UNIVERSITY OF CAPE COAST

# A COMPARATIVE STUDY OF THE QUALITY AND SHELF LIFE OF FISH SMOKED USING CHORKOR OVEN AND AHOTOR OVEN

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2022

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# A COMPARATIVE STUDY OF THE QUALITY AND SHELF LIFE OF FISH SMOKED USING CHORKOR OVEN AND AHOTOR OVEN

BY

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Thesis submitted to the Department of Fisheries and Aquatic Sciences of the School of Biological Sciences, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of a Master of Philosophy degree in Integrated Coastal Zone Management

SEPTEMBER 2022

# DECLARATION

## Candidate's Declaration

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

Candidate's Signature: ..... Date: .....

Name: Samuel Bridge Nkansah

## Supervisors' Declaration

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

Principal Supervisor's Signature: ..... Date: .....

Name: Dr Jerry Ampofo-Asiama

Co-Supervisor's Signature: ..... Date: .....

Name: Dr. Isaac Okyere

## ABSTRACT

A number of traditional fish processing methods exist in Ghana with the most common being smoking using the Chorkor oven. Studies have, however, shown that smoking with Chorkor oven has both health and environmental implications through release of PAHs and other compounds that are carcinogenic, and increased deforestation which accelerates climate change through excessive use of firewood. The Ahotor oven was designed in order to address the issues posed by the use of Chorkor oven. To enhance its adoption, a comparative study was carried out to determine the quality and the shelf life of products smoked using Chorkor oven and Ahotor oven. Two fishing communities, namely; Winneba and Shama-Kesewokan were selected as the study locations while Atlantic chub mackerel (*Scomber colias*) was the selected species. Fish samples at both sites were smoked using both ovens and analyzed with respect to safety and shelf-life. Results revealed that aroma, texture, moisture and protein varied significantly while appearance, taste, acceptability, ash content, fiber content did not vary significantly in quality and shelf life indicators of fish smoked using the two oven types at the two study sites. TVB-N and PV values obtained were both within maximum acceptable limits for smoked fish smoke with two ovens. PAHs for Chorkor oven smoked samples were higher than those smoked with Ahotor oven, however, they both exceeded the EU maximum residue limit of PAHs in smoked fish. From this research, it can be concluded that fish smoked with these two ovens are not significantly different in terms of quality and shelf life, however, there is the need for a standardized method of fish smoking.

**KEYWORDS**

Oxidation

Physicochemical

Proximate

Sensory

Shelf life

Spoilage

## ACKNOWLEDGEMENTS

My sincere gratitude goes out to Dr. Jerry Ampofo-Asiama and Dr. Isaac Okyere, who served as my supervisors, for their significant commitment, mentorship, support, and direction during the period of my studies. I appreciate them a lot.

I would also want to thank Africa Centre of Excellence in Coastal Resilience (ACECoR) project for financing my research.

My appreciation also goes to Dr. Ing. Nazir Kizzie-Hayford, senior lecturer, Department of Biochemistry, University of Cape Coast, Cape Coast and laboratory technicians, Department of Biochemistry research laboratory, University of Cape Coast, Cape Coast for their immense contribution throughout my MPhil research.

My profound gratitude also goes out to Mrs Vivianne Geraldo, Mr Delove Asiedu, Isaac Kwame Badu and the ACECoR team for their immense contributions to make this study a success.

## DEDICATION

To Madam Dora Frimpomaa and Mrs. Rebecca Kwakye

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| | |
|---|---|
| FAO | Food and Agriculture Organization |
| GDP | Gross Domestic Product |
| MoFAD | Ministry of Fisheries and Aquaculture Development |
| AWEP | African Women's Entrepreneurship Program |
| FTT | FAO-Thiaroye Processing Technique |
| UN | United Nations |
| SDG | Sustainable Development Goals |
| LMEs | Large Marine Ecosystems |
| PUFAs | Polyunsaturated Fatty Acids |

# CHAPTER ONE

## INTRODUCTION

Globally, there is now significantly more demand for fishery resources due to an increase in world population which seeks to find cheap sources of proteins to feed the ever-increasing population (FAO, 2022). Fish is widely consumed and the least expensive source of protein in Ghana (Asiedu *et al*., 2018), constituting about 60% of the amount of animal protein consumed. (FAO, 2018). Fisheries sector also contributes significantly to the country's development particularly in job creation (Bank of Ghana, 2008). One key challenge facing the sector in Ghana is post-harvest losses (Assan *et al*., 2019). To deal with this problem, a number of techniques are employed in the processing of fish after harvest to enhance quality and lengthen shelf life. Fish processing by smoking is very popular with the use of Chorkor oven the most prominent (UNDP/TCDC, 2001). According to Owusu, (2019), Chorkor oven is reported to have negative influence on the environment and human health because of high fuel consumption, high smoke generation and high amount Polycyclic Aromatic Hydrocarbons (PAHs) in its product that are carcinogenic and dangerous to both processors and consumers. Due to this limitation, other oven types such as the Ahotor oven have been developed. Limited information, however, exists concerning the quality and shelf life of fish smoked using Ahotor oven compared to the Chorkor oven.

