioye *et al.*, 2002; Adebayo-Tayo *et al.*, 2008; Fafioye *et al.*, 2008) and *Penicillium*, *Mucor*, and *Aspergillus* spp. in smoked fish in Ghana (Plahar *et al.*, 1999). Adebayo-Tayo *et al.* (2008) also reported the presence of aflatoxin in all the smoke-dried fish sampled. In the present study, the occurrence of yeast and moulds to a magnitude of 10^4–10^5 g^{-1} in the salted and dried fish may result in spoilage and may potentially be hazardous to health if consumed. Based on these results, the major public health problem that may result from eating the traditionally salted and dried koobi and kako would be mycotoxins. It is therefore important that the drying process of salted and dried fish is adequately monitored to minimize contaminations with mould.

3.4 Discussion

In this study, *Salmonella* was not detected in any of the samples analysed. In similar studies by Plahar *et. al.* (1999), on smoked fish products and Nerquaye-Tetteh *et al* (1978) to isolate various micro-organisms on fermented fishery products obtained from the open markets in Ghana, *Salmonella* spp., were not isolated. Some of the fish sampled were contaminated with microbial flora and yeast and mould. One sample of fried bonga recorded 10^6 levels of coliform bacteria. Aerobic bacteria was detected in four samples of fried bonga with counts reaching 10^6. The reason for this contamination could be related to poor food handling practices along the fish chain, including, the failure to chill or refrigerate freshly caught fish, poor hygiene and sanitation and cross-contamination during processing and post-processing, placing fish in dirty basins, equipment, fish boxes and baskets. Moreover, the presence of bacterial pathogens, such as *S. aureus* in thermally treated fish products and stored products can be attributed to human and animal sources following post-processing contamination during preparation and storage. *C. perfringens* and *Salmonella* spp. can also be transferred this way or carried by foods themselves. Fish handled in this way may support the growth of both spoilage and pathogenic bacteria, and toxin formation in the finished product and become vehicles for consumer illness. Other researchers have reported

varying levels of microbial loads in traditionally processed fish (Adu-Gyamfi, 2006; Diei-Ouadi and Mgawe, 2011; Kombat *et al.,* 2013). Most of the vegetative cells of bacteria detected should be readily destroyed during hot thermal processing, except heat resistant bacterial spores. However, the primary pathogens of concern are the spore formers and producers of heat-stable toxins including, *S. aureus* and *C. botulinum*, as well as xerophilic moulds that produce mycotoxins. The extensive mould growth observed in some of these fish products can also result in marked deterioration in quality and contribute to off-flavour.

Dried products are usually considered shelf stable and are, therefore, often stored and distributed unrefrigerated. In this study smoked herrings, smoked catfish, salted and dried koobi and kako can be classified as dried products and can be stored and distributed unrefrigerated. However, smoked mackerel and fried bonga should be stored and retailed under refrigerated conditions. The characteristic of dried foods that makes them shelf stable is their low water activity levels. Gram-negative bacteria require a higher a_w than Gram-positives for their development (Jay, 1992). Staphylococci grow best in foods in which the competing organisms are present in low numbers including dried, salted and low water activity foods (Vishwanath *et al.*, 1998). For toxic levels of enterotoxin to occur, increases of about 10^6 to 4×10^7 CFU/g staphylococcal levels must be reached (Anunciacao *et al.*, 1995; Walls and Scott, 1997; Fujikawa and Morozumi, 2006). This level of *S. aureus* was not observed in the samples analysed in this study except in one sample of smoked mackerel (Table 3.3). Toxins produced by *S. aureus* will not be eliminated by processing. Some toxins may also not be destroyed if they have already been formed in the product. Because many hazards can enter the food chain at different points a preventative approach that controls processes is the preferred method for improving safety. This approach requires steps to reduce the prevalence of these pathogens in the food throughout the food production chain, that is, from catch to table food safety approach. *S. aureus* is able to grow in a wide range of temperatures (7 to 48.5°C with an optimum of 30 to 37°C) (Schmitt *et al.*, 1990), pH (4.0 to 10.0, with an optimum of 6.0 to 7.0) (ICMSF, 1996), and sodium chloride concentrations (up to 25% NaCl) (ICMSF, 1996), and survive

at a minimum water activity of 0.83 (Lotter and Leistner, 1978; Bergdoll, 1989; Schmitt *et al.*, 1990). These characteristics enable *S. aureus* to grow in a wide variety of foods as well as persist in stressful environments (e.g. dry surfaces) for long periods. It can produce enterotoxin from 10 to 46°Cat a_w above 0.88 (Lotter and Leistner, 1978). A water activity of 0.85 or below will prevent the growth and toxin production of all pathogenic bacteria, including *S. aureus* and *C. botulinum*, and is critical for the safety of a shelf-stable dried product. For xerophilic moulds, a water activity of 0.5 to 0.75 is recommended to assure a shelf-stable dried product. The production of koobi and kako does not include cooking or pasteurisation that destroys pathogenic microorganisms. Owens and Mendoza (1985) have stated that the pH level of fermented fish products should be below 4.5 in order to inhibit pathogenic bacteria. The results of this study showed that all the salted and dried fish had pH level above 5. *Salmonella* can grow at a temperature range from 7 to 49.5^{o}C with an optimum of 35-37^{o}C, and at pH levels between 3.8 and 9.5 with an optimum of 7-7.5 (NZFSA, 2001). The minimum a_w value for growth of *Salmonella* strains is 0.93 (Varnan and Evans, 1991; Bremer *et al.*, 2003) with an optimum of 0.99 (Mattick *et al.*, 2000). Although the proliferation of *Salmonella* is inhibited at *aw*, 0.93 (D'Aoust, 1997), the pathogen can survive in low a_w foods for long periods (Jung and Beuchat, 1999; Arkoudelos *et al.*, 2003; Ristori *et al.*, 2007). The survival of *Salmonella* and *S. aureus* in low a_w traditionally processed fish products, and their association with different storage temperatures has been little studied. Therefore, the contamination of these fish products with pathogenic bacteria could pose public health risks to consumers and to importing countries.

3.5 Conclusion

The results of this investigation show some degree of bacteriological contamination of a variety of traditionally processed fish products. Overall microbiological qualities of the majority of processed fish products sampled were acceptable. The fish products with the largest number of unsatisfactory rates of indicators and pathogens were fried bonga and smoked mackerel. The hazard associated with retailed traditionally processed fish, determined as the presence of specific bacterial pathogens

and indicators, was relatively low for these samples. Fried bonga and smoked mackerel are classified as high risk and potentially hazardous requiring identification of the critical control points for remedial action during processing and storage. In contrast, smoked herrings and smoked catfish samples tested are low to medium risk, and salted and dried koobi and salted and dried kako are classified as low risk. The results of this study highlight the need to monitor the use of drying, salting and smoking in the traditional West African fish processing settings so as to control the intrinsic properties of the final fish product and minimise any food safety risks associated with the products. It should be noted that the precise history of these products is not known. As shown in this study, the fish products that were adequately dried (smoked herrings and smoked catfish, salted koobi and kako) had low water activity levels and have potentially low to medium risks associated with them. However, smoked mackerel products could have high biological risks associated with them because of their high moisture content and high water activity compared to reference normative values for food safety and bacterial growth. Fried bonga was similarly high in pH, moisture content and water activity thus rendering them high risk products. Since traditionally processed fish is widely consumed in West Africa and exported to European Union countries, it is important that its microbiological assessment be available. It is recommended that consumers should be informed about the possible health hazards related to each of these fish products since careful handling is required in some circumstances to prevent contamination and growth of any pathogens present.

Chapter 4

4.0 Effects of storage temperature on microbiological, sensory and shelf-life changes in salt-dried fish and hot-smoked fish products from Ghana.

4.1 Introduction

While no confirmed outbreaks of food-borne illness have been directly attributed to the consumption of smoked or salted fish in Ghana, probably because of the lack of monitoring, these products have been found to be subject to contamination with pathogenic microorganisms (Ababouch, 1990; Essuman, 1992; Mensah, 1997; Plahar *et al.,* 1999; Nerquaye-Tetteh *et al.*, 2002; Akinola *et al.,* 2006; Anihouvi *et al.*, 2006; Nyarko *et al.*, 2011). Several of the studies conducted in Ghana have not documented the presence of *Salmonella* in cured fish in Ghana, with the exception of Nyarko *et al.* (2011) who reported the presence of *Salmonella typhi* in smoked *Sardinella aurita* in a community market. However, in the US and other countries, studies have also documented the presence of *Salmonella* spp. and *S. aureus* in similar seafood or fish products including salted/dried fish, dried anchovies and the potential of these products to disseminate pathogens to humans (Heinitz *et al.,* 2000; Huss *et al.*, 2000; Ling *et al.*, 2002; Kumar *et al.,* 2009). The presence of *S. aureus* in smoked fish has also been documented as an important gastroenteritis-causing pathogen in Ghana (Essuman, 1992; Mensah, 1997; Plahar *et al.*, 1999; Nerquaye-Tetteh *et al.,* 2002; Nyarko *et al.,* 2011). Although *S. aureus* must grow to approximately 10^5 cfu/g to produce toxin and cause illness (Bergdoll, 1989), it can survive for extended periods under conditions where growth is inhibited. Therefore, the potential impact on the safety and quality of these products must be first understood. In general, salmonellosis is transmitted when *Salmonella* cells are introduced into food. Contamination of fish and seafood is most often the result of faecal contamination through polluted water, infected food handlers or cross-contamination during production or transport (Lunestad and Borlaug, 2009). Poor hygienic practices during handling and transportation from landing centres to fish markets, multiplication in food due to inadequate storage temperature, insufficient cooking or cross-contamination are often implicated in salmonellosis outbreaks (Ryan, *et al.,* 1996; Todd,

1997). The main transmission routes of this pathogen are foods of animal origin contaminated with faecal matter (Haeghebaert *et al.*, 2003; Swartz, 2002). Good hygiene practices before, during, and after food preparation can reduce the chances of contracting an illness.

Limited information has been published on the growth of bacterial food pathogens in commercially processed, heavily salted and dried fish or hot smoked fish stored under different temperature conditions in Ghana. The survival of *Salmonella* in food is influenced by different factors, including temperature, water activity and pH of the food. Low temperatures are used to retard chemical reactions and the action of food enzymes, and to slow or stop growth and activity of microorganisms in food (Frazier and Westhoff, 1988). A well-designed inoculation study or other published scientific research can be used to determine whether a food can be held without time/temperature control (FDA, 2005). As part of a series of studies to establish the safety of traditionally processed fish products from Ghana, this study was conducted to establish the effects of salting, water activity and storage temperature on the survival and growth of *S. aureus* strain NCTC 8532 and *Salmonella* Typhimurium strain NCTC 74 in salted and dried fish and smoked fish products stored at 4°C and 25°C. The second part of this study investigated the impact of product water activity and storage temperatures on overall quality, shelf-life and sensory characteristics. The study forms part of a wider investigation of the safety and quality of traditional fish products.

4.2 Materials and methods

4.2.1 Sampling and preparation of fish products

A total of six batches each of two smoked fish products (catfish and herrings) and two salt-dried fish (koobi and kako) products were obtained from retail outlets in London. The fish products were all traditionally processed in Ghana and imported into the UK. All products were transported to the laboratory within 1 hr of purchase and refrigerated (4 ± 1^{o}C) until used. The samples were divided

into lot 1 and lot 2 and put in plastic containers with lids. Lot 1 was further sub-divided into two and used for inoculated and un-inoculated studies. Lot 2 was used for quality, sensory and shelf-life studies. The fish samples were individually and aseptically cut into 25g pieces with approximate weights of 25g. The cut pieces were randomly assigned, each to one of two treatments, inoculated and un-inoculated.

4.2.1.1 Inoculum preparation

Salmonella Typhimurium (NCTC 74) and *S. aureus* (NCTC 8532) were selected for the challenge study of foodborne pathogens. *S. aureus* was selected because of its extreme tolerance of low water activity, its potential for common transfer by human hands and its ability to grow and produce toxin at ambient temperatures. *S.* Typhimurium was selected because of its ability to grow at ambient temperature. The broth culture of each organism was prepared following the procedures described in Section 3.2.2.1

4.2.1.2 Inoculation of fish slices with Salmonella and *S. aureus* and storage

To inoculate the fish slices, 0.1 ml of serially diluted overnight culture of *Salmonella* Typhimurium or *S. aureus* were surface inoculated into each 25g slice and distributed as evenly as possible with a sterile bent plastic spreader to yield a starting count of 4 log cfu/g of product. The sliced fish pieces were then allowed to dry for at least 30 min. Fifty percent of the inoculated fish products was stored at 4 ± 1°C (to simulate refrigeration) and the other 50 percent at 25 ± 1°C (to simulate ambient temperature) throughout the product shelf life. Positive and negative microbial controls were included throughout the experiments to ensure that the background microflora on the fish slices was minimal and that all plating media were working properly. The control samples were inoculated with sterile distilled water and stored under the same conditions. Three individual replicates of each experiment were performed, in all cases. Viable counts of the samples were made immediately after inoculation (t^0) and subsequently on day 1, 6, 12 and 18 of storage for each microorganism.

4.2.1.3 Microbial sampling and recovery procedures

At pre-determined time intervals during storage, each of the inoculated and un-inoculated plastic containers was opened and the contents subjected to physico-chemical and microbiological analysis to determine and quantify bacterial growth, survival, or inactivation over time. All the experiments were performed in duplicate. In each case, the entire slice (25.0 g) was aseptically removed and transferred into sterile stomacher bags and stomached for 2 min with 225 ml of Maximum Recovery Diluent (MRD, Oxoid). The resultant filtrate was serially diluted in MRD and spread on appropriate plates. The numbers of viable *Salmonella* and *S. aureus* cells in both batches of inoculated and un-inoculated pieces of products were determined. *Salmonella* were determined by plating 0.1ml aliquots of the diluted sample on XLD (Oxoid) plates. Plates were incubated at 37°C for 24 hours. The presence of *Salmonella* spp. and *S. aureus* in each of the products was determined following the methods described in Section 3.2.2.2 and 3.2.2.3, respectively.

4.2.2 Quality, shelf-life and sensory analysis

Un-inoculated samples were used for sensory analysis and shelf-life studies. A panel of trained students (N = 10) analysed the fish products. The panellists were trained and briefed on the nature of the experiment without disclosing the identity of the samples. The panellists were male and female (50:50) and were chosen to be representative of the consumer population. Sensory analysis (assessment of some organoleptic properties) was carried out following the methods described by Ruiz-Capillas and Moral (2001a, 2001b). The selected fish slices were wrapped in aluminium foil. The panellists were required to evaluate a range of locally available and culturally familiar traditionally processed African fish products on the basis of appearance, odour, texture, and overall acceptability using a standard score sheet and to record any comments about product characteristics. Sensory evaluation was conducted between 12 noon and 2 pm and focused mainly on visual appearance, texture examination and odour. Hand-wash liquid was provided to the panellists to wash their hands in-between samples and after the analysis. The samples were not tasted.

Each characteristic was scored on a one to nine hedonic scale-rating, where 9 = excellent; 1 = extremely poor. Higher scores indicate higher quality products and products with very low scores or 1 were regarded as low quality. All product groups including smoked products and salted products were assessed on the basis of their appearance (9 = very acceptable to 1 = extremely unacceptable), odour (9 = characteristic product odour to 1 = extreme off odour), texture (9 = very good texture to 1 = extremely bad texture), and overall acceptability (9 = very acceptable to 1 = extremely unacceptable) on the nine point descriptive scale. On the basis of the sensory scores, the samples were classified with a score of 7–9 indicating "very good to excellent" quality, a score of 4.0–6.9 "good" quality, and a score of 1.0–3.9 denoting "unacceptable" quality. Lots scoring less than 4 were therefore rejected. Rejection time was determined as the time taken to reach the mean acceptability rating of 50 per cent of panellists for a sample was within the 1.0-3.9 score range or the average score grades the sample as spoiled. All the experiments were performed in duplicates

4.2.3. Physico-chemical analysis

The pH and water activity levels of the salted/dried fish and the salted/smoked fish were determined. The a_w of representative product samples were measured with a Decagon water activity meter (CX-1, Decagon Devices Inc., Washington, USA) as described in Section 3.3.3.1. The pH levels of similar samples were also measured using a Corning pH meter 240 following the method described in Section 3.3.3.2.

4.2.4 Data analysis

The average log cfu/g for the fish slices for each sampling day was calculated and plotted against time to provide a microbial survival/growth curve. To evaluate the effects of storage temperature and a_w on the change in *Salmonella* and *S. aureus* populations (in log cfu), correlation coefficients (r values) were computed. Mean sensory scores were computed and graphically presented.

4.3 Results

4.3.1 Results of physico-chemical and microbiological analysis of fish products

4.3.1.1 Physico-chemical and microbiological analysis of kako

Mean a_w of dry-salted kako at baseline (day 0) was 0.74 and the mean pH was 6.6 (Table 4.1). The low $a_{w,}$ observed in the majority of samples were most likely due to the curing period, the concentration of salt and the drying time. The a_w decreased in all samples of kako throughtout the storage period. This played a role in *Salmonella* Typhimurium and *S. aureus* inhibition in kako. Arkoudelos *et al.* (2003) in their study of the survival of *Salmonella* Enteritidis on salted sardines observed a similar trend of a drop in a_w values from the initial level of 0.93 to 0.69 in 5 days. Besides a_w, other factors also affect adaptation and multiplication of bacteria, such as pH, temperature and oxidation–reduction potential (Jay, 1992). However, the pH levels observed in these samples were not low enough to inhibit *Salmonella* Typhimurium or *S. aureus. S.* Typhimurium and *S. aureus* counts of salted dried kako during the storage period are shown in Fig. 4.1. On day 1, *S.* Typhimurium decreased by 1.2 log cycles in kako stored at 4°C and 1.8 log units in kako stored at 25°C. The population of *S.* Typhimurium decreased continuously throughout the storage period at the two temperatures. *Salmonella* were not detected in kako by day 12 and later in the storage trial.

Survival of *S. aureus* in kako during 18 days of storage was similar at 4°C and at 25°C. Mean counts of *S. aureus* on day 0 were 4.49 and 4.47 log cfu/g at 4 and 25°C, respectively. Mean counts after 18 days of storage at 4 and 25°C were 1.28 and 1.25 log cfu/g, respectively. The difference between counts of *S. aureus* in kako held at 4^oC and 25^oC were not statistically significant after 18 days of storage ($p > 0.05$). Statistical analysis using Pearson's correlation showed that *Salmonella* (Fig. 4a-b) and *S. aureus* counts (Fig. 4.2c-d) observed in kako strongly correlated with the water activity levels observed in kako (R^2=0.9443; Fig. 5.2a). Normal ambient (25°C) temperature did not appear to affect water activity and pH of samples (Table 4.1) as shown by the non-significant p-values obtained for all the samples tested.

Table 4.1. Water activity and pH values of salted and dried kako collected from retail outlets in London

Storage time	4°C Mean ± SE	4°C Range	25°C Mean ± SE	25°C Range	p-value
Water activity					
Day 0	0.74 ± 0.018	0.61 - 0.83	0.73 ± 0.018	0.63 - 0.86	0.99
Day 1	0.72 ± 0.016	0.62 - 0.82	0.71 ± 0.015	0.63 - 0.81	0.87
Day 6	0.69 ± 0.015	0.59 - 0.77	0.68 ± 0.010	0.62 - 0.75	0.65
Day 12	0.70 ± 0.035	0.57 - 0.75	0.65 ± 0.006	0.59 - 0.71	0.27
Day 18	0.67 ± 0.016	0.56 - 0.75	0.64 ± 0.008	0.61 - 0.75	0.38
pH value					
Day 0	6.56 ± 0.116	5.70 - 7.11	6.64 ± 0.081	6.04 - 7.06	0.76
Day 1	6.58 ± 0.113	5.70 - 7.17	6.43 ± 0.115	5.67 - 7.23	0.60
Day 6	6.41± 0.120	5.70 - 7.13	6.43 ± 0.113	5.67 - 7.20	0.97
Day 12	6.37 ± 0.111	5.68 - 7.03	6.37 ± 0.097	5.77 - 6.97	0.98
Day 18	6.37 ±0.108	5.70 - 6.98	6.37 ± 0.116	5.67 - 6.97	0.98

Mean±SE of 6 samples

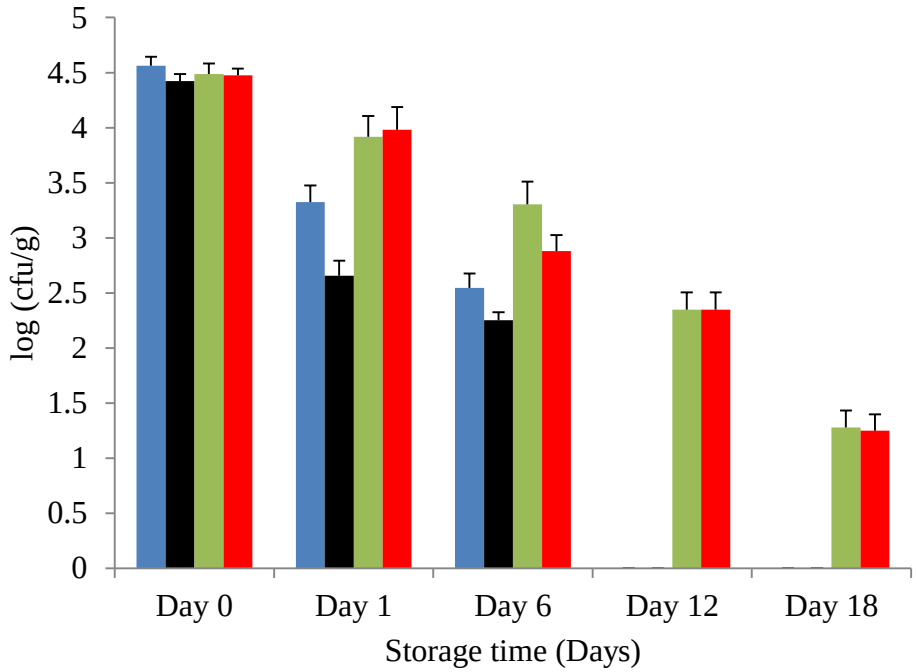

Fig. 4.1. Survival of *Salmonella* Typhimurium (at 4°C● and 25°C●) and *S. aureus* (at 4°C● and 25°C●) in kako

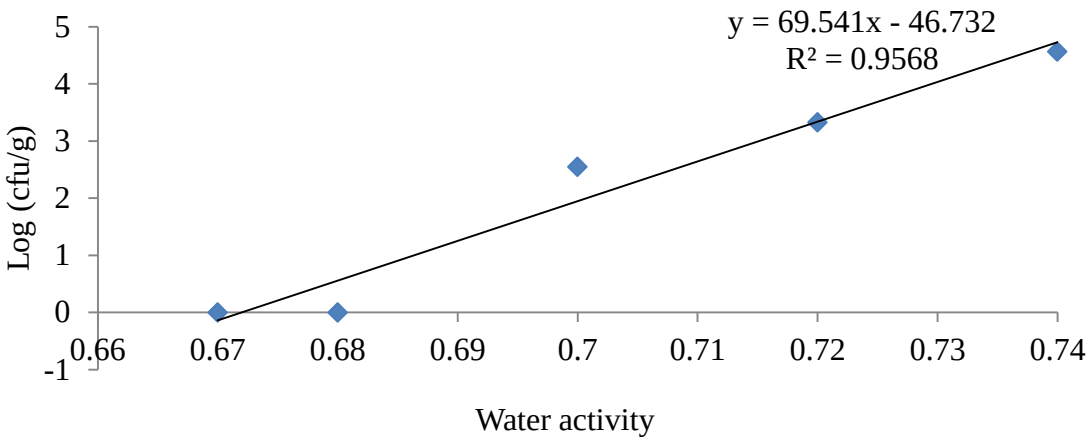

Fig. 4.2a. Correlation between water activity of kako stored at 4^{O}C and survival of *Salmonella* Typhimurium

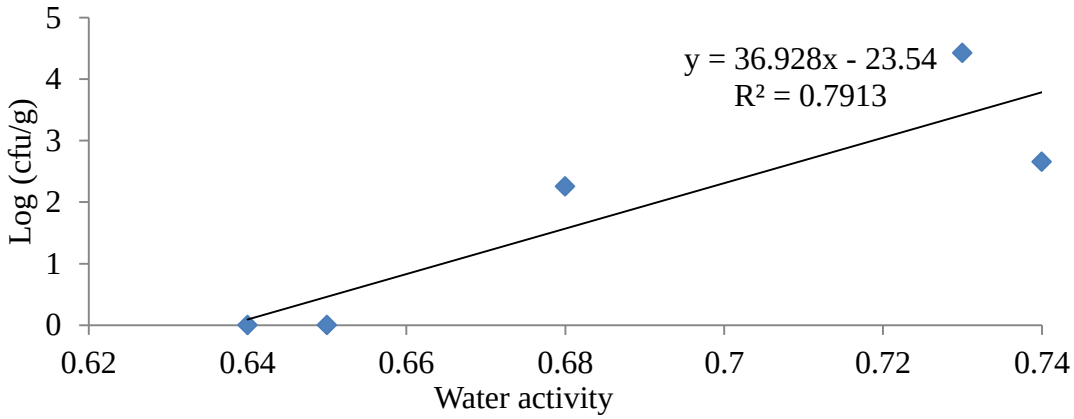

Fig. 4.2b. Correlation between water activity of kako stored at 25^{O}C and survival of *Salmonella* Typhimurium

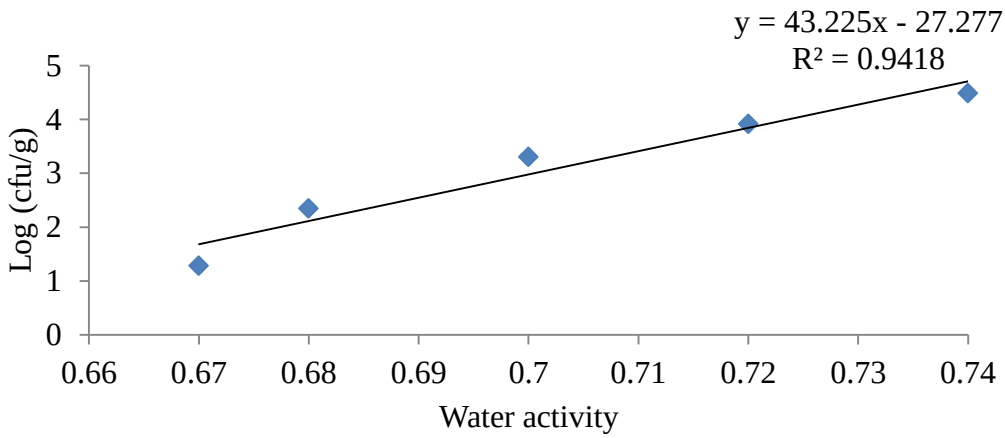

Fig. 4.2c. Correlation between water activity of kako stored at 4^{O}C and survival of *S. aureus*

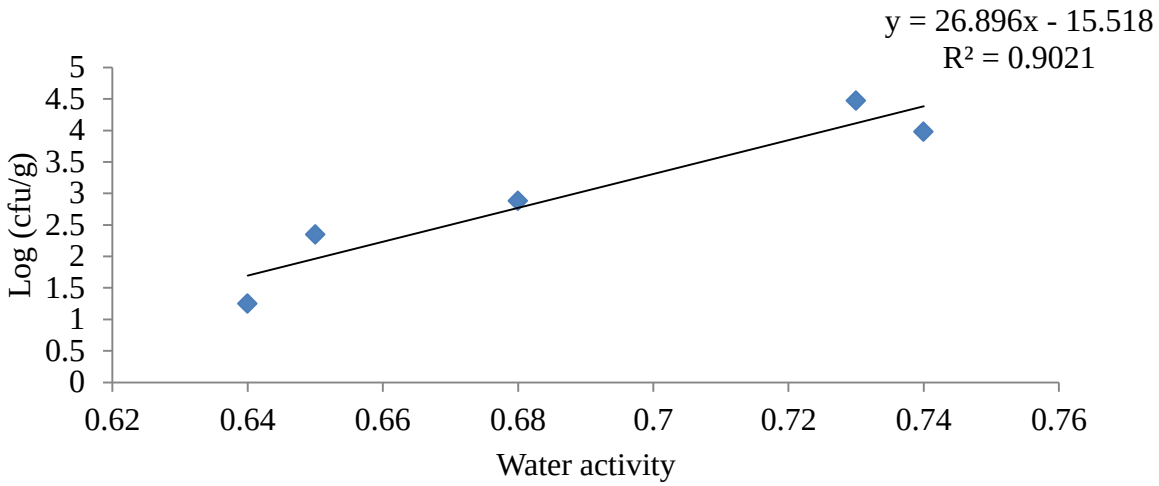

Fig.4.2d. Correlation between water activity of kako stored at 25^{O}C and survival of *S. aureus*

4.3.1.2 Physico-chemical and microbiological analysis of koobi

The mean a_w of dry-salted tilapia (koobi) sample was 0.74 and the mean pH was 6.9 at 25°C and these played a role in the inhibition *S.* Typhimurium and *S. aureus* in koobi (Table 4.2) and render koobi microbiological safe (Table 4.2). Koobi has traditionally been described as a salted and fermented fish product.

Table 4.2. Water activity and pH values of salted and dried koobi collected from retail outlets in London

	4°C		25°C		
Storage time	Mean ± SE	Range	Mean ± SE	Range	p-value
Water activity					
T0	0.72 ± 0.01	0.64 - 0.79	0.74 ± 0.01	0.63 - 0.85	0.44
T24	0.71 ± 0.01	0.63 - 0.79	0.72 ± 0.01	0.63 - 0.80	0.80
Day 6	0.70 ± 0.01	0.62 - 0.77	0.69 ± 0.01	0.62 - 0.79	0.67
Day 12	0.70 ± 0.01	0.62 - 0.78	0.68 ± 0.01	0.63 - 0.75	0.60
Day 18	0.68 ± 0.01	0.61 - 0.75	0.68 ± 0.01	0.61 - 0.74	0.86
pH value					
T0	6.65 ± 0.13	5.97 - 7.77	6.90 ± 0.09	6.25 - 7.64	0.40
T24	6.66 ± 0.09	6.07 - 7.43	6.89 ± 0.08	6.35 - 7.63	0.23
Day 6	6.57 ± 0.09	5.97 - 6.98	6.87 ± 0.09	6.29 - 7.54	0.19
Day 12	6.83 ± 0.09	6.00 - 6.93	6.83 ± 0.09	6.27 - 7.65	0.26
Day 18	6.74 ± 0.07	6.03 - 6.97	6.74 ± 0.07	6.25 - 7.37	0.33

The range of pH observed in these products (6.57-6.90) does not lend evidence to this. *S.* Typhimurium and *S. aureus* counts of salted dried tilapia (koobi) during the storage period are shown in Fig. 4.3. Initial *S.* Typhimurium populations in koobi samples were 4.52 $\log_{10}$ cfu/g and 4.45 $\log_{10}$ cfu/g at 4°C and 25°C, respectively. At 4°C and 25°C, *Salmonella* counts in koobi decreased steadily and no cells were detected by the 18th day of storage after enrichment. On koobi stored at 25°C, the cell counts of *S. aureus* decreased from an initial 4.39 log cfu/g count on day 0, reaching 1.91 log cfu/g on day 12. Similarly, at 4°C, *S. aureus* counts in koobi decreased from an initial count of 4.43 to 2.14 log cfu/g on day 12. No significant differences between samples stored at 4°C and 25°C were detected. *Salmonella* or *S. aureus* were not recovered from koobi on day 18.

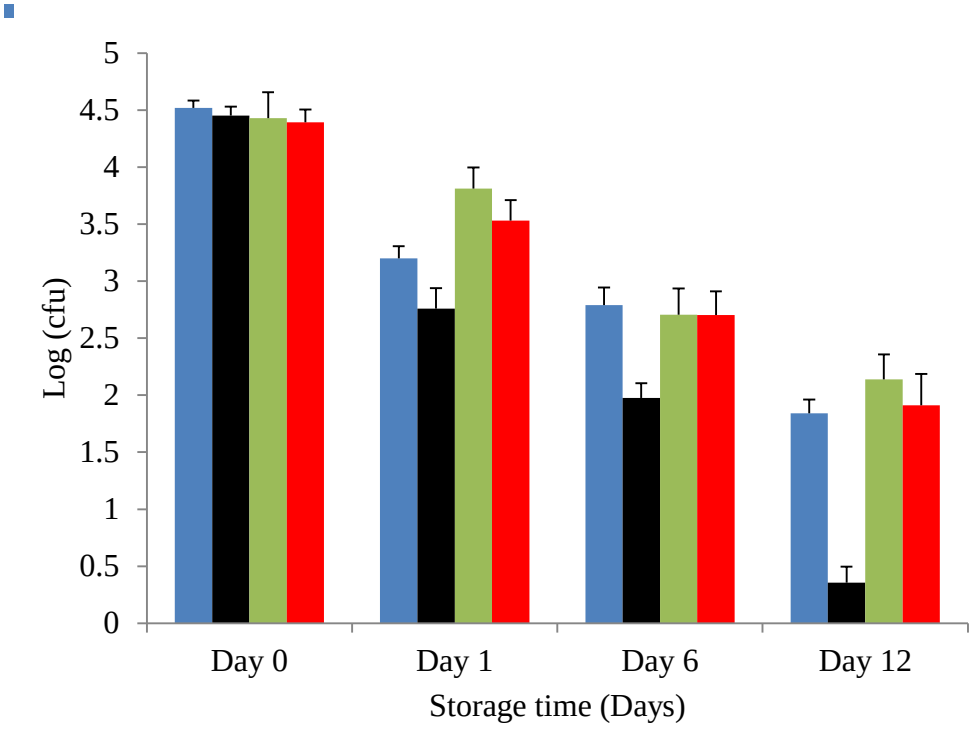

Fig. 4.3. Survival of *Salmonella* Typhimurium (at 4°C● and 25°C●) and *S. aureus* (at 4°C● and 25°C●) in koobi.

A reduction in a_w of the koobi resulted in an increase in the death of *Salmonella*. Normanno *et al.* (2005) have reported no growth of *S. aureus* at temperatures below 8°C combined with low pHs. However, potential food safety problems may arise when the fish samples are not adequately salted and dried so as to achieve low water activity levels. Pearson correlation analysis showed a strong correlation (R^2=0.99) between a_w levels of koobi and *Salmonella* (Fig.4.4a-b) and *S. aureus* counts

(Fig. 4.4c-d). Low (4°C) and normal ambient (25°C) temperature did not appear to affect water activity and pH of samples (p = 0.44) (Table 4.2) as shown by the non-significant p-values obtained for all the samples tested.

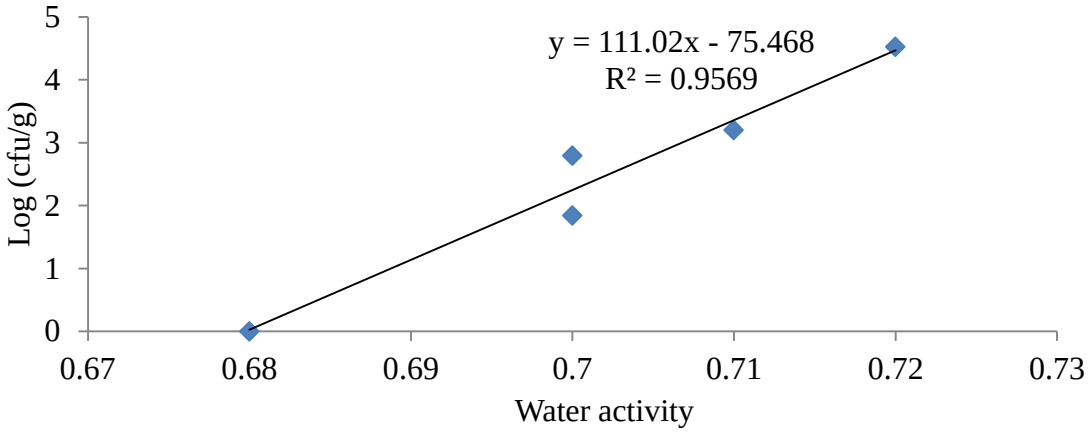

Fig. 4.4a. Correlation between water activity of koobi stored at 4^{O}C and survival of *Salmonella* Typhimurium

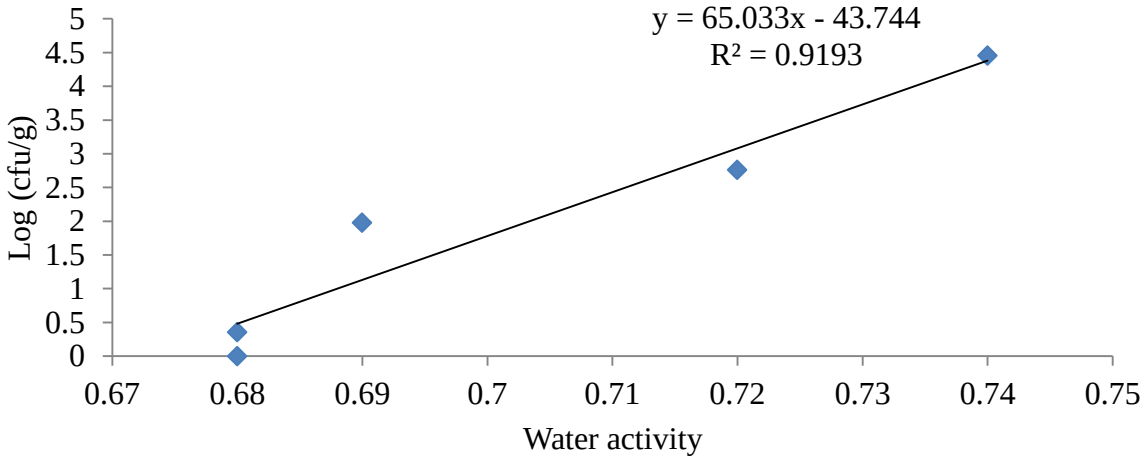

Fig.4.4b. Correlation between water activity of koobi stored at 25^{O}C and survival of *Salmonella* Typhimurium

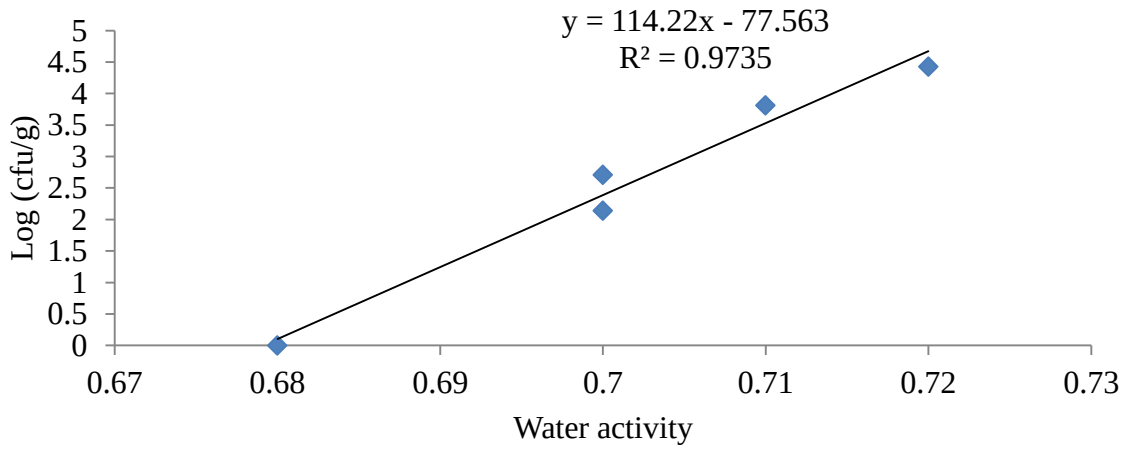

Fig .4.4c. Correlation between water activity of koobi stored at 4^{O}C and survival of *S. aureus*

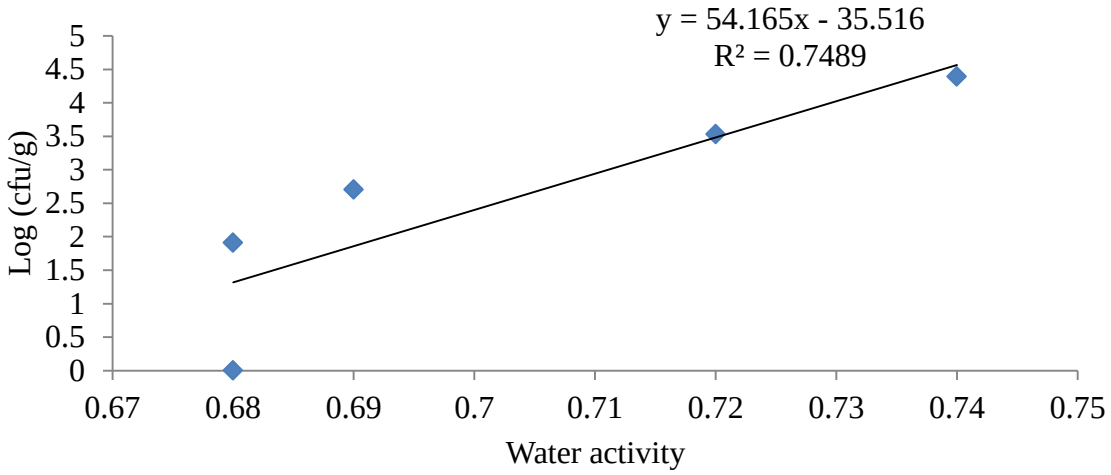

Fig. 4.4d. Correlation between water activity of koobi stored at 25^{O}C and survival of *S. aureus*

4.3.1.3 Physico-chemical and microbiological analysis of herrings

The mean a_w of smoke-dried herrings sampled was 0.84 and this decreased throughout the storage period, reaching 0.72 and 0.69 for samples stored at 4°C and 25°C, respectively, after 18 days of storage (Table 4.3). The low a_w played a role in the inhibition *S.* Typhimurium and *S. aureus* in smoke-dried herrings. Similarly, the mean pH level of smoke-dried herrings was 6.7 and this decreased to 6.4 after 18 days. However, the pH levels of this product varied widely (4.2 to 9.3) and may support the growth of *S.* Typhimurium and *S. aureus*. *S.* Typhimurium and *S. aureus* counts of smoke-dried herrings during the storage period are shown in Fig. 4.5. The result showed that

irrespective of the storage temperature, there was significant reduction in *S.* Typhimurium and *S. aureus* counts throughout the storage period in smoke-dried herrings from the initial mean levels. Initial mean levels of *S.* Typhimurium in smoked herrings were 4.28 log cfu/g for samples stored at 4°C and 25°C. The numbers of *S.* Typhimurium decreased gradually throughout the storage period reaching 1.05 log and 1.0 log cfu/g on the 18th day of storage at 4°C and 25°C, respectively.

Table 4.3. Water activity and pH values of smoked herrings collected from retail outlets in London

	4°C		25°C		
Storage time	Mean ± SE	Range	Mean ± SE	Range	p-value
Water activity					
Day 0	0.83 ± 0.01	0.75 - 0.89	0.84 ± 0.01	0.74 - 0.89	0.76
Day 1	0.80 ± 0.01	0.73 - 0.86	0.81 ± 0.01	0.73 - 0.88	0.74
Day 6	0.76 ± 0.01	0.69 - 0.84	0.75 ± 0.01	0.72 - 0.79	0.67
Day 12	0.74 ± 0.01	0.65 - 0.78	0.71 ± 0.01	0.63 - 0.75	0.13
Day 18	0.72 ± 0.01	0.62 - 0.78	0.69 ± 0.01	0.63 - 0.74	0.17
pH value					
Day 0	6.79 ± 0.07	6.31 - 7.54	6.65 ± 0.07	6.33 - 7.65	0.40
Day1	6.66 ± 0.06	6.28 - 7.24	6.68 ± 0.07	6.33 - 7.25	0.92
Day 6	6.57 ± 0.06	6.25 - 7.23	6.54 ± 0.07	6.25 - 7.25	0.84
Day 12	6.53 ± 0.06	6.18 - 6.94	6.45 ± 0.05	6.22 - 6.97	0.54
Day18	6.46 ± 0.05	6.16 - 6.88	6.41 ± 0.05	6.13 - 6.76	0.70

However, no significant difference in *S.* Typhimurium counts were observed between samples stored at 4°C and 25°C. Mean initial counts of *S. aureus* were 4.33 log and 4.38 cfu/g in smoked herrings stored at 4°C and 25°C, respectively. These steadily decreased throughout the storage period reaching 1.05 log and 0.84 log cfu/g on the 18th day of storage for samples stored at 4°C and 25°C, respectively. However, higher levels of *S. aureus* counts were recovered from smoked herrings stored at 4°C than at 25°C on day 12, but difference was not significant.

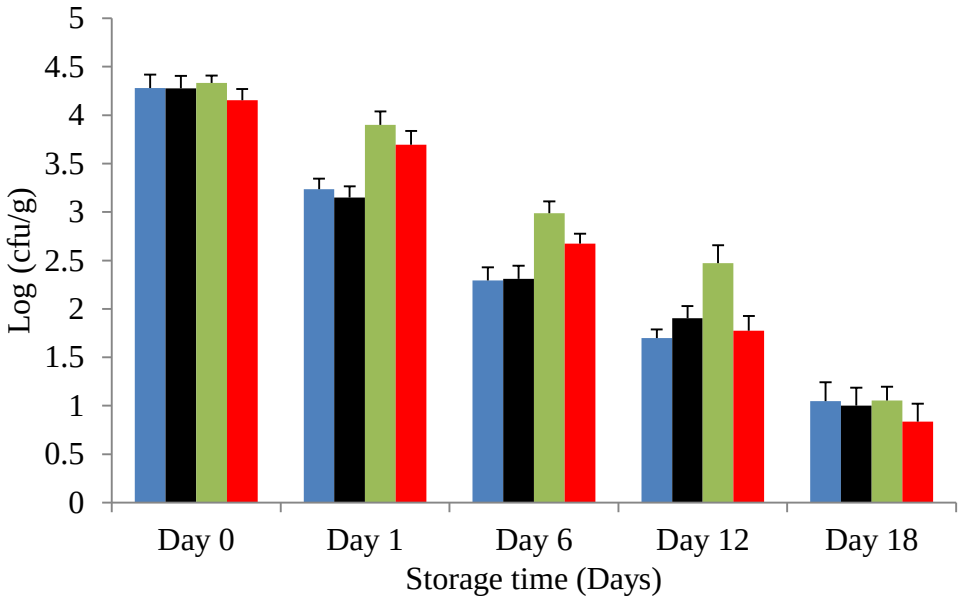

Fig. 4.5. Survival of *Salmonella* Typhimurium (at 4°C● and 25°C●) and *S. aureus* (at 4°C● and 25°C●) in smoked herrings

The Pearson correlation analysis showed that there was a strong correlation ($R^2 \geq 0.91$) between a_w of smoked herrings and *Salmonella* and *S. aureus* counts in smoked herrings stored at 4°C (Fig. 4.6 a-d).

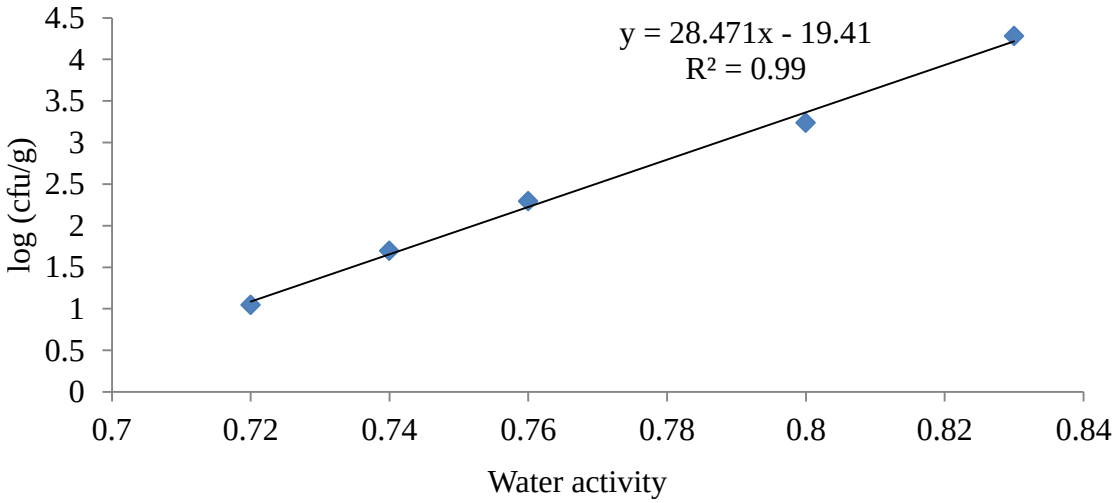

Fig. 4.6a. Correlation between water activity of smoked herrings stored at 4°C and survival of *Salmonella* Typhimurium

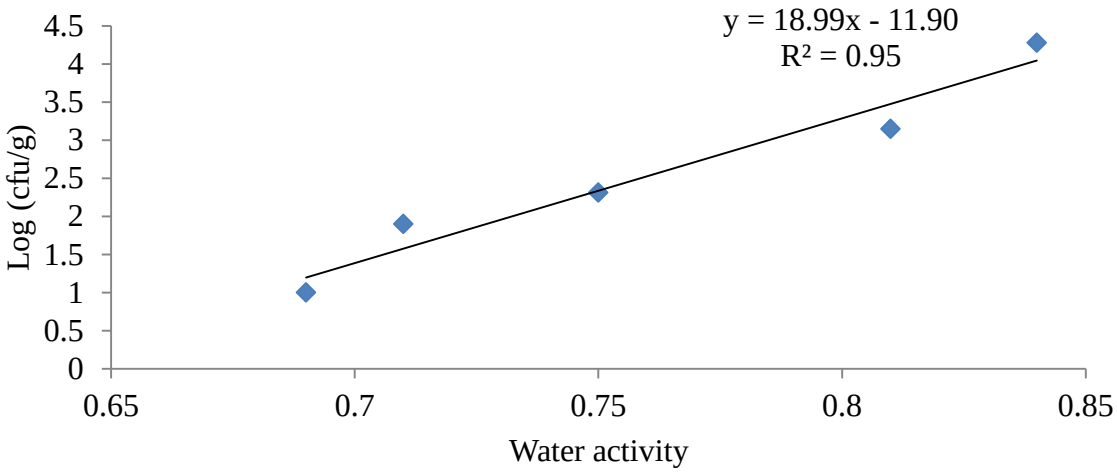

Fig. 4.6b. Correlation between water activity of smoked herrings stored at 25ºC and survival of *Salmonella* Typhimurium

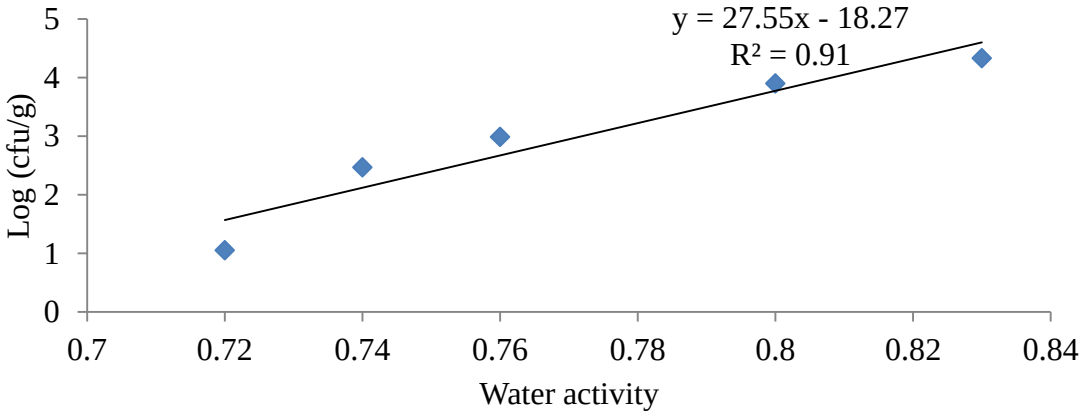

Fig. 4.6c. Correlation between water activity of smoked herrings stored at 4ºC and survival of *S. aureus*

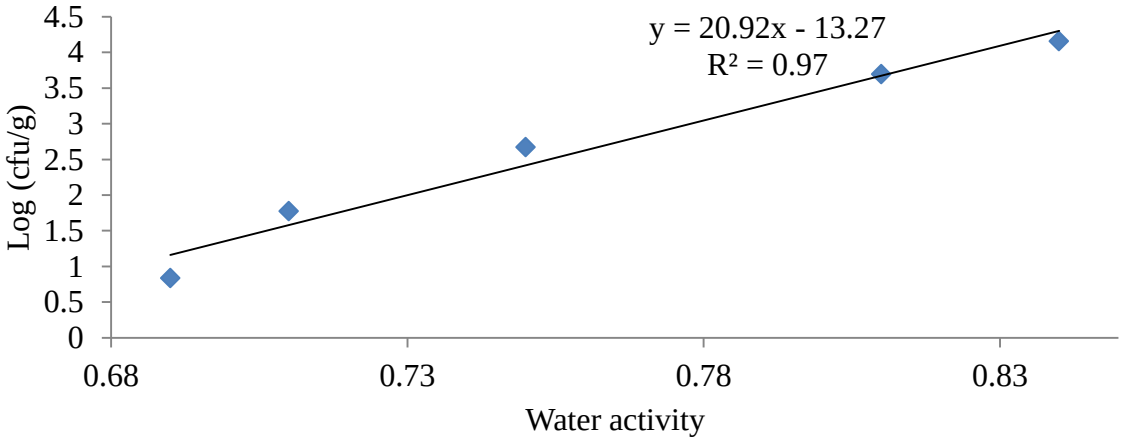

Fig. 4.6d. Correlation between water activity of smoked herrings stored at 25ºC and survival of *S. aureus*

4.3.1.4 Physico-chemical and microbiological analysis of catfish

The mean a_w of smoke-dried catfish sampled was 0.80 and this decreased throughout the storage period, reaching 0.76 and 0.74 for samples stored at 4°C and 25°C, respectively, after 18 days of storage. The low a_w played a role in the inhibition *S.* Typhimurium and *S. aureus* in smoke-dried catfish and render smoke-dried catfish microbiological safe. Similarly, the mean pH levels of smoke-dried catfish were 6.8 and 6.7 for samples stored at 4°C and 25°C, respectively (Table 4.4). This level of pH would not inhibit *S.* Typhimurium and *S. aureus.*

Table 4.4. Water activity and pH values of smoked catfish collected from retail outlets in London

	4°C		25°C		
Storage time	Mean ± SE	Range	Mean ± SE	Range	p-value
Water activity					
Day 0	0.79 ± 0.01	0.75 - 0.83	0.80 ± 0.01	0.72 - 0.87	0.59
Day 1	0.79 ± 0.01	0.75 - 0.85	0.79 ± 0.01	0.73 - 0.84	0.72
Day 6	0.78 ± 0.01	0.73 - 0.83	0.76 ± 0.01	0.71 - 0.83	0.41
Day 12	0.76 ± 0.01	0.69 - 0.80	0.75 ± 0.01	0.68 - 0.78	0.31
Day 18	0.76 ± 0.01	0.69 - 0.80	0.74 ± 0.01	0.63 - 0.78	0.27
pH					
Day 0	6.86 ± 0.07	6.56 - 7.71	6.74 ± 0.04	6.39 - 7.15	0.31
Day 1	6.67 ± 0.02	6.41 - 6.81	6.67 ± 0.03	6.45 - 6.90	0.83
Day 6	6.66 ± 0.01	6.56 - 6.78	6.67 ± 0.03	6.25 - 6.90	0.85
Day 12	6.66 ± 0.03	6.48 - 6.79	6.72 ± 0.03	6.44 - 6.90	0.33
Day 18	6.63 ± 0.02	6.47 - 6.76	6.71 ± 0.03	6.45 - 6.87	0.14

Effects of storage temperature on the survival of *S.* Typhimurium and *S. aureus* in smoked catfish are shown in Fig. 4.7. *Salmonella* numbers decreased during storage at all temperatures and throughout the storage period. There was a 1.6 log units decrease in *Salmonella* counts from 4.37 log on day 0 to 2.79 log on day 1 in catfish samples stored at 25°C. This was significantly greater (p= 0.008) compared to a 1.0 cfu/g decrease observed in smoked catfish stored at 4°C which decreased from log 4.29 on day 0 to log 3.30 cfu/g on day 1. Generally, the results showed a significantly higher number of *S.* Typhimurium in samples stored at 4°C than those stored at 25°C throughout the study period. This is likely due to the low levels of water activity recorded in the samples stored at 25°C compared to those stored at 4°C (Table 4.5). No significant differences were observed in the counts of *S. aureus* in smoked catfish stored at 4 or 25°C during the first 24 hours of

storage. The mean *S. aureus* counts on day 6 was significantly lower at 25°C (2.36 logs) than at 4°C (3.0 logs). Similarly, mean *S. aureus* numbers were significantly lower ($p < 0.05$) at 25°C (1.08 logs) than at 4°C (1.84 logs) on storage day 12. *S. aureus* was not detected on day 18 in any of the smoked catfish samples.

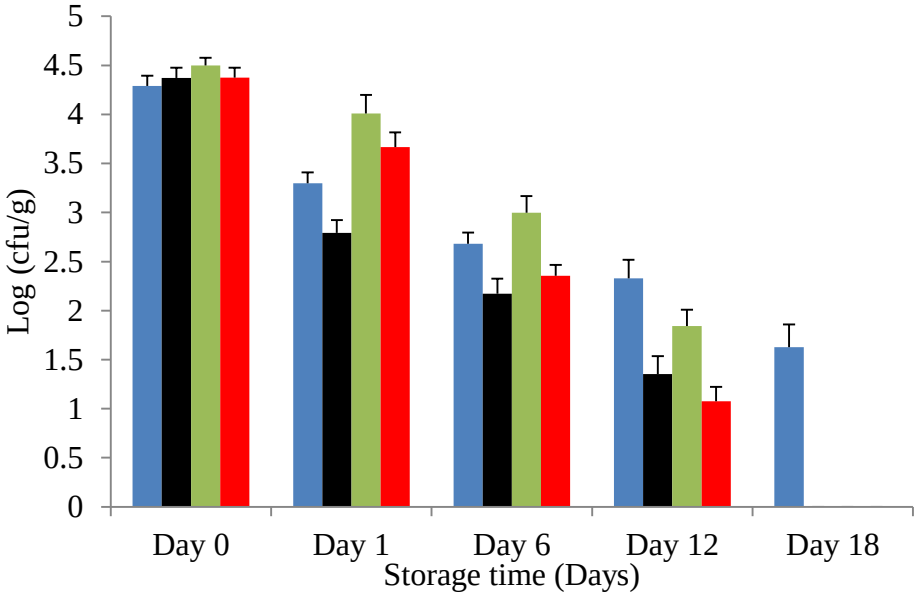

Fig. 4.7. Survival of *Salmonella* Typhimurium (at 4°C● and 25°C●) and *S. aureus* (at 4°C● and 25°C●) in smoked catfish

The Pearson correlation analysis showed a strong correlation ($p<0.05$) between *S.* Typhimurium counts and a_w of smoked catfish (Fig. 4.10a-d).

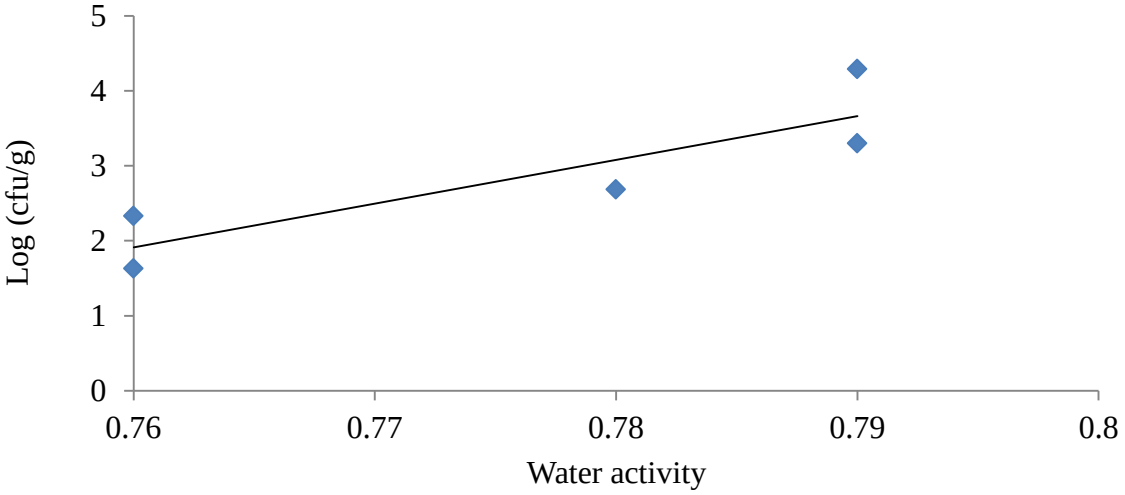

Fig. 4.8a. Correlation between water activity of smoked catfish stored at 4°C and survival of *Salmonella* Typhimurium

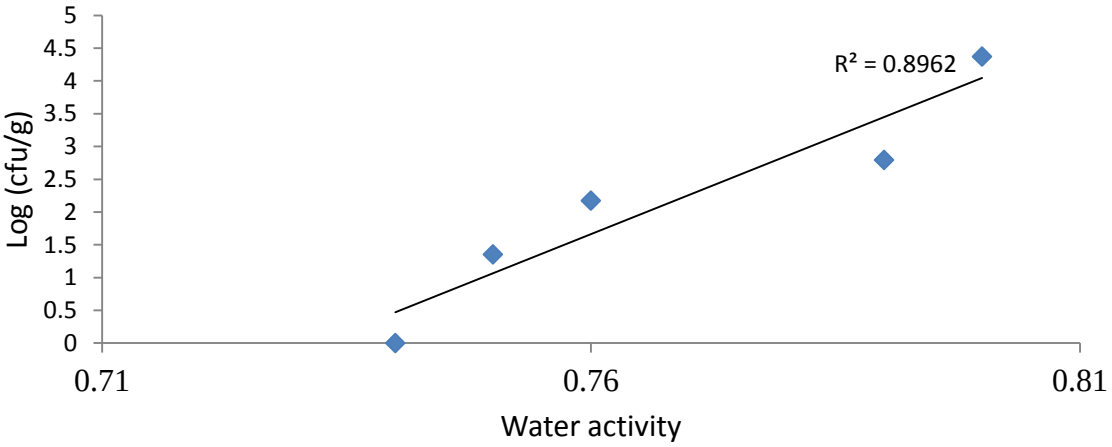

Fig. 4.8b. Correlation between water activity of smoked cat fish stored at 25°C and survival of *Salmonella* Typhimurium

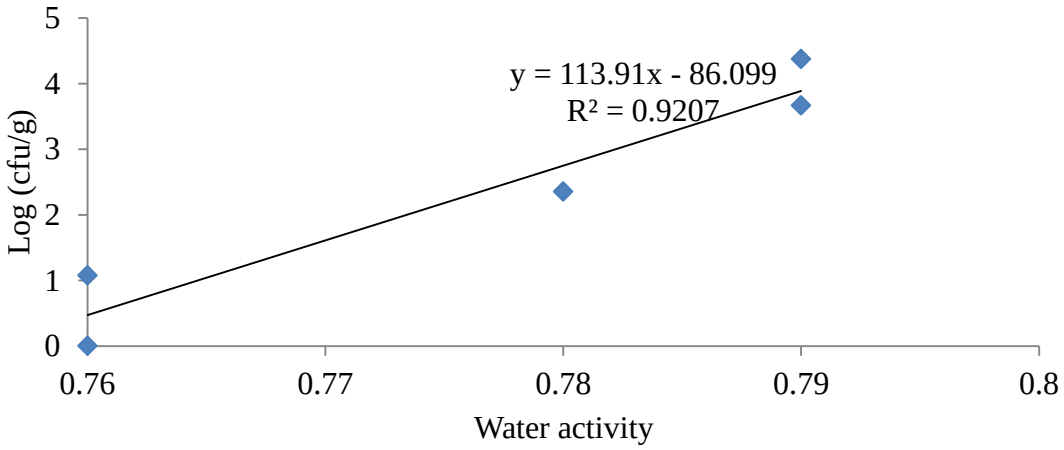

Fig. 4.8c. Correlation between water activity of smoked catfish stored at 4°C and survival of *S. aureus*

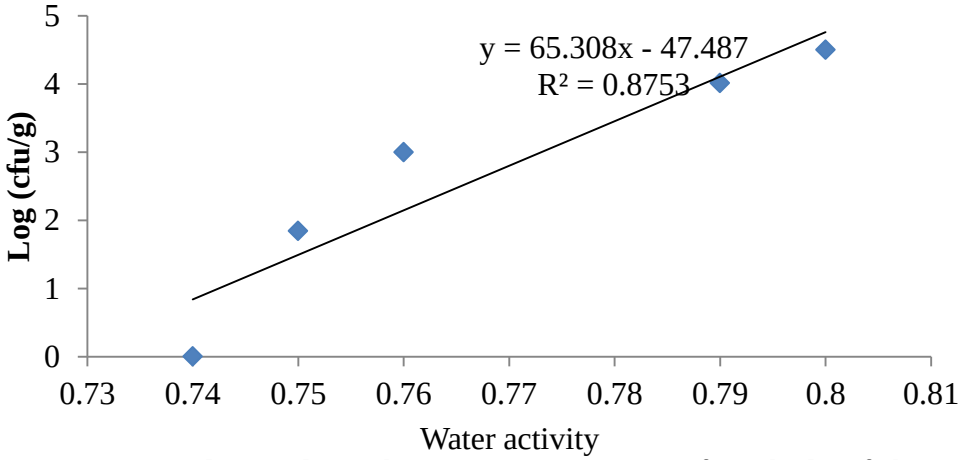

Fig. 4.8d. Correlation between water activity of smoked catfish stored at 25°C and survival of *S. aureus*

4.3.2 Results of sensory analysis

Table 4.5 is a summary of shelf life of the salted and smoked fish analysed by panellists.

Table 4.5. **Table of shelf life of traditionally salted and dried fish and smoked fish products stored at 4°C and 25 °C**

Fish Product	Rejection day	
	4 ± 1°C	25 ± 1°C
Koobi	>72	>72
Kako	>72	>72
Smoked catfish	>72	>72
Smoked herrings	>72	>72

4.3.2.1 Sensory analysis of salted and dried kako and koobi products

Most salted and dried samples received scores above 7 on the first day of sampling for appearance, odour, texture and overall acceptability. Mean odour scores were however, below 7. On the whole therefore, all samples were classified as "very good to excellent" by panellists. Figure 4.9 shows the sensory scores of koobi. The effect of 72 days of storage on the sensory scores of koobi was minimal despite a general decline in sensory parameters.

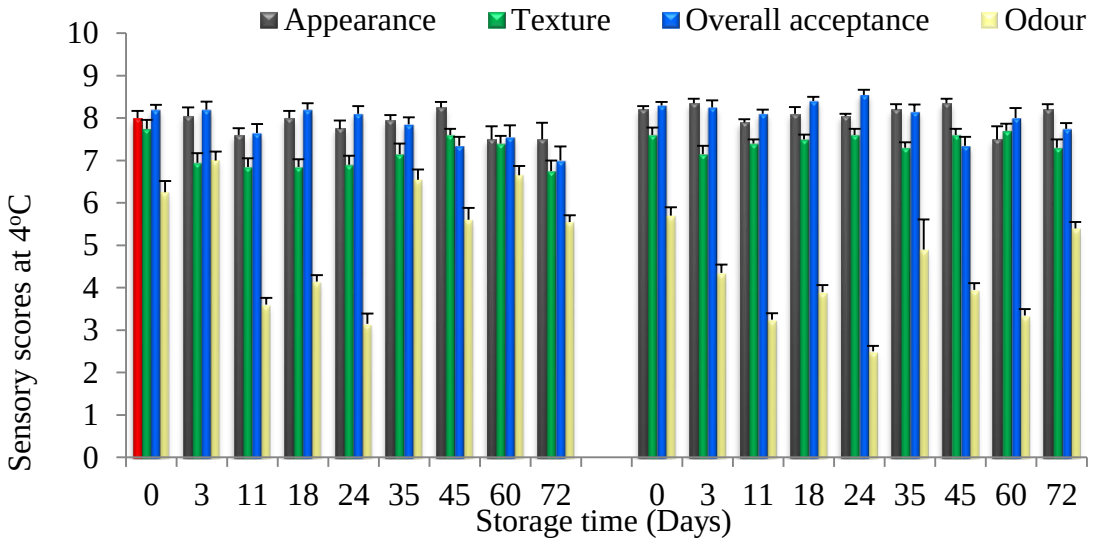

Fig. 4.9. Sensory evaluation of salted and dried tilapia (koobi) stored at 4 and 25°C

The appearance, texture and overall acceptability scores of koobi were significantly higher at storage temperature 25°C than at 4°C. Mean odour scores were significantly higher at 4°C than at

25°C. Mean appearance and overall acceptability scores were between 7 and 9 (very good to excellent score) throughout the storage period. Mean scores for texture were relatively high, but koobi scored low for odour. Figure 4.10 shows the sensory scores of kako. With the exception of overall acceptability, there was no difference in appearance, texture and odour scores for kako stored at 25°C and at 4°C. Appearance and texture scores remained above 7 throughout the storage period for kako stored at 4°C. However, odour and overall acceptability scores decreased during the same period for products stored at 4°C. For kako stored at 25°C, appearance, texture and overall acceptability remained relatively high during storage.

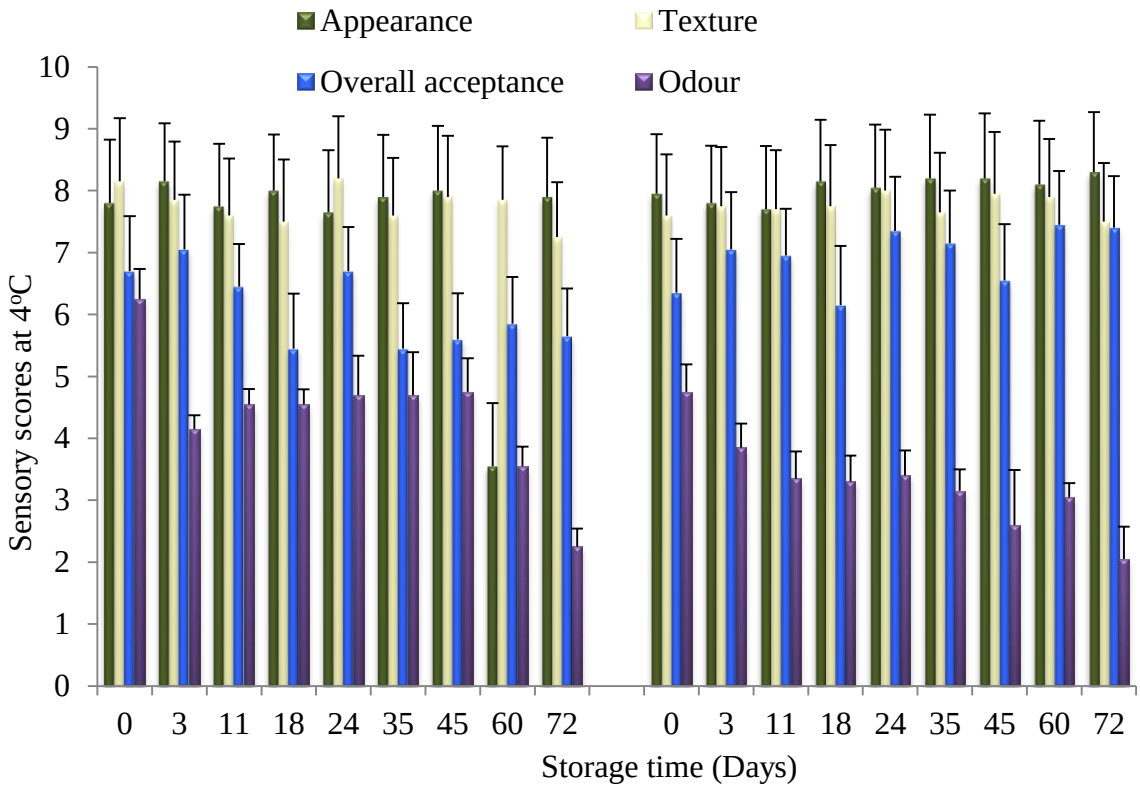

Fig. 4.10. Sensory evaluation of kako stored at 4 and 25°C.

Odour scores, however, decreased with increasing storage time, probably due to decreasing water activity and decreased microbial activity. Acceptability or rejection of the salted and dried fish products was not found to be influenced by odour of the products. Samples stored at 25°C scored higher than those stored at 4°C, except for odour. The odour characteristics were described as strong, pungent or fermented and rancid. Panellists commented that the aroma from salted and

fermented products were generally acceptable because this imparts a characteristic flavour to food. Texture of koobi and kako were described as dry, leathery and hard.

4.3.2.2 Sensory analysis of smoked herrings and smoked catfish products

As the results show, smoked catfish and smoked herring samples were scored as excellent or very good throughout the entire storage period. Mean scores for appearance, odour, texture and overall acceptability of smoked catfish and smoked herring samples were above 7.0 throughout the 72 day storage period. Appearance, odour, texture, and the overall acceptability scores of mackerel samples decreased regardless of storage temperature. Figure 4.11 shows the results of the sensory analysis of smoked catfish. Catfish products sampled received significantly higher scores for appearance, texture, odour and overall acceptance throughout the storage period. Generally, catfish products stored at 25^{o}C received higher scores for appearance, texture, odour and overall acceptability than samples stored at 4^{o}C throughout the storage period. However, this difference was not significant. Overall acceptability, odour, texture and appearance scores for catfish products stored at 25^{o}C were in the 7-9 range and declared "very good to excellent". For catfish samples stored at 4^{o}C, sensory scores for acceptability remained between 7-9 throughout the storage period, however, this was lower than the acceptability scores for their counterparts stored at 25^{o}C with means of 7.44 ± 0.83 0.87 and 7.74 ± 0.68 0.71, respectively. Texture, odour and appearance scores followed a similar pattern to acceptability scores, and there were no observations of deterioration in sensory features. Mean scores for texture were 6.83 ± 0.95 and 7.34 ± 0.63; mean odour scores were 6.88 ± 0.79 and 7.39 ± 0.60; and mean appearance scores were 7.37 ± 0.87 and 7.74 ± 0.71 at 4^{o}C and at 25^{o}C, respectively.

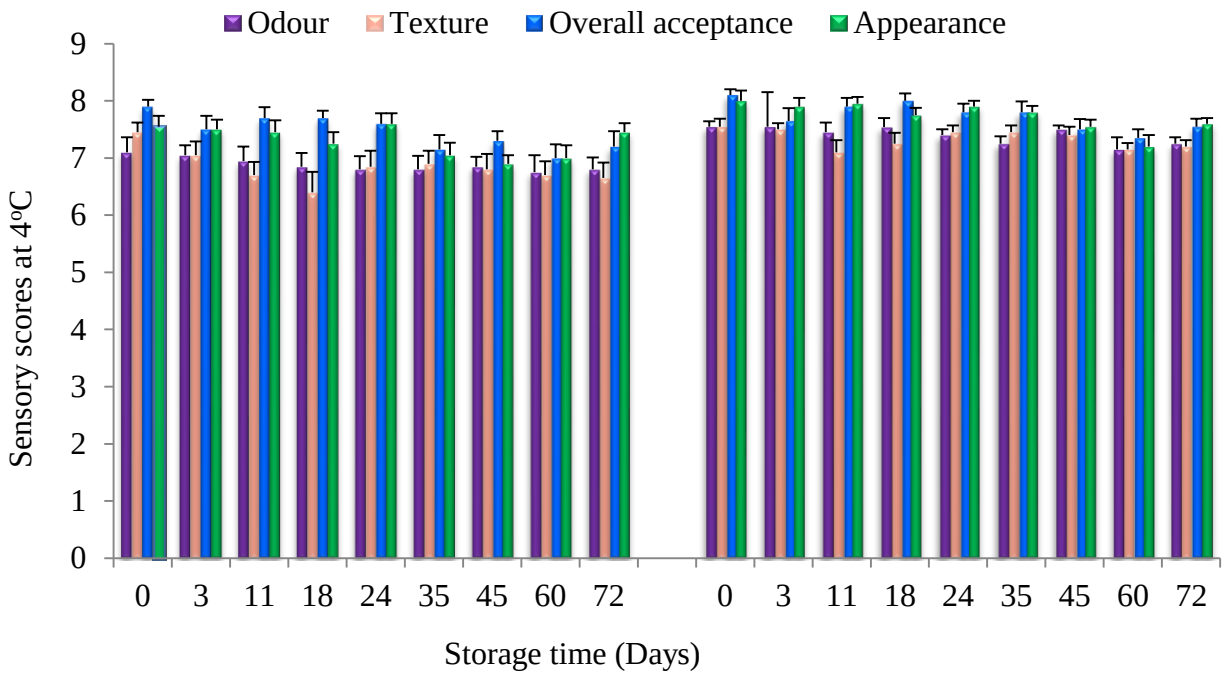

Fig. 4.11. Sensory scores of smoked catfish stored at 4 and 25°C

Figure 4.12 shows the sensory scores of smoked herrings. In general, after 72 days of storage the overall scores for appearance for smoked herrings only decreased slightly with increasing storage time and the higher sensory scores at 25°C may be attributed to improved drying. Samples stored at 25°C scoring higher than those stored at 4°C. As storage time progressed, the sensory scores of samples of smoked herrings decreased and this decrease was higher in products stored at 4°C than for products stored at 25°C. Smoked herrings are usually stored as dried products Overall acceptability scores for smoked herrings were 7.25 and 7.5 for samples stored at 4°C and 25°C on the 72nd day of storage. None of the smoked herring samples was rejected on the 72nd day of assessment, an indication that this product may have a longer shelf-life beyond 72 days. The texture, odour, appearance and overall acceptability remained significantly unchanged throughout the storage time. Refrigeration and freezing lower the temperature of food to levels at which bacterial metabolic processes are stopped and the rates of chemical and biochemical reactions reduced and therefore, are well-known techniques for extending the shelf-life of food products (Norhana *et al.*, 2010). It is important that GMPs and PRPs are strictly adhered to during processing, storage, transportation, retail and consumer handling of these products. Refrigeration

did not however, have any significant impact on the shelf-life and sensory properties of the salted and dried fish (koobi and kako) and smoke-dried catfish and herrings. These were dried products with low water activity and can therefore be regarded as low risk products even under ambient conditions.

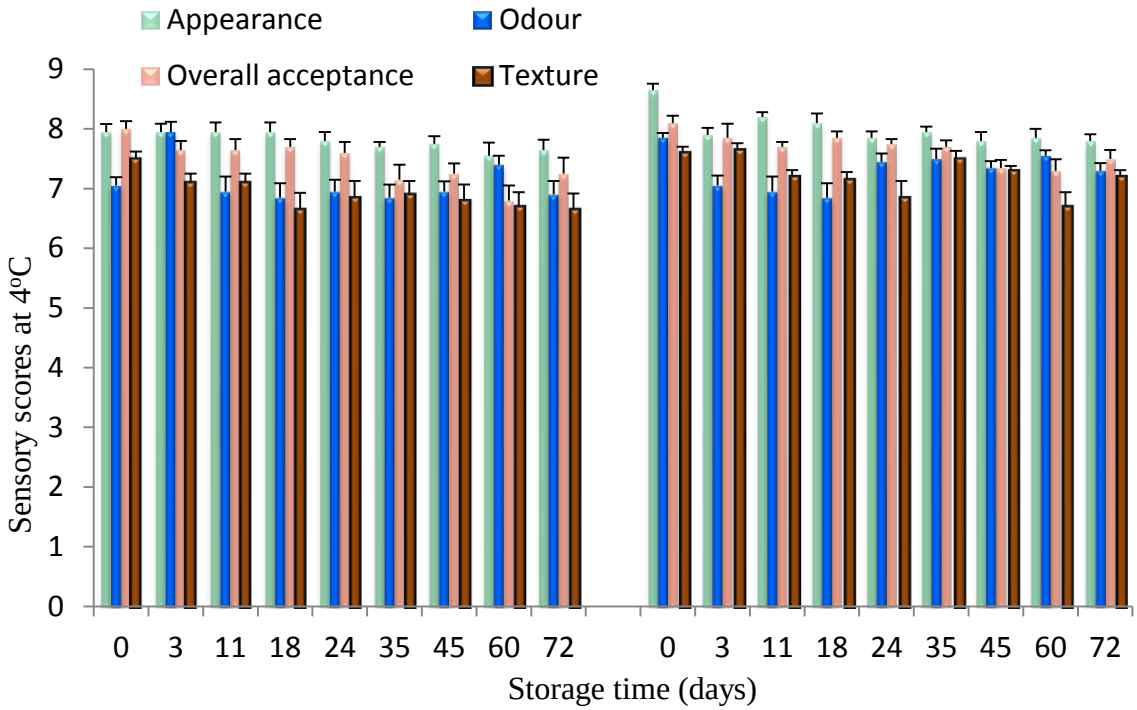

Fig. 4.12. Sensory evaluation of smoked herrings stored at 4 and 25ºC

4.4 Discussion

Studies on survival of *Salmonella* and *S. aureus* in artificially contaminated salted-dried tilapia (koobi), shark (kako), smoke-dried herrings and smoke-dried catfish from West Africa have to date not been reported in the scientific literature. The findings from this study show that in smoke-dried fish samples (smoked herrings and smoked catfish) *Salmonella* and *S. aureus* counts decreased throughout the storage period. Similarly, *S.* Typhimurium and *S. aureus* counts decreased in salted and dried fish (koobi and kako) throughout the storage period. This decrease in number seems rather likely to be due to their low water activity levels and the drying process involved in the processing of these fish products. This drying process continues even after processing and in storage. However, the possibilities for the growth of *Salmonella* and *S. aureus* under the a_w conditions observed in these products is small and probably negligible. The minimum a_w for the growth of *Salmonella* strains is 0.92-0.93 (Bremer *et al.*, 2003) and the optimum is 0.99 (Mattick *et*

al., 2000). The highest a_w levels observed in this study were kako (0.83), koobi (0.79), smoke-dried herrings (0.89) and smoke-dried catfish (0.80). However, *Salmonella* can tolerate many stressful conditions and can survive in low a_w foods for long periods (Jung and Beuchat, 1999; Arkoudelos *et al.*, 2003; Ristori *et al.*, 2007). In this study *S.* Typhimurium survived for 6 days in kako, 12 days in koobi, 18 days in smoked herrings, 12 days at 25°C and 18 days at 4°C in smoke-dried catfish. Wijnker *et al.* (2006) have also found that at a_w levels of 0.85 or lower, *S.* Typhimurium inoculated (5 log cfu/g) on salted natural casings could survive less than 15 days during storage at 20± 1.5°C. In contrast to these findings, long term survival of *Salmonella* has been shown in salted horse mackerel (Mol *et al.*, 2010) and salted sardines (Arkoudelos *et al.*, 2003). Arkoudelos *et al.* (2003) reported that at a_w levels of 0.69, *Salmonella* Enteritidis survived in salted sardine for 60 days. Mol *et al.* (2010) however, observed that *Salmonella* survived longer in salted samples than in salted-dried and dried samples. These differences may be due to variations in the drying process of fish.

Staphylococci thrive in environments relatively free of competition from other bacteria, such as foods with high concentrations of salt and sugar that impede the growth of other organisms (Aycicek *et al.*, 2005). Basti *et al.* (2006) have reported the presence of *S. aureus* in heavy-salted fish and heavy-salted, cold-smoked fish. Staphylococci have also been shown to grow best in salty and low water activity-containing foods in which competing organisms are in reduced numbers (Vishwanath *et al.*, 1998). In this study, at 4°C and 25°C *S. aureus* survived for 12 days in koobi and smoke-dried catfish and 18 days in kako and smoke-dried herrings. The findings also show that *S. aureus* and *Salmonella* numbers declined with time under both refrigeration and ambient conditions of storage. At 4 and 25°C *S.* Typhimurium and *S. aureus* survived in dry salted koobi (a_w range: 0.61 – 0.85) for 12 days. At 4 and 25°C *S.* Typhimurium survived in dry salted kako (a_w range: 0.57 – 0.83) for only 6 days and *S. aureus* survived for up to 18 days. These findings are consistent with those of Ristori *et al* (2007) who reported that at low a_w greater numbers of *Salmonella rubislaw* survived in ground black pepper stored at 5°C, than at 25°C and 35°C. The minimum number of ingested salmonellae necessary to produce clinical symptoms in humans

remains a contentious issue (D'Aoust, 1985). Akman and Park (1974) had earlier reported that large doses of salmonellae are required to initiate food poisoning. These large doses can arise only through massive contamination or through light contamination followed by the opportunity for growth before ingestion (Akman and Park, 1974). D'aoust (1985) has also reported that very few salmonellae can be infectious and the US FDA has put the infective dose at as few as 15-20 cells (FDA, 2009).

According to the U.S. Food and Drug Administration, a toxin dose of less than 1.0 μg in contaminated food will produce symptoms of staphylococcal intoxication and this toxin level is reached when *S. aureus* populations exceed 10^5 cfu/g (FDA, 1992). Other studies report that for toxic levels of enterotoxin to occur, increases of about 10^6 to 4×10^7 cfu/g staphylococci levels must be reached (Anunciacao *et al.,* 1995; Walls and Scott, 1997; Fujikawa and Morozumi, 2006). In this study, only smoked mackerel samples recorded higher than 10^5 cfu/g growth of *S. aureus.* NaCl and other solutes inhibit *S. aureus* from staphylococcal enterotoxin A synthesis, glucose utilization, and respiratory activity (Taormina (2010). Reduced levels of water activity may inhibit toxin synthesis more than growth. The decline in the number of *S.* Typhimurium and *S. aureus* in the salted fish products and smoke-dried herring and catfish may be attributed to high salt level and low water activity of the products. These conditions do not favour the growth of *Salmonella* or survival and would inhibit growth and toxin production by *S. aureus*. Dry salt application to animal-derived products appears particularly lethal to bacterial pathogens (Taormina, 2010). However, *Staphylococcus* is more salt-tolerant than most other bacteria. Lowering of a_w by NaCl is viewed by some researchers as most likely the primary cause of microbial growth inhibition (Shelef and Seiter, 1993). Very low levels of NaCl may however provide a stimulatory, rather than inhibitory effect on *Salmonella* (Taormina, 2010). Jung and Beuchat (1999) reported a protective effect of refrigeration temperature on the viability of *S.* Typhimurium. In this study, the numbers of *S.* Typhimurium in the refrigerated samples were higher than in the samples stored under ambient conditions. Refrigeration may therefore have some protective effect on *S.* Typhimurium. Although *Salmonella*

does not grow in a_w below 0.93 (Varnan and Evans, 1991), it has been reported that the bacteria may survive for long periods (Sperber, 1983) under low a_w and low temperature conditions.

The preservation of fish products by rendering the fish unsuitable for microbial proliferation has long been realised by reducing a_w through drying and salting (Sen 2005). Decreasing a_w further eliminates bacterial growth, and only extremophiles (such as halophiles or osmophiles) and filamentous fungi are capable of developing on dried, salted fish (Pitt and Hocking, 1997). The aim of salting and drying is not only to extend the shelf-life of fresh fish, but also to provide desirable sensorial changes (Andres *et al.*, 2005). In this study salted-dried koobi and kako, and smoke-dried catfish and herrings were stored beyond 72 days without any significant changes in sensory characteristics. In addition to the preservation effect, temperature has been shown to be an important environmental parameter influencing the growth rate and type of spoilage microorganisms of highly perishable foods such as fish products. In this study storage temperature did not significantly affect sensory characteristics and shelf life of the fish products under consideration. The educational message here is that it is more important to avoid contamination with microorganism at all costs during processing, and prior to storage of the food product since some organisms can survive low temperature storage conditions. It is also recommended that processing periods should be long enough to reduce a_w sufficient to inhibit pathogens. In conclusion, this study indicated that *S.* Typhimurium and *S. aureus* may survive in salted and dried koobi, kako and smoke-dried herrings and catfish but their numbers decrease rapidly with storage time. Other hazards could be present such as histamines. Salmonellae can survive 40 weeks at refrigerator temperatures (Park *et al.,* 1970). However, traditional food preparations in Africa involve a long period of cooking. Since *Salmonella* spp. is heat labile, any surviving *Salmonella* in these products would be destroyed during intense cooking. However, any staphylococcal enterotoxin formed by *S. aureus* would not be destroyed by cooking. In addition, some hot-smoked mackerel are sometimes consumed without further cooking. This may pose risk of foodborne infections and intoxications.

Chapter 5

5.0 Food safety knowledge, attitudes, practices and concerns of consumers and food handlers in Ghana

5.1 Introduction

Food safety issues are of concern to the regulatory authorities in Ghana and attempts are being made to improve their operations (Amoa-Awua *et al.,* 2007). Ghana Food and Drugs Board (FDB) data show that in 2006 alone, 297,104 cases of food borne diseases and 90,692 deaths from food and personal hygiene-related illnesses were reported (FDB, 2008). It has also been estimated that one in forty people suffer each year from serious food-borne disease (Anon, 2008a). The Ministry of Health estimates that eight deaths occur every hour in Ghana due to inadequate sanitation and as many as 420,000 out-patient cases of food and water borne diseases occur each year with an annual death rate of not less than 65,000 (Anon, 2008a; Anon, 2008b). Thus the impact of food-borne illness on public health and clinical services are not insignificant. A significant proportion of foodborne illnesses arise from poor food handling and hygiene practices of consumers (Scott *et al.,* 1982; Bean and Griffin, 1990; Williamson *et al.,* 1992; Scott, 1996; Redmond and Griffith, 2003b). Poor hygienic practices in food businesses result from either a lack of knowledge or negligence and are considered a major contributor to the prevalence of foodborne illnesses (WHO, 2000a). This is especially the case in small businesses and commercial catering (Fein *et al.,* 1995; Howes *et al.,* 1996; Motarjemi and Käferstein, 1999; Olsen *et al.,* 2000; WHO, 2000b; Clayton *et al.,* 2002; Clayton and Griffith, 2004; Egan et al., 2007; Knight *et al.,* 2007).

5.1.1 Study Rationale and scope of the survey

There is currently limited information available regarding food safety awareness, attitudes and practices of food industry employees and consumers in Ghana. In addition, there have been only a few published studies on HACCP in Ghana. The only two reported studies are on cassava-based convenient foods (Johnson *et al.* 2008) and kenkey (Amoa-Awua *et al.* 2007). This study investigated the hygiene perceptions of consumers and food handlers in industries processing fish.

5.1.2 Study goal and objectives

The goal of this part of the study was to identify: (a) food safety practices, attitudes, and knowledge of users of traditional fish products, consumers and fish industry employees; and (b) the major risk factors that may contribute to food-borne disease outbreaks. The objectives of the study were to:

- identify food safety practices that contribute to the occurrence of foodborne illnesses in retail foodservice operations;
- identify the areas where food safety knowledge is lacking among commercial food handlers and consumers;
- assess the level of public concern about perceived risks associated with various food production, processing and safety issues; and
- identify food safety training needs of retail foodservice employees

The following hypotheses were tested:

Null hypothesis 1 (Ho1): Current traditional food safety knowledge, perceptions and practices among fish retailer/handlers and consumers in Accra meet satisfactory food safety and quality standards.

Null hypothesis 2 (Ho2): Good food safety attitudes and practices currently exist among stakeholders in Accra, Ghana to assure a higher degree of safe food among the population.

5.2 Survey methodology

A cross-sectional survey was conducted to obtain information about commercial food handlers' and consumers' knowledge, attitudes, practices and concern of a variety of food safety and hygiene issues. Two questionnaires were designed, one for consumers (Appendix A) and another for fish industry employees (fishermen, fish processors, fishmongers, cold store workers and vendors) or commercial users of traditional fish products (restaurants and commercial catering facilities) (Appendix B). The questionnaires were administered in the Greater Accra region of Ghana between June and July 2007.

5.2.1 Questionnaire design

Each of the questionnaires consisted of a demographic section as well as questions that addressed food safety knowledge of respondents including personal hygiene, knowledge of food hazards, causal agents of food poisoning and food borne illness and high-risk food groups. Other questions were designed to assess food safety practices and attitudes, self-reported food-handling practices, food safety concerns, cross-contamination, food safety training, profile of food processing or vending establishment and the impact of food safety requirements on food business.

Most of the questions were closed-ended and asked for a check box yes/no/don't know or true/false/don't know answer; or asked the respondent to select from a pre-defined set of possible answers, usually numerical. Other sections were followed by four response options, *always, most of the time, sometimes* and *never* or a check box yes/no/don't know answer. Perceived susceptibility was assessed by asking, "How common do you think it is for people in Ghana to become sick from food poisoning?" followed by four response options using the hedonic (Likert) rating scale (Babbie, 2005), ranging from 1 = very common, 2 = somewhat common, 3 = not very common and 4 = don't know or 1 = always, 2 = most of the time, 3 = sometimes and 4 = never. Respondents were also asked to choose one of five options, *not at all concerned, slightly concerned, concerned, highly concerned and extremely concerned,* to show the extent to which they were worried or concerned about a number of food safety issues. The food handlers' questionnaire also covered sources of food safety information, barriers to compliance, confidence in food safety competent authorities, food safety training and impact of food safety requirements on business. Finally, the last four sections were administered only to commercial food handlers and included questions on food safety training, barriers to training, profile of the food service facility, sources of food safety information and impact of food safety practices on market opportunities. These questions were compiled from an extensive review of the food safety literature using simple, concise, specific and closed-ended questions.

5.2.2 Pilot study

Questionnaires were pilot-tested in ten food business units and 15 households to assess question clarity and validity, identify response options and gauge interview duration. Based on feedback questionnaires were revised. The results of these pilot studies were not included in any further assessment.

5.2.3 Sampling, subject recruitment and assignment and delivery of food handler questionnaire

The survey was divided into two parts involving household consumers and food service workers (food handlers) in different districts of Greater Accra. Districts were selected by means of a cluster sampling procedure (Farmer et al., 1996) to ensure distribution from the Eastern, Southern, Central, Western and Northern parts of the region. A total sample of 224 adults (consisting of 109 consumers and 115 commercial food handlers) was interviewed. The age distribution of subjects ranged from 18 years to 64 years with a male: female ratio of 49.5:50.5 (household consumers) and 30.1:60.9 (food handlers) respectively. All questionnaires were administered by face-to-face interviews. Each business or household was visited by personnel trained in conducting face-to-face interviews and administering this questionnaire. All interviewers had educational backgrounds in food science and nutrition. Questionnaires were prepared in English, but interviewers translated the questions into the preferred local dialects of the respondents, including, *Ga, Ewe, Twi, Frafra, Hausa* and *Kasim*. To avoid response bias, care was also taken not to lead respondents in answering the questions in a specific manner. All respondents were encouraged to answer honestly.

5.2.4 Respondents' consent and data protection

For ethical reasons, subject recruitment was purely voluntary and based on prior informed consent. Subjects were first approached and the survey explained to them. The letter of consent was either given to them or read to those who could not read and subjects asked if they would volunteer to take part. Assurances of confidentiality and their freedom to withdraw from the study at any time were given. Those who declined to take part were excluded from the study. A total of 224 subjects

consented to take part and are included in this report. Respondents were assured that no information they provided would be passed on to third parties e.g. their manager or health and safety enforcement officers.

5.2.5 Data analysis

The questionnaire responses were analysed using the statistical software program, SPSS version 18.0 and Excel 2010. Mean responses with standard error of means and percentages of responses in each category were calculated and presented in tabular or graphical form. Descriptive statistics were used to summarize the demographic data. To examine the relationship among and between the variables, cross-tabulations, χ^2 test, independent sample t-test, Pearson correlation coefficient and analysis of variance were used and significant differences determined between and among groups.

5.3 Results and Discussion

5.3.1 Demographic profile of respondents

Demographic characteristics of survey participants are shown on Table 5.1. Of the 224 respondents, 109 were household consumers and 115 were commercial food handlers. The mean age of food handlers was 38.7 years, the majority were female (60.9%) and married (67.8%). Twenty-three percent of food handlers surveyed had no form of formal education. Compared with women, men were more likely to have at least some primary education (p=0.008). The high proportion of female participants among the food handlers reflects the high ratio of the female population involved in traditional food handling in Ghana. The mean age of the consumers surveyed was 35.6 years, most (70.6%) had secondary level education, 54.1% were married and just over half (50.5%) were female. Nearly 6% of the consumers surveyed were unemployed and 17% were students. The rest of the consumers were all full-time, part-time or self-employed.

Table 5.1. Demographic characteristics of respondents

Factor	Level	Consumers n	Consumers %	Food handlers n	Food handlers %
Age group	18-24	25	22.9	9	7.8
	25-34	28	25.7	36	31.3
	35-44	29	27.5	32	27.8
	45-54	21	19.3	35	30.4
	55-64	5	4.6	3	2.6
Gender	Male	54	49.5	45	39.1
	Female	55	50.5	70	60.9
Marital status	Single	47	43.1	28	24.3
	Married	59	54.1	78	67.8
	Others	3	2.8	9	7.8
Education	None	0	0.0	27	23.5
	Primary	29	26.6	32	27.8
	Secondary	77	70.6	25	21.7
	Tertiary	3	2.8	31	27.0
Work status	Employed full time	55	50.5	43	37.4
	Employed part time	15	13.8	8	7.0
	Self-employed	13	11.9	64	55.7
	Unemployed	6	5.5	0	0.0
	Student	19	17.4	0	0.0
	Others	1	0.9	0	0.0
Income group					
Below GH¢ 10, 000 p.a.		35	32.1	41	35.7
GH¢ 10,000 – 15,000 p.a.		29	26.6	36	31.3
GH¢ 15,001 – 20,000 p.a.		12	11.0	18	15.7
GH¢ 20,001 – 30,000 p.a.		16	14.7	15	13.0
GH¢ 30,001 and over p.a.		13	11.9	5	4.3
Missing		4	3.7		
In the last 12 months have you experienced any foodborne illness?					
	Yes	86	78.9	87	75.7
	No	23	21.1	28	24.3
Is it common to get food poisoning in Ghana?					
	Very common	84	77.1	67	58.3
	Somewhat common	13	11.9	31	27.0
	Not very common	5	4.6	4	3.5
	Don't know	7	6.4	13	11.3

The majority of food handlers (67.0%) and consumers (58.7%) earned below GH¢ 15,000 per annum (the equivalent of £6000 in 2007), making them low income earners. These findings further

corroborate previous studies which show that fishing communities in Ghana have low incomes and less income stability because of wide seasonal fluctuations in fish catch (Bortei-Doku, 2000). A very high number of the respondents, including 75.7% of food handlers and 78.9% consumers reported contracting some form of foodborne illness in the 12 months prior to the survey. Significantly a higher proportion of consumers (77.1%) than food handlers (58.3%) surveyed said it was very common to become sick from food poisoning because of the way the food was prepared or handled in Ghana (p=0.014). Respondents with secondary or lower education (68.9%) were more likely to say that foodborne diseases were very common in Ghana than those with higher education (50.6%) (p = 0.52). Female respondents (69.6%) were also more likely than their male (44.4%) counterparts to say that foodborne diseases were very common (p = 0.62).