**Background to the Study**

For many people, especially in the developing countries, fishery products are key food and income sources (FAO, 2016c). The fishing sector serve as a significant commercial activity, particularly in Africa, with about 10% of the total population depending on the sector for their source livelihoods (FAO, 2016a). The dependence on fish is more pronounced in the coastal regions and localities near major river systems (Gilberg, 1966). Fish makes up a substantial portion of the animal protein consumed within coastal regions of Western Africa where it has served as a backbone of the local economy for ages (Johnny *et al*., 2020). By means of foreign exchange and revenue generation, the fisheries industry contributes significantly to Ghana's economy. Currently, the sector contributes roughly 3% to the Ghana's GDP, generates an estimated $1 billion in revenue and employs approximately 10% of the population (MoFAD, 2016). According to FAO, (2016b), the sector employs approximately 2.6 million people, it significantly contributes to the nation's nutritional security, with fish serving as the main source of animal protein for the majority of Ghanaians. Ghana consumes 20% more fish annually per person than the global average of 20 kg (FAO, 2016b).

Amidst the sector's significant contribution to Ghana's economic growth, it is confronted with various challenges, with the most significant being the lack of efficient fish processing techniques (Gyan *et al*., 2020). Fresh fish has a pH that is almost neutral, increased water activity, and nutrients that can promote microbial growth leading to faster deterioration after harvest (Belusso *et al*., 2016; de Alba *et al*., 2019). As such, some level of processing to enhance

the quality and extend shelf life of fish for further distribution and marketing is needed.

In Ghana, four main techniques are employed in the post-harvest processing of fish. These are smoking, salting, drying and frying; smoking is the frequently utilized processing technology (Sakyi *et al*., 2019). According to Asiedu *et al*. (2018), about 70–80% of local fish consumption is in the smoked form. Smoking is carried out for a variety of purposes, including extending shelf life, enhancing flavour, and reducing wastage during bumper catches, and preservation for the lean season (Pemberton-Pigott C *et al*., 2016).

Two (2) main methods of fish smoking are employed in Ghana which are wet and dry hot smoking (Adei *et al*., 2019). Dry hot smoking is carried out at high temperatures and involves a cooking stage and an actual smoking stage based on the type of species to be smoked, its use and period of preservation (Alhassan *et al*., 2014). A moist adaptable product with a moisture content of 40–55% is produced by wet hot smoking, which takes around 1-2 hr to finish and has a short shelf life of just 1-3 days. Dry hot smoking, however, can be completed between 10-18 h and produces fish with a moisture content of 10-15%. Storage of hot smoked fish under appropriate condition can lead to a product with 6-9 months shelf life (Anon, 2007).

The most popular oven employed in fish smoking in Ghana is the Chorkor oven (Nunoo *et al*., 2019). Chorkor oven was developed by the United Nations' Food and Agriculture Organization (FAO) in partnership with Ghana's Council for Scientific and Industrial Research and adopted for use around 1969(UNDP/TCDC, 2001). However, fish smoked with Chorkor oven have been observed to contain high amounts of Polycyclic Aromatic Hydrocarbons

(PAHs). Some forms of PAH are known to be carcinogenic and drawn a lot of attention over the years (Akpambang *et al*., 2009). Also, it has been reported that excessive firewood is used with the generation of huge amounts of smoke when Chorkor oven is employed (Ford *et al*., 2020). In addition, when using Chorkor oven, the fish is exposed to smoke from the burning wood directly which deposit hazardous substances such as, formaldehyde, sulphur oxides and dioxins, in addition to some heavy metals (Codex alimentarius, 2016). These can have detrimental effects on the health of both consumers and processors (Bomfeh *et al*., 2019), with deforestation and climate change a possible consequence of excessive firewood usage (Okyere-Nyarko *et a*l., 2015).