The perception that foodborne disease was very common in Ghana varied with age. Significantly, only 7.1% and 13.1% of younger respondents (18-25) and older respondents (56-64) thought that foodborne diseases were very common in Ghana (p = 0.022). These perceptions among respondents may not necessarily reflect the incidence of food poisoning. It is apparent that very young and older respondents did not regard it as such a problem. From this result, the fact that people are concerned about the condition should hopefully influence their own preventive practices. The true burden of foodborne illness in Ghana is likely under-reported and any official data for foodborne illness may represent only the tip of the iceberg as in many other countries (Mossel, 1989; Wheelock, 1999; Soon *et al.*, 2011). Although many foodborne diseases are self-limiting, it is important that foodborne diseases are reported at health facilities so that outbreak investigations can be carried out in a timely and systematic manner, and appropriate prevention and control measures applied.

Respondents who reported having had some foodborne diseases cited diarrhoea (28.1%), vomiting (33.9%), abdominal cramps (15.2%), headache (10.3%), fever/chills (0.5%) and constipation (1.9%) (Fig. 5.1). Significantly, only 14.5% of those who reported having had foodborne disease, including

19.3% of consumers and 2.6% of food handlers, said their foodborne disease was diagnosed in the hospital.

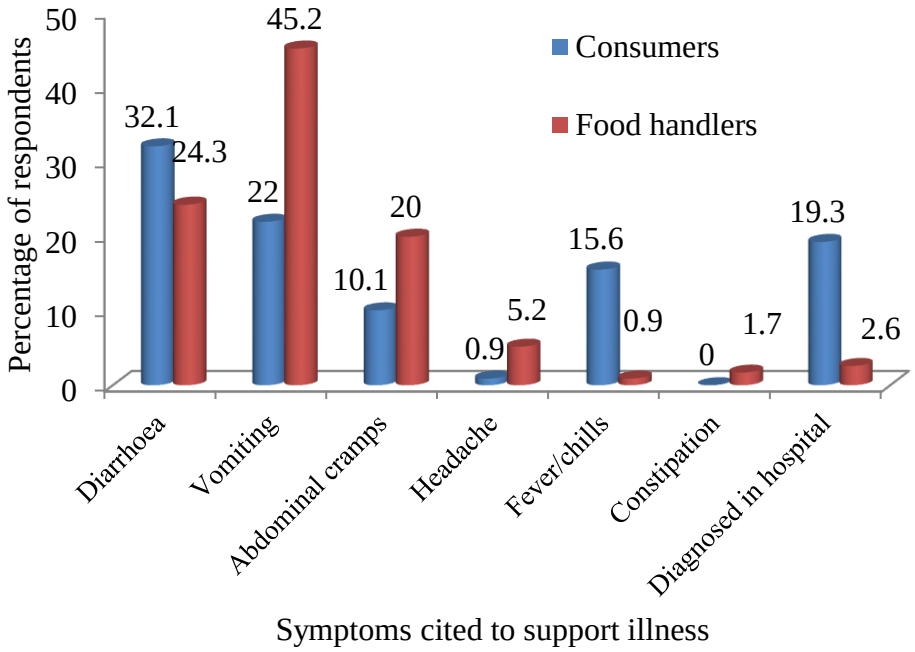

Fig. 5.1 Reasons cited by respondents as evidence of their contraction of foodborne infections

5.3.2 Food safety knowledge assessment

5.3.2.1 Knowledge of food safety hazards

A significant majority (70.0%) of the respondents perceived microbiological hazards as the greatest threat to food safety followed by pesticides (58.0%) ($p < 0.001$) (Table 5.2). A higher percentage of consumers (78.9%) compared with food handlers (61.7%) identified microorganisms as the main risk to food safety ($p < 0.001$). However, a slightly higher percentage of food handlers (60.0%) than consumers (56.0%) identified pesticides as the main risk to food safety ($p = 0.001$). In surveys conducted in America (Sloan, 1998), Japan (Hoban, 1999) and in New Zealand (Scully, 2003), microbial contamination was regarded as the most significant food safety problem by most of the respondents. In contrast, in a survey in the Caribbean region, consumers rated pesticide residues as the highest perceived food safety risk (Jackson *et al.*, 2003). Risk perception is largely influenced by food safety information and communication provided by the media, public authorities, peer groups and is amplified by trust in the information sources and food safety scares (Yeung and Morris, 2001; Yee *et al.*, 2005; Lobb *et al.*, 2007). The majority of respondents were aware that insects (96.9%), food

handlers (91.5%) and raw food materials (82.1%) could serve as vehicles for the transmission of food poisoning bacteria. Significantly ($p = 0.01$), a higher percentage of consumers (93.3%) than food handlers (89.6%) perceived food handlers as vehicles for the transmission of food poisoning bacteria. Proper hand washing has been recognized as one of the most effective measures to control the spread of pathogens. Survey participants were asked how long hands should be rubbed together with soap during hand washing.

Table 5.2. Knowledge of sources of food safety hazards and hand washing exhibited by consumers and food handlers

Statement	Consumers %	Food handlers %	p-value
Perception of major food safety problems			
Pesticides	56.0	60.0	p<0.001
Hair	0.0	17.4	0.0004
Microorganisms	78.9	61.7	0.03
Food poisoning bacteria may be brought into the kitchen by			
By insect	96.0	97.4	0.5
By handlers	93.3	89.6	0.01
In raw food	82.1	81.7	0.43
When washing your hands, you should rub your hands together with soap for at least			
20 seconds	33.0	34.8	$p < 0.05$
5 seconds	20.2	11.3	
10 seconds	44.0	48.7	
Don't know	2.8	5.2	

Significantly, only 33% ($p < 0.05$) of consumers and 34.8% ($p < 0.05$) of food handlers believe that hands should be washed for at least 20 seconds. Chi-squared analysis showed that knowledge of hand washing requirements was not influenced by age, gender or education. To prevent food poisoning, consumers and food handlers must be aware of the importance of the appropriate sanitation of kitchen utensils as well as thorough hand washing procedures. However, there are no guidelines for hand washing in Ghana.

5.3.2.2 Participants' perception of where food safety problems will most likely occur

When the respondents were asked to identify ''Where food safety problems were most likely to occur", the majority identified the home (91.6%) and restaurants (84.4%) (Table 5.3).

Table 5.3. Knowledge of likely sources or places where food safety problems can occur exhibited by consumers and food handlers (N=224)

	All Respondents		Consumers (n=109)					Food handlers (n=115)				
				Education	Age	Gender		Education	Age	Gender		
	n	%	(%)	p-value	p-value	p-value	%	p-value	p-value	p-value		
Consumers (n=109)												
Personal hygiene of consumer	202	90.2	89.0	0.374 ns	0.233 ns	0.174 ns	91.3	0.086 ns	0.325 ns	0.086 ns		
Personal hygiene of food handlers	202	90.2	88.1	0.507 ns	0.190 ns	0.400 ns	92.2	0.335 ns	0.226 ns	0.035 s		
Personal hygiene on farm	186	82.2	88.1	0.377 ns	0.134 ns	0.109 ns	77.4	0.0001 s	0.701 ns	0.153 ns		
Abattoir	202	90.2	90.8	0.929 ns	0.206 ns	0.748 ns	89.6	0.318 ns	0.693 ns	0.326 ns		
Processing factory	190	84.8	84.4	0.816 ns	0.208 ns	0.248 ns	85.2	0.071 ns	0.466 ns	0.937 ns		
Restaurant	189	84.4	82.6	0.714 ns	0.240 ns	0.739 ns	86.1	0.557 ns	0.186 ns	0.325 ns		
Supermarket	175	78.1	75.2	0.900 ns	0.146 ns	0.354 ns	80.9	0.088 ns	0.504 ns	0.720 ns		
Retailers	207	92.4	91.7	0.179 ns	0.001 s	0.282 ns	93.0	0.349 ns	0.700 ns	0.390 ns		
Storage	214	95.6	96.3	0.703 ns	0.014 s	0.572 ns	94.8	0.748 ns	0.453 ns	0.429 ns		
Home	205	91.6	93.6	0.445 ns	0.021 s	0.126 ns	89.6	0.404 ns	0.220 ns	0.910 ns		
Cooking	193	86.3	89.9	0.196 ns	0.483 ns	0.221 ns	82.6	0.053 ns	0.151 ns	0.145 ns		
Pets and pests	209	93.3	93.6	0.950 ns	0.198 ns	0.428 ns	93.0	0.680 ns	0.154 ns	0.710 ns		
Temperature abuse	159	71.1	73.4	0.666 ns	0.108 ns	0.273 ns	68.7	0.348 ns	0.279 ns	0.021 s		

Ns = not significant; s = significant (significance was set at the 5% level).

This result does not support previous studies which suggest that consumers generally underestimate the percentage of food safety problems that originate from home (Williamson *et al.*, 1992; Altekruse *et al.*, 1996). Abattoirs (90.2%), supermarkets (78.1%), food processing units (84.8%) and retail units (92.4%) were identified by respondents, as likely places where food poisoning could occur. Improper cooking procedure (86.3%), storage (95.6%) and temperature abuse (71.1%) were perceived as possible reasons for food poisoning. Respondents also associated personal hygiene of consumer (90.2%), food-handlers (90.2%) and personal hygiene on the fish farm (82.2%) to the likely occurrence of food poisoning. Chi square analysis of the influence of gender, education and age showed that among food handlers, the higher the educational status, the higher the perception of poor hygiene as a source of foodborne disease problems ($p<0.0001$) (Table 6.3). A statistically significant difference was also observed between male and female food handler respondents in their perception of hygiene and temperature abuse as likely sources of food safety problems ($p<0.035$). Among consumers, age was a significant factor in the perception that retailers and the home were sources of food safety problems. No significant difference was detected between food handlers and consumers in their perception of likely causes of food poisoning. These results show that people can relate hygiene and sanitation to food safety problems and such understanding should constitute a basis for food safety education.

5.3.2.3 Knowledge of good personal hygiene requirements and practices

Poor personal hygiene amongst food handlers is one of the most common contributors to outbreaks of food poisoning (Collins, 2001; Cogan *et al.*, 2002). In this study, most respondents (>92%; $p<0.05$) were aware of proper personal hygiene requirements including proper hand-washing, daily bathing, regular dental checks, hand-washing with soap and running water, thorough hand-drying and covering cuts and infections (Table 5.4). The hands of food handlers can be pivotal as vectors in the spread of foodborne disease due to poor personal hygiene or cross-contamination (Setiabudhi *et al.*, 1997). Significantly, most consumers (>97%; $p<0.05$) and food handlers (>88%; $p<0.05$) were aware of the need to wash their hands after touching their hair, using a handkerchief, visiting

Table 5.4. Food Handlers' and consumers' knowledge of good hygiene requirements (N=224)

Statements	Responses (%)	Education χ^2	Education p-value		Age χ^2	Age p-value		Gender χ^2	Gender p-value	
Consumers (n=109)										
Proper hand washing	98.2	0.847	0.655	ns	1.604	0.808	ns	2.075	0.150	ns
Daily bathing	98.2	0.847	0.932	ns	5.179	0.738	ns	2.075	0.354	ns
Getting regular dental checks	96.3	1.729	0.019	s	0.610	0.225	ns	1.41	0.494	ns
Washing hands with soap and running water	96.3	1.726	0.786	ns	0.800	0.214	ns	1.41	0.494	ns
Drying hands thoroughly	91.7	1.782	0.939	ns	1.590	0.479	ns	2.174	0.537	ns
Covering cuts and infections	97.2	1.282	0.527	ns	7.762	0.101	ns	0.362	0.547	ns
Sanitising surfaces in contact with food	97.2	3.594	0.464	ns	6.280	0.039	s	1.028	0.311	ns
Food handlers (n=115)										
Proper hand washing	100	-	-	-	-	-	-	-	-	-
Daily bathing	98.3	1.681	0.641	ns	3.816	0.282	ns	1.308	0.253	ns
Getting regular dental checks	88.7	11.091	0.086	ns	7.399	0.286	ns	0.441	0.802	ns
Washing hands with soap and running water	98.3	1.681	0.641	ns	1.053	0.788	ns	1.308	0.253	ns
Drying hands thoroughly	92.2	8.714	0.190	ns	6.994	0.321	ns	2.005	0.367	ns
Covering cuts and infections	97.4	8.347	0.039	s	2.008	0.571	ns	1.98	0.159	ns
Sanitising surfaces in contact with food	91.3	8.191	0.515	ns	7.948	0.539	ns	1.399	0.706	ns

ns = not significant; s = significant (significance was set at the 5% level).

Table 5.5. Food handlers' and consumers' knowledge of when to implement hand washing during food handling (N=224)

Statements	Correct Responses (%)	Education χ^2	Education p-value		Age χ^2	Age p-value		Gender χ^2	Gender p-value	
Consumers (n=109)										
Touching your hair	97.2	0.820	0.664	ns	1.912	0.752	ns	2.036	0.153	ns
Using a handkerchief	94.5	9.115	0.058	ns	12.67	0.124	ns	1.001	0.606	ns
Using the toilet	97.2	1.282	0.527	ns	4.387	0.356	ns	0.324	0.569	ns
Touching pimples or sores	98.2	0.847	0.655	ns	3.514	0.476	ns	0.000	0.990	ns
Coughing or sneezing	96.3	1.726	0.786	ns	9.251	0.322	ns	4.001	0.135	ns
Handling the rubbish	99.1	0.419	0.811	ns	2.539	0.638	ns	1.028	0.311	ns
Biting your nails	93.6	8.945	0.062	ns	3.120	0.108	ns	1.363	0.506	ns
Touching pets and other animals	100.0	-	-	-	-	-	-	-	-	-
Food handlers (n=115)										
Touching your hair	88.7	14.04	0.121	ns	10.85	0.286	ns	0.573	0.903	ns
Using a handkerchief	92.2	8.191	0.515	ns	7.948	0.539	ns	1.399	0.706	ns
Using the toilet	98.3	2.020	0.568	ns	4.467	0.215	ns	0.101	0.751	ns
Touching pimples or sores	100	-	-	-	-	-	-	-	-	-
Coughing or sneezing	97.4	4.606	0.595	ns	4.266	0.641	ns	0.743	0.69	ns
Handling the rubbish	98.3	1.961	0.581	ns	2.087	0.554	ns	1.308	0.253	ns
Biting your nails	96.5	1.733	0.630	ns	8.868	0.031	s	0.347	0.556	ns
Touching pets and other animals	99.1	3.288	0.349	ns	4.264	0.234	ns	0.648	0.421	ns

ns = not significant; s = significant (significance was set at the 5% level).

their toilet, touching pimples or sores, coughing or sneezing, handling the rubbish, biting their nails during food preparation and after touching pets and animals (Table 5.5). Chi square analysis did not reveal significant differences in terms of gender, age or educational level among respondents. However, the degree of knowledge exhibited by the respondents is unlikely to be translated into improved food safety practice. This view is supported by Rheinländer *et al.* (2008) who reported that hygiene practices of food handlers in Kumasi, Ghana, including hand washing, were insufficient to ensure the safety of food. Other studies show that knowledge alone does not always result in improved food safety practices (Howes *et al.,* 1996; Chang *et al.,* 2003; Walker *et al.*, 2003a; Tokuc *et al.,* 2009). Poor personal hygiene after visiting the lavatory can result in the hands being heavily contaminated with enteric pathogens (Taylor *et al.,* 2000; Barza, 2004). Washing hands with soap and water before preparation of food makes food poisoning less likely to occur (Altekruse *et al.,* 1995).

5.3.2.4 Cleaning and sanitation in the kitchen and food processing area

To gain further insight into the dynamics of kitchen sanitation and cleaning practices, respondents were asked about dish washing and use of cutting boards. The majority of consumers (>94.5%; $p<0.05$) and food handlers (85.2%; $p<0.05$) were aware that dishes and utensils must be washed with hot soapy water and that dishes and utensils must be rinsed and dried with clean napkins (Table 5.6). Significantly, only a minority of consumers and food handlers thought that dishes and utensil could be dried with used napkins (<11.3%; $p<0.05$) and dishes and utensils should be dried with their apron (<11.9%; $p<0.05$). The survey found that 45.0% of consumers and 64.3% of food handlers would wash their cutting board with only water after trimming raw chicken or meat. However, 91.7% of consumers and 93.9% of food handlers would clean and sanitize the surface if they had the sanitising materials. The majority of respondents did not however know the difference between cleaning and sanitising. Just over 10% of consumers and 13.9% of food handlers dried the cutting board with a paper towel. Epidemiologic surveillance summaries of foodborne diseases clearly indicate that poor hygienic practices are important contributors to outbreaks of foodborne

Table 5.6. General food safety knowledge scores of consumers and food handlers in food businesses in Accra

	Consumers' Response (%)			Food handlers' Response (%)		
Statement	True	False	Don't know	True	False	Don't know
Which of the following can be used to kill bacteria in foods?						
Disinfectant	13.8	75.2	11.0	11.3	78.3	10.4
Cold water	33.9	56.0	10.1	43.5	53.0	3.5
Detergent	29.4	59.6	11.0	41.7	55.7	2.6
Scrubbing brush/sponge	33.9	56.0	10.1	40.9	54.8	4.3
After trimming raw chicken on a cutting board, I						
Rinse the surface with water.	45.0	53.2	1.8	64.3	33.9	1.7
Dry the surface with a paper towel.	10.1	80.7	9.2	13.9	79.1	7.0
Clean and sanitize the cutting surface.	91.7	4.6	3.7	93.9	2.6	3.5
Dishes and utensils in the kitchen or processing unit are						
Washed in hot soapy water or dish washer	96.3	1.8	0.9	85.2	5.2	8.7
Rinsed and dried with a clean napkin	94.5	5.5	0.0	95.7	4.3	0.0
Rinse and dried with a used napkin	11.0	86.2	2.8	11.3	83.5	5.2
Left on the drainer to dry	88.1	9.2	2.8	87.8	7.0	5.2
Air-dried	74.3	16.5	9.2	84.3	10.4	5.2
Not dried with apron	86.2	11.9	1.8	81.7	8.7	9.6
Knowledge of pet and animal control in kitchen area						
Food or dirty dishes are left on the benches	6.4	91.7	1.8	4.3	93.0	2.6
Fly screens are used	85.3	3.7	11.0	87.8	3.5	8.7
Food covers are used	95.4	3.7	0.9	96.5	2.6	0.9
Pets not allowed in the kitchen	11.0	87.2	1.8	10.4	89.6	0.0
Pets have their own feeding bowl	82.6	14.7	1.8	91.3	3.5	2.6

diseases (Patil *et al.,* 2004). It is therefore important that consumers and food handlers are aware of behaviours and practices that may result in the spread of foodborne illnesses.

5.3.2.5 Knowledge of food storage practices, temperature control and cross-contamination

A significant minority of consumers (45.0%) and food handlers (38.3%) had the misguided perception that rotating food to use the oldest food first was bad food storage practice ($p < 0.05$) (Table 5.7). Some 73.4% of consumers and 74.8% of food handlers correctly indicated that storing raw meat above ready-to-eat food was bad food storage practice. Temperature is a critical factor for ensuring the safety and quality of many food products. Thawing and freezing food over and over again was classified as bad food storage practice by 78% of consumers and 83.5% of food handlers. Whereas 56.9% of consumers indicated that covering and labelling food before storage was bad practice, only 39.1% of food handlers thought so. The majority of respondents surveyed displayed poor knowledge of the temperature at which bacteria can multiply. Only 46.8% of consumers and 32.2 % of food handlers correctly indicated that at body temperature (37^{o}C) bacteria grow quickly or quicker. Similarly, only 40.4% of consumers and 31.3% of food handlers knew that bacteria can readily multiply at 25^{o}C or room temperature. This result is however, significantly higher than that observed in a survey by Kennedy *et al.* (2005), in which only 22% of respondents were aware of the temperature ranges that supported microbial survival and growth. Significantly, only 12.8% of consumers and 11.3% of food handlers in food business were able to specify the correct temperature level recommended for holding hot food prior to hot service. Temperature or thermal treatments constitute a critical control point for most of the traditional smoking, frying or cooking of fish and meat products. Poor understanding of temperature control could therefore be a major hindrance to effective HACCP implementation (Walker *et al.,* 2003). In warm tropical conditions, any abuse of temperature during food storage and display could prove a public health disaster. It is therefore vital that food handlers are aware of and apply appropriate food storage temperature at all times. Only 11% of consumers and 14.8% of food handlers used thermometers to determine the doneness or internal cooking temperature of large portions of fish. Nearly 70% of food handlers and 56.9% of consumers would usually taste the fish to verify if it is well cooked.

Table 5.7. Knowledge of food storage practices as exhibited by consumers and food handlers in Accra, Ghana

Food safety statement	Correct responses (%) Consumers	Food handlers
Rotating food to use oldest food first is bad food storage practice	45.0	38.3
Covering and labelling food before storage is bad food storage practice	56.9	39.1
Storing raw meat above ready-to-eat food is bad food storage practice	73.4	74.8
Thawing and freezing food over and over is bad food storage practice	78.0	83.5
At body temperature (37^{o}C) food poisoning bacteria Grow quickly	46.8	32.2
Harmful bacteria readily multiply at 25^{o}C	40.4	31.3
Check refrigerator temperature regularly	9.2	20.9
Hot holding food temperature should not be below 63^{o}C	12.8	11.3
Ice point and boiling methods are recommended methods for calibrating food thermometers	68.8	37.4
In the refrigerator, cooked food is stored above raw foods	38.5	28.7
To ensure that meat is thoroughly cooked to safe temperature I cut in the middle to see if the meat/fish is pink	28.4	7.8
To ensure that meat is thoroughly cooked to safe temperature I smell the meat/fish	2.8	7.8
To ensure that meat is thoroughly cooked to safe temperature I taste the meat/fish	56.9	69.6
To ensure that meat is thoroughly cooked to safe temperature I use a food thermometer	11.0	14.8
Cross-contamination is most likely to occur when you cut ready-to-eat food on a cutting board used for fresh meat	86.2	84.3
Cross contamination is likely to occur when you touch raw meat and switch to touch cooked or ready-to-eat food.	86.2	80.9

N=109 consumers, 115 food handlers

Twenty-eight per cent of consumers and 7.8% of food handlers usually cut in the middle, and 2.8% of consumers and 7.8% of food handlers said they smell the fish to verify that it is well cooked. The practice of tasting fish to determine its doneness is not acceptable as this could lead to infection if the fish was not fresh, to start with, and if the fish was undercooked. The majority of consumers (86.2%) and food handlers (84.3%) were aware that to prevent cross-contamination, cutting boards and utensils used to cut raw meat should not subsequently be used for cooked foods or ready-to-eat food (Table 5.7). Consumers (86.2%) and food handlers (80.9%) were also aware that cross contamination was most likely to occur when they handle raw fish and subsequently switch to handle cooked food without washing their hands. However, significantly, only 38.5% of consumers and 28.7% of food handlers knew that in the refrigerator cooked food must be stored above raw foods ($p < 0.05$).

5.3.2.6 Familiarity with food safety terms

Respondents' familiarity with some food safety terms including HACCP, CCP and GMP, is shown in Figure 5.2. Only a small minority of food handlers (19.1%) and consumers (21.1%) were familiar with HACCP. There was no significant difference in the level of HACCP knowledge between consumers and food handlers (p=0.699). Similarly, only 22.0% of consumers and 21.7% of food handlers were familiar with CCP and the difference was not statistically significant (p=0.960). It is essential to have hygienically designed equipment and prerequisite programmes (PRPs) as well as Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP) and sanitation standard operational procedures in place, prior to HACCP implementation (Panisello and Quantick, 2001; Walker *et al.,* 2003b; Roberto *et al.,* 2006; Kök, 2009). A higher percentage of consumers (26.6%) were familiar with Good Manufacturing Practice (GMP) than food handlers (23.5%) (t=0.538, p=0.591). This was perhaps due to the lack of or relatively low level of education among food handlers.

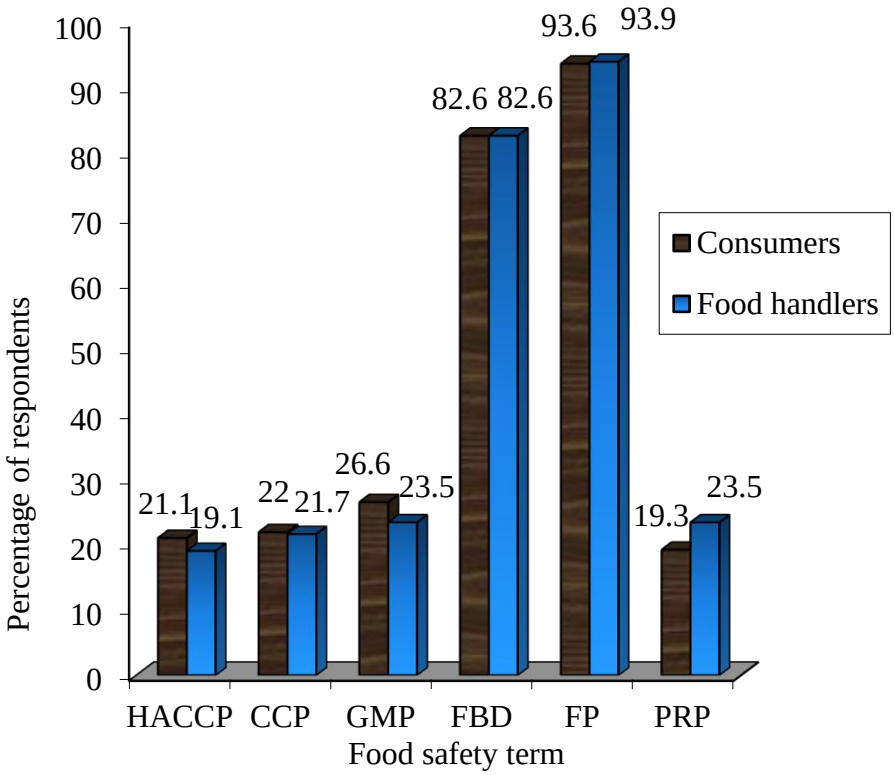

Figure 5.2. Food handlers' and consumers' awarenes of food safety and HACCP terms

Only a minority of consumers (19.3%) and food handlers (23.3) were familiar with pre-requisite programmes (PRPs) (t=0.766, p=0.445). The lack or low level of formal education among food handlers would pose a challenge to introducing GMP and risk-based food safety management like HACCP into their operations unless these are simplified, properly tailored and targeted. However, familiarity of the terms food poisoning and foodborne disease was high among both consumers and food handlers. The majority of food handlers (93.9%) and consumers (93.6%) were familiar with food poisoning and foodborne disease. In all cases statistical analysis did not show any significant difference between consumers and food handlers.

5.3.2.7 Knowledge of high risk food groups

Perceived personal vulnerability to disease is believed to be an important initiator for preventative behaviours (Bennett and Murphy, 1999). When asked to classify chicken, beef, fruits, vegetables, shellfish and eggs in terms of their potential as carriers of harmful foodborne microorganisms, over

half (54.1%) of consumers and 62.2% of food handlers surveyed thought raw chicken was very likely to carry harmful foodborne microorganisms (Table 5.8).

Table 5.8. Consumers' and food handlers' risk perception of foods

Statement	Perception that food may contain foodborne microorganisms (%)				
	Very Likely	likely	May be	Unlikely	Very unlikely
Consumers (n = 109)					
Raw chicken	54.1	11.9	18.3	10.1	5.5
Raw beef	47.7	15.6	18.3	11.9	6.4
Raw fruits	38.5	10.1	33.0	8.3	10.1
Raw vegetable	48.6	10.1	22.0	13.8	4.6
Raw shellfish	33.9	10.1	26.6	22.0	7.3
Raw eggs	24.8	9.2	25.7	20.2	20.2
Food handlers (n = 115)					
Raw chicken	62.6	11.3	12.2	20.0	4.3
Raw beef	52.2	15.6	18.3	11.9	6.4
Raw fruits	20.0	11.3	32.2	14.8	21.7
Raw vegetable	42.6	12.2	27.8	12.2	5.2
Raw shellfish	25.2	10.4	33.9	23.5	7.0
Raw eggs	13.9	8.7	43.5	20.0	13.9

Nearly half (47.7%) of consumers and 52.2% of food handlers believed that beef was a very likely source of harmful food poisoning microorganisms. Raw vegetables were perceived by 48.6% of consumers and 42.6% of food handlers as more likely to have harmful microorganism, and higher than raw eggs and raw shellfish. The mean food safety perception ratings were classified as low- (between 0 and 2), medium- (between 2 and 4) or high (between 4 and 5) on the basis of gender, age and education (Fig. 5.3a and 5.3b). Fewer than thirty-four percent (33.9%) of consumers and 25.2% of food handlers thought raw shellfish was very likely to contain harmful microorganisms. Similarly, only 24.8% of consumers and 13.9% of food handlers thought raw eggs were very likely to have harmful microorganisms. Among consumers and food hadlers, better educated people perceived raw egg and raw shellfish as high risk and vegetables as low risk. Among food handlers, older respondents (55+) rated fruits, vegetables, raw shellfish and eggs as high risk products. Significantly, all food handlers rated chicken as low risk. In terms of gender, there were no differences between male and female in their risk perception.

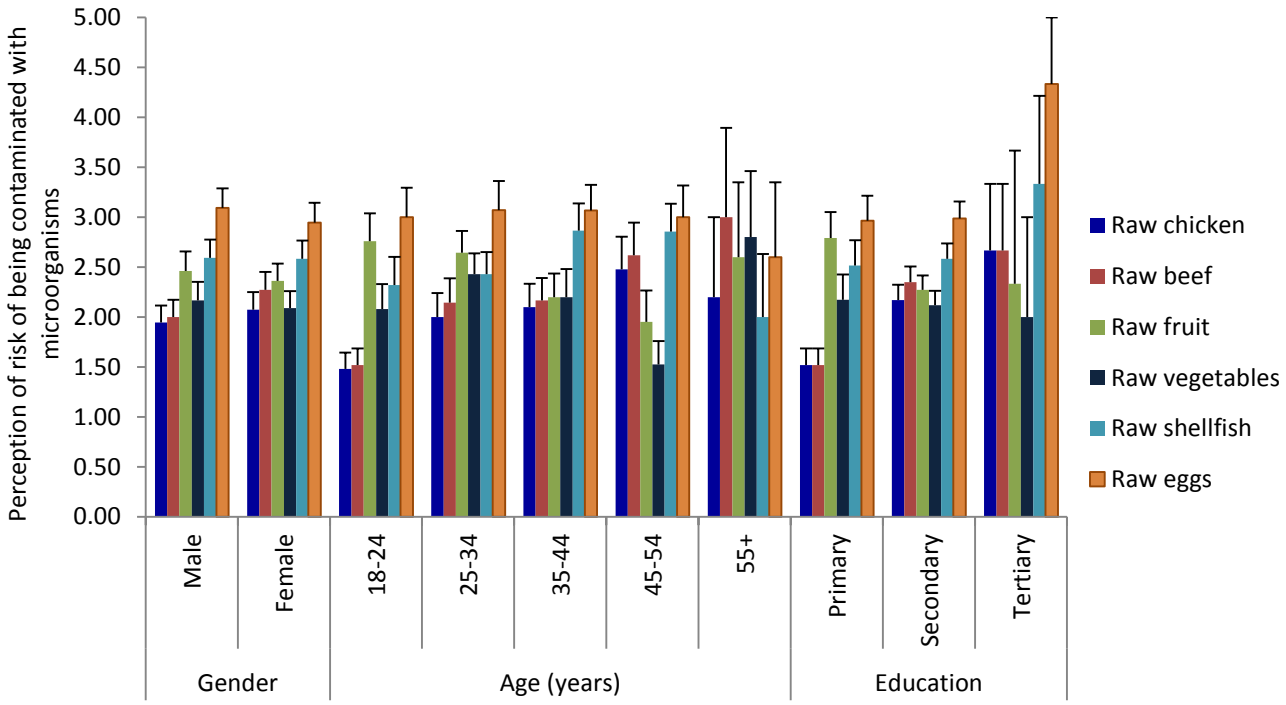

Fig. 5.3a Consumers' perception of foods that have high risk of microbial contamination

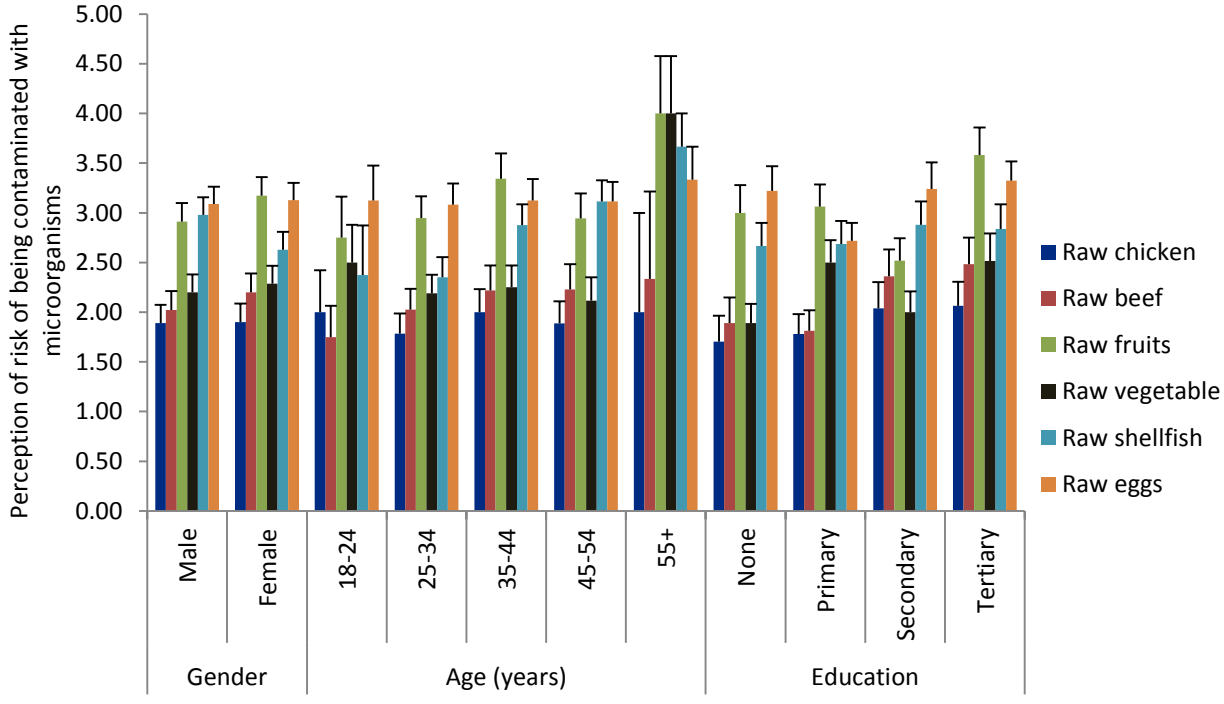

Fig. 5.3b Food handlers' perception of foods that have high risk of microbial contamination

5.3.3 Extent of food safety concerns in Ghana

Results from this study show varied levels of food safety concern among Ghanaians surveyed (Figure 5.4). Respondents had at least high concerns about pesticide residues in food (81.7%), use of antibiotics in the production of food (69.2%) and use of hormones in animal production (68.8%). This level of concern reported here are higher than those previously reported elsewhere e.g. Brewer and Prestat (2002) and Brewer and Rojas (2008) with regard to pesticides and hormones in studies conducted in the US. However, only 32.1% of consumers had high or very high concerns for the use of additives/colourings/preservatives in food.

About novel food technologies, 50.9% of respondents expressed high or very high concern about food irradiation and another 50.9% of respondents expressed serious concerns about genetically modified foods although they did not know much about these technologies. Irradiation carried out under conditions of Good Manufacturing Practices (GMPs), is recommended as a safe and effective food processing and preservation method that can reduce the risk of food poisoning and preserve foods without detriment to health and with minimal effect on nutritional quality (The Institute of Food Science and Technology, 1999). Comments made by respondents about genetically modified food included, "*don't know what effect it will have on me"," don't know what it is", "we need to know the health risks"*. Although there has been little research conducted on consumer attitudes towards genetically modified foods in developing countries, a study by Pachico and Wolf (2002) found that 66% of respondents in Colombia were willing to try genetically modified foods, and the willingness to purchase genetically modified foods was high among those who felt they did not have adequate or high quality foods available at home.

The survey on hygiene and sanitation included restaurants, traditional food service areas ('chop-bars'), butchers' shop and home. Within this category, only 8.9% of respondents had high or very high concern about hygiene standards at home, which goes to confirm the generally held belief by consumers that their foodborne illness is caused by food prepared somewhere other than the home.

The low level of concern about food hygiene at home corroborates studies by Redmond and Griffith (2004) which indicate that consumers associate a low personal risk of food poisoning from home-produced food.

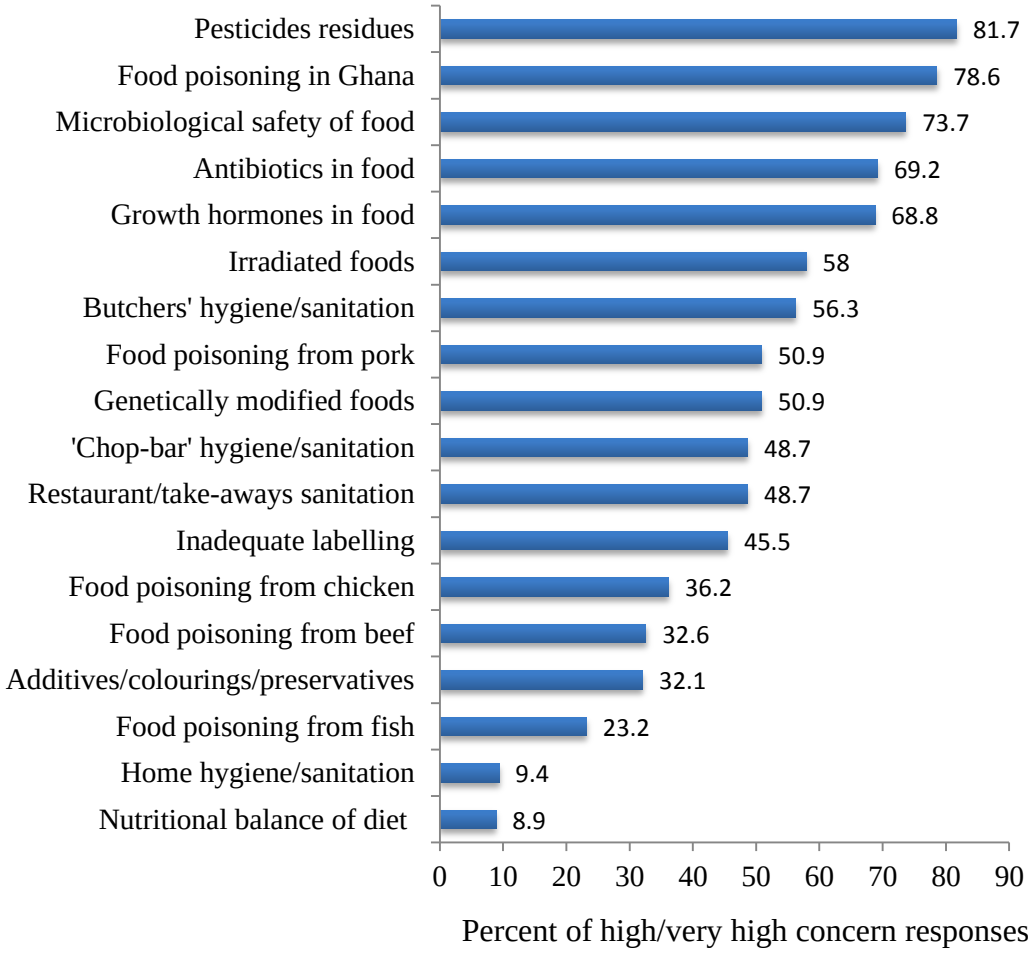

Fig. 5.4. Respondents who have high or very high concern about food safety issues

In Redmond and Griffith's (2003a) view, the actual proportion of food safety incidents that originate in the home is likely to be much higher than reported. An under-estimation of personal risk to food, as findings in this study suggest, may prevent consumers from taking appropriate steps to reduce their exposure to food-related hazards (Frewer *et al.,* 1995). Other studies estimate that between 50% and 87% of reported foodborne disease outbreaks have been associated with the home (Redmond and Griffith, 2003b). Improving consumer food safety behaviour in domestic settings is necessary to reduce the risk and incidence of food poisoning (Anderson *et al.*, 2000; Redmond *et al.*, 2001; Redmond and Griffith 2003a). In contrast to the low level of concern expressed about food hygiene at home, 52% of respondents were very concerned about hygiene standards in 'chop-

bars' and 48.7% were very concerned about the hygiene standards in main stream restaurants and "take-aways". Other concern expressed by respondents was a 56.3% high concern rating for hygiene standards in the butchers' shop. The traditional catering sector ('chop-bars') constitute the largest food service business in Ghana, providing convenience and value to consumers who dine outside the home. Foodborne disease outbreaks can be costly for restaurants in terms of negative publicity, loss of consumer trust, and loss of customers as well as legal costs (Grover and Dausch, 2000).

Within the category of microbiological hazards including food poisoning from Products of Animal Origin (POAO), 78.6% of respondents considered food poisoning in Ghana as an issue of high or very high concern and 73.7% expressed high or very high concerns about the microbiological safety of their food. When respondents were asked about getting food poisoning from POAO, 50.9% expressed serious or high concerns about getting food poisoning from eating pork, 36.2% were highly concerned about getting food poisoning from chicken, 32.6% from beef. However, only 23.2% had high or very high concerns about getting food poisoning from eating fish. It appears from this survey that respondents did not particularly view fish or fish products as high risk as far as microbial contamination was concerned. Microbiological health hazards may be present in fresh fish and need to be controlled to prevent outbreaks of foodborne diseases. Poor handling practices and the high ambient temperatures of the tropics may result in fish safety problems (Plahar *et al.*, 1999; Diei-Ouadi and Mgawe, 2011).

5.3.3.1 Mean ratings of food safety concerns in Ghana

Concern rating were classified as either low- (between 1 and 2), medium- (between 2 and 3) or high-risk (between 3 and 5) using means on a scale of 1-5 (i.e. low-high concern) (Appendices G1 to G4). Average concern in food safety, represented by the mean scores of the eighteen statements, was high (3.20 ± 0.173). Significantly (F = 0.012), consumers had an overall higher mean concern rating (3.29 ± 0.190) than their food handler counterparts (3.11 ± 0.173). The youngest age group (18-24) registered the lowest mean concern rating (1.68 ± 0.236), followed by elderly respondents

(55+) with mean concern rating of 2.85 ± 0.181(Appendix G2). Significantly ($p < 0.001$), the age groups 25-34, 35-44 and 45-54 showed high concerns for the safety of their food. Female respondents worried more (3.22±0.177) about the safety of their food than their male counterparts (3.17 ± 0.181; t = 2.11, p = 0.097) (Appendix G3). Previous studies have reported that generally, women perceive greater risks than men (Grobe *et al.,* 1999; Dosman *et al.,* 2001; Fox *et al.,* 2001). In this study, female respondents indicated slightly higher level of concern (3.67 ± 0.118) about irradiated foods than their male counterparts (3.62 ± 0.140). However, this difference was not significant (P= 0.759). Misra *et al.* (1995) have observed that females treated food irradiation as more serious problem even though women had lower stated awareness of irradiation. Respondents who had no education were the least concerned about the safety of the food (2.99 ±0.186; F = 2.74, p = 0.726) (Appendix G4). The data from this study showed that consumer concern in the safety of food is fairly high in Ghana (i.e. above the midpoint). Misra *et al*. (1995) found that education level significantly affects risk perception for irradiation and suggested that female respondents with less than a college education and low income treat irradiation as a more serious problem. Dosman *et al.* (2001) also suggested that highly educated respondents usually perceive less risk in the sphere of food safety.

5.3.4 Food handlers' perception of the Ghana Food and Drugs Board

To ensure that food safety practices are implemented at every stage of the food chain, national and local food safety inspection and monitoring is essential. Respondents were asked to rate the Ghana Food and Drugs Board's ability to monitor food safety and respond to their food safety needs on a scale of 1-5, where 1 = very poor and 5 = excellent. There is a fairly high level of confidence in the Ghana Food and Drugs Board assuring food safety. The Ghana FDB was rated very poor by 6.0% and poor by 5% of the food handlers interviewed and very good (19%) or excellent (22%), respectively (Fig. 5.5). The role of the FDB is to safeguard and promote public health by ensuring the safety of food. As these findings reflect the opinion of industry respondents, it can be a direct reflection of the extent to which the FDB is known and the extent to which food safety inspection and monitoring is currently being conducted. For any food regulatory framework to be developed

and for it to work effectively, the public needs to know more about the regulatory bodies and how they function.

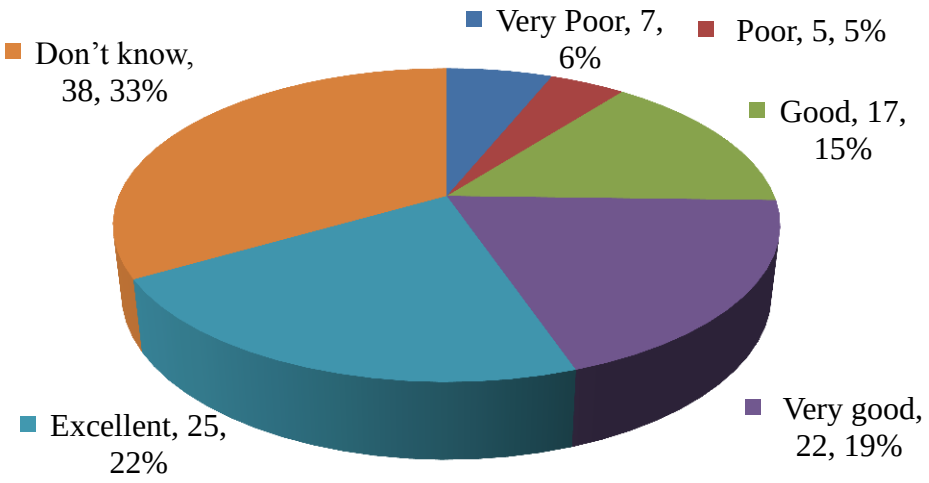

Fig. 5.5. Food handlers' perception of the Ghana Food and Drugs Board

5.3.5 Food safety training and attitudes, perceptions and challenges

Education and training of food industry personnel in hygiene and sanitation is a recognised means of improving food handling practices and consequently the safety of food. The results of this survey indicate that only 28.7% (33) of food handlers had attended staff seminars in the last 2 years and less than a third of them (31.3%) had received some training on food safety and hygiene related to their jobs in the 12 months preceding the survey (Table 5.9). More than half (52%) of food handlers viewed food safety training as very useful and nearly half (49.6%) said it was very important that production employees in their establishment participate in food safety training. More than half (58.3%) of the respondents could not say how much time they spent on food safety training. Poor staff training in food hygiene is a real threat to the safety of food. Hence effective training is an important prerequisite to successful implementation of a food safety management system (Arvanitoyannis and Kassaveti, 2009). When asked about the food safety capabilities of other staff in their establishments, only a minority of food handlers (24.3%) thought that production employees in their establishments knew about food safety hazards and how to control them.

Table 5.9. Food handlers' responses on food safety training issues

Item	Frequency (n=115)	Percentage (%)
Have you or any staff attended food safety seminar in the last 2 years?		
Yes	33	28.7
No	57	49.6
Not aware	6	5.2
Cannot say	19	16.5
Have you received food safety training in past 12 months?		
Yes	36	31.3
No	55	47.8
Don't know	18	15.7
How useful was your last food safety training to you?		
Very useful	60	52.2
Moderately useful	8	7.0
Somewhat useful	12	10.4
Minimally useful	20	17.4
Not at all useful	12	10.4
How important is it to participate in food safety training?		
Very important	57	49.6
Somewhat important	7	6.1
Not very important	3	2.6
Not at all important	3	2.6
Cannot say	45	39.1
How long does it take to train new employees on food safety?		
Zero hours	11	9.6
Less than half day	3	2.6
Half a day	4	3.5
One day	9	7.8
1-3 days	7	6.1
More than 3 days	13	11.3
Cannot say	67	58.3
Do production employees know food safety hazards and their control?		
Yes	28	24.3
No	29	25.2
Cannot say	40	34.8
Don't know	18	15.7

Training and education of those involved in the preparation, processing and handling of food are critical lines of defence in the prevention of most types of foodborne illness (Black *et al.,* 1981). However, training designs which primarily emphasise the provision of information seldom translate into positive attitudes and behaviours (Ehiri *et al.,* 1997). The low levels of food safety and hygiene

training observed in this survey raise serious concerns about the safety and quality standards in the traditional food processing and catering settings. These findings provide an opportunity to review current training provision and practices and ways in which training can be scaled up to benefit people working in the food service sector in Ghana. Providing training and information on safe food handling to food handlers would also help to facilitate or persuade behaviour modification. In addition, their health is not periodically evaluated by an independent health authority.

When food handlers were asked about the main challenges limiting their ability to undertake food safety training, cost of training (34.8%), illiteracy (18.3%), the lack of training institutions (8.0%) and lack of training materials (8%) were regarded as their main challenges (Fig. 5.6).

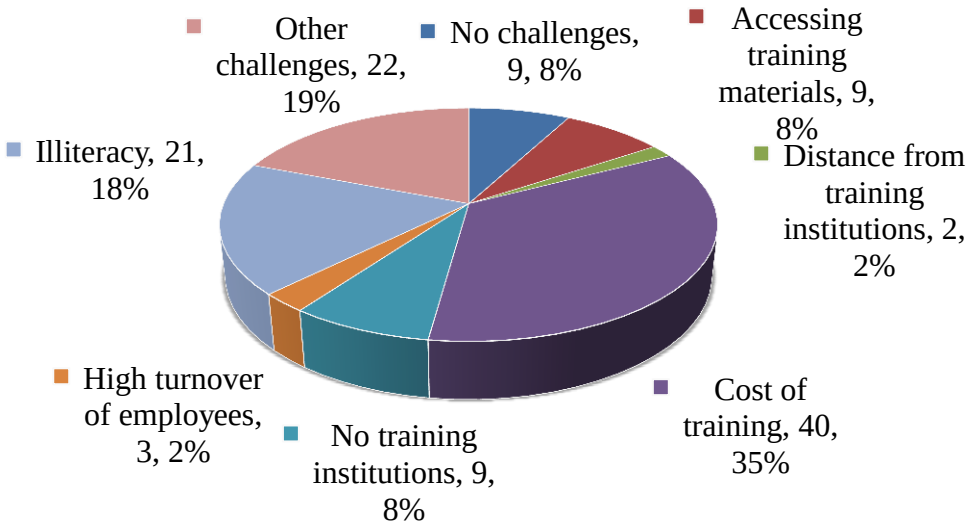

Fig. 5.6. Food safety challenges affecting food handlers in Ghana

Other researchers have identified personnel resources, cost of training, lack of materials and resources for teaching, literacy, socioeconomic standards, lack of interest, lack of motivation, lack of trainers, time, characteristics of the trainers, among others as the potential barriers to training (Mortlock et al., 2000; Nummer et al.,2010). Griffith (2000) observed that behavioural change (including the implementation of required hygiene practices) is not easily achieved and that consideration must be given to motivation, constraints, barriers and facilities as well as to cultural aspects. It is also important that training of trainers' programmes are instituted to help develop

personnel with the requisite skills to train food handlers. Training is only as good as the trainer (Nummer *et al.,* 2010).

5.3.6 Food safety requirements and the food industry in Ghana

Only 21.7% of food handlers thought that food safety requirements had helped significantly to market their products (Table 5.10). A minority (13 %) said it helped moderately and 2.6% said it had no impact on marketing opportunities. Based on these findings, it is clear that some industry stakeholders know that they stand to gain an advantage in the market place if they meet standard food safety and quality requirements. However, the majority of respondents are yet to make positive links between product safety and marketing opportunities. Only 13.9 and 6.1 % of food handlers surveyed said their companies found it very difficult or difficult, respectively, to comply with standard food safety requirements.

Others said it was neither difficult nor easy (8.7%) and 11.3% found it somewhat easy or easy to comply. However, a greater number of respondents (69) representing 60% of respondent could not say whether it was easy or difficult complying with food safety requirements. This represents a significant area of concern, as it is very important that food handlers comply with standard food safety requirements. Industry supports needs to be improved so as to make it easy to comply with requirements. The major challenges identified as impediments to food safety compliance were cost (27%), time (25.2%), access to training (19.1%), lack of access to technical and scientific information (13.9%), lack of management commitment (7.8%), lack of employee commitment/attitude (6.1%) and high turn-over of employees (0.9%).

Table 5.10. Impact and challenges of food safety requirements on food businesses

Factor	Frequency (n = 115)	Percentage (%)
Has standard food safety requirements helped in the marketing of your products		
Hindered significantly	0	0.0
Hindered moderately	1	0.9
Had no impact	3	2.6
Helped moderately	15	13
Helped significantly	25	21.7
Cannot say	71	61.7
Has standard food safety requirements helped to create new markets for your products		
Hindered significantly	0	0.0
Hindered moderately	0	0.0
Had no impact	5	4.3
Helped moderately	9	7.8
Helped significantly	25	21.7
Cannot say	76	66.1
Level of ease or difficulty in complying with standards food safety requirements		
Very difficult	16	13.9
Somewhat difficult	7	6.1
Neither difficult nor easy	10	8.7
Somewhat easy	10	8.7
Very easy	3	2.6
Cannot say	69	60.0
Major challenges experienced in complying with food safety requirements		
Management commitment	9	7.8
Employee commitment/attitude	7	6.1
High Turn-over of employees	1	0.9
Access to technical information	16	13.9
Access to training	22	19.1
Cost	31	27.0
Time	29	25.2

5.3.6.1 Staff and management commitment and participation in firm's food safety programmes

Implementation of a comprehensive food safety management system would require both staff and management commitment and active participation. Only 15.7 % and 7.0% participated fully or a lot, respectively, in the development of their firms' food safety plan (Table 5.11). The rest either had moderate participation (7.0%), some participation (14.8%) or no participation at all (9.6%). With regards to the level of daily participation in their company's food safety operations, 47.8% of

respondents could not say how much they were involved, 13.9% participated fully, 7.8% participated a lot, 7.0% moderately, 14.8% had some participation and 8.7% did not participate at all.

Table 5.11.Participation of food handlers in firm's food safety programme

Factor	Frequency	Percentage (%)
Own level of participation in developing your firm's food safety programme		
No participation	11	9.6
Some Participation	17	14.8
Moderate Participation	8	7.0
A lot of Participation	8	7.0
Full Participation	18	15.7
Cannot say	53	46.1
Own level of participation in day to day operation of your firm's food safety programme		
No participation	10	8.7
Some Participation	17	14.8
Moderate Participation	8	7.0
A lot of Participation	9	7.8
Full Participation	16	13.9
Cannot say	55	47.8

5.3.7 Self-reported food safety practices of consumers

To assess food safety attitudes, participants responded to various statements adapted from Medeiros *et al.* (2001a), on a 4-point Likert-scale, where 1 was "always" and 4 was "never". Table 5.12 shows a summary of all participants' responses to questions on their food safety practices, including cleaning and disinfection practices, hot-holding and reheating, storage and temperature control, use of equipment and managing cuts and infections. The results indicate that some consumers and food handlers are generally aware of food safety principles and the majority claim to use hygienic food handling procedures most of the time (Table 5.12). The results also indicate that unsafe food handling behaviours may be prevalent including unfamiliarity with the correct procedure for freezing and thawing of foods.

5.3.7.1 Self-reported cleaning, disinfection and Prevention of cross-contamination

Consumers (90.8%) were more likely than food handlers to always clean and sanitise cutting surfaces after cutting raw meat (75.7%) (Table 5.12). Only 44.0% of consumers and 47.8% of food handlers always wash cutting board, knife, and counter top with hot soapy water. Similarly, only 13.8% of consumers and 23.5% of food handlers routinely (always) wash dirty dishes in hot soapy water. Slightly more consumers (69.7%) than food handlers (61.7%) always wash fruits and vegetables thoroughly under running water. 42.2% of consumers and 44.3% of food handlers always air-dry their dishes after washing. 71.6% of consumers and 73% of food handlers always clean and sanitise utensils after use. 67.9% of consumers and 72.2% of food handlers always discourage pests by keeping kitchen clean. Using the same equipment and utensils for cooked and raw foods can increase the risk of cross-contamination. Most consumers (68.8%) and 55.7% of food handlers said they always store cold food in the freezer as much as possible. Only one-fifth (19.3%) of consumers and 37.4% of food handlers reported that they always thaw frozen foods in the refrigerator. The study showed that 51.4% of the consumers and 44.3% of food handlers routinely store raw meat below ready-to-eat or cooked food in refrigerator. However, 71.6% of consumers and 60% of food handlers always keep raw meat separate from cooked food. Whereas 55% of consumers and 36.5% of food handlers always keep food covered when in the fridge only 22% of consumers and 10.4% of food handlers cover and correctly label prepared food before storing. Nearly forty per cent (34.9%) of consumers and 27% of food handlers always use the oldest food products first, and 12.8% of consumers and only 6.1% of food handlers divide food into smaller containers to cool more quickly.

Table 5.12. Self-reported food safety practices of consumers and food handlers in Accra, Ghana

	Consumers (%)				Food handlers (%)			
Statement	Always	Most of the time	Sometimes	Never	Always	Most of the time	Sometimes	Never
Cleaning and Disinfection								
Clean sanitise cutting surface after cutting raw meat	90.8	6.4	1.8	0.9	75.7	15.7	7.8	0.9
Wash cutting board, knife, counter top with hot soapy water	44	18.3	22.9	14.7	47.8	19.1	20	13
Clean and sanitise utensils after use	71.6	25.7	2.8	0	73	20	6.1	0.9
Wash hands before preparing and handling raw meat or poultry	68.8	27.5	3.7	0	68.7	24.3	7	0
Wash fruits and vegetables thoroughly under running water	69.7	20.2	6.4	3.7	61.7	23.5	14.8	0
Wash dirty dishes in hot soapy water	13.8	25.7	49.5	11	23.5	12.2	36.5	27.8
Wash hands in running water and soap	59.6	16.5	22	1.8	54.8	21.7	21.7	1.7
Air dry dish where possible	42.2	28.4	24.8	4.6	44.3	25.2	26.1	4.3
Discourage pests by keeping kitchen clean	67.9	24.8	4.6	2.8	72.2	16.5	8.7	2.6
Hot Holding and Reheating								
Hot food kept hot and cold food cold	56.9	24.8	16.5	1.8	50.4	30.4	17.4	1.7
Reheat left over thoroughly before serving	79.8	10.1	10.1	0	73	16.5	8.7	1.7
Cook high risk food thoroughly	83.5	9.2	5.5	1.8	74.8	15.7	7.8	0.9
Reheat left-over food steaming hot	58.7	18.3	22	0.9	51.3	13.9	31.3	3.5
Storage and Temperature Control and Cross Contamination								
Store cold food at 5 degrees celcius or less	36.7	22	27	14.7	25.2	17.4	45.2	12.2
Store cold food in freezer as much as possible	68.8	16.5	13.8	0.9	55.7	33.9	9.6	0.9
Thaw frozen foods in refrigerator	19.3	9.2	37.6	33.9	37.4	15.7	27	20
Keep raw meat separate from cooked food	71.6	21.1	5.5	1.8	60	23.5	14.8	1.7
Store raw meat below ready-to-eat/cooked food in the refrigerator	51.4	12.8	23.9	11.9	44.3	28.7	20.9	6.1
Use the oldest food products first	34.9	25.7	33	6.4	27	20.9	44.3	7.8
Divide food into smaller containers to cool more quickly	12.8	7.3	43.1	36.7	6.1	15.7	53	25.2
Cover and correctly label prepared food before storing	22	10.1	24.8	43.1	10.4	6.1	16.5	67
Keep food covered when in the fridge	55	26.6	18.3	0	36.5	28.7	29.6	5.2
Keep food covered when on the bench	77.1	19.3	3.7	0	60	30.4	9.6	0
Use of Equipment								
Regularly check refrigerator temperature	33	15.6	25.7	24.8	14.8	13	27	45.2
Use calibrated food thermometer when checking food temperature	13.8	1.8	10.1	73.4	5.2	5.2	6.1	83.5
Use clean equipment, not hands to pick food	33	32.1	34.9	0	32.2	34.8	30.4	2.6
Cuts and Infections								
Cover cuts and infections on hands	57.8	26.6	12.8	2.8	63.5	24.3	10.4	1.7
Avoid preparing food when sick	26.6	24.8	40.4	8.3	25.2	17.4	45.2	12.2

5.3.7.2 Self-reported hand-washing, cooking, reheating, hot holding, cooling and thawing and use of equipment

More than two-thirds of consumers (68.8%) and food handlers (68.7) reported that they always wash hands before preparing and handling raw meat or poultry. More than half (59.6%) of consumers and 54.8% of food handlers routinely wash their hands in running water with soap. Similarly, 58.7% of consumers and 51.3% of food handlers always reheat left over steaming hot. Just under three-quarters (74.8%) of food handlers and 83.5% of consumers always cook high risk food thoroughly. More than half of consumers (56.9) and just over half of food handlers (50.4) said they always keep hot food hot, and cold food, cold. Just over a quarter of food handlers (25.2%) and 36.7% of consumers always store cold food at 5^{o}C or less. Just 33% and 32.2% of consumers and food handlers respectively use clean equipment, not hands, to pick food. Only 13.8% of consumers use a calibrated food thermometer when checking food temperature as many as 73.4% never do this. Similarly, even fewer food handlers (5.2%) said they always use calibrated thermometers to check food temperature. Only a third (33%) of consumers and 14.8% of food handlers who were interviewed regularly check refrigerator temperature.

5.4 Discussion and conclusion

The present study has attempted to find any gaps in food safety knowledge, practice or attitude among consumers and food handlers in Ghana in order to address food safety problems in the traditional fish processing sector. The objective of this survey was to ascertain knowledge of safe food-handling, attitudes and behaviours towards safe food-handling of consumers and handlers of traditionally processed fish in Ghana. The study also explored perceived risk of contracting foodborne illness and food safety concerns in Ghana. The hypothesis tested was that, sufficient knowledge of food safety and practice existed among Ghanaians to ensure good food safety practices. Overall, participants answered knowledge questions about safe food-handling behaviours correctly. It should be noted that by using multiple choice questions, participants would have a high probability of randomly guessing the correct response which can lead to artificially high correct

answers. Both consumers and food handlers generally knew they should wash their hands before cooking, should wash their hands after using the toilet, keep pests and pets out of the food processing area, and use different cutting boards for high risk food and low risk food. However, knowledge of time-temperature control was not adequate. Previous studies have revealed three key factors that play a decisive role in the occurrence of food poisoning, especially with regard to food handlers: knowledge, attitude, and practice (Angelillo *et al.*, 2001a; Patil *et al*, 2005). Poor knowledge and practice of time temperature-temperature control, especially in the tropics, can negate much of the effort made to improve food safety.

The findings also indicate that a great majority of food handlers have very positive food safety attitudes. Respondents also have a high level of concern for food safety standards in Ghana. These findings support the hypothesis and suggest that the level of awareness of food safety and practice should be sufficient to assure a good level of food safety practice. Several researchers have however, identified gaps between levels of self-reported food safety knowledge and actual food-handling practices of consumers and food handlers, and concluded that food safety knowledge was not always positively correlated with hygienic food handling (Fein *et al.,* 1995; Wilcock *et al.*, 2004; Tobin *et al.,* 2005; Badrie *et al.,* 2006). It was however also quite clear that the respondents recognised training on food safety particularly in food service outlets to be insufficient (around 31% training provision). This needs to be urgently addressed by food safety educators. This is particularly important as it reflects knowledge of good manufacturing and trading practices in the food sector with implications on food safety for consumers. Limited training provision was attributed to the cost of training, the lack of food safety training places and illiteracy. It is also important to note that if in the commercial sector there is limited training and screening of workers, the level of screening and training would most likely be even less among independent small holder traders or street food vendors. Other studies suggest that training does not always result in increased food safety knowledge and a positive change in food handling behaviour (Howes *et al.,* 1996; Powell *et al.,* 1997; Clayton *et al.,* 2002; Green *et al.,* 2005; Seaman and Eves, 2008). Nevertheless,

the results of this study suggest that the level of knowledge, attitudes and practices of consumers and food handlers in Ghana needs to be improved. To be effective food safety and hygiene training needs to target changing those behaviours most likely to result in foodborne illness (Egan *et al.*, 2007). It is essential to have hygienically designed equipment and prerequisite programmes (PRPs) as well as Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP) and sanitation standard operational procedures in place, prior to HACCP implementation (Panisello and Quantick, 2001; Walker *et al.,* 2003b; Roberto *et al.,* 2006; Kök, 2009). In this study, proper hand washing, time-temperature control, prevention of cross-contamination and general hygiene and sanitation training were identified as the critical areas requiring appropriate food safety training intervention. Substantive food safety training can be built on the knowledge base and positive attitude of the respondents. And this should focus on basic concepts and requirements of PRPs, including personal hygiene (Adams and Moss, 1997). To ensure this, there should be some form of induction training with regular updating and refresher courses for the food handlers. These findings further support the need for such training provision.

This study sheds light on hygiene perceptions and practices consumers and food handlers in Ghana. It is clear that respondents' perceptions play an important role in determining hygiene practices, as has been shown in previous studies (Nielsen *et al.,* 2001; Yeung and Morris, 2001; Yee *et al.,* 2005; Usfar *et al.,* 2010). Furthermore, perceptions are shaped by existing culture and norms within the community (Usfar *et al.,* 2010). It appeared that the more educated in the age groups 25 to 50 years were more concerned about food safety and perceived that foodborne illnesses were a major concern in Ghana. Young people and the older age groups on the other hand did not perceive food safety risk to the same extent. This age and education disparity in food safety risk of illness perception merits further investigation. It is also noteworthy that respondents did not particularly see fish and fish products as 'high risk' in terms of microbial contamination and food safety risk. They rather thought meats and chicken were more high risk. This raises the question as to how people perceive fish and fish processing in Ghana. Did it mean that the traditional processing

methods employed now are deemed satisfactory and safe? This study highlight the need to further study the actual food handling practices and to identify any gaps between self-reported food safety practices and actual food safety practices. The picture painted from the survey should also contribute to the overall review process for food safety in Ghana and contribute to the formation of a framework for addressing the problem of food safety in Ghana. Further work using other question types, such as open ended questions would also be important.

Chapter 6

6.0 Effects of sodium chloride and storage temperature on *Staphylococcus aureus* and staphylococcal enterotoxin A and B production in smoked fish products

6.1 Introduction

S. aureus is a major cause of illness (including gastroenteritis) in humans worldwide. It is an indicator of deficient hygiene of food processing (Soriano *et al.,* 2002). Possible sources of contamination of *S. aureus* are human (FDA, 2001; Sattar *et al.,* 2001; Huss, 2003), contaminated surfaces and utensils (Reij *et al.,* 2004; Sneed *et al.,* 2004; DeVita *et al.,* 2007), ingredients (Hansen *et al.,* 1995) and raw fish (Ferreira *et al.,* 2007). *S. aureus* produces enterotoxin when the population reaches 5 log cfu/g and this is possible in products with high a_w levels above 0.85. Although several studies have reported the presence of *S. aureus* in traditional smoked fish products in Ghana, production of enterotoxins has not been previously reported in these fish products (Mensah, 1997; Plahar *et al.,* 1999; Akinola *et al.,* 2006; Anihouvi *et al.,* 2006; Nyarko *et al.,* 2011). In Ghana, smoke-drying of fish is used to extend shelf-life and ensure year-round supply. Smoke-dried or semi-dried fish are produced by hot-smoking (over an open fire) and drying over low heat. The process may involve the use of sodium chloride as curing agent. However, there is no guidance for the processing, use of additives, final pH, moisture content, water activity or standard requirements for shelf-life for smoke-dried fish in the country. The final products have wide range of a_w levels, variable shelf-life and are usually stored and retailed under ambient conditions in the tropics. Consequently, smoked mackerel has been described as potentially high risk, and smoked catfish and herrings as potential variable or medium to high risk products as reported in Chapter 3.0 of this thesis.

If environmental conditions during food storage and preparation allow the growth of *S. aureus* (i.e. time and temperature abuse) staphylococcal enterotoxins may be produced, being potentially harmful for consumers (Todd *et al.,* 2008). The key to controlling *S. aureus* and limiting their potential risk is

an understanding of the intrinsic and extrinsic factors that influence its growth in foods (McMeekin *et al*. 2002; McCann *et al*., 2003; Valero *et al.,* 2007). Sodium chloride applied either directly or as brine serves multiple functions, amongst which is the inhibition of microorganisms. The antimicrobial action of sodium chloride comprises a non-specific water activity reduction effect and an additional inhibitory effect. This part of the study investigates the survival and the formation of staphylococcal enterotoxins A (SEA) and B (SEB) in high risk smoked fish (mackerel) and medium to high risk smoked fish (smoked catfish) model systems. The model systems consisted of macerated and salted smoked catfish or smoked mackerel, inoculated with *S. aureus* reference strain (NCTC 10657) that produces staphylococcal enterotoxins A and B.

6.2 Materials and methods

6.2.1 Sample collection and preparation

Fish products tested included smoked mackerel, smoked catfish and salted and dried tilapia products. Fresh catfish, Atlantic mackerel, and tilapia were obtained from the fish market at Billingsgate. The fish was transported in ice chests packed with ice cubes to a designated processing site where they were cleaned, scaled, gutted, gills removed and washed and carefully arranged on mesh wire trays according to common traditional practice employed in Ghana. The fish were initially hot-smoked over an oven fired with hard wood for three hours. This was followed by a second phase of smoking over moderate fire for 8 hours to continue the drying process and reduce the moisture content. Samples of processed fish were also collected from the retail market for comparison. The fish samples were cut into pieces and blended using a Kenwood blender.

6.2.1.1 Sample preparation and culture preparation

Sodium chloride was added to blended fish samples to achieve 0, 5, 10 or 15% (w/w) sodium chloride. Processed fish samples and the samples collected from retail markets were separately bulked together according to the fish type and the sodium chloride treatment they were subjected to and aseptically mixed thoroughly. Enterotoxigenic *S. aureus* (NCTC 10657) strain which produces SEA and B was maintained on Nutrient agar (Oxoid) slopes at 4^{o}C. The culture was transferred to

fresh Nutrient agar slopes every four weeks. Overnight culture was prepared by inoculating a loopful of individual colony of *S. aureus* (NCTC 10657) into 10 ml Nutrient broth (Oxoid) followed by incubation at 37 ± 1^{o}C for 18 hours. From this, a 10-fold dilution series was prepared in Nutrient broth and 1 ml of the 10^{-2} or 10^{-4} dilutions was added for every 100 g of smoked fish to yield initial levels of 10^{3} or 10^{4}cfu/g of smoked fish sample. After thoroughly mixing together, 100 g of each formulation was tightly packed into 180 ml sterile plastic pots in a modification of the system described by Deibel *et al.* (1961). The loaded plastic pots were incubated at 30°C and duplicate samples were taken at 0, 1 3 and 7 days to determine growth and toxin production. Un-inoculated samples were used as control.

6.2.2 Sample analysis

At the pre-determined time intervals, each pot was opened. Portions were used to determine microbial load and evaluate the production of *S. aureus* enterotoxin. Three experiments were performed in duplicate.

6.2.2.1 Enumeration of *S. aureus*

A sample of 25 *g* of fish was weighed from each pot, added to 225 ml of buffered peptone water in a stomacher bag and homogenised with a Colworth stomacher (Seward, London. UK). Serial decimal dilutions were prepared and 0.1 ml of suitable decimal dilutions spread onto the surfaces of Baird-Parker agar plates. The plates were incubated for 48 hours at 37°C. Duplicate plates for each dilution. Aerobic bacteria were determined on Plate Count Agar (PCA) (Oxoid CM 463) as described in section 3.4.3.6.

6.2.2.2 Enterotoxin assay

The Reverse Passive Latex Agglutination method (RPLA) was used to detect enterotoxin with a SET-RPLA detection kit (Oxoid). In this method, latex particles sensitized with antibodies of staphylococcal enterotoxin react with the enterotoxins in the specimen and form agglutinations. This detection kit has a sensitivity of 1–2 µg/ml (Anon, 1990). To test for staphylococcal enterotoxins 10g of sample was homogenised with 10ml of sodium chloride solution (0.85%) in a stomacher 400

(Seward Medical, London, England) for 1 min and then centrifuged at 900g at 4° C for 30 minutes. The supernatant fluid was gently taken up with a capillary tube and filtered through a 0.2µm-0.45µm low protein-binding membrane filter. The filtrate was retained and assayed for enterotoxin content. The agglutination reactions were classified according to the manufacturer's instructions as, +++ (complete agglutination), ++, + (small pellet visible in the centre of the agglutination latex), +/- (just detectable difference from negative control well) and - (negative). Reactions scoring +++, ++, and + were considered positive.

6.2.3. Physico-chemical analysis

This included moisture, pH and water activity of the salted/dried fish and the salted/smoked fish were determined. The a_w of representative product samples were measured with a Decagon water activity meter (CX-1, Decagon Devices Inc., Washington, USA) as described in Section 3.3.3.1. The pH levels of similar samples were measured using a Corning pH meter 240 following the method described in Section 3.3.3.2.

6.3. Results and discussion

6.3.1 Effect of sodium chloride, water activity, temperature and pH on growth of *S. aureus* in smoked catfish

Salt concentration, water activity, pH and temperature can affect the survival or proliferation of microbial pathogens in food. Results of *S. aureus* counts, aerobic plate counts, salt concentration, water activity and pH values of smoked catfish samples are shown in Tables 6.1. The pH levels of smoked catfish samples analysed were between 6.16 and 6.71. This level of acidity is not high enough to inhibit staphylococci growth. Generally the addition of sodium chloride (0, 5, 10 and 15 % (w/w) to smoked catfish resulted in a decrease in water activity corresponding to 0.99, 0.92, 0.81 and 0.77, respectively. The water activity level of the sample from retail outlets was 0.93. *S. aureus* were absent in all the control samples analysed. Treatment with sodium chloride (5, 10 and 15 % (w/w) presented statistically significant inhibitory effect ($p < 0.001$) on the survival of *S. aureus* in smoked

Table 6.1. Growth and enterotoxin A and B production of S. aureus in relation to sodium chloride concentration, water activity, pH and storage time of smoked catfish at 30oC.

NaCl (% w/w)	pH	Water activity	Time (Days)	Low inoculum *S. aureus* counts (log cfu/g)	Low inoculum Aerobic counts (log cfu/g)	SEA	SEB	High inoculum *S. aureus* counts (log cfu/g)	High inoculum Aerobic counts (log cfu/g)	SEA	SEB
0	6.54	0.987	0	3.54 ± 0.05	3.79 ± 0.03	-	-	4.06 ± 0.55	4.75 ± 0.29	-	-
			1	5.37 ± 0.65	6.08 ± 0.65	-	-	7.14 ± 0.31	7.59 ± 0.08	++	+
			3	4.69 ± 0.54	5.15 ± 0.66	+	+	5.84 ± 0.64	6.56 ± 0.59	+++	+++
			7	4.29 ± 0.36	4.85 ± 0.17	+	+	5.65 ± 0.56	6.52 ± 0.61	+++	+++
5	6.39	0.924	0	3.10 ± 0.30	3.69 ± 0.08	-	-	4.58 ± 0.09	4.70 ± 0.17	-	-
			1	5.02 ± 0.78	5.44 ± 0.83	-	-	6.52 ± 0.20	7.17 ± 0.16	+	+
			3	4.37 ± 0.63	5.11 ± 0.53	-	-	4.73 ± 0.44	5.27 ± 0.62	+	+
			7	4.45 ± 0.41	5.20 ± 0.72	-	-	4.87 ± 0.34	5.67 ± 0.53	+	+
10	6.38	0.814	0	2.47 ± 0.15	3.27 ± 0.12	-	-	4.61 ± 0.14	4.80 ± 0.19	-	-
			1	3.61 ± 0.59	4.15 ± 0.56	-	-	4.82 ± 0.37	5.63 ± 0.11	-	-
			3	2.72 ± 0.36	3.57 ± 0.13	-	-	3.57 ± 0.56	3.52 ± 0.10	-	-
			7	2.83 ± 0.32	3.57 ± 0.14	-	-	3.26 ± 0.35	3.61 ± 0.14	-	-
15	6.16	0.766	0	2.82 ± 0.33	3.39 ± 0.08	-	-	4.31 ± 0.22	4.67 ± 0.14	-	-
			1	2.72 ± 0.50	3.45 ± 0.24	-	-	4.05 ± 0.15	4.99 ± 0.40	-	-
			3	1.86 ± 0.45	2.64 ± 0.36	-	-	2.50 ± 0.54	2.94 ± 0.28	-	-
			7	2.01 ± 0.55	2.92 ± 0.40	-	-	2.78 ± 0.24	2.99 ± 0.20	-	-
Inoculated retail samples	6.71	0.927	0	3.56 ± 0.22	4.94 ± 0.52	-	-	4.78 ± 0.22	5.86 ± 0.54	-	-
			1	5.87 ± 0.17	6.13 ± 0.28	+	+	7.50 ± 0.11	7.78 ± 0.22	+	++
			3	5.62 ± 0.11	6.40 ± 0.02	+	+	6.99 ± 0.30	8.45 ± 0.37	++	+++
			7	5.48 ± 0.03	6.36 ± 0.33	+	+	7.07 ± 0.35	8.20 ± 0.11	++	+++
Un-inoculated retail Samples (control)	6.71	0.927	0	2.52 ± 0.01	3.35 ± 0.36	-	-				
			1	3.54 ± 0.01	3.93 ± 0.25	-	-				
			3	3.75 ± 0.31	4.49 ± 0.13	-	-				
			7	3.80 ± 0.32	4.18 ± 0.37	-	-				

catfish. There was no such inhibitory effect on *S. aureus* inoculated into unsalted catfish stored at 30^{o}C. *S. aureus* survived in all unsalted samples and samples formulated with 5% sodium chloride and stored at 30^{o}C. Survival of *S. aureus* was generally variable, but declined with increasing sodium chloride concentration and decreasing a_w of the catfish products. In the formulation containing 15 % (w/w) sodium chloride *S. aureus* counts decreased throughout the 7 days of storage reaching 2.01±0.55 at 30^{o}C on day 7. Regression analysis showed that *S. aureus* count decreased by 0.281 for a unit increase in NaCl. This marginal effect is statistically significant ($p<0.001$) and 33% of the variation in *S. aureus* is explained by NaCl ($r^2=0.3320$). The growth of *S. aureus* in smoked catfish was significantly affected by the inoculum size. At the lower initial inoculum level (10^2 cfu/g) *S. aureus* counts increased by nearly 2 log cycles by day 1 in the smoked catfish formulated with 5% (w/v) sodium chloride. At the higher inoculum level (10^4 cfu/g), cell counts of *S. aureus* in unsalted catfish reached 7.14 ± 0.31 cfu/g after 24 hours of storage compared to 5.37 ± 0.65 for the lower inoculum (10^2 cfu/g).

The effects of storage temperature on the survival of *S. aureus* in smoked catfish samples are shown in Table 6.2. Decreasing the storage temperature significantly inhibited the growth of *S. aureus* in smoked catfish. At 4^{o}C growth of *S. aureus* in the refrigerated samples was inhibited, reaching 3.85 ± 0.338 cfu/g on the seventh day from an initial level of 3.48 ± 0.08 cfu/g in unsalted catfish samples. For smoked catfish samples treated with 5% (w/w) sodium chloride and stored at 4^{o}C there was a reduction in growth from an initial count of 3.42 ± 0.06 cfu/g at time 0 to 3.18±0.25 on storage day 7. The levels of *S. aureus* also declined in the formulation containing 10 and 15 % (w/w) sodium chloride. *S. aureus* was able to grow in the unsalted catfish stored 30^{o}C reaching 5.37 ± 0.65 cfu/g after 24 hours from an initial inoculum of 3.54 ± 0.05 cfu/g. However, cell counts of *S. aureus* subsequently decreased till the seventh day. Counts of *S. aureus* increased by log 1.83 cycles in the unsalted catfish stored at 30^{o}C over the same period, and gradually decreased to 4.29±0.17 cfu/g after 7 days of storage. *S. aureus* did not grow in catfish stored at 4^{o}C at any level

Table 6.2. Effect of temperature on survival of *Staphylococcus aureus* in laboratory-formulated smoked catfish

Inoculum size	Sample	*S. aureus* survival at 4°C		*S. aureus* survival at 30°C	
		Day 0	Day 7	Day 0	Day 7
Low	Unsalted	3.48 ± 0.08	3.85 ± 0.34	3.54 ± 0.05	4.29 ± 0.36
	5% NaCl	3.42 ± 0.06	3.18 ± 0.25	3.10 ± 0.30	4.45 ± 0.41
	10% NaCl	3.18 ± 0.17	2.83 ± 0.36	2.47 ± 0.15	2.83 ± 0.32
	15% NaCl	3.06 ± 0.04	1.53 ± 0.12	2.82 ± 0.33	2.01 ± 0.55
	Inoculated retail samples	3.47 ± 0.07	3.55 ± 0.10	3.56 ± 0.22	5.48 ± 0.03
	Uninoculated retail samples	2.15 ± 0.37	2.42 ± 0.08	2.52 ± 0.01	3.80 ± 0.32
High	Unsalted	4.94 ± 0.42	4.61 ± 0.16	4.06 ± 0.55	5.65 ± 0.56
	5% NaCl	4.86 ± 0.28	3.67 ± 0.10	4.58 ± 0.09	4.87 ± 0.34
	10% NaCl	4.76 ± 0.25	3.02 ± 0.25	4.61 ± 0.14	3.26 ± 0.35
	15% NaCl	4.67 ± 0.14	2.64 ± 0.134	4.31 ± 0.22	2.78 ± 0.240
	Inoculated retail samples	4.54 ± 0.17	4.91 ± 0.30	4.07 ± 0.35	8.20 ± 0.11

of NaCl concentration. Statistical analysis showed that *S. aureus* count increased by 0.24 log cycles for a unit increase in temperature. This marginal effect is statistically significant ($p<0.001$) but only 5% of the variation in *S. aureus* count is explained by temperature alone ($r^2=0.05$). A summary of the regression analysis for smoked catfish (Table 6.3) show that temperature, NaCl, a_w, pH, inoculum size had significant ($p<0.001$) effects on the rate of decline of the *S. aureus* population in smoked catfish.

Table 6.3. Table of multiple regression analysis results for the survival of *S. aureus* and aerobic bacteria in smoked catfish

Factor	Rate of decline	Significance	R^2
S. aureus			
NaCl	-0.13	p<0.001	0.33
a_w	8.24	p<0.001	0.24
ph	2.92	p<0.001	0.17
Time	-0.04	p= 0.163	0.00
Inoculum size	-1.21	p<0.001	0.25
Uninoculated	-1.81	p<0.001	0.25
Interactive effect of temperature, sodium chloride, water activity, pH, time and inoculum size			
NaCl	-2.678	p=0.258	
a_w	-98.32	p=0.290	
ph	-43.60	p=0.269	
Time	-0.09	p<0.0001	
Inoculum size	-1.18	p<0.0001	
Aerobic bacteria			
NaCl	0.12	p<0.0001	0.31
Aw	9.51	p<0.0001	0.10
Ph	4.18	p<0.0001	0.11
Time	-.035	0.535	0.00
Inoculum size	-1.33	p<0.0001	0.09
Uninoculated	-1.97	p<0.0001	0.09
Interactive effect of temperature, sodium chloride, water activity, pH, time and inoculum size			
NaCl	-2.89	0.256	
a_w	-106.35	0.287	
Ph	-47.59	0.262	
Time	-.071	0.002	
Inoculum size	-1.09	p<0.0001	

It is important to note that although the r^2 values for temperature ((r^2 = 0.05), NaCl (r^2 = - 0.33), a_w (r^2 = 0.24), pH (r^2 = 0.17), time (r^2 = 0.00), inoculum size (r^2 = 0.25) and un-inoculated (r^2 = 0.25) were low, the correlation between *S. aureus* counts and these factors were significant ($p<0.001$), indicating a strong inhibition on the survival of *S. aureus*. Interactive effect of temperature, sodium chloride, water activity, pH, time and inoculum size on survival of *S. aureus* in smoked catfish was highly linear (r^2 = 0.62). Analysis of the cumulative effect of temperature, sodium chloride, a_w, pH, time and inoculum size also showed a linear effect on the aerobic bacteria count observed on smoked catfish.

6.3.2 Effect of sodium chloride, water activity, temperature and pH on growth of *S. aureus* in smoked mackerel

The growth and entertoxin production of *S. aureus* in smoked mackerel as influenced by sodium chloride concentration (w/w), water activity, inoculation dose (low and high) and pH at 30ºC holding temperature is shown on 6.4. The inhibitory effects of sodium chloride on *S. aureus* in the smoked mackerel products (Table 6.4) was similar to those observed with *S. aureus* in salted smoked catfish samples (Table 6.2). Treatment with sodium chloride (10 and 15 % (w/w) presented statistically significant inhibitory effect ($p < 0.001$) on the survival of *S. aureus* in smoked mackerel. Growth was not recorded in the samples formulated with 10% (w/w) NaCl (a_w levels of 0.79 and pH of 6.16) and 15% (w/w) NaCl (a_w levels of 0.75 and pH of 6.13).There was no such inhibitory effect on *S. aureus* in unsalted smoked mackerel or smoked mackerel treated with 5% sodium chloride. At 30ºC, the population of *S. aureus* in unsalted smoked mackerel (a_w levels of 0.96 and pH of 6.29) with an inoculation size of 3.55 ± 0.14 log cfu/g increased to 6.01 ± 0.62 log cfu/g in 12 h but subsequently decreased to 3.10 ± 0.067 log cfu/g by the seventh day. Similarly, the population of *S. aureus* in salted smoked mackerel formulated with 5% NaCl (a_w levels of 0.90 and pH of 6.20) with an inoculation size of 3.50 ± 0.26 increased to 5.78 ± 0.77 log cfu/g in 12 h but subsequently decreased to 2.81 ± 0.08 log cfu/g by the seventh day. This observation is very important for smoked fish products, in which the intrinsic properties of the fish (pH, a_w and salt) and the storage temperature must interact to prevent growth or preferably promote inactivation of the

Table 6.4. Growth and enterotoxin A and B production of *S. aureus* in relation to sodium chloride concentration, water activity, pH and storage time in laboratory-formulated smoked mackerel at 30°C.

NaCl (% w/w)	pH	Water activity	Time (Days)	Low inoculum *S. aureus* counts (log cfu/g)	Low inoculum Aerobic counts (log cfu/g)	SEA	SEB	High inoculum *S. aureus* counts (log cfu/g)	High inoculum Aerobic counts (log cfu/g)	SEA	SEB
0	6.29	0.96	0	3.55 ± 0.14	4.15 ± 0.20	-	-	4.13 ± 0.58	4.67 ± 0.43	-	-
			1	6.01 ± 0.62	6.81 ± 0.69	+	-	7.36 ± 0.38	7.88 ± 0.22	+	+
			3	5.67 ± 0.09	7.14 ± 0.34	++	+	6.49 ± 0.66	7.08 ± 0.47	++	++
			7	3.10 ± 0.07	5.64 ± 0.57	++	++	3.79 ± 0.66	7.05 ± 0.53	++	++
5	6.20	0.90	0	3.50 ± 0.26	3.75 ± 0.30	-	-	4.53 ± 0.20	5.02 ± 0.37	-	-
			1	5.78 ± 0.77	6.40 ± 0.90	-	-	6.70 ± 0.17	7.18 ± 0.32	-	+
			3	4.48 ± 0.69	6.22 ± 0.29	-	-	5.55 ± 0.71	6.14 ± 0.74	+	+
			7	2.81 ± 0.08	5.36 ± 0.26	-	-	3.31 ± 0.29	6.11 ± 0.50	+	+
10	6.16	0.79	0	3.08 ± 0.16	3.28 ± 0.25	-	-	4.50 ± 0.21	4.92 ± 0.14	-	-
			1	3.74 ± 0.37	4.59 ± 0.51	-	-	5.02 ± 0.22	5.32 ± 0.36	-	-
			3	3.00 ± 0.43	3.55 ± 0.14	-	-	4.07 ± 0.51	4.78 ± 0.62	-	-
			7	1.89 ± 0.47	3.68 ± 0.09	-	-	2.63 ± 0.65	4.65 ± 0.61	-	-
15	6.13	0.75	0	3.36 ± 0.15	3.84 ± 0.39	-	-	4.52 ± 0.26	4.82 ± 0.10	-	-
			1	3.10 ± 0.69	3.48 ± 0.64	-	-	4.23 ± 0.17	4.69 ± 0.40	-	-
			3	2.27 ± 0.56	3.06 ± 0.41	-	-	3.28 ± 0.46	3.62 ± 0.52	-	-
			7	1.77 ± 0.38	3.46 ± 0.08	-	-	2.03 ± 0.25	3.56 ± 0.51	-	-
Inoculated	6.28	0.94	0	3.52 ± 0.50	4.32 ± 0.39	-	-	5.13 ± 0.34	6.82 ± 0.48	-	-
Retail			1	5.74 ± 0.08	5.98 ± 0.15	-	-	7.50 ± 0.08	8.03 ± 0.26	++	++
Samples			3	5.69 ± 0.04	6.00 ± 0.24	+	+	7.32 ± 0.20	7.95 ± 0.30	+++	+++
			7	3.18 ± 0.33	6.03 ± 0.33	+	+	4.24 ± 0.15	8.09 ± 0.39	+++	+++
Un-inoculated			0	2.50 ± 0.18	4.04 ± 0.41	-	-				
Retail	6.28	0.94	1	3.55 ± 0.03	4.17 ± 0.37	-	-				
Samples			3	3.64 ± 0.11	4.29 ± 0.20	-	-				
(control)			7	2.30 ± 0.69	4.37 ± 0.23	-	-				

pathogen (Whiting *et al.,* 1996). Furthermore, it was also observed that the growth of *S. aureus* in the smoked mackerel products tested was in general faster in samples with high inoculation size than in samples with low inoculums size under similar holding condition. The effect of storage temperature (5^{o}C and 30^{o}C) on the growth behaviour of *S. aureus* in smoked mackerel products is shown on Table 6.5. Temperature had a strong effect on the probability of growth and toxin production by *S. aureus* in smoked mackerel. There was a rapid rise in both *S. aureus* and aerobic plate population when smoked mackerel was stored at 30^{o}C. At 30ºC, much higher growth was recorded in the unsalted smoked mackerel (a_w level of 0.96 and pH of 6.29), reaching 7.36 ± 0.38cfu/g after 24 hours. Growth was also recorded in salted smoked mackerel formulated with 5% NaCl (a_w levels of 0.90 and pH of 6.20) and in the inoculated retail samples (a_w levels of 0.94 and pH of 6.28) at this temperature. Storing smoked fish under ambient temperature conditions favoured growth of *S. aureus* but at 4^{o}C growth of this pathogen was inhibited. Similarly at 4ºC, growth did not occur in the unsalted mackerel and mackerel formulated with 5% NaCl but remained nearly stable.

As NaCl concentration increased, counts of *S. aureus* decreased continuously, reaching 1.86 ± 0.380 cfu/g and 1.31 ± 0.91 cfu/g in smoked mackerel formulated with 10 and 15% (w/w) NaCl, respectively, after seven days of storage at 4^{o}C. Generally, *S. aureus* grew more rapidly at 30^{o}C. There was only slight unexplained increase in *S. aureus* counts in unsalted smoked mackerel, pH 6.29 and a_w 0.96 at4^{o}C and this occurred with the first 12 h of storage. However, there was marked growth in unsalted samples stored at 30^{o}C, ranging from an initial count of 3.55±0.14 cfu/g to 6.01±0.62 cfu/g after 24 hours of storage and finally decreasing to 3.10±0.07 cfu/g on day 7. For the salted mackerel, a high growth occurred at 30^{o}C, pH 6.2 and aw 0.90, reaching 5.78±0.77 after 24 hours of storage. At 10% (w/w) and 15% (w/w) sodium chloride treatments, counts of *S. aureus* decreased regardless of the storage temperature.

Table 6.5. Growth of *Staphylococcus aureus* and enterotoxin production in smoked mackerel inoculated with log 10^2 *S. aureus* under different temperature conditions

Inoculum size	Sample	*S. aureus* survival at 4°C Days) 0	Day 7	*S. aureus* survival at 30°C Day 0	Day 7
Low	Unsalted	3.15 ± 0.16	3.89 ± 0.30	3.55 ± 0.14	3.10 ± 0.07
	5% NaCl	3.19 ± 0.35	3.26 ± 0.24	3.50 ± 0.26	2.81 ± 0.08
	10% NaCl	3.21 ± 0.18	1.86 ± 0.38	3.08 ± 0.16	1.89 ± 0.47
	15% NaCl	3.14 ± 0.17	1.31 ± 0.91	3.36 ± 0.15	1.77 ± 0.38
	Inoculated retail samples	3.80 ± 0.41	2.40 ± 0.75	3.52 ± 0.50	3.18 ± 0.33
	Uninoculated retail samples	2.55 ± 0.10	1.80 ± 0.44	2.50 ± 0.18	2.30 ± 0.69
High	Unsalted	4.94 ± 0.24	2.84 ± 0.10	4.13 ± 0.58	3.79 ± 0.66
	5% NaCl	4.84 ± 0.30	2.14 ± 0.44	4.53 ± 0.20	3.31 ± 0.29
	10% NaCl	4.54 ± 0.14	1.66 ± 0.07	4.50 ± 0.21	2.63 ± 0.65
	15% NaCl	4.56 ± 0.10	1.58 ± 0.24	4.52 ± 0.26	2.03 ± 0.25
	Inoculated retail samples	5.67 ± 0.45	2.74 ± 0.12	5.13 ± 0.34	4.24 ± 0.15

A summary of the regression analysis for smoked mackerel is shown in Table 6.6. Results from the regression analysis show that temperature, NaCl, aw, pH, inoculum size had significant ($p<0.001$) effects on the rate of decline of the *S. aureus* population in smoked mackerel.

Table 6.6. Table of multiple regression analysis results for the survival of *S. aureus* and aerobic bacteria in smoked mackerel

Factor	Rate of decline	P>|t|	r^2
Staph. aureus			
Temp	0.04	p<0.0001	0.11
NaCl	-0.13	p<0.0001	0.30
a_w	7.55	p<0.0001	0.21
Ph	9.58	p<0.0001	0.18
Time	-0.03	0.296	0.00
Inoculum size	-1.23	p<0.0001	0.25
Uninoculated	-1.95	p<0.0001	0.25
Interactive effect of temperature, sodium chloride, water activity, pH, time and inoculum size			
Temp	0.03	p<0.0001	0.61
NaCl	-0.08	0.208	
a_w	5.27	0.198	
Ph	-3.35	0.444	
Time	-0.06	0.006	
Inoculum size	-1.14	p<0.0001	
Aerobic bacteria			
Temp	0.04	p<0.0001	0.10
NaCl	-.14	p<0.0001	0.33
Aw	8.71	p<0.0001	0.26
Ph	11.20	p<0.0001	0.24
Time	-0.03	0.319	0.00
Inoculum size	-1.13	p<0.0001	0.19
Uninoculated	-1.63	p<0.0001	0.19
Interactive effect of temperature, sodium chloride, water activity, pH, time and inoculum size			
Temp	0.03	p<0.0001	0.58
NaCl	-0.11	0.121	
a_w	4.88	0.277	
pH	-4.44	0.356	
Time	-0.05	0.033	
Inoculum size	-0.99	p<0.0001	

It is important to note that although the r^2 values for temperature (($r^2 = 0.11$), NaCl ($r^2 = - 0.30$), a_w ($r^2 = 0.21$), pH ($r^2 = 0.18$), time ($r^2 = 0.00$), inoculum size ($r^2 = 0.25$) and un-inoculated ($r^2 = 0.25$)

were low, the correlation between *S. aureus* counts and these factors were significant ($p<0.001$), indicating a strong influence on the number of viable *S. aureus*. Interactive effect of temperature, sodium chloride, water activity, pH, time and inoculum size on survival of *S. aureus* in smoked catfish was highly linear ($r^2 = 0.61$), however this effect was statistically significant ($p<0.001$) only for temperature and inoculum size. Analysis of the cumulative effect of temperature, sodium chloride, aw, pH, time and inoculum size also showed a linear effect on aerobic bacteria count in smoked catfish ($r^2 = 0.58$). Total aerobic counts were lower in the higher salt samples and these differences were statistically significant ($P < 0.0001$). Similarly, total aerobic counts at 4^oC were lower than at 30^oC. There was significant difference in total aerobic counts between storage temperatures ($P< 0.0001$).

6.3.3 Enterotoxins A (SEA) and B (SEB) production in smoked catfish and smoked mackerel

The results show that varying amounts of SEA and SEB were produced in smoked catfish and smoked mackerel. No SEA and SEB were produced in any of the unsalted smoked catfish and smoked mackerel samples stored at 4^oC. These results are consistent with studies by Hung *et al.* (1993), and Yang et al. (2001), who reported no growth and enterotoxin production by *S. aureus* held at 5°C, in rice products and in egg products, respectively, regardless of initial inoculum size. In salted catfish and mackerel, SEA and SEB were detected only in samples formulated with 5% (w/w) sodium chloride and stored at 30^oC. The results demonstrate the inhibitory effects of low temperature, low water activity and sodium chloride on the survival and production of enterotoxins by *S. aureus* in smoked catfish and smoked mackerel. The population of *S. aureus* in unsalted smoked catfish with low inoculum reached 5.37 ± 0.65 cfu/g on day 2 in samples stored at 30^oC. SEA and SEB levels were low in these samples. However when unsalted smoked catfish was inoculated with the higher level of inoculum (10^4 cfu/g), counts of *S. aureus* reached 7.14 ± 0.31 cfu/g in samples stored at 30^oC, resulting in complete agglutination (+++) for enterotoxins A and B within 24 h.

Similar unsalted catfish samples inoculated with lower inoculum size did not yield detectable levels of enterotoxins A and B until the third day and this was detected at the lowest detectable level (+). These results therefore indicate a dose-dependent effect of inoculum on enterotoxin production. Other studies have indicated the importance of inoculum size on the ability of a microbial population to initiate growth (Razavilar and Genigeorgis, 1998; Masana and Baranyi, 2000; Pascual *et al.,* 2001; Robinson *et al.,* 2001) or the location of the growth/no growth boundary for different strains of bacteria (Robinson *et al.,* 2001). At 30^{o}C, SEA and SEB were detected only in the samples formulated with 5 % (w/w) sodium chloride and inoculated with high inoculum. No SEA and SEB were present in any of the un-inoculated catfish from the retail outlets. However, SEA and SEB were detected in the inoculated retail samples inoculated with low and high inoculum and stored at 30^{o}C.