The incomplete combustion of wood, as well as other sources, such as cooking meat and other food products at very high temperatures results Polycyclic Aromatic Hydrocarbons in food products (Center for Disease Control, 2009). According to Essumang *et al*. (2012) high consumption of smoked fish products in the Ghanaian diet may be a factor in the rise in cancer cases, particularly breast cancer among older females. Indeed, United States Environmental Protection Agency (USEPA), Agency of Toxic Substances and Disease Register (ATSDR) and International Agency for Research on Cancer (IARC), the European Community (EC) have all classified PAHs as pollutants of high priority due to their mutagenic and carcinogenic effects (Kafeelah *et al*., 2015). The resulting effect is a possible rejection of smoked fish from Ghana on the international market due to the presence of PAH (Bomfeh *et al*., 2019). Aside from PAH, the high amount of smoke generated in the operation of Chorkor oven can predispose fish smokers to respiratory diseases such as lung cancer (Sakyi *et al*., 2019). Thus, there is therefore the need to promote the use

of modern and efficient smoking ovens, which addresses the limitation of Chokor oven.

**Statement of the Problem**

The Chorkor oven is the most popular oven used to smoke fish in Ghana (Nunoo *et al*., 2019). The usage of the Chorkor oven is associated with high amount of smoke generation in its operation, high amount of fuel consumption and high amount of Polycyclic Aromatic Hydrocarbon (PAH) in its smoked product (Ford *et al*., 2020).

These challenges have negative impact on the health of processors and consumers (Aheto *et al*., 2017), the environment (Owusu, 2019). Due to the challenges and limitations connected with using the Chorkor oven, improved ovens like the Morrison, FAO Thiaroye Technology (FTT), and Ahotor were developed (Entee, 2015a). While the use of Morrison and FTT ovens have been restricted due to factors such as purchase and installation costs, Ahotor oven usage is being promoted due to its relatively cheaper cost. Several studies have shown that the amount of smoke generated, firewood usage and levels of PAH in smoked fish are much improved when Ahotor oven is used compared to Chorkor oven. However, limited information is known on the effect associated of using Ahotor oven on the general quality of smoked fish.

**Purpose of the study**

Considering that Chorkor oven is the most popular oven for smoking fish in Ghana, both fish smokers and consumers may be familiar with the quality (both sensory and physicochemical) and the shelf life of fish on the market smoked using Chorkor oven.

Thus, to help promote the usage of Ahotor oven, it is important to compare the quality and the shelf life of fish smoked using Ahotor oven to that of Chorkor oven. This can help determine whether fish smoked using Ahotor oven has comparable quality to that smoked using Chorkor oven.

**Objectives**

The primary objective of this study was to assess the quality and the shelf life of fish smoked with Chorkor and Ahotor Oven. Specifically, this work seeks to;

1. Evaluate the sensorial difference in quality of smoked fish from Chorkor oven and Ahotor oven.
2. Assess the difference in quality of smoked fish from Chorkor oven and Ahotor oven based on physical (moisture content, fat content and protein content) and chemical analysis (brix, colour, and hardness/firmness).
3. Assess the shelf life of smoked fish from Chorkor oven and Ahotor oven under ambient temperature (25 - 27°C) and refrigeration temperature (4°C).

**Research Hypotheses**

These null hypotheses were investigated in light of the study's objectives;

1. Fish smoked using Ahotor oven and Chorkor oven has the same sensory qualities.
2. There is no the difference in quality of smoked fish from Chorkor oven and Ahotor oven based on physical (moisture content, fat content and protein content) and chemical analysis (brix, colour, and hardness/firmness).

3. Fish smoked using Chorkor oven and Ahotor oven have same shelf life at ambient temperature (25–27°C) and at refrigeration temperature (4°C).

**Significance of the Study**

Achieving quality healthcare, reducing hunger and decreasing the rate of poverty in the world are enshrined within the United Nation Sustainable Goal (SDGs) of the United Nations (Goal 2, 3 and 4 respectively). The Fisheries sector of Ghana contributes significantly to the economy, the intake of fish in in the country is rated as 20% which is higher than that that of the world of 20kg (FAO, 2016).

According to the Asiedu, *et al*., (2018), the smoked fisheries sector is key for food security, job creation, foreign exchange and income generation, all of which aids the economy's long-term viability, smoked fish represents between 70% to 80% of the fish consumed locally (Asiedu, *et al*., 2018). A variety of fish processing techniques are employed in fish. The Chorkor oven is the most common used technique for fish smoking (Nunoo *et al*., 2019). As part of the measures taken by the Fisheries Commission, Ghana to reduce depletion of fish stock is use of efficient fish processing technology

The significance of this study in the context of countries such as Ghana is to provide scientific data which will significantly contribute to the adoption of efficient fish processing technique which enhances smoked fish's quality and shelf life in Ghana. This study seeks to provide bases for the achievement of quality healthcare, reducing hunger and decreasing poverty which are highlighted in the United National Sustainable Goal (SDGs)

**Limitations**

The usage of frozen mackerel in this study due to the fact that it was difficult to obtain fresh mackerel from the landing sites of the study areas could influence the results. According to Puke & Galoburda, (2020), raw material is one of the characteristics that influences the quality of smoked fish. To cater for this, it was ensured that the frozen fish used for this study was obtained from one source and the fish smoked by the same person using the different processing techniques in each study area.