The population of *S. aureus* in unsalted smoked mackerel with low inoculum reached 6.01 ± 0.62 cfu/g on day 2 in samples stored at 30^{o}C and SEA was detectable at this stage (characterised by small pellet visible in the centre of the agglutination latex). SEA and SEB were detected in these samples on the third day of storage. At high inoculum (10^4 cfu/g) and 30^{o}C storage temperature, counts of *S. aureus* in unsalted smoked mackerel reached 7.36 ± 0.38 cfu/g within 24 hours and agglutination reactions showed complete agglutination for SEA and SEB. For the salted mackerel samples, SEA and SEB were not detected in any of the samples stored at 4^{o}C and in the samples inoculated with low inoculum. At 30^{o}C, SEA and SEB were detected only in the samples formulated with 5% (w/w) sodium chloride and inoculated with high inoculum. No enterotoxins were detected in the smoked mackerel formulated with higher than 5% (w/w) sodium chloride. No SEA and SEB were present in any of the un-inoculated smoked mackerel from the retail outlets. However, SEA and SEB were detected in the inoculated retail samples stored inoculated with low and high inoculum and stored at 30^{o}C.

6.4 Discussion and conclusion

Plahar *et al.,* (1999) reported the incidence of *S. aureus* in smoked fish in Ghana. Heavy contamination of fish with SEB and SEA producing strains of *S. aureus* have also been reported in

processed fish samples in Nigeria (Sokari, 1991). Studies show that *S. aureus* is capable of producing enterotoxins under a wide range of temperatures (Bergdoll, 1989; Schmitt *et al.,* 1990). Despite extensive handling and widespread sale of smoked fish products under ambient conditions in developing countries like Ghana, to our knowledge there have not been previous studies investigating the survival and production of enterotoxins by *S. aureus* in this kind of fish products in the country. Based on the assumption that the pathogen can be introduced into fish through raw materials, handling, and unsanitary procedures and equipment (Pepe *et al.,* 2006), this study has demonstrated the ability of *S. aureus* to produce enterotoxins in salted smoked mackerel and smoked catfish at low temperature (4^oC) and at 30^oC storage conditions. Microbial survival and/or growth depend not only on water activity (a_w) but also on the chemical and physical properties of the humectant (Stewart *et al*., 2002). Lanciotti *et al.* (2001) studied the effect of temperature, pH, a_w and ethanol concentration on the probability of growth of *S. aureus*, but only at growth temperatures above 10°C. Moreover, Lanciotti *et al.* (2001) in their study used glycerol instead of NaCl as humectant to adjust a_w levels. Stewart *et al.* (2002) studied the effect of different humectants on the growth of *S. aureus*, but only at optimal growth temperature (37°C). In the present study, the inhibitory effect of NaCl, a_w and temperature on *S. aureus* was investigated. The results show that 10% (w/w) sodium chloride was able to limit the growth of *S. aureus* below the level that can produce enterotoxins.

Several studies have reported the tolerance of *S. aureus* to high concentrations of sodium chloride (Bergdoll, 1989; Thomas and Wimpenny, 1996; Bayani and Azanza, 2005). Rieman *et al.,* (1972) reported *S. aureus* growth and toxin production in laboratory media with sodium chloride concentrations of up to 15% (w/v) and in food with sodium chloride concentrations of 10% (w/v) at the pH normally found in cured meats. Whether growth at such a high sodium chloride concentrations was due to inadvertent selection of a few salt-tolerant cells or by other metabolic processes was not determined. However a number of studies have attributed the osmotolerance of *S. aureus* to NaCl to its ability to maintain its outer membrane structural integrity (Hajmee et al.,

2006) and accumulate osmoprotectants such as proline, choline, taurine and glycinebetaine under osmotic stress (Neidhardt *et al.*, 1990; Townsend and Wilkinson, 1992; Jablonski and Bohach, 1999).

In this study the addition of 10% (w/w) salt to smoked catfish or smoked mackerel would seem to constitute a substantial hurdle for *S. aureus* to overcome and grow to reach levels that can cause food safety problems. Generally therefore, the model used in this study showed a decline in *S. aureus* populations with increasing salt concentration and with storage time. This decline was higher in smoked fish products stored at refrigeration temperature (4^oC) than similar fish products stored at simulated ambient conditions (30^oC). *S. aureus* is a mesophilic bacterium and temperature is one of the most important growth controlling factors that affect the location of the growth/no growth boundaries (Lanciotti *et al*., 2001; Fujikawa and Morozumi, 2006). Decreasing the storage temperature constituted an additional hurdle which together with NaCl significantly inhibited the growth rate of *S. aureus* in smoked catfish and mackerel. These findings are in agreement with results from other studies which highlight the inhibitory effects of low temperature on growth rate of *S. aureus* in different foods (Lindgvist *et al*., 2002; Wong *et al*., 2004; Rho and Schaffner, 2007).

The results also show that although *S. aureus* may be inhibited in salted smoked fish and refrigerated smoked fish, the pathogen can remain dormant under extremely low temperatures, low a_w and high salt concentrations. This may be due to the ability of *S. aureus* to tolerate low water activity food. Smoked fish products in which *S. aureus* can survive and remain dormant may become hazardous if the fish is used as an ingredient in other foods in which staphylococci can grow. However although *S. aureus* survived in smoked catfish and smoked mackerel formulated with 10% and 15% (w/w) sodium chloride, enterotoxins were not detected in these samples. Generally, as the sodium chloride concentration increased from 0 to 15% in these samples, the yields of enterotoxins A and B decreased to undetectable levels. McLean *et al.* (1968) have observed that, although sodium chloride concentrations of up to 10% had a relatively slight effect

on total growth, they caused a definite decrease in toxin production above 3% NaCl. The result also shows that initial inoculum size was very important in determining the survival of *S. aureus* and the production of enterotoxins in smoked catfish and mackerel products. These results therefore suggest that even if smoked mackerel or smoked catfish become contaminated with low (10^2 cfu/g) *S. aureus*, the population of the bacteria is likely to decline with time in adequately salted smoked fish and may not to grow to levels that could produce toxins. Other studies have highlighted the importance of inoculum size on the ability of a microbial population to initiate growth (Masana and Baranyi, 2000; Pascual *et al*., 2001; Robinson *et al*., 2001).

The present study extends our knowledge of the combined effects of NaCl, a_w, pH and temperature on the growth of staphylococci and on the subsequent production of enterotoxins A and B in smoked fish. Treating smoked catfish and smoked mackerel with sodium chloride can therefore make them safe to store by lowering the water activity to a point that will not allow *S. aureus* to grow. Other factors, including pH, water activity, were also significant. This implies that the effect of sodium chloride treatment is more pronounced when other interactive factors, including the intrinsic composition of the food and storage temperature act together in synergy. Genigeorgis (1989) has also highlighted the importance of the intrinsic characteristics of the food (pH, water activity, E_h, preservatives, competing microbial flora, natural food) and extrinsic parameters of processing and storage (temperature, freezing, irradiation, dehydration, packaging, humidity) in inhibiting *S. aureus*. In this study, when one of the growth conditions improved, for example higher growth temperature, the effects of sodium chloride on *S. aureus* decreased. The risk of *S. aureus* contamination is high when food handlers with skin infections contaminate foods that are undercooked or when food is left under ambient temperature and is generally associated with extensive manual handling, inadequate heating and/or inappropriate storage of the food (Catteau, 1993; Sattar *et al.,* 2001; Le Loir *et al.,* 2003; Smyth *et al.,* 2004; Sneed *et al.,* 2004; Pepe *et al.,* 2006; DeVita *et al.,* 2007). For smoked catfish and smoked mackerel destined for ambient storage therefore, the processes applied must ensure that the water activity levels are low enough to prevent

the growth of *S. aureus* to the threshold level of 10^5 cfu/g (Notermans and Heuvelman, 1983; USDA, 2007).

Whilst staphylococci can be destroyed easily, the enterotoxins are heat stable and may be present in food when *S. aureus* are absent (Balaban and Rasooly, 2000). The minimal water activity for the *S. aureus* growth is in the range from 0.83 to 0.86 *a*w (Troller and Stinson 1975). Fish processors must therefore aim at achieving a_w levels below 0.82 in order to ensure their safety. This can be achieved in fish smoking by the addition of salt and prolonging the drying period under low heat conditions. The results suggest that the interaction between a number of factors, including, temperature, water activity, salt, pH and inoculum size could be more important at influencing the growth of *S. aureus* in smoked fish. For smoked fish formulated with 5% (w/w) sodium chloride or unsalted fish products the drying period must be long enough to reduce the water activity to lower than 0.85 in order to enhance the antimicrobial properties of these products and prevent the growth and toxin production by *S. aureus*. The raw material quality, handling, equipment, and sanitary procedures as well as the heating, storage and retail of the fish must be improved so that fish does not become contaminated with *S. aureus* during any of these stages. The use of appropriate utensils, gloves e.t.c will greatly improve safety of smoked fish. Furthermore, standardising the preparation methods would help minimise the variability in product characteristics and ensure that traditional fish products are safe.

Chapter 7

7.0 Self-reported and observed food safety practices in fish processing units in Ghana

7.1 Introduction

Commercial food establishments are a potential source for outbreaks of foodborne diseases. It is also widely recognised that food handlers play a critical role in spreading foodborne infections. Food workers who do not carry out appropriate food safety practices and good personal hygiene, including handwashing at the appropriate times, can contaminate food. Food safety surveys conducted in many countries provide general indications of the food safety practices undertaken by commercial food handlers (Manning, 1994; Angelillo *et al.*, 2000, 2001b; Clayton *et al.*, 2003; Walker *et al.*, 2003a). Many of these studies show that food handlers tend to overestimate the frequency with which they carry out food safety practices (Oteri and Ekanem, 1989; Manning and Snider, 1993; Howes *et al.*, 1996). Consequently, it has been argued that direct observation, although not without its limitations, represents a more accurate and reliable method of capturing food handlers' actual hygiene practices and place the behaviour in context (Gittelsohn *et al.*, 1997; Redmond and Griffith, 2003a). Data on food handling practices in Ghana are limited and much of the information collected to date concerns food safety awareness and knowledge rather than actual food handling practices (King *et al.*, 1998; Nuer, 2001; Acheampong, 2005; Annor and Baiden, 2011). This survey was undertaken to identify and compare differences between self-reported food-handling behaviours and actual food safety behaviours of fish handlers in Ghana. Specific information on purchasing, transport, storage, thawing, processing, retail and hygiene practices was requested in the questionnaire. The primary purpose was to provide data to support food safety promotion. Specifically, the objectives of this study were to:

1. determine whether fish handlers followed food safety guidelines in the purchasing, storage, processing and retail of fish,

2. compare the self-reported food safety behaviour of fish handlers with their observed food safety behaviour and,

3. determine any barriers to food safety compliance and food safety inspectors views, challenges and limitations about the enforcement of food safety and hygiene regulations.

It was hypothesised that:

1. fish handling practices during purchasing, storage, transportation, processing and retail would not meet food safety standards,

2. most fish handlers know the basics of food safety but do not always practice these behaviours

The data reported here are qualitative, obtained through structured interviews and direct observations of purchasing, transportation, storage, thawing, processing and retailing and hygiene practices. The observed food safety practices were compared according to socio-demographic variables and prior food safety education.

7.2 Methodology

7.2.1 Interviews with fish handlers and food safety enforcement officers

This study took a dual approach, examining the roles and activities of food handlers and enforcement agents and communication between the two groups. The study was conducted between January and February 2011 to collect data on contributing factors to food safety problems in the traditional fish processing sector in Ghana. The sample was composed of 161 randomly selected fish handlers from 4 districts in the Central region (Gomoa, Mfantsiman, Cape Coast and the Komenda, Edina, Eguafo, Abirem Districts) and 3 districts from the Greater Accra region (Tema, Accra and Ga) of Ghana, using a cluster sampling procedure (Kelly, 2006). Sixty self-completed questionnaires were also distributed to staff of the Food and Drugs Board and seven local authorities in the Greater Accra and Central Regions of Ghana to collect data on food safety enforcement and compliance. Forty-eight of the sixty questionnaires were returned, a response rate of 80 per cent. A two-stage sampling method was used in which in the first stage, the survey districts were selected by means of cluster sampling and in the second stage, a convenient sample of respondents within the selected districts were interviewed and observed. Respondents were at least 18 years old. Five interviewers were recruited and trained by the principal investigator to administer the questionnaire. Before data was collected, the interviewers took turns to interview each other for

practice after which a convenient sample of 20 fish handlers was selected to pilot-test the questionnaires. The questionnaires were revised using comments collected from the pilot test.

7.2.2 Food safety questionnaire design

The fish handlers' questionnaire (Appendix D) centred on fish-handling and preparation practices, personal hygiene, and hand-washing and food handlers' perceptions of food safety. This was based on Codex Alimentarius Food Hygiene Basic Text (CAC, 2009) and the Codex Codes of Practice for fish and fishery products (CAC/RCP 52-2003). Food safety opinions and sources of information, food handling unit food safety policies, food safety management and business culture as well as supervision, peer support, regulatory compliance and training programmes were also assessed. Other questions focused on factors essential to successful implementation and challenges during implementation of food safety practices. The study also sought to identify stages in the food chain that appeared to be particularly problematic for food businesses. The questionnaire for the enforcement agents (Appendix E) was created after interviews with food safety inspectors from the Food and Drugs Board and the public health units of the districts and metropolitan assemblies. The questions were either of yes/no format, Likert rating scales format or open, with the interviewees selecting responses from a list provided in the questionnaire and recording those not on the list as "other". The officers were asked to rate their competence with some items on a five-point answer scale, with categories of "1 = not competent, 2 = moderately competent, 3 = competent, 4 = very competent and 5 = extremely competent" categories. The questionnaire consisted of 30 questions.

7.2.3 Self-reported and observed fish handling practices

Participant observation of fish handlers at landing, processing and vending sites as well as the state of hygiene and sanitation in and around the handling sites was conducted using a checklist adapted from the Codex basic text on food hygiene (CAC, 2009) and the Codex Codes of Practice for fish and fishery products (CAC/RCP 52-2003) (Appendix F). Twenty-eight premises were randomly selected and the structured checklist used to interview food workers actively employed in the fish industry about their self-reported and observed food safety behaviours. Selected commercial units

were visited and meetings held with managers and/or workers and owners to arrange for observation, followed by assessment of food safety practices and compliance at control points (landing sites, retail units, processing and storage facilities) by fish handlers during their operations.

7.2.4 Participant observation procedures

During the visit, a tour of the landing sites, transport facilities, processing units, fish storage units, waste storage areas, water reservoirs and water sources was conducted under the guidance of the fish handlers and/or managers and/or owners. Important and relevant observations were recorded using the checklist. Presence of public and sanitary utilities were determined, availability of toilets, adequate washing facilities, electricity, and refrigeration/freezer storage at handling and processing units and in retail outlets. The exterior of the landing/processing/vending premises were assessed. The appearance of fish handlers, processors and retailers was noted. Participants in the study were observed on an individual basis. After the tour a question and answer (Q&A) session was held with managers and/or employees or owners of the fish handling unit (landing sites, cold stores, transport, processing, and retail and storage units) for a survey on self-reported practices using the checklist (Appendix F).

7.2.4.1 Coding observed behaviours

The observational checklist was used to track the following behaviours: hand-washing, avoiding cross-contamination, sanitation and hygiene. The number of times a particular action was required to be correctly performed and the number of times it was correctly performed was recorded using a coding scheme. This scheme was applied to behaviours for which a correct practice was defined (e.g. properly washing hands after use of the toilet, rinsing hands with water and wiping with a towel). A second coding scheme was applied to the premises (infrastructure) structure and its suitability for fish processing, fish handlers' skills and knowledge. These remaining behaviours were coded as either yes (i.e. observed) or no (i.e. not observed).

7.2.5 Statistical analysis

Questionnaire responses were entered into an electronic database (Access 2010, Microsoft Corporation, Redmond, WA). Entry-validation checks were performed on all questionnaires by manually comparing the database and hard-copy versions. The data were then exported and analysed for means, standard deviations and correlation using Excel (Excel 2010, Microsoft Corporation, Redmond, WA) and SPSS (Version 18, Chicago, IL). Descriptive statistics, including frequencies and percentages, were calculated for all variables. Observed food safety practices and self-reported practices were compared. Results were presented in tables. Results of statistical analyses were also reported with a significance level of $p \leq 0.05$.

7.3 Results

7.3.1. Demographic characteristics of fish handlers

The demographic characteristics of the 161 fish handlers interviewed in this survey are shown in Table 7.1. The results show that 67.1% of the respondents were female. These results are consistent with previous studies which show that women are largely responsible for fish processing and handling in Ghana (Odotei, 2002; Britwum *et al.*, 2006). The mean age of the respondents was 36.6 years and nearly a third (27%) of them had no formal education.

The majority (69.5%) of the fish handlers had been working in the fish industry for at least 5 years and in various stages of the fish chain, including fishing (13.7%), fresh fish retail (38.5%), fish processing (25.5%), transportation (9.3%) and processing and retail (8.7%). The majority (77%) had no food safety certification and had never heard of Hazard Analysis and Critical Control Point (HACCP). This is not surprising since small and micro businesses are more likely to be unfamiliar with HACCP. Taylor *et al.* (2011) have also reported low levels of HACCP awareness among food handlers in studies carried out in Barbados, Dubai, Nigeria and Oman. The 26 (16.1%) fish handlers who had heard of HACCP, cited the press (30.8), food safety inspectors (23.1%) food safety seminars (15.4%) and the Food and Drugs Board (11.5%) as their source of HACCP information. Some of these sources, including the press are not reliable sources of HACCP information.

Table 7.1. Demographic characteristics of respondents

Factor	Level	n	%
Age group	18-24	11	6.8
	25-34	62	38.5
	35-44	50	31.1
	45-54	35	21.7
	55-64	3	1.9
Gender	Male	53	32.9
	Female	108	67.1
Education	No school	43	26.7
	Primary	61	37.9
	Secondary	51	31.7
	College	4	2.5
	Higher education	2	1.2
Number of years in fish business			
	1-4	27	16.8
	5-9	58	36.0
	10-19	54	33.5
	20-29	11	6.8
	30-45	11	6.8
Food safety certification			
	Yes	35	21.7
	No	124	77.0
Primary area in food business			
	Fishing	22	13.7
	Fresh fish retail	68	38.5
	Fish processing	41	25.5
	Fish transport	15	9.3
	Fish processing and retail	14	8.7
	Others	7	4.3
Ever heard of hazard analysis and critical control points (HACCP)?			
	Yes	26	16.1
	No	124	77.0
Source of HACCP information			
	Food safety inspector	6	23.1
	The press	8	30.8
	Food safety seminars	4	15.4
	Food and Drugs Board	3	11.5
	Others	5	19.2
Rank your understanding of HACCP			
	Very Poor	5	19.2
	Poor	14	53.8
	Good	4	15.4
	Very good	2	7.7
	Excellent	1	3.8

Only a minority of those who indicated that they had heard of HACCP said they had good (15.4%), very good (7.7%) or excellent (3.8%) knowledge of HACCP. This lack of knowledge of the HACCP concept is a main barrier to its implementation. The survey also found that none of the fish firms had any documentation of food safety management.

7.3.2. Fish handling practices and their safety

7.3.2.1. Raw fish handling practices and their safety

At least 51.9% of fish handlers handle raw fresh, frozen or thawed fish (Table 7.2). The fresh fish are usually bought directly from fishermen or their agents. However, in many cases frozen fish are imported fish retailed in cold stores. An important determinant of fresh fish safety and overall quality during storage, distribution and consumption is the time/ temperature conditions. In this study, just over 76% of fish handlers use home fridges or freezers to store raw fish. After buying fresh fish 42.2% always and 46.6% sometimes use clean ice chests, basins, boxes packed with ice flakes or cubes to transport fish to the processing sites. As many as 54.7% did not have ice flakes or cubes to quickly reduce and maintain the temperature of fish to 5^{o}C or below during capture, retail, transportation or purchase. The quality and freshness of fish rapidly declines post-mortem due to a variety of microbial and biochemical degradation mechanisms (Pigott and Tucker, 1990; Whittle *et al.,* 1990; Olafsdóttir *et al.,* 1997). Some 38.5% of the fish handlers spend one to two hours and another 29.2% spend more than two hours transporting fish to processing sites. Thus, there is the possibility that high ambient temperatures and long pre-processing periods together with the long distances from the landing sites to processing units may accelerate the deterioration of fish quality and can result in potential health risks (Ababouch *et al.,* 1996; Cheke and Ward. 1998; Karungi *et al.,* 2004). To slow the mechanisms involved in quality loss and microbial growth, appropriate interventions including fish refrigeration immediately after capture, cooling and storage in either flake ice (Nunes *et al.*, 1992) or ice slurries (Rodríguez *et al.,* 2004; Rodríguez *et al.,* 2006; Barros-Velázquez *et al.,* 2008; Rey *et al.,* 2012) or preservation with chemical agents (Hwang and Regenstein, 1995) are required. Nearly half (47.2%) of the fish handlers thawed fish in tap water and 18.6% thawed fish in the sun or along-side the mud ovens used for fish smoking. Inappropriate

defrosting may further accelerate microbial growth and spoilage. More than one-half of the respondents (51.6%) said they sometimes refreeze thawed fish whilst 30.4% always refreeze thawed fish.

Table 7.2. Fish handlers' handling of fresh, frozen and thawed fish products

Factor	n	%
Type of raw fish handled		
Fresh	72	44.7
Frozen	67	41.6
Thawed	9	5.6
Others	13	8.1
Do you have a fridge or freezer?		
Yes, a fridge	2	1.2
Yes, Freezer	81	50.3
Yes, Fridge and freezer	40	24.8
No	38	23.6
Raw fish placed in clean ice chests/basins/boxes during transportation to processing site		
Yes, always	68	42.2
Yes, sometimes	75	46.6
No	18	11.2
Time between purchase of raw fish and processing		
Up to one hour	51	31.7
From one to two hours	62	38.5
Two hours or more	47	29.2
How you thaw frozen fish		
No thawing at all	29	18.0
In hot water	8	5.0
In cold water	76	47.2
On counter	6	3.7
In fridge	9	5.6
In the sun or along-side mud oven	30	18.6
Others	2	1.2
Refreeze thawed fish		
Yes, always	49	30.4
Yes, sometimes	83	51.6
No	27	16.8

7.3.2.2. Processed fish handling practices and their safety

Nearly half (44.7%) of fish handlers cooled processed fish to room temperature before storing it in the fridge, 24.8% stored processed fish in open air, at room temperature and 18.6% outdoor in the sun. Processed fish was stored for 24 hours (54%), one week (35.4%), one month or less (6.8%),

one to three months (1.9%) and over three months (1.2%) to ensure drying. Observations showed that much of the smoked fish was left on/in the smoking oven for several days and occasionally reheated to facilitate drying. Similarly, salted tilapia was dried in the sun. Though this process facilitates drying, it exposes processed fish to the elements and could pose a public health risk if not properly controlled. Plahar *et al*. (1999) reported a protective top cover. However, this practice was not observed in this study. When asked about risks associated with their storage methods, the majority (79.5%) said there were no risks associated with their way of fish storage. Among those who thought there were risks associated with the way fish was stored (20.5%), 8.7% mentioned food poisoning and 13% mentioned fungal attack as the likely risk associated with fish storage. Whereas 31.4% of respondents thought the risks inherent in their fish storage practice would increase, 54.3% thought their storage methods would decrease the risks. Others (14.3%) thought poor storage can contribute to fish contamination with pathogenic and spoilage microorganisms. Unless potentially protected inherently, simply storing hazardous foods such as smoked fish or salted fish in the open without regard to temperature and microbial growth may increase the risk of contamination with microorganisms which may cause foodborne illnesses. Pathogens which may survive as a result of inadequate heat treatment, or introduced as a result of poor handling practices and post-processing contamination may increase to levels that may cause foodborne illnesses in products with high a_w level. Almost two-thirds (61.5%) of fish handlers were of the opinion that smoked fish products in Ghana were very safe and 35.4% said smoked fish was somewhat safe, the latter group clearly unsure of the certainty of fish safety overall (Table 7.3). Only 19.3% thought that it was not safe to leave smoked fish in the open. A majority (75.8%) of fish handlers thought their fish products posed a low risk to consumers and 94.4% of them expressed their willingness to change the way they handled fish if they knew people could become sick after eating improperly handled fish. Adu-Gyamfi (2006) reported total viable counts of 2.45 to 9.09 $\log_{10}$ cfu/g, coliform counts of 0 to 8.13 $\log_{10}$ cfu/g and mould and yeast counts of 0 to 5.87 $\log_{10}$ cfu/g in smoked mackerel and smoked tuna on open display in retail outlets in Accra, a selected site for this survey.

Table 7.3. Processed fish storage practices

Fish handling practice	n	%
How do you store processed fish?		
In open air, at room temperature	40	24.8
Outdoor in the sun	30	18.6
Cool it to room temperature and store in fridge	72	44.7
Put into fridge immediately	14	8.7
Others	5	3.1
Reasons for storing processed fish in open air		
To dry properly	42	26.1
I have no other way	17	10.6
No fridge to store	23	14.3
Best way to store	63	39.1
Others	14	9.2
How long do you store processed fish in open air?		
24 hours	87	54.0
One week	57	35.4
One month or less	11	6.8
One to three months	3	1.9
Three months or more	2	1.2
Any risks associated with way of fish storage?		
Yes	33	20.5
No	123	76.4
What risks associated with way of fish storage		
Food poisoning	14	8.7
Fungal growth	21	13.0
Others	36	22.4
Would this risk increase or decrease?		
Increase	11	31.4
Decrease	19	54.3
No change	5	14.3
Opinion of safety of smoked fish		
Very safe	99	61.5
Somewhat safe	57	35.4
Not safe	4	2.5
Not at all safe	1	0.6
Opinion of safety of smoked fish left in the open		
Very safe	56	36.6
Somewhat safe	66	41.0
Not safe	31	19.3
Not at all safe	5	3.1
In your view what level of risks do your fish products pose to consumers		
Low risk	122	75.8
Medium risk	15	9.3
High risk	12	7.5
If you knew people could become sick after eating improperly handled processed fish, would you change the way you handle fish?		
Yes	152	94.4
No	9	5.6

7.3.3. Food safety and hygiene awareness and hand-washing practices

7.3.3.1. Knowledge of good hand-washing and personal hygiene practices

The hands of food handlers are an important vehicle for the spread of potentially pathogenic microorganisms from faeces, nose and skin to food and for cross-contamination (Allwood *et al.*, 2004; Sneed *et al.,* 2004; Fry *et al.,* 2005). In this study, more than half (57.8%) of the respondents said they always washed their hands before handling raw fish and 39.8% said they did so sometimes (Table 7.4). Nearly half (49.7%) of fish handlers who wash their hands do so with only tap water or water stored in drums. Just over a third (37.3%) of the fish handlers said they wash their hands with detergent and hot water and a minority (9.3%), said they wipe their hands with a cloth towel. Desmarchelier *et al.* (1999) have reported that hand washing with water alone has no effect on *S. aureus* counts on hands and that the reduction of bacteria on hands depends on the mechanical action, the duration and the type of soap and sanitizers used.

The main problem observed during this study was the absence of sanitary and hand washing facilities, adequate levels of water supply and soap in majority of the premises visited (Table 7.4). These may serve as barriers to achieving effective levels of hand washing in these premises. A logical step towards reducing the risks of foodborne illness from fish handling premises should focus on educating food handlers, improving the environmental conditions under which the trade is carried out and providing essential services including water, sanitary and hand washing facilities (CAC, 2009). The majority (78.3%) of fish handlers reported that they were well informed about food safety (Table 7.4). However, only 34.8% regularly received food safety information. Only 14.9% of fish handlers did not make any effort to receive food safety information.

Table 7.4. Hand-washing and food safety regulation compliance among fish handlers

Fish handling practice	n	%
Do you wash hands before handling raw fish?		
Yes, always	93	57.8
Yes, sometimes	64	39.8
No	3	1.9
Others	1	0.6
How do you clean your hands after handling raw fish?		
No cleaning	2	1.2
Wipe with towel	15	9.3
Wash with water only	80	49.7
Wash with detergent and hot water	60	37.3
Others	4	2.5
Well informed about food safety?		
Yes	126	78.3
No	32	19.9
Do you frequently receive food safety information?		
Yes	56	34.8
No	103	64.0
How much effort do you make to get food safety information?		
A great deal	23	14.3
Some effort	52	32.3
A little	62	38.5
None	24	14.9

Only a minority (8.1%) of respondents were not aware of the importance of separating raw from processed fish and 3.1% did not think it important or effective to wash raw fish before processing (Table 7.5). Only 3.1% of handlers did not know that hand-washing after using the toilet was important or effective, 9.9% did not know that hand-washing after handling raw fish was important and 7.5% did not know that hand-washing after shaking hands was important during food handling. Similarly, 3.7% did not know that hand-washing after handling money was important and 1.9% did not know that hand-washing after handling refuse was important. These results clearly show that basic knowledge on hygiene and hand-washing was good. Annor and Baiden (2011) in their study of food handlers in food business in Accra also observed that although food handlers in Accra had satisfactory level of food hygiene knowledge, they lacked knowledge on specific hazards and their knowledge was not always put into practice. Clayton *et al.* (2002) have also observed that whilst food handlers were aware of food safety behaviours, the majority did not always comply.

Table 7.5 Perception of the importance or effectiveness of health and personal hygiene practices

	Not important/ Effective		Moderately important/effective		Important/ effective		Very important/ effective	
	n	%	n	%	n	%	n	%
Washing raw fish	5	3.1	34	21.1	52	32.3	70	43.5
Keeping raw fish separate from processed fish	13	8.1	20	12.4	43	26.7	85	52.8
Hand-washing after using the toilet	5	3.1	15	9.3	36	22.4	105	65.2
Hand-washing after handling raw fish	16	9.9	22	13.7	53	32.9	70	43.5
Hand-washing after shaking hands	12	7.5	38	23.6	68	42.2	43	26.7
Hand-washing after touching money	6	3.7	50	31.1	53	32.3	52	32.3
Hand-washing after handling refuse	3	1.9	26	16.1	49	30.4	83	51.6
Thoroughly cooking fish	9	5.6	28	17.4	70	43.5	54	33.5
Fish safety by looking	22	13.7	32	19.9	74	46.0	33	20.5
Freezing food	12	7.5	34	21.1	77	47.8	38	23.6
Washing hands for 20 seconds	12	7.5	61	37.9	57	35.4	31	19.3
Using anti-bacterial soap to wash hands	4	2.5	23	14.3	65	40.4	69	42.9
Washing counter-top with hot soapy water	3	1.9	34	21.1	71	44.1	53	32.9
Mopping the kitchen floor	8	5.0	31	19.3	75	46.6	46	28.6

In contrast, other studies reveal poor personal hygiene knowledge among food handlers and failure to observe good personal hygiene practices in Accra (King *et al.*, 1998; Nuer, 2001; Acheampong, 2005). Mensah *et al.* (2002) have observed that the lack of running water and basic sanitary facilities prevent food handlers from carrying out food safety actions.

7.3.3.2. Awareness of food safety legal requirements

Ghana's national legislation on hygiene and safety of food is based on Codex standards (CAC, 2009). The majority of fish handlers (88.8%) were aware that it was a legal requirement to produce safe food (Fig. 7.1).

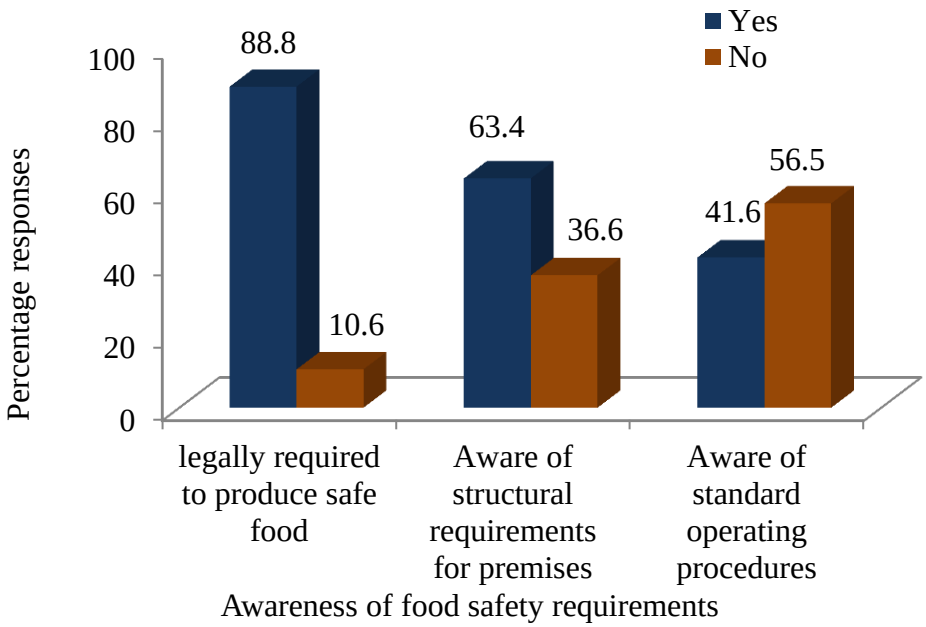

Fig. 7.1. Fish handlers' awareness of food safety legal requiremnets

7.3.3.3. Perception of the level of food safety awareness in the fish industry in Ghana

Lack of knowledge about standard operating procedures (SOPs) can result in increased risk. The majority (63.4%) reported that they were aware of structural requirements for food handling premises. However, more than half of respondents (56.5%) were not aware of any standard operating procedures in the fish processing industry. Mandatory training may improve knowledge and enforcement on these requirements.

Table 7.6 Fish handlers' perception of food safety in fish industry in Ghana

Factor	n	%
Food safety is understood and communicated in fish industry in Ghana		
Strongly agree	39	24.2
Agree	74	46.0
Disagree	33	20.5
Strongly disagree	15	9.3
Food safety principles are understood by employees		
Not very well	15	9.7
Not well	7	4.3
Uncertain	37	23.0
Well understood	86	53.4
Very well understood	10	6.2
Supervisors understand principles of food safety		
Not very well	12	7.5
Not well	8	5.0
Uncertain	37	23.0
Well understood	82	50.9
Very well understood	19	11.8
How would you describe food safety within your firm?		
Food safety is not part of our vision	10	6.2
Food safety is a necessary and unavoidable cost	75	46.9
Food safety is an opportunity to build brand value	58	36.2
Food safety is a means of differentiation for our company	17	10.6
If you thought fresh fish was unsafe would you report		
Yes	126	78.3
No	19	11.8
If you thought fresh fish was unsafe would you buy?		
Yes	8	5.0
No	146	90.7
Refuse	7	4.3
If you thought fresh fish was unsafe would you buy if price is reduced?		
Yes	29	18.0
No	94	58.4
Refuse	38	23.6

Nearly half (46%) of fish handlers thought that they understood food safety and 24.2% thought that food safety issues were very well understood in Ghana (Table 7.6). More than half (53.4%) of fish handlers thought that fish handlers understood food safety principles and over half (50.9%) of the respondents thought that their supervisors understand food safety principles. The importance of food safety in the respondents' firms were described variously as, a necessary and unavoidable cost (46.9%); food safety is an opportunity to build brand value (36.2%); food safety is a means of differentiation for our company (10.6%); and food safety is not part of our vision (6.2%). The majority (78.3%) of respondents indicated that if they thought fresh fish was unsafe to consume they would report it. Over 90% of the fish handlers said they would not buy

unsafe fresh fish. However, at a reduced price, only 58.4% of the fish handlers said they would not buy unsafe fish. This affirms the fact that for economic reasons, food safety measures may be sacrificed.

7.3.4. Food safety compliance and motivations for compliance

Only 45.3% of fish handlers had been issued licenses to operate their fish business (Table 7.7). This indicates that many of the fish businesses were unregistered or not licensed to operate. Among the businesses that were registered to operate, only 34.2% were inspected before the licenses were issued. This may be due to the lack of food safety inspectors. Under these circumstances regulating or inspecting these premises would be difficult. In this study, when fish handlers were asked to comment on food safety compliance levels of other fish handlers, they rated only 26.1% of their fellow fish handlers as compliant most of the time and 42.2% as compliant sometimes. This may be evidence of their own self-reflection. Approximately 60.9% of respondents have not been assessed on the level of their food safety compliance and 74.5% said they have never been informed of any non-compliance. Regarding their firm's level of food safety compliance, 37.9% rated their compliance level as acceptable. The majority (74.5%) have never been informed of non-compliance. It would appear from these findings that levels of compliance need to be improved. Approximately 14.3% of fish handlers were driven by fear of prosecution and sanctions, 8.7% were driven by the quest to meet industry and customer expectations, 6.8% were driven by fear of spreading foodborne disease and 0.6% were driven by the desire to promote brand image. Only 0.6% of enterprises complied because of their desire to prevent food borne disease. The study identified key hindrances to compliance to include lack of knowledge/understanding about what constitutes compliance (21.3%), poor understanding of legislative requirements (23%). Other respondents listed a combination of several factors, including cost and the lack of information (36.1%).

Table 7.7. Food safety compliance and motivations

Factor	n	%
Have permit to operate?		
Yes	73	45.3
No	69	42.9
License not required	19	11.8
Was site inspected before license issued?		
Yes	55	34.2
No	100	62.1
Others	3	1.8
Are fish handlers complying with food safety standards?		
Yes, sometimes	68	42.2
Yes, most of the time	42	26.1
No	47	29.2
Has your level of food safety compliance been assessed?		
Yes	63	39.1
No	98	60.9
What is the level of your company's food safety compliance?		
Non compliance	20	12.4
Very low compliance	45	28.0
Low compliance	27	16.8
Acceptable compliance	61	37.9
Almost total compliance	6	3.7
Full compliance	1	0.6
Informed of any none compliance?		
Yes	38	23.6
No	120	74.5
Reasons for complying with food safety regulations		
Fear of prosecution and sanctions	23	14.3
To meet industry and customer expectations	14	8.7
Fear of being named and shamed	16	9.9
Fear of spreading food borne disease	11	6.8
To promote brand image	1	0.6
Fear of prosecution/meeting industry standards	7	4.3
All of the above	31	19.3
Reasons given by those who find it difficult to comply		
Poor knowledge/understanding of what constitute compliance	13	21.3
Poor understanding of legislative requirements	14	23.0
Do not consider particular issues to constitute compliance	4	6.6
Cannot implement appropriate control methods	4	6.6
No food safety guidance information	3	4.9
Cost of compliance too high	1	1.6
Others	22	36.1

7.3.4.1 Inspections and opinion of inspections

The survey also revealed inconsistencies in the reported inspection regime (Table 7.8). Approximately 42% of fish handlers were inspected when necessary, 26.7% said they were inspected twice a year and 13.7% were inspected once a year. Half (50%) of the fish handlers

said the inspectors mainly advised them on food safety during inspections, 21% said inspectors looked for violations and applied sanctions, 16.7% said the inspectors run food hygiene courses during visits and 11.9% said inspectors adopted a highly educational approach and encourage them to comply with food safety standards. Sanctions applied against violators included heavy financial penalty (16.7%) or light financial penalty (11.1%).

Table 7.8 Food safety compliance

Factor	n	%
Number of times visited by inspectors in the last one year?		
Inspected when necessary	67	41.6
Once a year	22	13.7
Twice a year	43	26.7
Once every two years	8	5.0
Once every five years	20	12.4
Actions taken by enforcement agents against fish handlers		
Highly educational approach to encourage me to comply	5	11.9
Visited and advised me	21	50.0
Run food hygiene courses	7	16.7
Looked for violations and applied sanctions	9	21.4
Nature of sanctions applied		
Cautioned/given final warning of closure	5	27.8
Heavy financial penalty	3	16.7
Light financial penalty	2	11.1
Notification of closure	1	0.6
Effects of the sanctions and penalties on you		
Hindered	1	2.7
Improved	33	89.2
No effect	3	8.1
What have you done to comply?		
No action taken	11	28.9
Followed the inspectors recommendations	27	71.1
Opinion about approach of government food safety agency		
Adversarial	92	57.1
Collaborative	69	42.9

More than a quarter of fish handlers (27.8%) said they were cautioned or given final warning and 0.6 were given notification of closure by inspectors. Most (89.2%) fish handlers were of the view that the inspections helped to improve food safety in their business. Most (71.1%) respondents said they followed the inspectors' recommendations following sanctions. Many fish handlers (57.1%) viewed their relationship with government food safety enforcement agencies as adversarial and 42.9% thought it was collaborative. The regulated may misunderstand or be misguided in their understanding of their legal duties (Hutter, 2001). The enforcement approach

is therefore very crucial in defining or promoting ongoing relationships between the regulator and regulated (Hutter, 1997, Hawkins, 1984 and 2002).

7.3.4.2 Requirements for improving food safety and HACCP compliance

The survey also revealed a variety of factors perceived by fish handlers as very important requirements for improving food safety and HACCP compliance in the fish industry (Table 7.9). Nearly 93% of the fish handlers believed that communication to industry stakeholders and the provision of food safety guidelines and manuals (92%) to fish handlers were very important for improving food safety and HACCP compliance in the fish industry. The government and its agencies can play facilitative roles by providing objective scientific information and raising awareness of the benefits of and the need for introducing HACCP and food safety management systems in the fish industry. Training is considered fundamental to effective food safety management. In this survey, 92.6% of the fish handlers surveyed identified training of fish handlers and quality managers as very important.

Table 7.9. Factors identified by fish handlers as important in helping them improve their food safety knowledge and compliance

	Not Important	Moderately Important	Very Import
Communication	9 (5.6)	18 (11.2)	133 (82.6)
Graphic presentation	7 (4.3)	18 (11.2)	136 (84.4)
Available local food safety experts	3 (1.9)	5 (3.1)	153 (95.0)
Training for quality managers	5 (3.1)	7 (4.3)	149 (92.6)
Programme materials/ guidelines and manuals	8 (5.0)	5 (3.1)	148 (92.0)
Training for production Workers	3 (1.9)	9 (5.6)	149 (92.6)
Financial incentives	3 (1.9)	4 (2.5)	154 (95.7)
Involving employees in developing the programme	5 (3.1)	7 (4.3)	149 (92.6)
Management commitment	5 (3.1)	7 (4.3)	149 (92.6)
Upgrading your facility	6 (3.7)	6 (3.7)	155 (96.3)
Acquiring food safety certificate	16 (9.9)	30 (18.6)	115 (71.5)
Obtaining a license to operate	24 (14.9)	33 (20.5)	104 (64.7)

Training will however only lead to improvement in food safety if the knowledge imparted leads to desired changes in food handlers' safety behaviour and practices (Seaman and Eves, 2006). Another factor identified by 92.6% of the fish handlers as very important to the successful

implementation of HACCP and food safety compliance is management commitment. Other studies have also identified lack of management commitment and understanding as a major impediment to successful implementation of HACCP and food safety compliance (Panisello *et al.*, 1999; WHO, 1999b; Sprenger, 2002). Other factors identified by the fish handlers were, financial incentives (95.7%), upgrading the fish processing facilities (96.3%) and certification (71.5%).

7.3.4.3 Opinions of fish handlers about the enforcement and food firm safety policies

The opinions of fish handlers about the enforcement guidelines, advice and communications from inspectors, as well as their views about the inspectors (Fig. 7.2) and their companies' specific food safety policies are shown in Fig. 7.3.

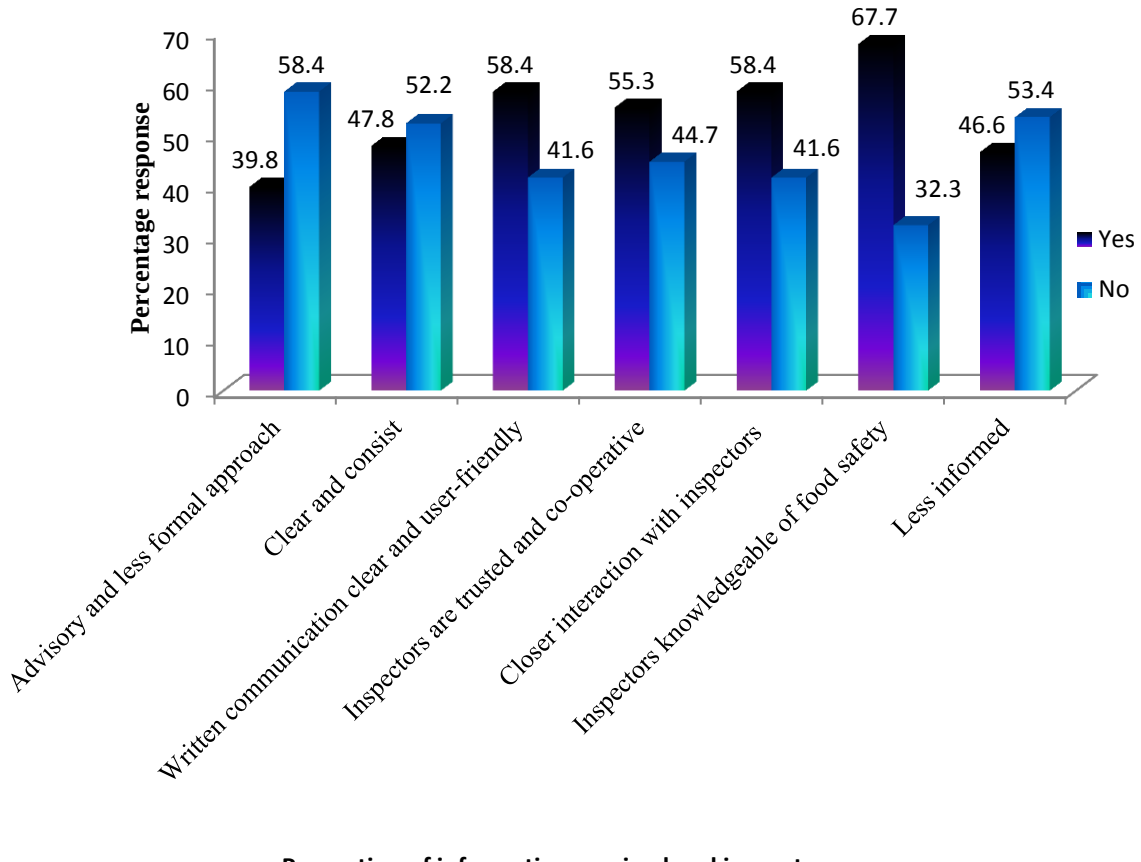

Fig. 7.2. Fish handlers' perceptions of food safety inspections and inspectors

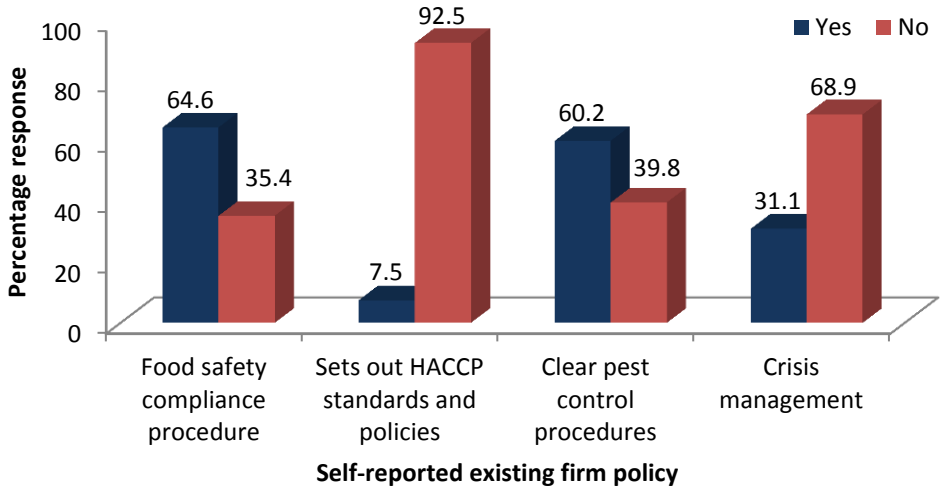

Fig. 7.3 Self-reported firm food safety policy

7.3.5. Food safety training

Training is fundamentally important to any food safety management system. In this study, two-thirds (68.9%) of fish handlers surveyed indicated that training in food safety was a legal requirement in Ghana and 74.5% of respondents had received some form of training on fish handling and food safety (Table 7.10). However, 31.7% were self-taught, 11.2% were taught by parents and 21.1% learned their skills through observations of other fish handlers. Nearly half of all fish handlers indicated that they had attended food handling and sanitation training in the last year. Nonetheless, only 14.9% of the fish handlers said they had formal training on food safety management. This is far lower than the 55% formal food hygiene training reported by Walker *et al.* (2003a) in a survey of small business food handlers in the UK. The low level of formal food safety training may contribute to poor food safety knowledge and skills. A food safety management programme is only as effective as the skills and knowledge of the team developing and implementing it because a weak analysis of the potential hazards will lead to ineffective food safety management (Manning and Baines, 2004). A minority (26.1%) of fish handlers identified the Food and Drugs Board, 8.1% mentioned the District Assemblies (i.e. local government authorities), training consultants (7.5%), corporate trainers (8.7%) and various combinations of these trainers (47.2%) as food safety training providers.

Table 7.10. Food safety and sources of training

Factor	n	%
Is food safety training a legal requirement in your industry?		
Yes	111	68.9
No	49	30.4
Trained in food hygiene and sanitation		
Yes	120	74.5
No	41	25.5
In the last year any training in food handling and sanitation		
Yes	80	49.7
No	78	48.4
How were you trained in food safety?		
Self-taught	51	31.7
Taught by parents	18	11.2
Formal training	24	14.9
Observing others	34	21.1
Self-taught/taught by parents	5	3.1
Self-taught/formal training	6	3.7
Self-taught/observing others	5	3.1
Taught by parents/formal training	4	2.5
Self-taught/taught by parent/formal training	5	3.1
Self-taught/taught by parent/observing others	1	0.6
Self-taught/formal training/observing others	3	1.9
Others	2	1.2
Who provided the training?		
FDB	42	26.1
District assembly	13	8.1
Training consultants	12	7.5
College/university	3	1.9
Corporate trainer	14	8.7
Others	76	47.2
Exchange of food safety information within industry		
Yes, always	17	10.6
Yes, sometimes	118	73.3
No	25	15.5
Willing to share best practice		
Yes, very willing	49	30.4
Willing	100	62.1
Not willing	7	4.3
Not very willing	5	3.1
Awareness of government support		
Yes	52	32.3
No	109	67.7
How did you become aware of government support?		
From involvement with industry associations	16	9.9
From interaction with government organizations	21	13.0
From interaction with food safety inspectors	18	11.2
Have you ever sort help from the Food and Drugs Board?		
Yes	52	32.3
No	107	66.5

Over 50% of fish handlers funded their own training and more than half of the respondents thought enough time and resources were being spent on training. For the majority (68.9%), the

effectiveness of their training was assessed by on the job observations. The majority (73.3%) said they sometimes shared information and 62% were willing to share best practices. This willingness to share information and to learn from each can be useful to fish handlers who cannot afford the cost of training. It is worth noting that 67.7% of fish handlers in this study are not aware of any form of government support for their industry and 67% have never sought for help from the FDB regarding their operations.

7.3.5.1. Factors that influence food safety training

Survey respondents recognised the benefits of food safety training. However a number of key issues including lack of time (24.8%), language problems (8.8%), cost (8.8%), lack of relevant food safety course (13%) and a combination of these various reasons were cited as barriers to training (Table 7.11).

Table 7.11 Factors that influence food safety training

Difficulties affecting food safety training	n	%
Difficulties encountered in training staff		
Language problems	14	8.8
High turnover	1	0.6
Lack of time	40	24.8
Have experienced staff who need no training	7	4.4
Lack of interest	10	6.2
Lack of course availability	5	3.1
Cost	14	8.8
Courses not relevant to business	21	13.0
Lack of time/cost	14	8.8
Lack of time/lack of courses/cost/	4	2.5
Lack of course availability/cost	6	3.7
Others	23	14.4
Reasons why you train your staff		
Fear of prosecution	4	2.5
Improve food hygiene	104	64.6
Satisfy EHO requirements	1	0.6
Certificates on display look good to customers	3	1.9
Enhance brand	12	7.5
To satisfy due diligence and food law requirement	2	1.2
Fear of prosecution/improve food hygiene	5	3.1
Improve food hygiene/enhance brand	3	1.9
Improve hygiene/looks good to customers	16	9.9
Fear of prosecution/improve hygiene/satisfy EHO	4	2.5
Others	7	4.3

These issues must be addressed if uptake and effectiveness of food safety training is to improve in Ghana. A great majority of respondents (64.6%) train their staff because they wanted to improve food hygiene.

7.3.5.2 Food safety training providers, sources of funding and content of training

To evaluate the effectiveness of food safety training available to fish handlers, respondents were asked to list the detailed composition of their training by answering yes or no to a list of questions. The results show that 36% of respondents had food safety training that included the role of the Ghana Food and Drugs Board and 54.7% were taught about public health legislation and regulation (Table 7.12). Only 23% said they had training that included HACCP. A majority (89.4%) had training that included safe food handling and storage as well as food handler hygiene and sanitation.

Other fish handlers mentioned food premise sanitation, design and maintenance (60.2%), Prevention of allergies, incidents and response (56.5%), Fish handling and processing (86.3%) and cross contamination and pest control (68.3%) as constituting part of their food safety training. There appears to be a need to standardize the food safety training and this should include detailed requirements for the prevention of contamination using risk-based management systems. Currently, HACCP is not a mandatory requirement for small-scale traditional fish processors in Ghana. Only 35.4% of food SMEs had a food safety compliance manager and 47.2% of food handlers said they had effective food management team in place.

Table 7.12 The food safety programme available for fish handlers included

Factor	n	%
Funding of training		
From own resources	85	52.8
Paid district assembly	15	9.3
Paid by FDB	24	14.9
NGO	2	1.2
Others	27	16.8
Enough time and resources spent on food safety training		
Yes	89	55.
No	63	39.1
Role of Food and Drugs Board		
Yes	58	36.0
No	102	63.4
Public health legislation and regulation		
Yes	88	54.7
No	72	44.7
HACCP-based principles		
Yes	38	23
No	122	75.8
Safe food handling and storage		
Yes	144	89.4
No	16	9.9
Food handler hygiene		
Yes	144	89.4
No	17	10.6
Food premise sanitation, design and maintenance		
Yes	97	60.2
No	64	39.8
Prevention of allergies, incidents and response		
Yes	91	56.5
No	70	43.5
Fish handling and processing		
Yes	139	86.3
No	22	13.7
Cross contamination and pest control		
Yes	110	68.3
No	51	31.7

7.3.5.3. Willingness to attend food safety training

Nearly 65% of fish handlers were satisfied or very satisfied with fish industry food safety standards. A majority (70.2%) of them expressed interest in learning about food safety and nearly two-thirds (62.1%) were willing to pay for food safety training and an overwhelming majority (95.0%) would attend food safety training if it was free (Table 7.13).

Table 7.13 Food safety management, training and business culture

Factor		n	%
Level of satisfaction with fish industry food safety standards			
Satisfied/very satisfied		104	64.6
Unsatisfied		40	24.8
Very unsatisfied		17	10.6
Level of interest in food safety and sanitation workshops			
Not very likely to attend		6	3.7
Not likely to attend		21	13.0
Uncertain		21	13.0
Very likely/likely to attend		113	70.2
Would you pay to attend food safety training?	Yes	100	62.1
	No	61	37.9
Would you attend free food safety training?	Yes	153	95.0
	No	8	5.0
Have you identified food safety risks in your business	Yes	123	76.4
	No	38	23.6
Staff shown how to handle fish safely	Yes	119	73.9
	No	39	24.2
Food safety is a subject of scheduled discussions	Yes	74	46.0
	No	85	52.8
Have you a compliance manager	Yes	57	35.4
	No	104	64.6
Have food safety management team	Yes	76	47.2
	No	85	52.8
Nominated compliance manager has high authority and can initiate food safety actions	Yes	58	40.8
	No	82	57.7

7.3.6 Self-reported and observed food safety practices in the traditional fish processing section in Ghana.

Food safety remains an important economic and public health issue with outbreaks of foodborne diseases resulting in costs to the individuals, industry and the economy. Most outbreaks occur in developing countries (Tauxe *et al.*, 2010). In this section of the study, the self-reported practices of fish handlers in 28 fish handling premises were compared with their observed practices including time/temperature abuse, sanitation and hygiene, and cross-contamination. One of the more the major findings of this study is that fish handlers, who were interviewed, over-reported their food safety practices (Tables 7.14 to 7.16).

7.3.6.1 Self-reported and observed fish handling, hygiene and temperature control at landing

The production of safe and quality fish and fishery products requires effective temperature control. In this study, 53.7% of the 28 fish handlers interviewed reported that fresh fish was always quickly covered with ice to keep the temperature below 5^{o}C. However, it was observed that, on 65 occasions that fresh fish was required to be chilled, this was done only on 22 occasions indicating 38.8% compliance ($P<0.05$). Fish was held under ambient temperature conditions for over three hours on at least 61% of the occasion. Kombat *et al.* (2013) have reported the presence of heterotrophic bacteria, coliform bacteria, yeast and moulds and *Bacillus cereus* in fresh fish from landing sites in Accra and Tema. The microbial levels detected in these samples were below the Ghana Standard Authority (GSA) and ICMSF standards (1.0 x10^{6}cfu/g for total heterotrophic counts; and 1.0 x10^{4}cfu/g for total colony counts, yeast and mould counts, and *Bacillus cereus* counts). However, under the hot tropical conditions, if fish is not immediately chilled, any microorganisms present are likely to multiply rapidly. Only 67.9% of the premises visited had insulated containers to transport fresh fish, compared to the 96.4% (39.3% always; 57.1% sometimes) who reported that they used insulated containers.

Observations showed that fish handlers were required to use insulated containers to transport raw fish on 68 occasions but significantly, this was done only on half of the occasions, indicating 50% compliance ($P<0.05$). Although a majority (78.6%) of respondents reported that they stored potentially hazardous fish under temperature control, this practice was observed only in 53.6% of premises. The opportunity to correctly store potentially hazardous fish under temperature control occurred 62 times but was performed only on 28 occasions, a compliance rate of 45.2% ($P<0.05$). Temperature is a very important factor with regard to quality, shelf life and safety of fish. Increase in temperature above 4°C can result in more rapid growth of both spoilage and pathogenic microorganisms present in fish and autolysis (Feldhusen, 2000; WHO, 1999a; Diei-Ouadi and Mgawe, 2011), with consequent quality loss, shorter shelf life and risk to consumer

Table 7.14 Self-reported and observed food safety practices during purchasing and storage of fish

Statement		Self-reported behaviours		Observed behaviours			Implementation of food safety practices		Compliance	
		n	%	n	%	χ^2	Required (n)	Attempted (n)	rate	P value
Temperature control of fresh fish										
Fresh fish quickly covered with ice to keep temperature below 5°C during purchasing	Always	10	35.7	7	70.0	0.166	65	22	38.8	<0.05
	Sometimes	13	46.4	8	61.5					
	Never	5	17.9	1	20.0					
Potentially hazardous fish stored under temperature control in premise	Always	7	25.0	7	100	0.074	62	28	45.2	<0.05
	Sometimes	15	53.6	8	53.3					
	Never	6	21.4	3	50.0					
Basins/boxes/chests insulated/protected to prevent heat loss/contamination	Always	11	39.3	9	81.8	0.192	68	34	50.0	<0.05
	Sometimes	16	57.1	10	62.5					
	Never	1	3.6	0	0.0					
Hygiene, sanitation and cross-contamination										
Fish placed in clean basin/boxes/ice chests	Always	16	57.1	13	81.2	0.887	65	38	58.5	0.001
	Sometimes	12	42.9	10	83.3					
	Never	0	0.0	0	0.0					
Harvest containers/packaging labelled to ensure traceability	Always	12	42.9	8	66.7	0.703	66	31	47.0	0.0004
	Sometimes	10	35.7	7	70.0					
	Never	6	21.4	3	50.0					
Processed fish packaged to prevent contamination	Always	11	39.3	11	100.0	<0.001	58	21	36.2	<0.05
	Sometimes	9	32.1	4	44.4					
	Never	8	28.6	0	0.0					
Raw and processed fish stored separately	Always	23	82.1	22	95.7	0.171	65	52	80.0	0.08
	Sometimes	3	10.7	2	66.7					
	Never	2	7.1	2	100.0					

health. Fish handling equipment and utensils can also act as sources of contamination. Clean basins, boxes and ice chests were used only on 38 occasions, indicating 58% compliance (P<0.001). Placing fish in dirty basins, equipment, fish boxes and baskets lead to increased microbial contamination and hasten the spoilage rate of fish (Diei-Ouadi and Mgawe, 2011). Regarding the use of labelled containers and packaging to transport fish, only 50.0% of the respondents had labelled containers compared to the 78.6% (42.9% always; 35.7% sometimes) who reported using labelled containers and packaging to transport fish. The use of labelled containers was required on 66 occasions but used only on 31 of this, indicating 47% compliance (P=0.0004). Over 71 % of those who were interviewed reported that they always (39.3%) or sometimes (32.1%) packaged processed fish to prevent contamination. Observations showed that this was likely to be done in only 50.0% of the premises visited. Packaging was done in 21 out of 58 work activities that required packaging, a compliance rate of 36.2% (P<0.05). Contaminated or uncooked raw foods can cause harmful microorganisms to be passed to safe foods and cause a foodborne illness (National Assessment Institute, 1998). Observation showed that in majority of the premises (85.7%), raw and processed fish were stored separately. This was nearly equal to self-reported practice (92.9%) in the premises. The opportunity to separate raw fish from processed fish occurred 65 times and was performed on 52 occasions, a high compliance rate of 80% (p=0.08).

7.3.6.2. Self-reported and observed fish handling, hygiene and temperature control during transportation, processing and distribution.

Direct participant observation showed that many of the fish handlers did not always engage in recommended safe food handling practices during transportation, processing and distribution of fish. There were deficiencies in food safety and hygiene practices especially in the areas of chilling, temperature control and cross contamination. For example, it was reported in all the fish handling premises visited that raw fish was always washed before processing (Table 7.15). Observations showed that fish was adequately washed 46 times out of 69 occasions, a compliance rate of 66.7% (P=0.003). Safe thawing procedures were sometimes complied with in 64.3% of the premises. However, this function had a low compliance rate of 32.8% (P<0.05) as most fish handlers did not

follow recommended safe food handling practices to thaw or defrost fish. Regarding the use of adequate procedures to prevent contamination or cross-contamination of fish, all the premises visited reported that they had adequate measures to prevent cross-contamination. Observations showed that study participants engaged in recommended measures to prevent cross-contamination only on 36.8% of occasions ($P<0.05$). Cross contamination by microbial pathogens may play an important role in sporadic as well as epidemic foodborne illnesses (Fendler *et al.,* 1998).

In 71.4% of the premises visited, potentially hazardous fish was left out of temperature control for more than 2 hours. This was higher than the 50 self-reported. Overall, on 29 out of 76 occasions, potentially hazardous fish was kept out of temperature control for more than 2 hours, a non-compliant rate of 32.8% ($P<0.05$). In the majority (89.3%) of premises, respondents reported that potentially hazardous fish was displayed under temperature control, however only 53.6% actually did so during observation. Overall, 21 out of 71 occasions, potentially hazardous fish was displayed under temperature control, a compliance rate of 29.6% ($P<0.05$). None of those who answered never were seen performing the function on any occasion. In general, there seems to be a low adherence to temperature control and hygienic food safety practice from the fish landing sites to the processing and retail sites. Kombat *et al.* (2013) in a previous microbiological study of fish in Accra and Tema in Ghana found that microbial loads in samples obtained from retail markets were significantly higher than those obtained at harvest and from landing sites. Adu-Gyamfi (2006) has also reported high levels of total viable counts, coliforms, mould and yeast in smoked mackerel and smoked tuna on open display in retail outlets in Accra. This may be due to the low hygiene compliance and poor rates of adherence to time–temperature control guidelines observed in the current study. This finding is consistent with previous research that showed deficiencies in prerequisites, including hygiene standards, handling conditions, and general food safety standards along the traditional fish processing chain in Ghana and other West African countries (Plahar *et al.*, 1999; Kleter, 2004; Akinola *et al*., 2006; Anihouvi *et al.,* 2006). Clearly, this raises the need for intensified food safety training and inspections along the chain.

Table 7.15 Self-reported and observed food safety practices during processing, transportation and distribution of fish

Statement		Self-reported behaviours		Observed behaviours			Implementation of food safety practices		Compliance	
		n	%	n	%	χ^2	Required	Attempted	rate	P value
Fish processing practices										
Fish adequately washed before use	Always	19	67.9	17	89.5	0.963	69	46	66.7	0.003
	Sometimes	9	32.1	8	89.7					
	Never	0	0.0	0	0.0					
Using safe procedures to thaw fish	Always	13	46.4	9	69.2	0.611	67	22	32.8	<0.05
	Sometimes	15	53.6	9	60.0					
	Never	0	0.0	0	0.0					
Use adequate procedures to prevent contamination/cross-contamination	Always	17	60.7	15	82.2	0.636	76	28	36.8	<0.05
	Sometimes	11	39.3	9	81.8					
	Never	0	0.0	0	0.0					
Potentially hazardous fish out of temperature control for more than 2 hours	Always	6	21.4	6	100.0	0.587	76	29	38.2	<0.05
	Sometimes	8	28.6	8	100.0					
	Never	14	28.6	6	62.5					
Potentially hazardous fish displayed under temperature control	Always	9	32.1	6	66.7	0.127	71	21	29.6	<0.05
	Sometimes	16	57.1	9	56.2					
	Never	3	10.7	0	0.0					
Fish transportation and distribution										
Potentially hazardous fish distributed under temperature control	Always	7	25.0	6	85.7	0.002	80	31	38.8	<0.05
	Sometimes	15	53.6	11	73.3					
	Never	6	21.4	0	0.0					
Fish distributed using appropriate packaging materials	Always	11	39.3	9	81.8	<0.001	101	43	42.6	<0.05
	Sometimes	11	39.3	10	90.0					
	Never	6	21.4	0	0.0					
Fish protected from cross-contamination	Always	20	71.4	15	75.0	0.057	86	31	36.0	<0.05
	Sometimes	7	25.0	7	100.0					
	Never	1	3.6	0	0.0					

In a majority (78.6%) of premises visited, it was reported that potentially hazardous processed fish was distributed under temperature control. This was higher than the 60.7% observed during the visits. Potentially hazardous fish was distributed under temperature control only on 38.8% of the occasion (P<0.05). Respondents in the majority (78.6%) of premises reported that they used appropriate packaging material to distribute processed fish, however, this was observed only in 67.9% of the premises (P<0.05). Similarly in 96.4% of the premises visited it was reported that they ensured that fish was protected from cross-contamination. However, observations showed that just over half (53.6%) of the fish handlers did this. Overall, compliance rate for this function was 36% (P<0.05).

7.3.6.3. Self-reported and observed personal hygiene practices of fish handlers

Discrepancies were found between self-reported and observed personal hygiene practices required to reduce health hazards related to food (Table 7.16). In 71.4% of premises visited fish handlers reported always (35.7%) or sometimes (35.7%) wearing proper uniforms. Observations showed that only 36.0% of handlers wore appropriate uniforms (p <0.05). In more than half (53.6%) of premises, respondents said they always practiced good personal hygiene and in 46.4% of respondents did so sometimes. However, in 113 work activities that needed good personal hygiene, fish handlers were observed to do so only on 61 occasions, a compliance rate of 54% (p = 0.001). Proper hand washing has been recognized as one of the most effective measures to control the spread of pathogens (Adler, 1999; Montville *et al.,* 2001). In 64.3% of the premises visited, fish handlers said they always washed their hands after handling garbage and in 35.7% of the premises fish handlers said they did so sometimes. Approximately 85.7% of those who said they 'always' washed their hands after handling garbage were seen doing so, and 92.9% of those who said they did it 'sometimes' were observed doing so. Out of 96 expected hand washing opportunities, hands were washed only on 51 occasions, a compliance rate of 53.1% (p = 0.0003). The most common failure to wash occurred when fish handlers were switching between handling raw fish and processed fish, touching unclean surfaces and handling money.

Table 7.16 Self-reported and observed fish handler handwashing and hygiene practices

		Self-reported behaviours		Observed behaviours			Implementation of food safety practices		Compliance	
Statement		n	%	n	%	χ^2	Required	Attempted	rate	P value
Wearing proper uniform	Always	10	35.7	10	100.0	<0.001	86	31	36.0	<0.05
	Sometimes	10	35.7	4	40.0					
	Never	8	28.6	0	0.0					
Good personal hygiene practiced	Always	15	53.6	15	100.0	0.274	113	61	54.0	0.001
	Sometimes	13	46.4	12	92.3					
	Never	0	0.0	0	0.0					
Washed hands after handling garbage	Always	18	64.3	12	85.7	0.541	96	51	53.1	0.0003
	Sometimes	10	35.7	13	92.9					
	Never	0	0.0	0	0.0					
Washed hands correctly before food Preparation	Always	14	50.0	15	83.3	0.172	74	52	70.3	0.003
	Sometimes	14	50.0	10	100.0					
	Never	0	0.0	0	0.0					
Hands washed with soap and water before handling fish	Always	14	50.0	11	78.6	0.888	93	41	44.1	<0.05
	Sometimes	11	10.7	8	72.7					
	Never	13	46.4	2	66.7					
Hands washed with soap and water after handling fish	Always	13	46.4	10	76.9	0.698	98	40	40.8	<0.05
	Sometimes	13	46.4	10	76.9					
	Never	2	7.1	1	50.0					
Hands washed long enough	Always	12	46.4	12	92.3	0.959	97	27	27.8	<0.05
	Sometimes	14	50.0	13	92.9					
	Never	1	3.6	1	100.0					
Used same towel to dry hand and dish	Always	5	17.9	4	80.0	0.011	67	24	35.8	<0.05
	Sometimes	11	39.3	10	90.9					
	Never	12	42.9	4	33.3					
Used disposable towel/hand-dryers	Always	2	7.1	2	100.0	<0.001	12	7	58.3	0.187
	Sometimes	2	7.1	2	100.0					
	Never	24	85.7	2	8.3					

Fifty percent of the participating premises said their staff always washed their hands correctly and the other 50% said their staff did so sometimes. Observations showed that hands were correctly washed 70.3% of the time before food preparation, indicating a high compliance rate ($p=0.003$). Hands were said to be washed with soap and water 'always' in 46.4% of premises and sometimes in another 46.4%. Among those who said they always or sometimes washed their hands with soap and water before handling fish 76.9% of them did so. Overall, hands were washed with soap and water on 41 occasions, a compliance rate of 44.1% ($p<0.05$). Hand washing compliance rate reported here are however higher than the 27% compliance rate reported by Green *et al.* (2006). The very low compliance rate reported by Green *et al.* (2006) is likely due to the fact that they limited their study to specific activities. On average, in 46.4% of premises, fish handlers reported that they 'always' washed their hands long enough and in 50% of premises handlers said they did so 'sometimes'. Among those who answered 'always', 92.3% were observed doing so and among those who answered 'sometimes' 92.9% were also observed doing so. Opportunities to wash hands occurred 97 times during the visits but significantly hands were washed adequately and long enough only on 27 occasions, a compliance rate of 27.8% ($p<0.05$). This rate of adequate hand hygiene practices is comparable to the 31% reported by Clayton *et al.* (2004). A failure to use soap occurred in 58 out of 98 occasions and a failure to dry hands adequately 43 out of 67 occasions. Soap was not available in a majority of the premises visited. Respondents reported that they used same towel to dry hand and dishes in 57.3% of the premises visited. Overall, in 24 cases out of 67, same towel was used to dry hands and dishes, a non-compliance rate of 35.8% ($p <0.05$). Only 14.2% of the premises indicated that they used disposable towel/hand-dryers, and in these premises employees were seen using paper towel on 58.3% of the occasion ($p=0.187$).

Improved personal hygiene and scrupulous hand-washing would lead to basic control of faeces-to-hand-to-mouth spread of potentially pathogenic microorganisms (Daniels *et al.,* 2002; Allwood *et al.,* 2004; Sneed *et al.,* 2004; Fry *et al.,* 2005).

Table 7.17 Self-reported and observed food premises standards and facilities

	Self-reported		Observed	
	n	%	n	%
Premise structure and hygiene				
Premise designed and constructed to meet legal standards	21	75.0	7	25.0
Floors/walls/ceilings kept clean	17	60.7	15	53.6
Floors/walls/ceilings in good repair	18	64.3	7	25.0
Food preparation area adequate and in good repair	18	64.3	13	46.4
Premise kept in satisfactory state of cleanliness	19	67.9	19	53.6
Food contact surface cleaned and sanitised	14	50.0	12	42.9
Premise in good state of repair	23	82.1	14	50.0
Waste containers maintained to prevent contamination	22	78.6	11	39.3
Effective pest control procedure in place	14	50.0	10	35.7
Doors/screens well sealed and self-closing	7	25.0	3	10.7
No evidence of pest present	12	42.9	8	28.6
Adequate supply of potable water	17	60.7	13	46.4
Adequate hand-washing facilities	22	78.6	17	60.7
Recalls				
Adequate system in place to ensure unsafe/unsuitable fish is recalled and not sold	6	21.4	2	7.1
Food handler skills and knowledge				
Staff have appropriate food safety skills and knowledge	21	75.0	16	57.1
Nominated food safety advisor adequately trained	13	46.4	11	39.3

However, there are many social, behavioural and infrastructural barriers that make it difficult for fish handlers in many of the premises visited to adhere to standard sanitation and hygienic practices. These findings agree with previous observations that a range of personal, social, and environmental factors influence food worker practices and that these factors need to be addressed to successfully change food workers' behaviour (Rennie, 1995; Ehiri and Morris 1996; Pittet, 2001).

7.3.6.4. Self-reported and observed fish handling premise structure and hygiene

Two-thirds (75.0%) of respondents indicated that their premises were designed and constructed to meet food safety standards, however, inspections showed that only a minority (25.0%) of fish processing and handling premises were designed and constructed to meet food safety standards (p=0.0003) (Table 7.17). Although a few of the processing sites had wooden structures with metal roofing sheets, the majority of fish handlers worked in open spaces, exposed to the elements. More than 60% of the fish handlers indicated that the floors/walls/ceilings of their premises were kept clean. Just over half (53.6%) of the premises visited had floors, walls and ceilings that were kept in hygienic conditions (p=0.597).

Although 64.3% of the fish handlers reported that their floors/walls/ceilings were in good repair, inspections showed that only 25% of the premises were in good repair (p=0.003). Similarly, 64.3% of respondents said their food preparation areas were adequate and in good order, however only 46.4% of the premises visited met this requirement (p=0.01). The results also indicate that 67.9% of respondents said they kept their premises in satisfactory state of cleanliness. Observations confirmed this. Half (50%) of the respondents said their food contact surface were regularly cleaned however only 42.9% of food contact surfaces were in clean states (p=0.599). The majority of the facilities did not have worktops or chopping boards but handled their fish in basins and cleaning of these basins was poorly done or neglected on some occasions. A majority (82.1%) of respondents said their premises were in good state of repairs however, only half of these (50%) were found to be in a good state of repair (p=0.01).

Nearly 78.6% of fish handlers reported that they had waste containers maintained to prevent contamination. Based on observation, only 39.3% of fish handlers had waste containers (p=0.002). Many of these containers were dirty and were conspicuously close to the processing sites. Half (50%) of respondents reported having effective pest control procedure in place. This was higher than the 35.7% observed during the visits (p=0.289). A minority (10.7%) of the premises had their doors screened, well-sealed and self-closing compared to a reported 25% (p=0.169).

About 42.9% of respondents indicated that there was no evidence of pests present in their premises in contrast to the observed 28.6% (p=0.272). Only 46.4% of the premises had adequate supply of potable water (p=0.292). Water was carried to many of the processing sites in containers. This water was usually not enough for dish washing, personal hygiene and food preparation. Warm water was usually not available. The majority of respondents (75%) said their staff had appropriate food safety skills and knowledge (p=0.164). Similarly, 46.4% of respondents said they had a nominated food safety supervisor who was adequately trained (p=0.597). Only 21.4% said they had adequate systems in place to ensure unsafe or unsuitable fish is recalled and not sold. Adequate hand-washing facilities were reported to be available in 78.6% of the premises visited. However, observations showed that although 60.7% of the premises had hand-washing facilities, these were not adequate and majority did not have running water ($p<0.05$). All the premises visited lacked sinks.

7.3.6.5. Interpretation

This study was designed to compare directly observed food safety behaviour with self-reported behaviour. To my knowledge, this study is the first to assess self-reported and observed food safety and hygiene practices along the fish chain in Ghana. The results show that the majority of fish handlers engaged in significantly fewer safe fish handling practices than was self-reported. This study supports the findings of other studies which also reported that food handlers tend to overestimate the frequency with which they carry out safe food handling practices (Oteri and

Ekanem, 1989; Manning and Snider, 1993; Howes *et al.*, 1996; Redmond and Griffith, 2003a; Abbot *et al.*, 2009).

Keeping fresh fish out for several hours under abuse temperature was a common behaviour. Chilling and refrigeration represent a useful means of suppressing microbial growth and extending shelf-life of fish. The proportion of participants who practise handwashing before and after handling raw or cooked fish was low. Sanitary and handwashing facilities were absent or inadequate in the majority of the premises visited. However importantly, the majority of fish handlers had more positive attitude toward proper handwashing after using the toilet.

The study identified a variety of factors which serve as barriers to good food handling practices in the fish industry in Ghana. Non-compliance with safe food handling practice was greatly influenced by the general poor food safety infrastructure, resulting in the majority of fish handlers working in open spaces, exposed to the elements. Furthermore, this study found that the low compliance to recommended food safety practice is compounded by problems with clean water and electricity supply, the lack of basic sanitation infrastructure, the lack of adequately skilled staff, the lack of training and technical assistance, poorly or inadequately developed compliance policies due to limited resources and often poor management.

These results agree with the findings of other studies, in which the lack of adequate infrastructure, including hygienic landing centres, electric power supply, potable water, roads, ice plants, cold rooms, refrigerated transport, and standard processing and packaging facilities were identified as barriers to safe food handling practice in many developing countries (Buckle *et al*., 1998; Abila, 2003; FAO, 2010).

Some studies have highlighted the effectiveness of training at improving food safety knowledge and food safety behaviours (Cohen *et al.*, 2001; McElroy and Cutter, 2004). However, training alone is

not enough as the infrastructure to support safe food handling is lacking in the communities in which this study was conducted. Further research, including identifying gaps in the infrastructure, and developing tailored food safety training programmes designed to improve food handling skills and address the deficiencies would add value to the available evidence. Future researchers might also focus on impact of food handler knowledge, food handler food safety training and the provision of infrastructure on food safety compliance. This study is limited by the number of participants.

7.3.7 Survey of food safety inspectors

7.3.7.1 Demographic characteristics of food safety inspectors

As part of this study, a survey was conducted to understand the nature of the work of food safety inspectors as well as the difficulties they encountered in carrying out their duties. The demographic characteristics of food safety inspectors interviewed are presented in Table 7.18. Thirty (62.5%) of inspectors were male and 18 (37.5%), female. Twelve (25%) of the inspectors had secondary, technical or vocational education, 15 (31.2%) had college education and 21 (43.8%) had higher (professional or graduate) education. Thirty-four (70.8%) of the inspectors had food safety certification, of which 21 (61.8%) had environmental health certificates and 13 (38.2%) had certificate in food premise inspection.

A majority (64.8%) of the inspectors had been working as inspectors for at least 5 years. Nearly all (91.7%) the inspectors surveyed had visited fish handlers in the last 12 months, mainly on routine visits (47.9%), to investigate unsafe food handling practice (14.6%) or to close down premises for violation of regulation (4.2%) and for other reasons (31.3%). These visits were mainly unannounced (83.3%). Nearly all (97.9%) of the inspectors have had food hygiene training but only 14 (29.2%) had training in HACCP.

Table 7.18. Inspectors' Demographic characteristics

Factor	n	%
Gender		
Male	30	62.5
Female	18	37.5
Education		
No school	0	0
Primary	0	0
Secondary/technical/vocational	12	25.0
College	15	31.2
Higher education (professional/graduate)	21	43.8
Have food safety/environmental health certificate		
Yes	34	70.8
No	14	29.2
What qualification do you hold?		
Environmental health officer certificate	21	61.8
Certificate in food premise inspection	13	38.2
Number of years employed as EHO/inspector/food safety expert		
1-4	14	29.0
5-9	10	20.8
10-19	11	23.1
20-29	9	18.9
30-32	1	2.1
Missing	3	6.2
Working hours/week		
More than 40	23	47.9
36-40	23	47.9
26-35	1	2.1
Less than 16	1	2.1
Have you visited any fish handlers in the last 12 months?		
Yes	44	91.7
No	4	8.3
Reasons for visit		
Routine inspectors	23	47.9
To investigate unsafe food handling practices	7	14.6
Close down premise for violation of regulation	2	4.2
Investigate consumer complaints	1	2.1
Others	15	31.3
Inspections announced or unannounced		
Announced	3	6.2
Unannounced	40	83.3
Announced and unannounced	3	6.2
Any training on food hygiene		
Yes	47	97.9
No	1	2.1
Any HACCP training?		
Yes	14	29.2
No	34	70.8
What HACCP certificate		
Foundation	10	20.8
Intermediate	2	4.2
Advanced	1	2.1
Missing	35	72.9

7.3.7.2. Views of food safety inspectors

Most inspectors (93.8%) kept records and 93.8% indicated that their inspections were monitored (Table 7.19). More than half (52.1%) of them said food handlers were not required to have food safety training but the majority of inspectors thought that food handlers needed appropriate training. The majority (79.2%) of inspectors said that food handlers were receiving the required training. However 93.8% of inspectors thought that trained food handlers were not applying the knowledge gained. These findings support previous studies that food handlers' knowledge and understanding of food safety are not always translated into actual behaviours and good food safety practices (Howes *et al.,* 1996; Ehiri *et al.,* 1997; Clayton *et al.,* 2003). Nearly 67% of inspectors believed that fish handlers did not understand the principles of food safety, 70.8% indicated that inspectors were not receiving adequate training and 55.3% believed that their authorities had the capacity and resources to build food safety expertise.

Strategies adopted by the inspectors to ensure food safety compliance included highly educational/preventative/conciliatory or advisory approach (31.2%), training (14.6%), deterrent measures (20.8%) and prosecution of offenders (14.6%). Previous empirical work in food safety compliance by Yapp and Fairman (2004), show that educational approaches to inspections are significantly more effective than inspections driven by enforcement objectives. Legalistic and punishment oriented strategies in the United States have also been found in some circumstances to achieve lower results than other more flexible regimes (Kagan and Axelrad, 2000). In this study, 47.9% of the inspectors thought that the preventive/conciliatory approach was more effective and the other half (47.9%) thought the inspections and sanctions were more effective. Other studies show that enforcement activity is better at achieving compliance with prescriptive requirements (Baldwin, 2004; Fairman and Yapp, 2005).

Table 7.19 Views of food safety inspectors

Statement	n	%
Do you keep records of your inspections?		
Yes	45	93.8
No	2	6.2
Are food handlers required to complete food safety training?		
Yes	23	47.9
No	25	52.1
Do food handlers need appropriate training in their operations?		
Yes	41	85.4
No	7	14.6
Are fish handlers getting the required training?		
Yes	10	20.8
No	38	79.2
Do they always apply the food safety knowledge they have?		
Yes	3	6.2
No	45	93.8
Do fish handlers understand food safety principles?		
Yes	13	27.7
No	32	66.7
As an inspector are your food safety activities monitored?		
Yes	45	93.8
No	3	6.2
Has the FDB or your agency addressed your training needs?		
Yes	14	29.2
No	34	70.8
Does your authority have the means to build food safety expertise?		
Yes	18	38.3
No	26	55.3
Regulatory tools available to inspectors		
Use of penalty infringement notice/on-the-spot fine	4	8.3
Initiation of legal action	0	0.0
Issuing of improvement notice	23	47.9
All of the above	14	29.2
When are these regulatory tools applied?		
After routine inspections of a food business	35	72.9
As a result of investigation of a complaint	4	8.3
After inspections/investigation of complaints	6	12.5
Strategies and sanctions applied to ensure compliance		
Highly educational/preventative/conciliatory/advisory approach	15	31.2
Run food hygiene courses	7	14.6
Adopt a deterrent strategy/detect violations and punish offenders	10	20.8
Serving notices and prosecuting offenders	7	14.6
Others	9	18.8
Most effective enforcement methods		
Preventive/conciliatory approach	23	47.9
Inspections and sanction	23	47.9
Preventive/conciliatory/sanctions approach	1	2.1

7.3.7.3 Factors affecting behaviour change and the adoption of efficient food safety management practices

A complex of factors including poor facilities (29.2%), lack of awareness of procedures (12.5%), failure to follow procedures (8.3%) and a combination of others were cited as constrains to the adoption of efficient food safety and quality management (Table 7.20). Many inspectors also thought that low awareness of health risks (45.8%), difficulties in shedding old habits (14.6%), lack of investments (8.3%), potential losses (4.2%) and other internal factors hindered behaviour change and the adoption of recommended food safety practice in the fish industry in Ghana. Important external factors that were identified by inspectors as constraints to behaviour change and the adoption of recommended food safety practice included the lack of credit (loans and subsidies) (14.6%), the inability to enforce food safety regulations and controls (14.6%), not giving recognition to those who adopt standard food safety practice (10.4%), and a combination of other reasons including those outlined above (37.5%). Fairman and Yapp (2005) are of the view that education, advisory visits and training can address a number of the attributes of legal requirements that make compliance difficult for SMEs. In order of most serious barriers, the majority of enforcement officers rated lack of access to information (41.7%), lack of support (41.7%), operational costs (39.6%), lack of money (38.3%), lack of experience (36.2%), lack of knowledge (35.4%), lack of compliance guidelines (34%), lack of time (21.3%) and lack of interest (8.3%). Similar barriers including lack of trust in enforcement and food safety officers, lack of motivation, and lack of knowledge and understanding of complex technical requirements for voluntary implementation of food safety protocols such as the HACCP (Hazard Analysis and Critical Control Point program) have been identified by Yapp and Fairman (2006) as the main barriers to implementing food safety requirements. In seeking to achieve compliance, a holistic, co-ordinated approach which factors in infrastructural development, incentives, training and inspections may facilitate adherence to food safety standards.

Table 7.20 Factors affecting behaviour change and barriers to regulatory compliance

Factors affecting adoption/behaviour change	n	%
Factors that constrain the adoption of efficient food safety and quality management		
Lack of competence	3	6.2
Failure to follow procedure	4	8.3
Lack of awareness of procedures	6	12.5
Poor facilities leading to impaired performance	14	29.2
Infrastructural difficulties	2	4.2
Inappropriate monitoring	3	6.2
Others	16	33.6
Internal factors that hinder behaviour change/adoption of recommended food safety practice		
Low awareness of health risks	22	45.8
Difficulties in shedding old habits	7	14.6
Investment	4	8.3
Potential losses	2	4.2
Others	13	7.1
External factors that hinder behaviour change/adoption of recommended food safety practice		
Lack of credit (loans and subsidies)	7	14.6
Lack of enforced regulations and controls	7	14.6
Lack of public awareness/media publicity	2	4.2
Recognition is not given to who adopt standard food safety practice	5	10.4
No provision for extra training	2	4.2
Lack of support for dedicated extension service	4	8.3
Lack of market incentive for 'safer food'	2	4.2
Others	18	37.5
Most serious barriers to food safety compliance		
Lack of money	31	66.0
Lack of time	13	27.7
Lack of experience	27	57.5
Lack of access to information	31	64.6
Lack of support	32	66.7
Lack of interest	11	22.9
Lack of knowledge	28	58.3
Lack of compliance guidelines	31	65.9
Operational costs	33	68.8

7.3.7.4 Food safety campaigns and provision of food safety information

If good hygiene practices are to become a norm in the food industry, a multi-dimensional promotion, which engages food handlers and emphasises primary prevention, is needed to persuade people to change their behaviour (Kreuter *et al.,* 2000; Elder *et al.,* 2009). In this study 77.1% of inspectors said they did not have any on-going food safety campaigns but 45.8% of them provided some form of food safety information through various media (Table 7.21).

Table 7.21. Food safety campaigns and provision of food safety information

Statement	n	%
Is there any on-going food safety campaign?		
Yes	11	22.9
No	37	77.1
How long has educational campaign been going on?		
1 year	2	4.2
2 years	1	2.1
5 years	2	4.2
About 10 years	2	4.2
Do you provide food safety information through the media?		
Yes	22	45.8
No	26	54.2
How to successfully reduce food safety risk in fish chain		
Use participatory approach	3	6.2
Develop appropriate communication channels	7	14.6
Benefits must outweigh costs	1	2.1
Facilitate access to accurate information	2	4.2
Supporting training and capacity building	6	12.5
Facilitating technology upgrading	2	4.2
All of the above	27	56.3
Do the inspectors understand food safety principles and practice?		
Not very well	8	16.7
Not well	7	14.6
Uncertain	3	6.2
Well	16	33.3
Very well	14	29.2
Level of satisfaction with fish industry efforts to comply with food safety requirements		
Very satisfied	1	2.1
Satisfied	21	43.8
Unsatisfied	21	43.8
Very unsatisfied	4	8.3

More than half (56.3%) of the inspectors thought that to reduce food safety risks in the fish chain, a combination of efforts including, the adoption of participatory approach, develop appropriate communication channels, benefits must outweigh costs, facilitate access to accurate information, supporting training and capacity building and facilitating technology upgrading needed to be applied. When the inspectors were asked about whether or not they understood food safety principles and practice, 33.3% indicated that they understood food safety principles well and 29.2% said they understood very well. Nearly half (48%) of the inspectors were not very satisfied with the level of fish industry efforts to comply with food safety requirements.

7.3.7.5 Inspectors' food safety competence

Government food control agencies play an important role in the development and/or application of HACCP systems and food safety compliance activities. In this regard, food safety inspectors must have the requisite food safety knowledge and skills to implement HACCP-based food safety compliance. In this survey food safety inspectors' knowledge on HACCP, food safety and food safety promotion was limited (Table 7.22). Only 41.7% of the inspectors said they were very competent in evaluating HACCP plans, 33.4% said they were very competent in developing food safety management system based on HACCP and 31.2% were very competent in carrying out HACCP audits/external verification.

From these results it is apparent that the majority of food safety inspectors are ill equipped to handle issues regarding HACCP. The skills and knowledge of food safety inspectors will need to be considerably improved to handle issues regarding HACCP, including developing, evaluating and auditing HACCP plans and general food safety management. Many countries have integrated the HACCP system into their regulatory mechanisms, as a way of reducing the incidence of food-borne disease as well as ensuring a safe food supply for the population, promote and facilitate trade in food products and to promote tourism (WHO, 1995; WHO, 1997). Under a mandatory HACCP programme, there is a crucial need for HACCP training and competencies to be developed, not only for the food industry personnel but also for food control regulators (Al-Kandari and Jukes, 2011). The majority (79.1%) of inspectors said they were familiar and knowledgeable of the entire "catch-to-table" continuum of the fish chain.

Table 7.22 Areas of competence of food safety inspector

Statement	Not competent		Moderately competent		competent		Very competent		Extremely competent	
	n	%	n	%	n	%	n	%	n	%
Evaluating HACCP plans and their evaluation	23	47.9	5	10.4	12	25.0	6	12.5	2	4.2
Developing food safety management system based on HACCP	23	47.9	8	16.7	7	14.6	8	16.7	1	2.1
Carrying out HACCP audits/external verification	26	54.2	7	14.6	5	10.4	10	20.8	0	0.0
Inspecting premises and processes for hygiene compliance	4	8.3	2	4.2	9	19.8	13	27.1	20	41.7
Sampling food during processing/storage/transport/sale	3	6.2	7	14.6	14	29.2	17	35.4	7	14.6
Recognising different forms of food decomposition	1	2.1	7	14.6	10	20.8	18	37.5	12	25.0
Identifying food which is unfit for human consumption	0	0	2	4.2	4	8.3	25	52.1	17	35.4
Identifying food which is otherwise deceptively sold	0	0	1	2.1	8	16.7	27	56.2	12	25.0
Recognizing/collecting/transmitting evidence	1	2.1	2	4.2	13	27.1	25	52.10	7	14.6
Voluntary compliance by means of quality assurance procedures	3	6.4	3	6.4	22	46.8	16	34.0	3	6.4
Inspecting/sampling/certification of food for export/import	3	6.2	8	16.7	11	22.9	19	39.6	7	14.6
Delivering of information/education/advice to stakeholders	2	4.2	5	10.4	14	29.2	19	39.6	8	16.7
Provision of balanced factual information to consumers	3	6.2	4	8.3	14	29.2	24	50.0	3	6.2
Provision of information packages to key food industry officers	4	8.3	5	10.4	16	33.3	20	41.7	3	6.2
Training of trainers/extension workers in food industry	2	4.2	7	14.6	21	43.8	15	31.2	2	4.2
Familiarity/knowledge of entire “catch-to-table” continuum of fish chain	6	12.5	4	8.3	15	31.2	17	35.4	6	12.5
Assisting with implementation of FDB approved food safety schemes	7	14.6	5	10.4	14	29.2	20	41.7	2	4.2
Assisting food manufacturers meet third-party certification schemes	9	18.8	4	8.3	17	35.4	17	35.4	1	2.1

7.4 Conclusion

This study has attempted to track the handling, preparation, transportation and retail of traditional fish products and to determine the implementation of specific food safety practices by fish handlers in Ghana. The results show inconsistencies between self-reported and observed food safety practices among fish handlers in Ghana and suggest that food safety compliance level is relatively low although there was some evidence of good practice in places. Although good food safety knowledge and a positive attitude toward food safety and hygiene was reported by the majority of food handlers, this knowledge and attitude was not supported by some of the food handling and hygiene practices observed. A significant proportion of fish handlers used unsafe food handling practices in their premises. The results particularly highlight infrequent hand-washing practices, the lack of sanitary facilities and sanitising chemicals, the lack of separate hand and dish-drying napkins, poor time-temperature control during handling and storage of fish and inappropriate fish handling facilities. In fact, studies show that shortcomings related to time/temperature control, improper hygiene and cross contamination contribute most significantly to incidence of foodborne illnesses (Motarjemi and Käferstein, 1999; Olsen *et al.*, 2000; FDA, 2004; Sumner *et al.*, 2004; Luning and Marcelis, 2006).

The low levels of food safety compliance could partly be attributed to inadequate food safety training, lack of basic sanitary facilities and infrastructure in the processing facilities and the workload of the fish handlers. This view is in line with Green and Selman's (2005) view that food handlers' ability to implement food safety was limited by time pressure; equipment and resource availability; food safety emphasis by management and co-workers; and food safety education and training. Clayton *et al.* (2003) have also noted that pressure of time may prevent food handlers from carrying out food safety actions. Actual food handling and hygiene practices were not predicted by self-report measures of practice. The findings are congruent with Abbot *et al.* (2009) who, using a similar evaluation strategy, found an increased likelihood of food handlers over-reporting their level of food safety compliance. The low rate of had hygiene, personal hygiene and premise cleanliness raise a lot of concern. The results also raise the need to use food safety training and education to

promote the adoption of desired food handling practices and improve knowledge and food safety practices.

The results also show that levels of competence among food safety inspectors are low and there is need to train inspectors. In addition to training, inspections and motivation, basic facilities are needed in the processing units to ensure food safety. In view of these findings, changing habits to good practice need to be given priority and attention must be given to establishing the most effective way of doing this. Practical training is clearly required in order to change habits and institute attitude changes which are reflected in good hand hygiene practice. At the same time, consideration could also be given to the provision of basic infrastructure. In short, this study confirms the existence of inherent barriers in the traditional fish industry which hinder the effective implementation of the HACCP food safety system. These barriers include knowledge, attitudinal and infrastructural and operational. Other researchers (Gilling *et al.*, 2001; Bas *et al.*, 2007; Taylor, 2008) have reported similar barriers. Food safety inspectors would also need to be retrained and equipped. Overall the study highlighted the need for greater food handler education regarding safe food handling practices in the fish industry. While the results of this study highlight the problems in the traditional fish industry, the results must also be interpreted with caution considering the small sample size of the study. From the point of view of HACCP, potential CCPs have been identified along the fish food chain and food inspectors have indicated very little training in HACCP. These findings need to be collated as part of a framework to inform the regulatory process, incorporating all the different stakeholders and actors in the fish food chain in Ghana.

Chapter 8

8.0 Overall Discussion

8.1 Discussion of results

The present study was set out in three key focus areas aimed at:

1) assessing the incidence of pathogenic microorganisms in traditional fish products from Ghana;

2) investigating the survival of *Salmonella* and enterotoxigenic *S. aureus* in fish; and

3) ascertaining links between food safety knowledge, concerns, practices and how these relate to current hygiene and sanitation conditions along the fish chain in Ghana.

8.1.1 The microbiological safety of sampled traditional retailed fish products

Microbiological analysis of traditional fish products did not detect *Salmonella* and *C. perfringens* in 25g and 1g, respectively of salted any of the samples analysed. Microbial counts, including total counts, coliform bacteria and *S. aureus* were low (< log 3 CFU/g) in smoked cat fish, smoked herrings, salted and dried koobi and kako and generally were within the limits set in the European Commission Regulation (EC 2073/2005) on microbiological criteria for foodstuffs. Total aerobic bacteria and coliform numbers, *S. aureus* and *B. cereus* in some samples of smoked mackerel and fried bonga were above the maximum acceptable limits, i.e. <5.0 $\log_{10}$ cfu/g for total aerobic counts, <3.0 $\log_{10}$ cfu/g for *S. aureus* and *B. cereus*, and zero tolerance for other pathogens (Mensah *et al.*, 2002). Fried fish are ready-to-eat fish products usually retailed under ambient conditions. The high temperatures involved in deep frying (up to 250^{o}C in some cases) are deemed too high for the survival of most bacteria. The protection derived from the method of fish processing does not necessarily confer absolute safety to the end product at the end-user phase if for instance, fried but cooled fish were served by a handler whose fingers were contaminated with *Salmonella* spp. or *S. aureus* because of poor personal hygiene. These findings raise questions about possible safety concerns around smoked mackerel and fried bonga. Ambient storage conditions for long periods of

time could result in pathogen growth and potentially render this fish unsuitable for human consumption.

The ranges of water activity (a_w) detected in fried bonga (0.82 – 0.95) show that *S. aureus* could grow to high levels in the samples and therefore, fried bonga was classified in this study as high risk fish product and potentially hazardous; and should therefore be retailed under strict temperature-time control. *S. aureus* is one of the most resistant bacteria species capable of tolerating low water activity (a_w) (Kannat *et al.,* 2006). As an indicator of hygiene and sanitary conditions, the presence of this organism in the retail smoked fish products and fried fish products analysed indicated that the sanitary conditions during processing, storage and retail were poor, and this may have created a conducive environment for their growth and a potential health risk to consumers. Several factors, including the bacteriological quality of the raw ingredients, delay in processing, inadequate refrigeration, poor personal hygiene; storage temperature and post-process contamination are among conditions that have been associated with staphylococcal growth and enterotoxin production (Wieneke *et al.,* 1993). Small numbers of *S. aureus* are to be expected in foods that have been exposed to human contact because of its ubiquitous distribution and the fact that *S. aureus* is a normal resident of human skin surface and the nostrils. Staphylococcal food contamination is often linked to workers who are carriers and/or to contact with inadequately cleaned equipment (Herrera *et al.,* 2006). Post-processing contamination by *S. aureus* represents a significant health hazard due to the elimination of microbes that would normally out-compete *S. aureus* (Gundogan *et al.,* 2005).

Even if *S. aureus* was absent on freshly processed fish products, opportunities for post-processing contamination exist during handling at the retail level because participant observation in this study has demonstrated that a majority of traditionally processed fish products are sold without adequate packaging. Furthermore, traditionally processed fish products are stored and vended under ambient conditions. Therefore, the presence of *S. aureus* in fried bonga and the smoked fish samples most likely resulted from post-processing handling contamination. It is recommended to use fish industry-specific PRPs as specified in the Codex Codes of Practice for fish and fishery products (CAC/RCP 52-2003) be applied in respect of post-process handling in this case. There is also a

need to educate fish workers on the importance of hygienic and sanitary practices and implementation GMP and HACCP.

Yeast and moulds were detected in the majority of fried bonga, smoked fish and salted and dried fish samples analysed, suggesting that the spores may have survived the effects of frying, salting, drying or smoking or may be due to post-processing contamination. The numbers of yeast and moulds were however below the maximum acceptable limits of $<10^4$ cfu/g for salted fish (FSAI, 2001). The xerophilic moulds, *Aspergillus* spp. and *Penicillium* spp., have been reported in fresh fish (Bagy *et al.* 1993; Efiuvwevwere and Ajiboye 1996), smoked dried salted fish (Atapattu and Samarajeewa 1990; Fafioye *et al.* 2002) and in salted dried fish products (Atapattu and Samarajeewa 1990; Jonsyn and Lahai 1992; Ahmed *et al.,* 2005). Various researchers have also reported dangerous levels of aflatoxin in dried fish (Okonkwo *et al.,* 1977). Spores of moulds often present in the air and soil contaminate fish during and after processing. Extensive mould growth not only cause important economic losses due to spoilage, but may also produce hazardous mycotoxins. To prevent mould growth during storage, moisture must be reduced to below 15% (Bala and Mondol, 2001). For smoked fish to survive mould attack during storage, moisture should be below 12% (Daramola *et al.,* 2007). Therefore, the drying process should be properly monitored to ensure adequate drying and prevent mould contamination. Results of the sensory analysis showed that koobi and kako were usually not well liked because of their 'strong and pungent' smell. However microbiological analysis showed that they are free of pathogenic microorganisms and on this basis, their wholesomeness and microbiological safety is without question, although the levels of salt concentration used to preserve them may have implications for total daily salt intake and risk of cardiovascular disease (Cohen *et al*., 2006).

8.1.2 Effect of holding temperature on survival *S*. Typhimurium and *S*. *aureus*

Temperature is one of the most important factors affecting growth and survival of microorganisms. Results of the challenge tests showed that at temperatures below 4°C, growth of *S. aureus* and *S.* Typhimurium were inhibited. *S.* Typhimurium and *S. aureus* counts were drastically reduced or

eliminated within a few days of storage of salted and dried products (koobi, kako) and hot-smoked herrings and catfish products, irrespective of storage temperature. These products were also generally characterised by very low a_w values. These observations are consistent with findings from previous studies (Humphrey *et al.*, 1989; Saeed and Koons 1993; Yang *et al.,* 2001; Lublin and Sela, 2008) in which it was observed that *Salmonella* and *S. aureus* showed no growth when held at 5°C. Other studies have reported no growth of *S. aureus* at temperatures below 8 °C combined with low pH (Normanno *et al.,* 2005). The range for *Salmonella* growth and survival is between 2 to 47°C with rapid and optimal growth occurring between 25 to 43°C (D'Aoust, 2001) and 37°C, respectively. Lanciotti *et al.* (2001) reported a minimum growth temperature value of 4.69°C for *Salmonella enteritidis*, whilst growth was reported at temperatures as high as 40°C. Others have reported complete inhibition of growth at temperatures below 7°C (Gray and Fedorka-Cray, 2002).

8.1.3 Fish safety, shelf-stability and the impact of water activity and storage temperature

The results also show a great variability in water activity and pH of the fish products sampled. Water availability as measured by a_w is an important growth parameter crucial for the survival of microorganisms including *Salmonella* (Hayes *et al.,* 2000), and has a direct implication for microbiological safety of food and is thus an important component of GMP within the food processing industry. The levels of a_w achieved are known to affect the survival of pathogens (Hew *et al.,* 2005) and also influences the storage stability of foods as some deteriorative processes in foods are mediated by water. At the same temperature, storage life of foods with low a_w is generally longer than foods with higher a_w. In this study, koobi, kako, smoked herrings and smoked catfish had longer shelf-lives. Microbiological analysis showed that *Salmonella* and *S. aureus* numbers decreased in kako and koobi held at 4^oC and at 30^oC. Pearson's correlation analysis also showed a strong association between a_w and *Salmonella* survival in kako (r^2 = 0.944, koobi (r^2 = 0.993), smoked herrings (r^2 = 0.998) and smoked catfish (r^2 = 0.848), respectively. Because of this association between physical property a_w and the chemical and microbiological properties of fish samples, it is appropriate to emphasise these aspects in any food safety education programme. This effect was also observed in smoked catfish, and smoked herring.

The decrease in numbers was higher in samples held at 30^{o}C than at 4^{o}C. This is unexplained, except to speculate that perhaps with already dry products e.g. kobi and kako, the higher environmental temperature, coupled with salting add to desiccation, thus rendering the environment less conducive for bacterial growth and reproduction. Thus the faster rate of decrease of *Salmonella* and *S. aureus* in the kako, koobi, smoked catfish and smoked herrings held at 30^{o}C could be the result of drying of the samples held under ambient conditions. Viable but non-culturable response of *Salmonella* and *S. aureus* at low temperature has also been reported (Asakura *et al.*, 2002; Masmoudi *et al.*, 2010). Asakura *et al.* (2002) observed that *Salmonella* becomes non-culturable under osmotic stress, but retain its pathogenicity. Loss of colony forming ability at low temperature is caused by exposure to oxidative stress (Wai *et al.*, 2000; Kong *et al.*, 2004; Masmoudi *et al.*, 2010). It is possible that *S. aureus* and *Salmonella*, facing high salt concentration, low a_w and low level of nutrients may activate survival mechanisms that depend on temperature (Leboeuf *et al.*, 2000; Giard *et al.*, 2001). Other studies show that bacteria which adapt to heavily stressed environments are more likely to survive levels of stress that would previously be considered lethal (Gahan *et al.*, 1996). Food safety relies primarily on the use of multiple hurdle technology (Leistner, 2000). Therefore, depending on processing, pathogens may be exposed to various stresses simultaneously (Niksic *et al.*, 2005; Yoon *et al.*, 2006) and these exposures may affect their survival, growth and replication to levels which convert them from mere hazards to actual disease risks.

8.1.4 Effect of salting, holding temperature and water activity on survival and enterotoxin production by *S. aureus*

S. aureus growth and enterotoxin production was inhibited in smoked catfish and mackerel formulated with higher than 5% (w/w) sodium chloride. Furthermore, reducing the sodium chloride concentration resulted in less log bacterial population reduction. Holding temperature, sodium chloride concentration, water activity, pH and inoculum sizes were all shown to interact and influence the growth, survival and enterotoxin production of *S. aureus* in smoked catfish and smoked mackerel. Higher inoculum levels were required to initiate growth of *S. aureus* and

enterotoxin A and B production in samples with higher salt concentration. At lower inoculum level, longer incubation period was required for *S. aureus* to begin to produce enterotoxins. The results also show that cell number and temperature were important factors that affected the production of enterotoxin by *S. aureus* in smoked fish products.

Regardless of the inoculum size, no enterotoxin was detected from fish products held at 4^{o}C during the entire 7 days holding period. Refrigeration (4°C) is therefore an appropriate method of lowering the incidence of *S. aureus* food poisoning. Higher levels of SEA and SEB were detected in smoked fish which were held at 30^{o}C and with high inoculation dose. This suggests that a combination of chemical and biological factors including, lower a_w, higher salt content of the product, low storage temperature in combination with adequate processing conditions would inhibit growth and production of enterotoxins by *S. aureus*. Any time and temperature abuse conditions during food storage and preparation that would allow for growth of *S. aureus* may result in the production of staphylococcal enterotoxins and potentially pose public health risks to consumers (Todd *et al.*, 2008). Furthermore, *S. aureus* produced a relatively higher level of enterotoxin on unsalted fish products than salted fish products. The results further suggest that there may be the need for fish handlers to change the way smoked mackerel and fried fish is stored and retailed as their inherent water activity levels may not inhibit the growth of bacterial pathogens like *Salmonella* and *S. aureus* under ambient conditions. *S. aureus* can survive in smoked fish products and remain dormant even in smoked fish held at 4^{o}C. Therefore, to ensure that smoked fish products will be safe for human consumption consumers should abide by temperature time requirements when handling smoked fish.

The findings suggest that current traditional processing methods may be contributing to food preservation and safety and therefore need to be explored as part of any comprehensive framework for improving and maintaining the microbial safety of fish products from Ghana and other West African countries. The importance of proper handling, processing and storage of food in the prevention of contamination however merits serious consideration. Furthermore the results show that a key critical control point applied by fish handlers i.e. heat treatment is often adequately

applied. Fish handlers may not be aware that heat treatment is a critical control point and therefore must be made aware of this and ensure that any measures applied at this stage add to overall safety. Salting, drying and hot-smoking steps can achieve a reduction in the levels of pathogenic microorganisms in processed fish but salt levels and salting practices differ markedly between processors.

Any pathogenic bacteria present in smoked, fried or salted fish products are most likely the result of post-processing re-contamination or inadequate processing. The extent of this contamination, both in terms of frequency and the level of pathogen present will subsequently be dependent on how the product is handled and maintained during final processing, distribution, marketing, and use by the consumer. Current post-processing handling and storage practices such as the ambient storage conditions of smoked fish products do not necessarily provide any guarantees against growth of pathogens to hazardous levels. Critical control points (CCPs) that guarantee that counts of microbial pathogens do not increase to hazardous levels can be introduced, e.g. by refrigeration or frozen storage or by ensuring that the water activity levels are reduced to below 8.2 during processing.

8.2 Food safety knowledge, attitudes, practices, concerns of consumers and food handlers in Ghana

This study has also highlighted gaps in food safety knowledge and some critical food safety violations along the fish chain regarding handling, hygiene and sanitation; and confirms that fish handlers over-estimate (exaggerate) their degree of food safety compliance, whilst at the same time recognising limitations in their knowledge. Results of participant observation have shown a general absence of GHP along the fish chain and non-adoption of specific PRPs and HACCP principles in the fishing trade in Ghana.

Survey results also show a great variability in the way that fish and fish products are handled, processed, distributed and marketed in (and from) Ghana. Correct handling of food during all stages of preparation and storage is vital in reducing the incidence of food borne illness (NHMRC, 2003). Although some fish handlers knew what proper procedures were, many failed to follow them during

fish handling, storage, processing and retail. This lack of fish handlers' performance of required food safety practices included time-temperature abuses, inadequate handwashing, inappropriate fish storage procedures and personal hygiene and sanitation problems. These findings are similar to those of Howes *et al.* (1996) who also observed that employees' food safety knowledge does not always translate into good food safety practices and that food handlers tend to overestimate their food safety practices (Howes *et al.,* 1996; Clayton and Griffith, 2004; Kennedy *et al.,* 2005; Byrd-Bredbenner*et al.*2007). Clayton and Griffith (2008) have also reported very little relationship between participants' self-reported and actual hand-washing behaviour.

The effects of socio-economic factors on non-compliance were also examined. The cause of non-adherence to food safety requirements in this population appears to be multi-factorial and include poor economy, poor facilities, apparent lack of cold chains, lack of handwashing and sanitary facilities, frequent disruptions in water and electricity supply. A major concern identified in this study is the fact that the majority of fish handlers surveyed did not report receiving the appropriate education and training on food safety. Inadequate knowledge about food safety and food safety management, inadequate training, inadequate inspections and nonchalant attitude associated with denial of the presence of problems along the chain were highly prevalent. Survey results also show that both food handlers and inspectors have very little knowledge of HACCP a risk-based food safety management system. Observations of food safety practices along the fish chain also reveal the absence of adequate time-temperature control from catch to retail. Majority of fish handlers who indicated that they were trained were either self-taught or taught by their parents. The degree to which these factors (either singly or in combination) contribute will probably be the subject of another study. However these findings and the links observed between the microbiological analysis and survey findings provide a useful framework for modelling on food safety guidance and regulation which can then be tested within the Ghanaian and West Africa context.

8.3 Food safety intervention measures for the traditional fish processing sector

The low levels of formal food safety and hygiene training for food handlers in Ghana found in this study raises serious concerns about the safety and quality standards in the traditional food processing and catering settings. The findings also provide an opportunity to review current training provision and practices and ways in which training can be scaled up to benefit people working in the food service sector in Ghana. Training and education of those involved in preparation, processing and handling of food is a crucial line of defence in the prevention of most types of food borne illness (Black *et al.*, 1981; Green and Selman, 2005). To reduce the incidence of foodborne illness, it is important to improve food handlers' food handling practices and knowledge (Green and Selman, 2005).

The results reveal the need for fish handler and consumer education regarding safe food handling practices from catch to the home. Food safety agencies should play an important role in the education and training of fish handlers. Training strategies need to emphasise hand hygiene actions, time-temperature control and cross-contamination. Providing appropriately designed and targeted food safety educational material about PRPs, SOPs, GHPs and GMPs to food handlers would also help to facilitate or persuade behaviour modification. Mullan *et al.* (2010) have suggested that future interventions need to target participant's understanding of safe food handling behaviour.

Food safety training should ideally be provided for all food handlers and inspectors before they begin to work in the food industry, supported and reinforced with periodic in-service continuing professional development (CPD) or refresher courses to ensure and maintain high standards of practice across all stakeholders. A risk-based approach to food safety management has been advocated, and a range of reviews have identified major risk factors contributing to food borne disease (Weingold *et al.*, 1994; Bryan, 1995; Ryan *et al.*, 1996; Coleman and Griffith, 1998; WHO, 2000a; Clayton and Griffith, 2004). Data from the present study show that some of these risk factors persist in the traditional fish chain. Typically these factors include inadequate heat treatment, inappropriate storage of foods, infected food handlers and cross-contamination (WHO,

2000a). Medeiros *et al.* (2001b) have suggested that food safety educational programs should be organized according to five categories namely: (1) personal hygiene, (2) adequate cooking, (3) avoiding cross-contamination, (4) cold storage/hot-holding, and (5) avoiding foods from unsafe sources. Any attempt to address food safety hazards and improve food safety in the traditional fish processing industry in Ghana must include a comprehensive plan that tackles hazards at the primary production and intermediate stages: i.e. before processing, during processing, transportation, storage and retail as well as educational programmes to educate food handlers and consumers to follow proper food handling practices. In addition, there is the need to periodically evaluate the health of food handlers in Ghana through appropriately targeted screening and certification. It is also of vital importance to properly train food safety educators in order to transmit food safety and hygiene principles fish handlers. As the results show, only 43.8% of the inspectors had higher (professional or graduate) qualification and only 29.2% were trained in HACCP.

A number of researchers (Manning and Snider, 1993; Clayton *et al.,* 2003; Clayton and Griffith, 2004; Green and Selman, 2005;) have observed that food safety education was not enough to encourage food handlers to perform proper food safety and sanitation procedures. The provision of basic hygiene and sanitation facilities along the chain, including water, cold chains and improvements in the processing facilities is also needed. It is hoped that as more attention is paid to the problems along the fish chain, food safety will be achieved across this and other related sectors. The human dimension including food handlers' and consumers' attitude towards food safety issues, food safety inspectors and professionals' attitude and behaviour towards food safety inspections and management; local authority and the governments' commitment to providing the required facilities and amenities merit further investigation. Further research, including microbiological, epidemiological and psychological is needed to help our fuller understanding of the food safety challenges along the chain, improve hygiene and sanitation practices, and improve training, interventions and inspections in the traditional fish processing sector. It is hoped that the findings from this study will help stimulate further interest and work in this vital aspect of food safety control in Ghana and elsewhere, especially in sub-Saharan Africa.

8.4 Conclusion

This thesis is the culmination of a number of years of work investigating food safety aspects of the fish processing business in Ghana. The study suggests that smoked herrings, smoked catfish, salted and dried koobi, salted and dried kako products are relatively low risk fish products. However, fried bonga and smoked mackerel products may support the growth of S. aureus and Salmonella and when an incorrect temperature is used for storage of the final product before consumption; such precooked products may represent a potential risk for consumers. Although the survey results indicated that majority of the food handlers and consumers had very good food safety knowledge, observations from catch to processing and retail show that the knowledge is not fully applied in food handling throughout the chain. Observed food handling practices appear to contradict self-reported practices and may indeed contravene standard food safety practices and need to be addressed. Key important utilities including, potable water supplies, safe disposal sites for wastes, refrigeration facilities, poor transportation are common. In addition some of the processing units are poorly sited and hygiene standards in these units must be addressed throughout the chain. A number of serious constraints including absence of PRPs that hinder the possible implementation of HACCP and standard food safety management were found. In addition, there are challenges posed by inadequate support from government and its agencies as well as from trade associations. Because of limited resources and tools, the Ghana Food and Drugs Board appear to be limited to a reactive rather than a pro-active role in providing leadership and enforcement of existing statutory regulations, however inadequate these may be at the present time. Consequently, processing decisions and food safety management in the traditional food processing chain needs to be addressed. However one also recognises the need for the consumer survey results to be interpreted with caution because of possible sampling bias based on the small sample size and the representativeness of the sample, albeit through a cluster (probability) sampling design. National food control systems are a key element in the protection of consumers from unsafe foods and from other fraudulent practices (Alomirah *et al.,* 2010). Based on the microbiological analysis, food

safety surveys and the observations along the traditional fish chain, four interlinked options have been proposed for intervention and the management of food safety risks in the traditional fish chain:

1. Education and training of fish handlers and enforcement officers (including training on the identification and adoption of good traditional practices, as well as training on GHP and risk-based food safety management, e.g. HACCP, and general public education to sensitise consumers),

2. The provision of reasonable level of basic infrastructure (adequate fish handling areas, potable water, sewage and refuse collection services),

3. Adoption of appropriate and enforceable regulatory framework including national and local byelaws. To achieve this, there must be institutional linkages between local and national government.

4. Facilitating credit availability to small and medium food business

This study has identified inadequate refrigeration, poor handling and the open display of processed fish far in advance of planned use, as well as the opportunity to transfer pathogenic microorganisms from infected food handlers along the fish chain. These conditions may contribute to contamination and allow the growth and production of the toxin in traditionally processed fish products. Moreover, any toxin that is not affected by subsequent cooking processes may result in food poisoning even if the fish is cooked before consumption. It is therefore crucial that any food safety management programme or risk assessment programme for the traditional fish processing and retail sector should considered human behaviour and practices along with the potential for contamination, growth and toxin production by microorganisms, including *S. aureus*.

8.4.1 Contributions of the study and future work

The study makes a number of contributions to theory, methodology and practice. Regarding theory, the research shows that storing koobi, kako, smoked herrings and smoked catfish under ambient conditions improve their quality and microbiological safety. Relating to practice, the study showed

that the high food safety knowledge level of food handlers is not fully applied practically in food handling. Food safety training that emphasises risk reducing strategies has the potential to help consumers, the government and food industry develop appropriate risk management strategies and effective risk communication message. This study focused on microbiological hazards. Doubtless, the nature of these hazards may differ from other types of food hazard. These hazards may arise from actions of different parties particularly consumers. Actions such as 'cooking well' to control microbiological hazard and refrigeration of fish regarded as 'high risk' would minimise the risk of food borne disease. Chemical hazards arise mainly during food production or food processing and this cannot be reduced by consumers' own control. Future studies would involve an investigation into levels of organochlorines and trace metals in the fish and water to determine if they are within recommended safe levels. Testing the proposed framework model developed from the present study would also provide further insight into addressing current food safety needs and hopefully provide a comprehensive food safety framework for fish products in Ghana. Finally, potential HACCP systems cannot be successfully applied if PRPs and GHPs are not in place (CCFH, 1998; Anandavally and FAO, 2002; CCFH, 2003). Further work on the development of appropriate science- and risk-based PRPs and GHP tools is needed. Therefore, future studies should involve developing an appropriate tool for use by the traditional production and processing sector as a basis for training. In addition, the use of different questionnaire designs could be employed, for example open ended questions, in order to elicit more detailed responses. This is because multiple choice questions can both guide the participant and also allow for a high proportion of guessed responses that may coincide with the correct response predicted.

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Appendix A: Questionnaire for households and consumers

Section A: Personal Data

Please indicate the appropriate box by a tick for the following items.
Gender: [1] Male [2] Female
Age …….

Marital Status: [1] Single [2] Married [3] Others

Education Background:
[1] Primary [2] Secondary [3] Tertiary [4] None

Employment Status:
[1] F/T Employed [2] P/T Employed [3] Self Employed
[4] Unemployed [5] Student [6] Others

Occupation: _____

Total Household Income:
[1] Below Gh¢10,000 p.a. [2] Gh¢10,000-15,000 p.a.
[3] Gh¢15,000-20,000 p.a. [4] Gh¢ 20,000-30,000 p.a.
[5] Gh¢ 30,000 or over p.a.

Section B: FOOD SAFETY KNOWLEDGE

1. The greatest food safety problem is
[1] Pesticides [2] hair [3] microorganisms [4] Don't know
2. Common symptom of food poisoning include
Headache/fever/chills [1] True, [2] False [3] Don't know
Diarrhoea/abdominal cramps [1] True, [2] False [3] Don't know
Rash [1] True, [2] False [3] Don't know
Constipation [1] True, [2] False [3] Don't know
Vomiting/fever/chills [1] True, [2] False [3] Don't know

3. When putting on disposable gloves to prepare food you should
[1] wash your hands and then put on gloves.
[2] put on gloves and then wash your gloved hands.
[3] put on gloves without washing your hands.
[4] Don't know

4. Food poisoning bacteria may be brought into the kitchen ….
In raw food [1] True, [2] False [3] Don't know
By insects [1] True, [2] False [3] Don't know
By food handlers [1] True, [2] False [3] Don't know

5. Food safety problems are most likely to occur
a. through lack of personal hygiene by the people who prepare and serve it. [1] True, [2] False [3] Don't know
b. through lack of hygiene in the farm. [1] True, [2] False [3] Don't know
c. at the abattoir / slaughter house. [1] True, [2] False [3] Don't know
d. in the food processing factory [1] True, [2] False [3] Don't know
e. in the restaurant [1] True, [2] False [3] Don't know
f. in supermarkets [1] True, [2] False [3] Don't know
g. due to improper handling by food retailer. [1] True, [2] False [3] Don't know
h. due to improper storage at home. [1] True, [2] False [3] Don't know
i. due to poor food handling at home. [1] True, [2] False [3] Don't know
j. due to improper cooking procedure. [1] True, [2] False [3] Don't know

k. when pests and pets come into contact with food [1]True, [2] false, [3] Don't Know
l. as a result of temperature abuse [1]True, [2] False, [3] Don't Know

6. Which of the following can be used to kill bacteria in foods?
Disinfectant [1] Yes, [2] No [3] Don't know
Cold water [1] Yes, [2] No [3] Don't know
Detergent [1] Yes, [2] No [3] Don't know
Scrubbing brush/sponge [1] Yes, [2] No [3] Don't know

7. After trimming raw chicken on a cutting surface, what must you do to the cutting surface?
a. Rinse the surface with water. [1] True, [2] False [3] Don't know
b. Dry the surface with a paper towel. [1] True, [2] False [3] Don't know
c. Clean and sanitize the cutting surface. [1] True, [2] False [3] Don't know

8. Cross-contamination is most likely to occur when you
a. cut ready to eat food on a cutting board used for fresh meat [1] True, [2] False [3] Don't know
b. touch raw meat and then touch cooked or ready-to-eat food. [1] True, [2] False [3] Don't know
c. check the refrigerator temperature regularly. [1] True, [2] False [3] Don't know
d. hold food at temperatures below 60°C. [1] True, [2] False [3] Don't know

9. At body heat temperature (37 ^{o}C) food poisoning bacteria
[1]Die [2] Do not grow [3] Grow quickly [4] Grow slowly [5] Don't know

10. Bacteria readily multiply at
[1] 10 ^{o}C [2] 25 ^{o}C [3] 75 ^{o}C [4] 120 ^{o}C [5] Don't know

11. When preparing food hands should be washed after
a. touching your hair [1]Yes, [2] No, [3] DK
b. using a handkerchief [1]Yes, [2] No, [3] DK
c. going to the toilet [1]Yes, [2] No, [3] DK
d. touching pimples or sores [1]Yes, [2] No, [3] DK
e. coughing or sneezing [1]Yes, [2] No, [3] DK
f. Handling the rubbish [1]Yes, [2] No, [3] DK
g. biting your nails [1]Yes, [2] No, [3] DK
h. touching pets or other animals [1]Yes, [2] No, [3] DK

12. Good personal hygiene practices include
a. proper hand washing. [1]Yes, [2] No, [3] DK
b. daily bathing. [1]Yes, [2] No, [3] DK
c. getting regular dental check-ups. [1]Yes, [2] No, [3] DK
d. washing hand with soap and running water [1]Yes, [2] No, [3] DK
e. drying hands thoroughly [1]Yes, [2] No, [3] DK
f. Cuts and infections on hands are covered [1]Yes, [2] No, [3] DK

13. Bad food storage practice is
a. rotating food to use the oldest food first [1]True, [2]False, [3] DK
b. covering and labeling food before storage [1]True, [2]False, [3] DK
c. storing raw meat above ready-to-eat food [1]True, [2]False, [3] DK
d. thawing and freezing food over and over again [1]True, [2]False, [3] DK

14. The HACCP system is used to
[1] identify and control possible food safety hazards.[2] keep the kitchen pest-free.
[3] identify faulty food preparation equipment. [4] choose what food to cook [5] Don't Know
15. In the kitchen/food processing room any surfaces that comes into contact with food must always cleaned and sanitized, [1]True, [2]False, [3] DK
16. A recommended method of calibrating food thermometers is the
[1] Ice-point method. [2] Boiling point method. [3] Room-temperature method. [4] DK

17. When washing your hands, you should rub your hands together with soap for at least
[1]. 20 seconds. [2] 5 seconds. [3] 10 seconds.

18. When cooking meat/fish, what is the correct way to determine if the meat/fish is cooked thoroughly?
[1]. cut into the middle and see if the meat/fish is pink [2]. smell the meat/fish
[3]. taste the meat/fish [4]. use a food thermometer

19. In the refrigerator, cooked foods should be stored
[1]above raw foods [2] below raw foods [3] it does not matter [4] DK

20. Dishes and utensils in the kitchen or processing unit are

a. washed in a sink of hot soapy water or dish washer	[1]True, [2]False, [3] DK
b. Rinsed and dried with a clean napkin	[1]True, [2]False, [3] DK
d. Rinse and dried with a used napkin	[1]True, [2]False, [3] DK
e. left on the drainer to dry	[1]True, [2]False, [3] DK
f. air-dried	[1]True, [2]False, [3] DK
g. dried with your apron	[1]True, [2]False, [3] DK

21. To control pets and animals

a. Food or dirty dishes are left on the benches	[1]True, [2]False, [3] DK
b. Fly screens are used	[1]True, [2]False, [3] DK
c. Food covers are used	[1]True, [2]False, [3] DK
d. Pets are allowed in the kitchen	[1]True, [2]False, [3] DK
e. Pets have their own feeding bowl	[1]True, [2]False, [3] DK

Please state the likelihood or unlikelihood of the following by circling the answer on a scale of 1 to 5, where 1 = very likely, and 5 = not at all likely and 3 = may be.

22. How likely do you think the following foods could contain germs or other microorganisms that could make you sick?

	Very likely		May be		Not at all likely
a. raw chicken	[1]	[2]	[3]	[4]	[5]
b. raw beef	[1]	[2]	[3]	[4]	[5]
c. raw fruits	[1]	[2]	[3]	[4]	[5]
d. raw vegetables	[1]	[2]	[3]	[4]	[5]
e. raw shellfish	[1]	[2]	[3]	[4]	[5]
f. raw eggs	[1]	[2]	[3]	[4]	[5]

23. Are you familiar with these terms as they apply to food safety?

HACCP	[1]Yes, [2]No
Critical control point (CCP)	[1]Yes, [2]No
Good manufacturing practice (GMP)	[1]Yes, [2]No
Food borne diseases	[1]Yes, [2]No
Food poisoning	[1]Yes, [2]No
Prerequisite programmes	[1]Yes, [2]No

Section C: FOOD SAFETY PRACTICES SURVEY
Write the number of your response in the box provided.
1. Always 2. Most of the time. 3. Sometimes 4. Never
I follow these food safety practices (or habits)...
24. clean and sanitize cutting surfaces after cutting up raw meat. [ ]
25. After cutting raw meat or chicken, I like to wash the cutting board, knife, and counter top with hot soapy water before continuing cooking. [ ]
26. I store cold foods at 5°C or less. [ ]
27. I reheat leftovers thoroughly before serving. [ ]
28. I keep food covered when on the bench [ ]
29. I Store cold food in the refrigerator as much as possible [ ]
30. I thaw frozen food in the refrigerator [ ]

31. I wash fruits and vegetables thoroughly under running water to remove dirt and other contaminants. [ ]
32. I regularly check the temperature of the refrigerator [ ]
33. I clean and sanitize cooking utensils after each use or when there is a chance that they have been contaminated. [ ]
34. High-risk foods are cooked thoroughly [ ]
35. I wash my hands before I prepare food and after handling raw meat or poultry. [ ]
36. Hot food is kept hot and cold food cold. [ ]
37. I cover cuts and infections on hands. [ ]
38. I use a calibrated food thermometer when checking food temperatures. [ ]
39. I discourage pests by keeping kitchen clean. [ ]
40. I use clean equipment, not hands to pick up food. [ ]
41. I divide large quantities of food into smaller containers to cool the food more quickly. [ ]
42. I cover and correctly label prepared food before storing. [ ]
43. I let dishes air dry where possible. [ ]
44. I use the oldest food products first. [ ]
45. I avoid preparing food when sick. [ ]
46. I reheat leftovers until steaming hot. [ ]
47. I keep raw meat separate from cooked food. [ ]
48. I store raw meat in the refrigerator below ready-to-eat or cooked foods. [ ]
49. I wash dirty dishes in hot, soapy water. [ ]
50. I wash hands in running water and soap. [ ]
51. I keep food covered when in the fridge [ ]

Section D: Food safety concerns

54. Have you ever experienced any food borne illness? (Please tick (√). [1] Yes [2] No

55. If yes, how did know?

[1] Had diarrhoea [2] Had vomiting [3] abdominal cramps
[4] Headache [5] Fever/chills [6] Constipation [7] was diagnosed in hospital

56. How common do you think it is for people in Ghana to become sick (from food poisoning) because of the way food is handled or prepared in?

[1] very common [2] somewhat common [3] not very common [4] don't know

Indicate your concern about the following question

57. I am concerned if I thaw perishable food on the kitchen counter. [1] Yes, [2]No [3] DK

58. Cooking and eating meat that is pink in the middle is important to me for my nutrition and health.

[1] Yes, [2]No [3] DK

59. I am interested in using a meat thermometer. [1] Yes,[2]No [3] DK

60. I worry that I may get sick if I eat meat that is not thoroughly cooked [1] Yes,[2]No[3] DK
61. I don't worry about washing my hands after playing with my pets. [1] Yes,[2]No [3] DK
62. I don't worry when I see pets and animals in the kitchen [1] Yes,[2]No [3] DK
63. I am worried that I may get sick if I eat fried fish in a restaurant. [1] Yes,[2]No [3] DK
64. I am worried if cooked foods are stored below raw foods in the refrigerator [1] Yes,[2]No [3] DK
65. I am concerned that I may get sick if I eat smoked fish [1] Yes,[2]No [3] DK

Section E: Consequent Loss

Please circle the answer on both sides, on the left hand side answer yes or no; and on right-hand side 1 = not at all, and 5 = very much that there could be serious loss.

Are the following likely to occur if you eat fish, chicken or meat products		If yes. how serious is the loss to you if it did occur?				
Occurrence		Serious loss				
		Not at all		N	Very Much	
[1] Yes, [2] No	66. I could become sick	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	67.I could die	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	68. My health could be adversely affected.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	69. My health could be adversely affected for long term.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	70. My money could be wasted. (e.g. disposal of food, payment for medicine)	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	71. I could lose income / job due to Poor health because of contaminated chicken meat.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	72. My time could be lost. (e.g.. sickness, seeking compensation)	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	73. I could be let down or embarrassed among friends / family due to the contaminated fish, chicken or meat I have bought.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	74. I could feel upset or personally dissatisfied due to the contaminated chicken meat I have bought.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	75. My lifestyle could be adversely affected.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	76. The taste of chicken could be adversely affected.	[1]	[2]	[3]	[4]	[5]

Section F: Sources of food safety information

Please tick (√) 1 of the answer choices.

77. How well informed would you say you are about food safety?

[1] Very informed [2] moderately informed
[3] somewhat informed [4] minimally informed [5] not at all informed

78. Does your council, government or trade association have a food safety website to keep you up to date?

[1] Yes [2] No [3] Not currently connected to the internet
[4] Not aware of website [5] Cannot say

79. How well informed are you about national food safety standards?

[1] Very informed [2] moderately informed [3] somewhat informed
[4] minimally informed [5] not at all informed

80. How well informed are you about international food safety standards?

[1] Very informed [2] moderately informed [3] somewhat informed
[4] minimally informed [5] not at all informed

81. How often do you try to find information about safe food handling?

[1] Always [2] Most of the time [3] Sometimes [4] Never

82. Which of the following sources of information on safe food handling are more useful?

[1] TV [2] Radio [3] Newspapers [4] Written material
[5] Health inspectors [6] The internet [7] Training course material [8] Seminars

Section G: Intention for future purchases

83. After an outbreak of food scare,
[1]. I will continue to purchase that product. [2]. I will purchase that product after 1 month.
[3]. I will purchase that product after 3 months. [4] I will never purchase that product

84. To select and purchase food

a. I check the cleanliness of the outlet before purchasing	[1] True,	[2] False
b. I take note of expiry dates on labels before buying	[1] True,	[2] False
c. I ensure that cold items are packed together	[1] True,	[2] False
d. I ensure cold items are taken home to the refrigerator as quickly as possible	[1]True,	[2]False

85. If there is evidence of microbiological risk in fish, chicken or meat, what would your response be?

	Very Unlikely		N		Very Likely
a. I will continue to purchase.	[1]	[2]	[3]	[4]	[5]
b. I will purchase fresh chicken meat again after 1 month.	[1]	[2]	[3]	[4]	[5]
c. I will purchase fresh chicken meat again after 3 months.	[1]	[2]	[3]	[4]	[5]
d. I will purchase fresh chicken meat again after 6 months.	[1]	[2]	[3]	[4]	[5]
e. I will buy chicken meat when evidence proved clear of the risk.	[1]	[2]	[3]	[4]	[5]

86. How concerned/worried are you about the following food safety issues?
1 = Not all concerned and 5 = extremely or highly concerned

The use of pesticides in food production	[1]	[2]	[3]	[4]	[5]
Getting food poisoning in Ghana	[1]	[2]	[3]	[4]	[5]
The use of additives/ colourings/preservatives in food	[1]	[2]	[3]	[4]	[5]
Hygiene standards in the chop-bar	[1]	[2]	[3]	[4]	[5]
Food and its safety in your daily life	[1]	[2]	[3]	[4]	[5]
Eating genetically modified foods	[1]	[2]	[3]	[4]	[5]
Getting food poisoning after eating chicken	[1]	[2]	[3]	[4]	[5]
Hygiene standards in the butchers' shop	[1]	[2]	[3]	[4]	[5]
The use of hormones in animal production	[1]	[2]	[3]	[4]	[5]
Hygiene standards of food in your home	[1]	[2]	[3]	[4]	[5]
The nutritional balance of your diet	[1]	[2]	[3]	[4]	[5]
Lack of information about food from the government	[1]	[2]	[3]	[4]	[5]
Getting food poisoning after eating pork	[1]	[2]	[3]	[4]	[5
Hygiene standards in the food industry	[1]	[2]	[3]	[4]	[5]
Hygiene standards of food in restaurants and take-aways.	[1]	[2]	[3]	[4]	[5]
Getting food poisoning after eating fish	[1]	[2]	[3]	[4]	[5]
Getting food poisoning after eating beef	[1]	[2]	[3]	[4]	[5]
The use of antibiotics in food production	[1]	[2]	[3]	[4]	[5]

87. Any other suggestion for reducing the food risks / improving the food safety:

Thank you for completing this questionnaire!

Appendix B: Questionnaire for food handlers

Section A: Personal Data
Please indicate the appropriate box by a tick for the following items.
Gender: [1] Male [2] Female
Age …….

Marital Status: [1] Single [2] Married [3] Others

Education Background:
[1] Primary [2] Secondary [3] Tertiary [4] None

Employment Status:
[1] F/T Employed [2] P/T Employed [3] Self Employed
[4] Unemployed [5] Student [6] Others

Occupation: _____

Total Household Income:
[1] Below Gh¢10,000 p.a. [2] Gh¢10,000-15,000 p.a. [3] Gh¢15,000-20,000 p.a.
[4] Gh¢ 20,000-30,000 p.a. [5] Gh¢ 30,000 or over p.a.

Section B: FOOD SAFETY KNOWLEDGE

1. The greatest food safety problem is
[1] Pesticides [2] hair [3] microorganisms [4] Don't know

2. Common symptom of food poisoning include

Headache/fever/chills	[1] True, [2] False [3] Don't know
Diarrhoea/abdominal cramps	[1] True, [2] False [3] Don't know
Rash	[1] True, [2] False [3] Don't know
Constipation	[1] True, [2] False [3] Don't know
Vomiting/fever/chills	[1] True, [2] False [3] Don't know

3. When putting on disposable gloves to prepare food you should
[1] wash your hands and then put on gloves. [2] put on gloves and then wash your gloved hands.
[3] put on gloves without washing your hands. [4] Don't know

4. Food poisoning bacteria may be brought into the kitchen ….

By insects	[1] True, [2] False [3] Don't know
By food handlers	[1] True, [2] False [3] Don't know
In raw food	[1] True, [2] False [3] Don't know

5. Food safety problems are most likely to occur

b.through lack of personal hygiene by	[1] True, [2] False [3] Don't know

the people who prepare and serve it.

b. through lack of hygiene in the farm.	[1] True, [2] False [3] Don't know
c. at the abattoir / slaughter house.	[1] True, [2] False [3] Don't know
d. in the food processing factory	[1] True, [2] False [3] Don't know
e. in the restaurant	[1] True, [2] False [3] Don't know
f. in supermarkets	[1] True, [2] False [3] Don't know
g. due to improper handling by food retailer.	[1] True, [2] False [3] Don't know
h. due to improper storage at home.	[1] True, [2] False [3] Don't know
i. due to poor food handling at home.	[1] True, [2] False [3] Don't know
j. due to improper cooking procedure.	[1] True, [2] False [3] Don't know
k. when pests and pets come into contact with food	[1]True, [2] false, [3] Don't Know
l. as a result of temperature abuse	[1]True, [2] False, [3] Don't Know

6. Which of the following can be used to kill bacteria in foods?

Disinfectant	[1] Yes, [2] No [3] Don't know
Cold water	[1] Yes, [2] No [3] Don't know
Detergent	[1] Yes, [2] No [3] Don't know
Scrubbing brush/sponge	[1] Yes, [2] No [3] Don't know

7. After trimming raw chicken on a cutting surface, what must you do to the cutting surface?

a. Rinse the surface with water.	[1] True, [2] False [3] Don't know
b. Dry the surface with a paper towel.	[1] True, [2] False [3] Don't know
c. Clean and sanitize the cutting surface.	[1] True, [2] False [3] Don't know

8. Cross-contamination is most likely to occur when you

a. cut ready to eat food on a cutting board used for fresh meat	[1] True, [2] False [3] Don't know
b. touch raw meat and then touch cooked or ready-to-eat food.	[1] True, [2] False [3] Don't know
c. check the refrigerator temperature regularly.	[1] True, [2] False [3] Don't know
d. hold food at temperatures below 60°C.	[1] True, [2] False [3] Don't know

9. At body heat temperature (37^{o}C) food poisoning bacteria

[1]Die [2] Do not grow [3] Grow quickly
[4] Grow slowly [5] Don't know

10. Bacteria readily multiply at

[1] 10^{o}C [2] 25^{o}C [3] 75 ^{o}C [4] 120^{o}C [5] Don't know

11. When preparing food hands should be washed after

a. touching your hair	[1]Yes, [2] No, [3] DK
b. using a handkerchief	[1]Yes, [2] No, [3] DK
c. going to the toilet	[1]Yes, [2] No, [3] DK
d. touching pimples or sores	[1]Yes, [2] No, [3] DK
e. coughing or sneezing	[1]Yes, [2] No, [3] DK
f. Handling the rubbish	[1]Yes, [2] No, [3] DK
g. biting your nails	[1]Yes, [2] No, [3] DK
h. touching pets or other animals	[1]Yes, [2] No, [3] DK

12. Good personal hygiene practices include

a. proper hand washing.	[1]Yes, [2] No, [3] DK
b. daily bathing.	[1]Yes, [2] No, [3] DK
c. getting regular dental check-ups.	[1]Yes, [2] No, [3] DK
d. washing hand with soap and running water	[1]Yes, [2] No, [3] DK
e. drying hands thoroughly	[1]Yes, [2] No, [3] DK
f. Cuts and infections on hands are covered	[1]Yes, [2] No, [3] DK

13. Bad food storage practice is

a. rotating food to use the oldest food first	[1]True, [2]False, [3] DK
b. covering and labeling food before storage	[1]True, [2]False, [3] DK
c. storing raw meat above ready-to-eat food	[1]True, [2]False, [3] DK
d. thawing and freezing food over and over again	[1]True, [2]False, [3] DK

14. The HACCP system is used to

[1] identify and control possible food safety hazards. [2] keep the kitchen pest-free.
[3] identify faulty food preparation equipment. [4] choose what food to cook
[5] DK

15. In the kitchen/food processing room any surfaces that comes into contact with food must always cleaned and sanitized, [1]True, [2]False, [3] DK

16. A recommended method of calibrating food thermometers is the

[1] Ice-point method. [2] Boiling point method. [3] Room-temperature method. [4] DK

17. When washing your hands, you should rub your hands together with soap for at least
[1]. 20 seconds. [2] 5 seconds. [3] 10 seconds.

18. When cooking meat/fish, what is the correct way to determine if the meat/fish is cooked thoroughly?
[1]. cut into the middle and see if the meat/fish is pink [2]. smell the meat/fish
[3]. taste the meat/fish [4]. use a food thermometer

19. In the refrigerator, cooked foods should be stored
[1]above raw foods [2] below raw foods [3] it does not matter [4] DK

20. Dishes and utensils in the kitchen or processing unit are

a. washed in a sink of hot soapy water or dish washer	[1]True, [2]False, [3] DK
b. Rinsed and dried with a clean napkin	[1]True, [2]False, [3] DK
d. Rinse and dried with a used napkin	[1]True, [2]False, [3] DK
e. left on the drainer to dry	[1]True, [2]False, [3] DK
f. air-dried	[1]True, [2]False, [3] DK
g. dried with your apron	[1]True, [2]False, [3] DK

21. To control pets and animals

a. Food or dirty dishes are left on the benches	[1]True, [2]False, [3] DK
b. Fly screens are used	[1]True, [2]False, [3] DK
c. Food covers are used	[1]True, [2]False, [3] DK
d. Pets are allowed in the kitchen	[1]True, [2]False, [3] DK
e. Pets have their own feeding bowl	[1]True, [2]False, [3] DK

Please state the likelihood or unlikelihood of the following by circling the answer on a scale of 1 to 5, where 1 = very likely, and 5 = not at all likely and 3 = may be.

22. How likely do you think the following foods could contain germs or other microorganisms that could make you sick?

	Very likely		May be		Not at all likely
a. raw chicken	[1]	[2]	[3]	[4]	[5]
b. raw beef	[1]	[2]	[3]	[4]	[5]
c. raw fruits	[1]	[2]	[3]	[4]	[5]
d. raw vegetables	[1]	[2]	[3]	[4]	[5]
e. raw shellfish	[1]	[2]	[3]	[4]	[5]
f. raw eggs	[1]	[2]	[3]	[4]	[5]

23. Are you familiar with these terms as they apply to food safety?

HACCP	[1]Yes, [2]No
Critical control point (CCP)	[1]Yes, [2]No
Good manufacturing practice (GMP)	[1]Yes, [2]No
Food borne diseases	[1]Yes, [2]No
Food poisoning	[1]Yes, [2]No
Prerequisite programmes	[1]Yes, [2]No

Section C: FOOD SAFETY PRACTICES SURVEY
Write the number of your response in the box provided.
1. Always 2. Most of the time. 3. Sometimes 4. Never
I follow these food safety practices (or habits)...
24. clean and sanitize cutting surfaces after cutting up raw meat. [ ]
25. After cutting raw meat or chicken, I like to wash the cutting board, knife, and counter top with hot soapy water before continuing cooking. [ ]
26. I store cold foods at 5°C or less. [ ]
27. I reheat leftovers thoroughly before serving. [ ]

28. I keep food covered when on the bench [ ]
29. I Store cold food in the refrigerator as much as possible [ ]
30. I thaw frozen food in the refrigerator [ ]
31. I wash fruits and vegetables thoroughly under running water to remove dirt and other contaminants. [ ]
32. I regularly check the temperature of the refrigerator [ ]
33. I clean and sanitize cooking utensils after each use or when there is a chance that they have been contaminated. [ ]
34. High-risk foods are cooked thoroughly [ ]
35. I wash my hands before I prepare food and after handling raw meat or poultry. [ ]
36. Hot food is kept hot and cold food cold. [ ]
37. I cover cuts and infections on hands. [ ]
38. I use a calibrated food thermometer when checking food temperatures. [ ]
39. I discourage pests by keeping kitchen clean. [ ]
40. I use clean equipment, not hands to pick up food. [ ]
41. I divide large quantities of food into smaller containers to cool the food more quickly. [ ]
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43. I let dishes air dry where possible. [ ]
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45. I avoid preparing food when sick. [ ]
46. I reheat leftovers until steaming hot. [ ]
47. I keep raw meat separate from cooked food. [ ]
48. I store raw meat in the refrigerator below ready-to-eat or cooked foods. [ ]
49. I wash dirty dishes in hot, soapy water. [ ]
50. I wash hands in running water and soap. [ ]
51. I keep food covered when in the fridge [ ]

Section D: Food safety concerns

54. Have you ever experienced any food borne illness? (Please tick (√). [1] Yes [2] No

55. If yes, how did know?

[1] Had diarrhoea [2] Had vomiting [3] abdominal cramps [4] Headache [5] Fever/chills [6] Constipation [7] was diagnosed in hospital

56. How common do you think it is for people in Ghana to become sick (from food poisoning) because of the way food is handled or prepared in?

[1] very common [2] some what common [3] not very common [4] don't know

Indicate your concern about the following question

57. I am concerned if I thaw perishable food on the kitchen counter. [1] Yes,[2]No [3] DK
58. Cooking and eating meat that is pink in the middle is important to me for my nutrition and health. [1] Yes,[2]No [3] DK
59. I am interested in using a meat thermometer. [1] Yes,[2]No [3] DK
60. I worry that I may get sick if I eat meat that is not thoroughly cooked [1] Yes,[2]No [3] DK
61. I don't worry about washing my hands after playing with my pets. [1] Yes,[2]No [3] DK
62. I don't worry when I see pets and animals in the kitchen [1] Yes,[2]No [3] DK
63. I am worried that I may get sick if I eat fried fish in a restaurant. [1] Yes,[2]No [3] DK
64. I am worried if cooked foods are stored below raw foods in the refrigerator [1] Yes,[2]No [3] DK
65. I am concerned that I may get sick if I eat smoked fish [1] Yes,[2]No [3] DK

Section E: Consequent Loss

Please circle the answer on both sides, on the left hand side answer yes or no; and on right-hand side 1 = not at all, and 5 = very much that there could be serious loss.

Are the following likely to occur if you eat fish, chicken or meat products		If yes how serious is the loss to you if it did occur?				
			Serious loss			
Occurrence		Not at all		N		Very Much
[1] Yes, [2] No	66. I could become sick	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	67.I could die	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	68. My health could be adversely affected.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	69. My health could be adversely affected for long term.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	70. My money could be wasted. (e.g. disposal of food, payment for medicine)	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	71. I could lose income / job due to poor health because of contaminated chicken meat.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	72. My time could be lost. (e.g.. sickness, seeking compensation)	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	73. I could be let down or embarrassed among friends / family due to the contaminated fish, chicken or meat I have bought.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	74. I could feel upset or personally dissatisfied due to the contaminated chicken meat I have bought.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	75. My lifestyle could be adversely affected.	[1]	[2]	[3]	[4]	[5]
[1] Yes, [2] No	76. The taste of chicken could be adversely affected.	[1]	[2]	[3]	[4]	[5]

Section F: Sources of food safety information

Please tick (√) 1 of the answer choices.

77. How well informed would you say you are about food safety?
[1] Very informed [2] moderately informed [3] somewhat informed
[4] minimally informed [5] not at all informed

78. Does your council, government or trade association have a food safety website to keep you up to date?
[1] Yes [2] No [3] Not currently connected to the internet [4] Not aware of website
[5] Cannot say

79. How well informed are you about national food safety standards?
[1] Very informed [2] moderately informed [3] Somewhat informed
[4] minimally informed [5] not at all informed

80. How well informed are you about international food safety standards?
[1] Very informed [2] moderately informed [3] Somewhat informed
[4] minimally informed [5] not at all informed

81. How often do you try to find information about safe food handling?
[1] Always [2] Most of the time [3] Sometimes [4] Never

82. Which of the following sources of information on safe food handling are more useful?
[1] TV [2] Radio [3] Newspapers [4] Written material
[5] Health inspectors [6] The internet [7] Training course material [8] Seminars

Section G: Intention for future purchases

83. After an outbreak of food scare,

[1]. I will continue to purchase that product. [2]. I will purchase that product after 1 month.
[3]. I will purchase that product after 3 months. [4] I will never purchase that product

84. To select and purchase food

a. I check the cleanliness of the outlet before purchasing	[1] True,	[2] False
b. I take note of expiry dates on labels before buying	[1] True,	[2] False
c. I ensure that cold items are packed together	[1] True,	[2] False
d. I ensure cold items are taken home to the refrigerator as quickly as possible	[1] True,	[2] False

85. If there is evidence of microbiological risk in fish, chicken or meat, what would your response be?

	Very Unlikely		N		Very Likely
a. I will continue to purchase.	[1]	[2]	[3]	[4]	[5]
b. I will purchase fresh chicken meat again after 1 month.	[1]	[2]	[3]	[4]	[5]
c. I will purchase fresh chicken meat again after 3 months.	[1]	[2]	[3]	[4]	[5]
d. I will purchase fresh chicken meat again after 6 months.	[1]	[2]	[3]	[4]	[5]
e. I will buy chicken meat when evidence proved clear of the risk.	[1]	[2]	[3]	[4]	[5]

86. How concerned/worried are you about the following food safety issues?
1 = Not all concerned and 5 = Extremely or highly concerned

The use of pesticides in food production	[1]	[2]	[3]	[4]	[5]
Getting food poisoning in Ghana	[1]	[2]	[3]	[4]	[5]
The use of additives/colourings/preservatives in food	[1]	[2]	[3]	[4]	[5]
Hygiene standards in the chop-bar	[1]	[2]	[3]	[4]	[5]
Food and its safety in your daily life	[1]	[2]	[3]	[4]	[5]
Eating genetically modified foods	[1]	[2]	[3]	[4]	[5]
Getting food poisoning after eating chicken	[1]	[2]	[3]	[4]	[5]
Hygiene standards in the butchers' shop	[1]	[2]	[3]	[4]	[5]
The use of hormones in animal production	[1]	[2]	[3]	[4]	[5]
Hygiene standards of food in your home	[1]	[2]	[3]	[4]	[5]
The nutritional balance of your diet	[1]	[2]	[3]	[4]	[5]
Lack of information about food from the Government	[1]	[2]	[3]	[4]	[5]
Getting food poisoning after eating pork	[1]	[2]	[3]	[4]	[5]
Hygiene standards in the food industry	[1]	[2]	[3]	[4]	[5]
Hygiene standards of food in restaurants and take-aways.	[1]	[2]	[3]	[4]	[5]
Getting food poisoning after eating fish	[1]	[2]	[3]	[4]	[5]
Getting food poisoning after eating beef	[1]	[2]	[3]	[4]	[5]
The use of antibiotics in food production	[1]	[2]	[3]	[4]	[5]

Section G: Food Safety Training

87. Have you or any of your staff attended any information seminars/sessions about safe food handling in the last 2 years?

□Yes □No □Not aware □Cannot say

88. In the past 12 months, on average, how much time (hours/days) did each production employee (not including managers and supervisors) spend on training related to your establishment's food safety management Plan? Please specify average number of hours.

□Average training per employee in Hours is _____ or Days is _____.

□ None (No training took place in that time period) □Cannot say

89. On average, how much time does each new production employee (not including managers and supervisors) spend on learning about the requirements of your establishment's food safety plan? Check one only

□ Zero hours □ Less than half a day
□ Half a day □ One day
□ 1-3 days □ More than 3 days
□ Cannot say

90. How would you rate the Food and Drugs Board's ability to respond to your establishment's questions related to food safety?

□1 □2 □3 □4 □5 □Don't know
(Poor Excellent)

91. How useful do you think training courses are as a source of information on safe food handling?

□ Very useful □ moderately useful □ somewhat useful
□ Minimally useful □ not at all useful

92. Would you say that production employees in your establishment (not including managers and supervisors) understand food safety hazards and how to control them?

□Yes □No □ Don't know □Cannot say

93. What training challenges, if any, has your establishment experienced? Please check all that apply.

□ No challenges □ Accessing training material □Distance from training institutions
□ Cost associated with training □No training institutions □High turn-over of employees
□ Seasonality □Illiteracy □Other Challenge(s) (Specify) _____ □Cannot say

94. How important is it for your establishment to have its production employees participate in training related to food safety?

□ Not at all important □Not very important □Somewhat important
□ Very important □Cannot say

Section H: Establishment Profile

95. What is your position or job title in the company?
Current Position/Title: _____

96. What was your own level of participation in the development of your company's food safety Plan?

□No participation □Some Participation □Moderate Participation
□A lot of Participation □ Full participation □Cannot say

97. What is your own level of participation in the day-to-day operation of your company's food safety Plan?

□No participation □ Some Participation □ Moderate Participation
□ A lot of Participation □ Full participation Cannot say

Section I: Impact of food safety practice on Markets

98. Has standard food safety requirements hindered or helped your company to maintain market for your food products?

□Hindered significantly □ Hindered moderately □ Had no impact
□ Helped moderately □ Helped significantly □ Cannot say

99. Has standard food safety requirements hindered or helped your company to enter new markets for your food products?

□ Hindered significantly □ Hindered moderately □ Had no impact
□ Helped moderately □ Helped significantly □ Cannot say

100. How would you rate your company's level of ease or difficulty in complying with standard food safety requirements to date?

□Very difficult □ Somewhat difficult □ Neither difficult nor easy
□ Somewhat easy □ Very easy □ Cannot say

101. What are the major challenges your company experienced in complying with the Standard food safety requirements? (Please check all that apply)

□ Management commitment □ Employee commitment/attitude
□ High Turn-over of employees □ Seasonality
□ Access to technical and scientific information □ Access to training
□ Cost □Time
□ Understanding food safety requirements □Language/literacy
□ Other (specify) _____
□No challenges □ Cannot say

102. How do you gauge consumer/buyer confidence in your food product(s)? (Please check all that apply)

□Consumer satisfaction survey □ Consumer feedback □ Buyer feedback
□ Third party audits □ Sales figures □ Do not gauge consumer confidence
□ Do not gauge buyer confidence □Other (please specify)_____
□Cannot say

Comments

Thank you for completing this questionnaire!

Appendix C: Photographic depiction/Participant Observation of food handling along the fish processing chain in Ghana.

C1: People buying fresh fish at landing sites

C2: Fish landing at the processing site

C3: People waiting to transport fresh fish. No temperature/ time control

C4: Transporting fish on unsuitable trucks.

C5: Toilet and washroom at the processing site

C6:Poor sanitation at a time control

C7: Pre-processing handling of raw fish.

C8: Poor hygiene during handling of raw fish

C9: Fish drying before smoking

C10: Post-processing handling of smoked fish at processing site

C11: Drying of smoked fish over low heat

Appendix D: Interviews with fish handlers

Location: ……..
Interviewer: Place a √ in the box of the selected answer(s). Do not read responses unless the directions indicate.

A. General and demographic questions

1. What is your age? ……

2. Gender? [1] Male [2] Female

3. What is the highest level of education you have completed?
[1] No school [2] Primary [3] Secondary
[4] College [5] Higher education (professional or post-graduate)
[6] Literacy classes only

4. Do you have food safety certification? [1] Yes [2] No

5. How many years have you been employed in the fishing/fish processing/fish retail business? …….

6. What is/are the primary area (s) in the fish handling chain you focus on? Tick all that apply.
[1] Fishing [2] Retail of fresh fish
[3] Fish processing [4] Fish transport [5] Processed fish retail

B. Fish handling and preparation

7. The raw fish you usually buy/sell is ……
[1] Fresh [2] Frozen [3] Thawed

8. For transportation to the processing site, are fish placed into clean basins/chests/bins/boxes in ice and properly protected to prevent heat, losses and cross contamination?
[1] Yes , always [2] Yes, sometimes [3] No

9. Is the temperature of the fish at catch/retail/purchase reduced as quickly as possible to below 5ºC?
[1] Yes [2] No

10. After purchasing the raw fish, how long does it take you before processing the fish?
[1] Up to one hour [2] From 1 h to 2 h [3] Two hours or more

11. Do you have a fridge or freezer?
[1] Yes, a fridge [2] Yes, a freezer [3] Yes, a fridge and freezer [4] No

12. How do you usually thaw frozen raw fish?
[1] No thawing at all [2] In hot water [3] In cold water
[4] On counter-top [5] With microwave [6] In refrigerator
[7] In the sun or alongside the mud oven

13. Do you refreeze thawed raw fish that is not immediately needed?
[1] Yes, always [2] Yes, sometimes [3] No

14. Do you wash your hands before you handle raw fish?
[1] Yes, always [2] Yes, Sometimes [3] No

15. How do you usually clean your hands after handling raw fish?
[1] No cleaning [2] Wiping with a towel [3] Wash with water only
[4] wash with detergents and hot water [5] Others (specify) ……

16. How do you usually store processed fish?
[1] In open air, at room temperature [2] Outdoors in the sun
[3] Cool it to room temperature and then store it in refrigerator
[4] Put it into refrigerator immediately after meals

17. Why do you store the fish in this manner?
[1] To make it dry properly [2] I have no other space to dry it
[3] I have no fridge to store in [4] it is the best way to dry it
[5] Other reasons specify …….

18. How long do you store processed fish in the open?
[1] 24 hr or less [2] One week or less [3] One month or less
[4] One month to three months [5] Three months or more

19. Are there any risks or dangers associated with storing/drying processed fish in this manner?
[1] Yes (go to 19a-c) [2] No (go to 20)

19a. If yes, what are the risks of storing/drying fish in this manner?
[1] Food poisoning [2] fungal growth, [3] other ……

19b. Would this danger increase or decrease when processed fish is dried in open air?
[1] Increase [2] Decrease [3] No change

19c. Do you know of a much safer way of storing the fish after processing? [1] Yes [2] No

20. How safe would you say it is to eat freshly smoked fish?
[1] Very safe [2] Somewhat safe [3] Not very safe [4] Not at all safe

21. How safe would you say it is to eat smoked fish that has been left in the open for up to a day?
[1] Very safe [2] Somewhat safe [3] Not safe [4] Not at all safe

22. In your view what level of risks do your fish products pose to consumers?
[1] Low risk [2] Medium risk [3] High risk [4] Don't know

23. If you knew people could become sick after eating improperly processed fish, would you change the way you do things? [1] Yes [2] No

C. Food safety opinions and sources of information

24. Do you feel well informed about food safety? [1] Yes [2] No

25. What are the sources of information that you think can most effectively reach people like you with information on food safety? (Please choose as many as applicable.)
[1] Newspapers and magazines [2] Radio
[3] TV [4] Billboards
[5] Leaflets, posters and other printed materials [6] Health workers
[7] Family, friends, neighbours and colleagues [8] Religious leaders
[9] Teachers
10] Other (please explain) .....

26. Do you frequently receive food safety information from the FDB/inspectors or the council?
[1] Yes [2] No

27. How much effort would you say you have made to get information regarding safe food handling and processing practices, if any? [1] A great deal [2] Some effort [3] A little [4] None
28. Have you ever heard the expression HACCP (Hazard Analysis Critical Control Point) system?
[1] Yes (if yes, go to 28a-b) [2] No (if no, go to 29)

28a. If yes, who did you first hear about the HACCP system from?
[1] The food/sanitary inspectors [2] in press
[3] During informative seminars [4] in literature
[5] From the Food and Drugs Board [6] through education
[7] Others …..

28b. How would you rank your understanding of HACCP?
[1] Very low [2] Low [3] Good [4] Very good [5] Excellent

29. On a scale of 1 - 5 where 1 = Not important, 2 = Moderately important , 3= Important, 4 = Very important and 5 = Extremely important, please indicate how important the following are in helping you improve your understanding and compliance with food safety and HACCP?

29a. Communication	[1]	[2]	[3]	[4]	[5]
29b. Graphic presentations	[1]	[2]	[3]	[4]	[5]
29c. Having a local food safety expert who is available when needed	[1]	[2]	[3]	[4]	[5]
29d. Training for quality managers	[1]	[2]	[3]	[4]	[5]
29e. Programme materials (guidelines and manuals)	[1]	[2]	[3]	[4]	[5]
29f. Training for production workers	[1]	[2]	[3]	[4]	[5]
29g. Financial incentives	[1]	[2]	[3]	[4]	[5]
29h. Involving employees in developing the programm	[1]	[2]	[3]	[4]	[5]
29i. Management commitment	[1]	[2]	[3]	[4]	[5]
29j. Upgrading your facilities	[1]	[2]	[3]	[4]	[5]
29k. Acquiring a food safety certificate	[1]	[2]	[3]	[4]	[5]
29l. Obtaining a licence to operate	[1]	[2]	[3]	[4]	[5]

30. To what extent do you agree that the importance of Food Safety is well understood and communicated within the fish industry in Ghana?
[1] Strongly agree [2] agree [3] disagree [4] strongly disagree

31. Is there any exchange of information between different operators regarding food safety best practices in key areas of food safety practice? [1] Yes, always [2] Yes, sometimes [3] No

32. Are you willing to share at least some best practices information with other operators in the fish industry?
[1] Very willing [2] Willing [3] Not willing [4] Not very willing

33. Are you aware of any government/FDB or council support programmes in the form of food safety training or financial support to fish firms? [1] Yes (go to 33a) [2] No (go to 34)

33a. If yes, how did you become aware of this support? (Please choose as many as applicable.)
[1] From involvement with industry associations
[2] From interaction with the government organizations
[3] From interaction with food safety inspectors

D. Regulatory compliance and inspections

34. Today, at what level would you place your company's food safety compliance efforts on a scale of 1- 6?
[1] None compliance [2] Very low compliance [3] Low compliance
[4] Acceptable compliance [5] Almost total compliance [6] Full compliance

35. How would you describe the approach of the government regulatory agency toward the fish industry?
[1] Adversarial relationship [2] collaborative relationship

36. Have you been issued a permit/license to operate a fish business?
[1] Yes [2] No [3] License not required

37. Was your site inspected before the licence was issued? [1] Yes [2] No

38. In the past one year, please estimate how many times you were visited by food safety inspectors.
[1] Inspected when necessary [2] Once a year [3] Twice a year
[4] Once every two years [5] Once every five years [5] Others ……

39. Is it legally required of you to produce only safe foods? [1] Yes [2] No

40. Are you aware of the structural requirements for food premises, fixtures, fittings, equipment and food transport vehicles? [1] Yes [2] No

42. Are you aware of any standard operating procedures (SOP) related to the receipt, storage, processing, display, packaging, transportation, disposal and recall of the fish you handle? [1] Yes [2] No

43. Are people in the fish industry complying with food safety requirement for your business? [1] Yes , sometimes (go to 43a) [2] Yes, most of the time (go to 43a) [2] No (go 43b)

43a. If yes, what are the key reasons why they comply with food safety and hygiene regulation and inspections? (Please choose as many as applicable.)
[1] Fear of prosecution and sanctions
[2] To meet industry and customer expectations
[3] Fear of been named and shamed (damaged reputation or brand)
[4] Fear of spreading food-borne disease
[5] To promote brand image
[6] Others (state) ……

43b. If no, why do you find it difficult to comply?
[1] We have poor knowledge and understanding of what constitutes compliance.
[2] We have poor understanding of legislative requirements for food safety and how they needed to be applied to our business.
[3] We do not consider particular issues to constitute compliance, for example structural issues are "irrelevant" to the food safety of the business.
[4] We cannot implement appropriate control methods
[5] There is no food safety guidance information
[6] Cost of compliance is too high
[7] Others (please state) …….

44. If you have problem with compliance with food safety requirement, have you ever sort any help from the FDB or any government agency? [1] Yes [2] No

45. Has the level of your compliance with food safety been assessed by the local authority or FDB?
[1] Yes [2] No
46. Have you ever been informed of any non-compliance? [1] Yes (go to 46a) [2] No (go to 47)
46a. If yes, what action did the enforcement agent take to ensure that you complied? (Please choose as many as applicable.)
[1] They adopted a highly educational approach to encourage me to comply
[2] They visited and advised me .
[3] They run food hygiene courses and food safety seminars?
[4] They looked for violations of the law and served notice/prosecuted me/punished me where I went wrong or where non-compliance is not remedied

46b. If you were sanctioned, what was the nature of the sanction or penalty?
[1] Cautioned [2] Heavy financial penalty [3] light financial penalty
[4] Named and shamed [5] Given final warning of closure [6] Notification of closure
46c. In what way has the sanction or penalty affected the way you do things in your business?
[1] Hindered [2] Improved [3] No effect

46d. What action did you take to ensure you complied?
[1] I did not take any action [2] Followed the inspectors' recommendations

47. Please indicate your agreement or disagreement by answering [1] = Yes, and [2] = No.

	[1]	[2]
Enforcement guidelines, advice and communications from the inspectors are …..		
47a given in a more advisory and less formal approach		
47b characterised by clarity and consistency so that I can understand		
47c written communications are clear and user-friendly		
The food safety inspectors who visit me		
47d are fair, trusted and co-operative		
47e have local knowledge and closer stakeholder relationships with us		
47f have very good food safety and hygiene knowledge specific to our industry		
47g Their approach is viewed as less consistent, less informed, and potentially susceptible to local political interference		
My company has specific, targeted, information in place which sets out		
47h How to comply with food safety in the fish industry		
47i HACCP standards and policies		
47j How to address pest control		
47k policies and standards addressing crisis management		

E. Food safety training

48. Is food safety training a legal requirement in your industry? [1] Yes [2] No

49. Have you had any training on hygiene, sanitation and food safety?[1] Yes [2] No

50. How did you acquire your food handling knowledge?
[1] Self Taught [2] Taught by parents [3] Observation of Others
[4] Formal Training [5] Others (please state) ……..

51. Does the food safety training programme available for fish handlers include the following? Please indicate by answering [1] = Yes, and [2] = No.

	[1]	[2]
51a Role of the Food and Drugs Board		
51b Public health legislation and regulations		
51c Food safety management principles (including HACCP-based principles)		
51d Safe handling, preparation, and storage (including basic microbiology, safe food supplies, adverse reactions to food, safe food preparation/storage)		
51e Food handler hygiene		
51f Food premises sanitation, design, and maintenance		
51g Prevention of food allergies, incidents and response		
51h Fish handling and processing		
51i Cross contamination and pest control		

52. In the past year was any training in food handling/sanitation provided for your employees?
[1] Yes [2] No

53. Who provides most of the food safety training for you and your staff?
[1] The FDB [2] The District Assembly [3] Training consultants
[4] College/University [5] Corporate trainer [6] Others (please state) ……..

54. How is the effectiveness of your food safety training program measured?
[1] Proficiency exams for participants
[2] On-the-job observations of food safety practices
[3] Occasional demonstrations of knowledge requested of line and supervisory staff.

55. How was the training funded?
[1] From own resources [2] Paid by District Assembly [3] Paid by FDB
[4] NGO [5] Others (please state) ……

56. Do you agree that the fish industry in your district of operation spends enough time and resources on food safety training? [1] Yes [2] No

57. On a scale of 1 - 4 where, [1] = Not Important/effective, [2] = Moderately important/effective, [3] = Important/effective and [4] = Very important/effective, please indicate how important or effective the following practices are in lowering the risk of food borne illness

Practices

57a. Using paper towel instead of sponge on kitchen counters	[1]	[2]	[3]	[4]
57b. Washing raw fish	[1]	[2]	[3]	[4]
57c. Keeping raw fish separate from processed fish	[1]	[2]	[3]	[4]
57d. Hand washing after using toilet	[1]	[2]	[3]	[4]
57e. Hand washing after handling raw fish/meat	[1]	[2]	[3]	[4]
57f. Hand washing after shaking hands	[1]	[2]	[3]	[4]
57g. Hand washing after handling money	[1]	[2]	[3]	[4]
57h. Hand washing after taking out the refuse	[1]	[2]	[3]	[4]
57i. Thoroughly cooking fish	[1]	[2]	[3]	[4]
57j. fish safety by looking	[1]	[2]	[3]	[4]
57k. Freezing food	[1]	[2]	[3]	[4]
57l. Wash hands for 20 seconds	[1]	[2]	[3]	[4]
57m. Use antibacterial soap to wash hands	[1]	[2]	[3]	[4]
57n. Wash counter top with hot soapy water	[1]	[2]	[3]	[4]
57o. Mop kitchen floor	[1]	[2]	[3]	[4]

58. Rate your level of satisfaction with the fish industry's efforts, through trade associations or other cooperative efforts, to assist individual retailers in developing effective food safety training programs.
[1] Very satisfied [2] Satisfied [3] Unsatisfied [4] Very unsatisfied

59. Will you be interested in attending food safety and sanitation workshops?
[1] Not very likely [2] Not likely [3] Uncertain [4] Likely [5] Very Likely

60. If you were asked to pay to attend food safety training would you participate? [1] Yes [2] No

61. If food safety training was made free would you participate? [1] Yes [2] No

62. In your experience, which of the following are reasons why you may find it difficult to train your staff?
[1] Language problems [2] High turnover of staff
[3] Lack of time [4] Have experienced staff, so no need for training
[5] Lack of interest [6] Lack of course availability
[7] Cost [8] Courses not relevant to business
[9] Too busy to release staff [10] Other ……..

63. What is the main reason why you may train your staff?
[1] Fear of prosecution [2] Improve food hygiene [3] Satisfy EHOs [4] Looks good to customers (certificates on display) [5] A means for brand enhancement
[6] To satisfy due diligence and food law requirements [7] Other (please specify) ……

F. Food safety perception, behaviour and practice

64. Please indicate how risky, appropriate, commonly practiced or acceptable the following practices/behaviours are in the daily activities in your processing unit using [1] or [2], where:

Risk	Appropriateness	Practice	Acceptability
[1]= Most risky	[1]= Most appropriate	[1]= Most practiced	[1]= Most acceptable
[2]= Least risky	[2]= Least appropriate	[2]= Least practiced	[2]= Least acceptable

Factor	risk	appropriate	practice	Acceptable
64a. Not having fish quality evaluation				
64b. Thawing frozen fish at room temperature 12 hours before processing				
64c. Drying smoked fish in open air				
64d. Exposing fresh fish without ice for more than 2 h				
64e. Insects, flies, rats (pests) in food processing area				
64f. Exposing fish to the floor of the boat				

64g. Retailing fresh fish under ambient conditions
64h. Retailing smoked fish under ambient conditions
64i. Not wearing work clothing while handling fish
64j. Using inappropriate tools and equipment to handle fish
64k. Forgetting to wash hands after using toilettes
64l. Not using fly/pest control nets/baits
64m. Thawing fresh fish in the open
64n. Thawing fresh fish in the fridge
64o. Smoking fish whole and ungutted
64p. Transporting fresh fish on open tracks, vans or lorries for long distances without ice.
64q. Not icing fresh fish for more than two hours between catch and landing

G. Food safety management and business culture

65. Have you identified any food handling and safety risks in your business? [1] Yes [2] No
66. Have you identified what food handling tasks different staff members carry out? [1] Yes [2] No
67. Have staff been told or shown how to handle food safely within your business? [1] Yes [2] No
68. Is food safety a subject of scheduled, regularly recurring discussion in your firm? [1] Yes [2] No
69. Do you have a compliance manager who monitors and enforces your company's compliance procedures and food safety set rules? [1] Yes [2] No
70. Do you have a food safety and quality management team? [1] Yes [2] No

71. Please rate and characterize the authority of the person responsible for monitoring and enforcing your company's compliance procedures and food safety set rules.
[1] Has high authority and can initiate food safety action or withdraw a product
[2] Has low authority level in the company's hierarchy

72. How well do you think that food safety principles and practice are understood by employees within your company? [1] Not very well [2] Not well [3] Uncertain
[4] Well [5] Very well

73. How well do you think that food safety principles and practice are understood by supervisors, senior Management or owners? [1] Not very well [2] Not well [3] Uncertain
[4] Well [5] Very well

74. How would you describe the position of food safety within your company's overall vision? [1] Food safety is not part of our vision
[2] Food safety is a necessary and unavoidable cost
[3] Food safety is an opportunity to build brand value
[4] Food safety is a means of differentiation for our company

75. If you thought the fresh fish was not safe for human consumption, would you report it?
[1] Yes [2] No [3] Refuse

76. If you thought the fresh fish was not safe, would you buy if the price was reduced?
[1] Yes [2] No [3] Refuse

78. If you thought you had an outbreak of food borne disease in your firm would you report it? [1] Yes
[2] No [3] Refuse

79. Comments: .....
……
……
……

Thank you very much for participating in our survey

Appendix E: Questionnaire for food safety enforcement officers

Location: ……

A. General and demographic questions

1. What is your age? ……

2. Gender? [1] Male [2] Female

3. What is the highest level of education you have completed?
[1] No school [2] Primary [3] Secondary/technical/vocational
[4] College [5] Higher education (professional/Graduate/post-graduate)

3. Do you have food safety/environmental health certification? [1] Yes [2] No

4. What qualification do you hold?
[1] qualified Environmental Health Officer certificate [2] Certificate in Food Premises Inspection
[3] Others (please state) ……..

5. How many years have you been employed as EHO/inspector/food safety expert? …….

6. Have you had any training on hygiene, sanitation and food safety? [1] Yes [2] No

7. Have you had any training on HACCP? [1] Yes [2] No

8. If yes, what HACCP certificate do you have?
[1] Foundation [2] intermediate [3] Advanced [4] Others ……

9. Working hours/week (excl. overtime)
[1] >40 [2] 36–40 [3] 26–35 [4] 16–25 [5] <16

B. Compliance and enforcement approaches

10. In the last 12 months have you visited any fish handlers, processors or retailers? [1] Yes [2] No

11. What was your reason for the visit? (Please choose as many as applicable.)
[1] Routine inspection
[2] Investigate unsafe food-handling practices and issues of non-compliance with regulations
[3] Carry out surveys or provide advice as part of a wider project
[4] Issue warning
[5] Close down premises for violation of regulations
[6] Investigate consumer complaints
[7] Investigate food-borne illnesses and food-borne outbreaks;

12. Are these visits or Inspections announced or unannounced? [1] Announced [2] Unannounced

13. What regulatory tools are available to inspectors when minimum standards are not being achieved? (Please choose as many as applicable.)
[1] The use of a Penalty Infringement Notice (on-the-spot fine)
[2] The initiation of legal action
[3] The use of an Improvement Notice to require work to be done within a specific time period
[4] The issuing of a Prohibition Order to require the mandatory closure of a food business until a further inspection discloses a satisfactory outcome.
[5] A combination of the above when a breach of the Food Safety Act has occurred

14. When are these regulatory tools applied? (Please choose as many as applicable.)
[1] After routine inspections of a food business
[2] As a result of the investigation of a complaint.

15. What strategies/range of sanctions do you employ to ensure compliance? (Please choose as many as applicable.)
[1] Adopt highly educational, preventative, conciliatory and advisory visits
[2] Run food hygiene courses and subject-specific seminars?
[3] Adopt a deterrent-based strategy which aims to detect violations of the law and punish offenders
[5] Adopt a more formal approach by prosecuting individual businesses and serving notices more frequently where non-compliance is not remedied.

16. Which of these enforcement methods have been very effective?
[1] A preventative, conciliatory, approach to enforcement,
[2] Inspections, sanctions
[3] Provision of advice
17. Do you keep records of your inspections? [1] Yes [2] No

18. Is there a government or FDB mandate in place to require food handlers to complete a food safety course? [1] Yes [2] No

19. In your opinion, do food handlers need appropriate training in their field of operation? [1] Yes [2] No
20. Are fish handlers/food handlers getting the required training? [1] Yes [2] No
21. Do they always apply the food safety knowledge they have? [1] Yes [2] No
22. In your opinion do fish handlers/food handlers understand food safety principles? [1] Yes [2] No

23. How do you assess food handlers' food safety knowledge and practices? (Please choose as many as applicable.)
[1] Proficiency exams [2] On-the-job observations of food safety practices
[3] Occasional demonstrations of knowledge requested of food handlers.

24. On a scale of 1 - 5 where 1 = Not competent, 2 = Moderately competent, 3= Competent, 4 = Very competent, and 5 = Extremely competent, please indicate how competent you are in carrying out the following responsibilities as an inspector.

	[1]	[2]	[3]	[4]	[5]
24a. Inspecting premises and processes for compliance with hygienic and other requirements of standards and regulations e.g. PRPs	[1]	[2]	[3]	[4]	[5]
24b. Evaluating HACCP plans and their implementation	[1]	[2]	[3]	[4]	[5]
24c. Sampling food during, processing, storage, transport, or sale to establish compliance, to contribute data for risk assessments and to identify offenders	[1]	[2]	[3]	[4]	[5]
24d. Recognizing different forms of food decomposition by organoleptic assessment.	[1]	[2]	[3]	[4]	[5]
24e. Identifying food which is unfit for human consumption.	[1]	[2]	[3]	[4]	[5]
24f. Identifying food which is otherwise deceptively sold to the consumer; and taking the necessary remedial action	[1]	[2]	[3]	[4]	[5]
24g. Recognizing, collecting and transmitting evidence when breaches of law occur, and appearing in court to assist prosecution	[1]	[2]	[3]	[4]	[5]
24h. voluntary compliance in particular by means of quality assurance procedures	[1]	[2]	[3]	[4]	[5]
24i. Carrying out inspection, sampling and certification of food for import/export	[1]	[2]	[3]	[4]	[5]
24j. The delivery of information, education and advice to stakeholders across the farm-to-table continuum.	[1]	[2]	[3]	[4]	[5]
24k. The provision of balanced factual information to consumers	[1]	[2]	[3]	[4]	[5]
24l. provision of information packages and educational programmes for key officials and workers in the food industry	[1]	[2]	[3]	[4]	[5]
24m. of train-the-trainer programmes and provision of reference literature to extension workers in the food industry	[1]	[2]	[3]	[4]	[5]
24n. Your familiarity and knowledge of the entire "catch to table" continuum of the fish chain operations and the food safety requirements?	[1]	[2]	[3]	[4]	[5]
24o. Development of bespoke food safety management systems based					

on HACCP principles	[1]	[2]	[3]	[4]	[5]
24p. Assisting with implementation of FDB approved food safety schemes	[1]	[2]	[3]	[4]	[5]
24q. HACCP audits/external verification	[1]	[2]	[3]	[4]	[5]
24r. Assisting food manufacturers meet third party certification schemes	[1]	[2]	[3]	[4]	[5]

25. As an inspector, are your food safety enforcement activities monitored? [1] Yes [2] No

26. Has the FDB or other control agencies addressed your specific training needs as a matter of high priority? [1] Yes [2] No

27. Does your local authority have the means of building food control expertise and skills in all interested parties, and thereby serve an essential preventive function. [1] Yes [2] No

28. What is the main factor that constrains the adoption of efficient food safety and quality management system in the fish industry in Ghana?
[1] Lack of competence
[2] Failure to follow procedure
[3] Lack of awareness of procedures
[4] Poor facilities leading to impaired performance
[5] Infrastructural difficulties
[6] Inappropriate monitoring
[7] Others (explain) ……..

29. What internal factors hinder behaviour-change or the adoption of recommended food safety practices?
[1] Low awareness about health risks
[2] Difficulties in shedding old habits
[3] Investment required
[4] Potential losses

30. What external factors hinder behaviour-change or the adoption of recommended food safety practices? (Please choose as many as applicable.)
[1] A lack of credit programme (loans (micro-credit), subsidies)
[2] Lack of enforced regulations and controls
[3] The lack of public awareness/media harassment about food safety problems
[4] The fact that recognition is not given to those who adopt standard food safety practice.
[5] The lack of incentives from government agencies for food handlers participating in food safety schemes
[6] The absence of provision for extra training
[7] A lack of support for more dedicated extension services trained in food safety,
[8] A lack of market incentive (e.g. certification programme) for 'safer food' combined with dedicated marketing channels and accessibility to customers with a higher willingness to pay for safer produce.
[9] Lack of public awareness creation to increase public demand for safer foods

31. How would you rate the following in terms of their contribution as barriers to regulatory compliance within SMEs in the fish industry? 1= Not important barrier, 2 = Moderately important barrier, 3= Important barrier, 4 = Very important barrier and 5 = Extremely important barrier

Lack of money	[1]	[2]	[3]	[4]	[5]
Lack of time	[1]	[2]	[3]	[4]	[5]
Lack of experience	[1]	[2]	[3]	[4]	[5]
Lack of access to information	[1]	[2]	[3]	[4]	[5]
Lack of support	[1]	[2]	[3]	[4]	[5]
Lack of interest	[1]	[2]	[3]	[4]	[5]
Lack of knowledge	[1]	[2]	[3]	[4]	[5]
Lack of compliance guidelines	[1]	[2]	[3]	[4]	[5]
Operational costs	[1]	[2]	[3]	[4]	[5]

32. Is there any on-going educational campaign and training programme to train food handlers on HACCP and food safety and quality management? [1]Yes, [2] No

33. How long has this been going on? …….

34. Do you provide food safety information and/or educational material through various media to assist in the safe preparation and handling of food? [1] Yes [2] No

35. What do you think is needed to make food safety risk-reduction measures successful? (Please choose as many as applicable.)

[1] Food handlers' needs and constraints should be incorporated into the formulation of recommended practices.
[2] A participatory approach between food handlers and scientist is needed
[3] Appropriate communication channels should be developed for effective outreach.
[4] The benefits of safer practices must outweigh the cost
[5] Facilitating access to accurate information on market opportunities for 'safer foods'.
[6] Supporting training and capacity building via skill development programmes and business development service programmes
[7] Facilitating the technological upgrading of products and processes through providing access to information/technologies and processes and support to procure them.

36. How well do you think that food safety principles and practice are understood by employees within your company?

[1] Not very well [2] Not well [3] Uncertain
[4] Well [5] Very well

37. Rate your level of satisfaction with the fish industry's efforts to comply with food safety requirements.

[1] Very satisfied [2] Satisfied [3] Unsatisfied [4] Very unsatisfied

38. Comments ……
……
……
……
……
……..

Appendix F: Self-reported and observed practices questionnaire

Item no.	Practice	Reported			Observed		Comments
		Always	Some times	Never	No. of times required	No. of times performed	
1	**Purchase and Receiving**						
1.1	Is the temperature of the fish at catch/retail/purchase reduced as quickly as possible to below 5ºC?						
1.2	For transportation to the processing site, are fish placed into clean basin/boxes/chests in ice?						
1.3	Are the basins/boxes/chests properly protected to prevent heat, losses and cross contamination?						
1.4	Are harvest containers/packaging individually labelled to ensure traceability?						
2	**Storage**						
2.1	Is processed fish packaged to prevent contamination?						
2.2	Are potentially hazardous fish stored under temperature control?						
2.3	Are raw and processed fish stored separately?						
3	**Processing**						
3.1	Are fish items adequately washed before use?						
3.2	Is thawing conducted using safe procedures?						
3.3	Are adequate procedures in place to prevent contamination including cross-contamination?						
3.4	Is potentially hazardous fish left out of temperature control for more 2 hours during preparation?						
3.5	Is potentially hazardous fish displayed under temperature control?						
5.	**Transportation and Distribution**						
5.1	Are potentially hazardous foods distributed under temperature control?						
5.2	Is appropriate packaging material used?						
5.3	Are all foods protected from contamination?						
6	**Food handler dress and hygiene**						

6.1	Are food handlers wearing proper uniform						
6.2	Are all food handlers following good personal hygiene practices?						
6.3	Are hand-washing facilities adequate?						
6.4	Are hands washed correctly before food preparation?						
6.5	Hand-washing after handling garbage						
6.6	Hand-washing with soap and water before handling fish						
6.7	Hand-washing with soap and water after handling fish						
6.8	Hand-washing performed long enough						
6.9	Is the same towel used for hand drying and drying dishes?						
6.10	Are there disposable hand towels or hot air dryers?						
7.	**Premises structure and hygiene**	Yes	NO		Present	Absent	Comments
7.1	Is the premise designed and constructed to meet legal requirements?						
7.2	Are floors, walls and ceilings kept clean						
7.3	Are floors, walls and ceilings in good repair?						
7.4	Are there adequate food preparation surfaces which are kept in good repair?						
7.5	Is the premise being kept in a satisfactory state of cleanliness?						
7.6	Are all food contact surfaces effectively cleaned and sanitised?						
7.7	Is the premise being maintained in a good state of repair?						
7.8	Are waste containers located and maintained so as to prevent contamination?						
7.9	Are effective pest control procedures in place?						
7.10	Outside doors have screens, are well-sealed, and are equipped with a self-closing device						
7.11	No evidence of pests is present						
7.12	Is there an adequate supply of potable water?						
8.	**Food Handler Skills and Knowledge**						
8.1	Do staff have appropriate skills and knowledge in food safety?						
8.2	Is the nominated Food Safety Supervisor adequately trained?						

8.3	Are food handlers using safe food handling procedures?					
8.4	Preparation is planned so ingredients are kept out of the temperature danger zone to the extent possible					
8.5	Food is handled with suitable utensils, such as single use gloves or tongs					
9.	**Recalls**					
9.1	Is there an adequate system in place to ensure that unsafe or unsuitable food is not sold or is recalled?					
General Comments						

Appendix G1. Analysis of concern ratings for specific food-related hazards, practices and food technologies

	Mean ± SEM concern/worry ratings by consumers and food handlers				
	Overall (n= 224)	Food handlers (n= 115)	Consumers (n= 109)	p-value	Concern rating
Irradiated foods	3.65 ± 0.090	3.48 ± 0.125	3.83 ± 0.122	0.054	High***
Genetically modified foods	3.24 ± 0.096	3.24 ± 0.139	3.24 ± 0.134	0.980	High
Pesticide residues in food	4.26 ± 0.075	4.25 ± 0.109	4.27 ± 0.103	0.927	Very high****
Antibiotics in food	3.85 ± 0.088	3.55 ± 0.129	4.17 ± 0.113	0.0004	High-very high
Growth hormones in food	3.98 ± 0.085	3.88 ± 0.122	4.09 ± 0.118	0.212	High-very high
Additives/colourings/preservatives	2.70 ± 0.106	2.57 ± 0.139	2.84 ± 0.161	0.190	Medium
Butchers hygiene/sanitation	3.34 ± 0.094	3.00 ± 0.141	3.69 ± 0.101	0.0001	High
Restaurant hygiene/sanitation	3.26 ± 0.087	2.95 ± 0.128	3.59 ± 0.110	0.0002	Medium-high
'Chop-bar' hygiene/sanitation	3.11 ± 0.089	2.88 ± 0.119	3.36 ± 0.130	0.007	Medium-high
Home hygiene/sanitation	1.64 ± 0.075	1.64 ± 0.106	1.65 ± 0.107	0.929	Low
Food poisoning in Ghana	4.30 ± 0.075	4.14 ± 0.110	4.47 ± 0.100	0.029	High
Microbiological safety of food	3.87 ± 0.082	3.97 ± 0.112	3.76 ± 0.119	0.214	High
Food poisoning from chicken	3.30 ± 0.099	3.32 ± 0.138	3.27 ± 0.143	0.779	High
Food poisoning from pork	2.85 ± 0.096	2.96 ± 0.137	2.73 ± 0.135	0.250	Medium**
Food poisoning from beef	2.86 ± 0.085	2.85 ± 0.118	2.87 ± 0.122	0.909	Medium
Food poisoning from fish	2.43 ± 0.099	2.48 ± 0.139	2.38 ± 0.142	0.608	Medium
Inadequate labelling	3.20 ± 0.092	3.07 ± 0.129	3.34 ± 0.131	0.145	High
Nutritional balance of diet	1.73 ± 0.071	1.70 ± 0.104	1.77 ± 0.099	0.603	Low*
Mean concern rating	3.20 ± 0.177	3.11 ± 0.173	3.29 ± 0.190	0.012	High

Between 1-2=Low*, between 2-3 = medium**, between 3-4 = High***, between 4-5 = Very high****

Appendix G2. Impact of age on concern ratings for specific food-related hazards, practices and food technologies

	Mean ± SEM of concern/worry ratings by age (years)						Concern
	18-24	25-34	35-44	45-54	55 and over	p-value	rating
Irradiated foods	3.18 ± 0.211	3.69 ± 0.158	3.60 ± 0.176	3.75 ± 0.191	3.13 ± 0.480	0.791	High***
Genetically modified foods	3.08 ± 0.258	3.39 ± 0.161	2.89 ± 0.195	3.57 ± 0.180	2.63 ± 0.565	0.065	Medium-high
Pesticide residues in food	3.79 ± 0.318	4.35 ± 0.139	4.29 ± 0.144	4.13 ± 0.161	4.25 ± 0.313	0.861	High-very high
Antibiotics in food	3.26 ± 0.282	3.95 ± 0.145	3.89 ± 0.174	3.73 ± 0.183	3.00 ± 0.627	0.346	High
Hormones in food	2.89 ± 0.248	4.05 ± 0.159	4.11 ± 0.153	4.04 ± 0.165	2.63 ± 0.500	0.034	Medium-very high
Additives/colourings/preservatives	2.05 ± 0.264	2.65 ± 0.204	2.84 ± 0.212	2.54 ± 0.202	2.13 ± 0.480	0.537	Medium
Butchers hygiene/sanitation	3.07 ± 0.276	3.35 ± 0.154	3.23 ± 0.173	3.27 ± 0.201	3.88 ± 0.515	0.696	High
Restaurant hygiene/sanitation	3.16 ± 0.288	3.09 ± 0.155	3.31 ± 0.157	3.09 ± 0.193	3.13 ± 0.580	0.081	High
'Chop-bar' hygiene/sanitation	2.97 ± 0.289	2.94 ± 0.156	3.13 ± 0.165	3.20 ± 0.181	3.25 ± 0.675	0.788	Medium-high
Home hygiene/sanitation	1.44 ± 0.290	1.34 ± 0.104	1.87 ± 0.163	1.68 ± 0.153	1.75 ± 0.313	0.119	Low*
Food poisoning in Ghana	3.71 ± 0.256	4.37 ± 0.113	4.34 ± 0.156	4.25 ± 0.151	3.88 ± 0.479	0.814	High-very high
Microbiological safety of food	3.69 ± 0.142	3.86 ± 0.142	3.86 ± 0.164	4.04 ± 0.163	3.50 ± 0.534	0.661	High-very high
Food poisoning from chicken	2.40 ± 0.222	3.38 ± 0.188	3.48 ± 0.178	3.04 ± 0.194	2.25 ± 0.526	0.118	Medium-high
Food poisoning from pork	2.50 ± 0.143	2.86 ± 0.177	2.87 ± 0.196	2.71 ± 0.200	3.00 ± 0.567	0.936	Medium-high
Food poisoning from beef	2.34 ± 0.283	2.74 ± 0.141	2.89 ± 0.151	2.95 ± 0.184	2.00 ± 0.422	0.199	Medium**
Food poisoning from fish	2.39 ± 0.263	2.51 ± 0.188	2.15 ± 0.178	2.45 ± 0.210	2.50 ± 0.598	0.395	Medium
Nutritional balance of diet	3.18 ± 0.211	3.69 ± 0.158	3.60 ± 0.176	3.75 ± 0.191	3.13 ± 0.480	0.885	High
Inadequate labelling	2.75 ± 0.256	3.39 ± 0.167	3.19 ± 0.166	3.05 ± 0.205	3.00 ± 0.500	0.740	Medium-high
Mean concern rating	1.68 ± 0.236	3.21 ± 0.193	3.20 ± 0.181	3.18 ± 0.180	2.85 ± 0.181	< 0.001	Low-medium-high

Between 1-2=Low*, between 2-3 = medium**, between 3-4 = High***, between 4-5 = Very high****

Appendix G3. Impact of gender on concern ratings for specific food-related hazards, practices and food technologies

	Mean ± SEM concern/worry ratings by gender			Concern
	Male	Female	p-value	rating
Irradiated foods	3.62 ± 0.140	3.67 ± 0.118	0.759	High***
Genetically modified foods	3.04 ± 0.148	3.40 ± 0.125	0.064	High
Pesticide residues in food	4.28 ± 0.104	4.24 ± 0.107	0.777	Very high
Hormones in food	3.95 ± 0.129	4.01 ± 0.114	0.659	High-very high
Antibiotics in food	3.82 ± 0.133	3.87 ± 0.118	0.763	High
Additives/colourings/preservatives	2.68 ± 0.164	2.72 ± 0.140	0.840	Medium
Food poisoning in Ghana	4.34 ± 0.110	4.26 ± 0.103	0.601	Very high****
Microbiological safety of food	3.78 ± 0.122	3.94 ± 0.110	0.338	High
Food poisoning from chicken	3.24 ± 0.154	3.34 ± 0.129	0.640	High
Food poisoning from pork	2.87 ± 0.144	2.83 ± 0.130	0.850	Medium**
Food poisoning from beef	2.78 ± 0.128	2.93 ± 0.113	0.379	Medium
Food poisoning from fish	2.34 ± 0.149	2.50 ± 0.133	0.446	Medium
Butchers hygiene/sanitation	3.34 ± 0.135	3.33 ± 0.122	0.932	High
Restaurant hygiene/sanitation	3.28 ± 0.134	3.24 ± 0.115	0.808	High
'Chop-bar' hygiene/sanitation	3.21 ± 0.133	3.03 ± 0.121	0.318	High
Home hygiene/sanitation	1.64 ± 0.118	1.65 ± 0.097	0.954	Low
Inadequate labelling	3.16 ± 0.142	3.23 ± 0.122	0.706	High
Nutritional balance of diet	1.70 ± 0.101	1.76 ± 0.101	0.664	Low*
Mean concern rating	3.17 ± 0.181	3.22 ± 0.177	0.097	High

Between 1-2=Low*, between 2-3 = medium**, between 3-4 = High***, between 4-5 = Very high****

Appendix G4. Impact of educational level on concern ratings for specific food-related hazards, practices and food technologies

	Mean ± SEM of concern/worry ratings by educational level					
	None	Primary	Secondary	Tertiary	*P*-value	Concern rating
Irradiated foods	2.85 ± 0.319	3.44 ± 0.163	3.94 ± 0.119	3.76 ± 0.235	0.0009	Medium-high
Genetically modified foods	3.19 ± 0.302	3.26 ± 0.179	3.17 ± 0.141	3.47 ± 0.254	0.758	High
Pesticide residues in food	4.30 ± 0.198	4.21 ± 0.157	4.29 ± 0.108	4.21 ± 0.197	0.959	Very high****
Antibiotics in food	3.56 ± 0.274	3.72 ± 0.174	4.06 ± 0.122	3.68 ± 0.238	0.167	High-very high
Hormones in food	4.00 ± 0.245	3.74 ± 0.176	4.17 ± 0.117	3.85 ± 0.228	0.194	High-very high
Additives/colourings/preservatives	2.48 ± 0.258	3.15 ± 0.218	2.45 ± 0.152	2.82 ± 0.275	0.044	Medium
Food poisoning in Ghana	4.00 ± 0.250	4.38 ± 0.150	4.49 ± 0.086	3.82 ± 0.244	0.010	High-very high
Microbiological safety of food	4.15 ± 0.225	3.82 ± 0.152	3.80 ± 0.127	3.91 ± 0.200	0.611	High-very high
Food poisoning from chicken	3.19 ± 0.297	3.43 ± 0.180	3.23 ± 0.151	3.35 ± 0.249	0.826	High***
Food poisoning from pork	2.56 ± 0.317	3.00 ± 0.169	2.78 ± 0.145	3.00 ± 0.250	0.504	Medium-high
Food poisoning from beef	2.63 ± 0.257	2.87 ± 0.161	2.85 ± 0.123	3.06 ± 0.223	0.631	Medium-high
Food poisoning from fish	2.19 ± 0.267	2.64 ± 0.200	2.34 ± 0.142	2.50 ± 0.268	0.501	Medium**
Butchers hygiene/sanitation	2.96 ± 0.309	3.48 ± 0.149	3.39 ± 0.130	3.21 ± 0.266	0.365	Medium-high
Restaurant hygiene/sanitation	2.52 ± 0.241	3.54 ± 0.147	3.24 ± 0.129	3.41 ± 0.247	0.007	Medium-high
'Chop-bar' hygiene/sanitation	2.81 ± 0.245	3.30 ± 0.177	3.24 ± 0.132	2.65 ± 0.211	0.057	Medium-high
Home hygiene/sanitation	1.93 ± 0.256	1.66 ± 0.163	1.53 ± 0.096	1.71 ± 0.187	0.430	Low
Inadequate labelling	3.15 ± 0.271	3.20 ± 0.178	3.14 ± 0.137	3.44 ± 0.240	0.736	High
Nutritional balance of diet	1.44 ± 0.180	1.98 ± 0.158	1.73 ± 0.102	1.53 ± 0.165	0.090	Low*
Mean concern rating	2.99 ± 0.186	3.27 ± 0.161	3.21 ± 0.198	3.19 ± 0.172	0.726	Medium-high

Between 1-2=Low*, between 2-3 = medium**, between 3-4 = High***, between 4-5 = Very high****