**Organization of the Study**

This study has been separated into six chapters. The introduction of the study covering the background, statement of the problem, purpose of the study, objectives and significance of the study is highlighted in chapter 1 (one). Chapter 2 (two) provides extensive literature pertinent to the study. An exhaustive literature on fish smoking and various studies on fish quality and shelf-life assessment is presented. The methodologies applied in this research is presented in chapter 3 (three). The study areas of this research are well-describe with a map. Method of data collection and statistical software used are described as well. Chapter 4 presents results of the study. The research's findings are presented in tables and graphs, each with a short description. Detailed analysis of results of the study are adequately discussed in chapter 5 (five). Summary, conclusions and recommendations of the study are given in Chapter six. A list of references presented in this study forms another section in this thesis.

# CHAPTER TWO

# LITERATURE REVIEW

Chapter two (2) examines studies pertinent to the subject of this study. It examines the state of fisheries in Ghana and Africa as a whole. This chapter also highlights on some of the contributions of Fisheries to the Ghanaian economy and the African economy as a whole, issues of post-harvest fish loss, fish preservation and fish smoking as a preservation method.

## Fisheries in Africa

The wealth of fisheries resources in African waters is well-known. The second, third, and fourth most prolific large marine ecosystems (LMEs) in the world are the Canary Current, Benguela Current, and Somali Coastal Current, respectively (Rosenberg *et al.*, 2014). African fisheries serve as a means of sustenance for about 35 million active people of the fisheries value change as well as their families (Belhabib *et al*., 2015; Teh & Sumaila, 2013). Despite this significance, Africa's fisheries are frequently hampered by a number of issues such as lack of data where it is estimated that majority of fish harvests are not included in official data, illegal fishing, wherein the North-Western region alone may be responsible for 10% to 20% of all values lost to illegal fishing worldwide and marginalization of key sectors for the economy, such as artisanal and subsistence fishing, which has led to a decline in these sectors leading to high poverty levels among coastal communities in Africa, rising migration to the coast, partly as a result of disputes between coastal communities and climate change (migrant and non-migrant fishers), high rate of sectoral disputes between the industrial fleet and small-scale fishers leading to a rise in piracy over space and fish stocks which brings about a number of maritime accidents,

decreased opportunities for fishing communities who depend directly on fish (Belhabib *et al*., 2019)

**Fisheries in Ghana**

The fisheries sector of Ghana contributes 4.5% to the country's annual GDP and indirectly supports livelihoods of about 2.2 million people or 10% of Ghanaians (MoFAD, 2016). The industry is made up of marine inland (freshwater and aquaculture) sectors. The marine, usually categorized into four sub-sectors which includes; small scale (or artisanal), semi-industrial (or inshore) and industrial, makes the highest contribution to local fish production, it accounts for about 85% of the total captures (Nunoo *et al*., 2015). The fisheries sector is generally categorized into four sub-sectors; small scale (or artisanal), semi-industrial (or inshore), industrial most of which are majority-owned by Chinese but operating under Ghanaian flags. Of these, small-scale fishing accounts for the majority of marine fisheries, harvesting over 70% of the fish landings using canoes with 73% of them being motorized (Akyeampong & Amador, 2013). Around 107,500 fishermen are employed in small-scale fisheries sector amounting to 80% of all fishermen in Ghana. An additional 500,000 people, of which are women, work in the processing and marketing of fish across Ghana. Inland fisheries are primarily focused on Lake Volta and nearby water bodies, accounting for up to 90% of the productivity of all inland fisheries and 15% of domestic harvest. (Lauria *et al*., 2018).

**Post-harvest fish loss and associated challenges**

It is crucial to make sure that the fish that are harvested reaches the consumer with a few losses as possible because fisheries around the world are approaching their limits of sustainable exploitation. One of the primary

challenges the entire fishing sector is facing is issues concerning post-harvest fish loss. The need to tackle this issue helps on improving food security by boosting the proportion of fish that are utilized for human food (Gyan *et al*., 2020). Policymakers and fishermen must grasp the post-harvest aspects of fishery development in order to expand the range of fishery products and meet customer demands for high quality. Fish losses is regarded as the highest of all commodities in the entire food supply chain (Kumar & Kalita, 2017). (Akintola & Lawal, 2011) estimated that, poor handling, inefficient preservation and processing methods employed in the fisheries lead about 50% of loss in fish before finally reaching the consumer.

Fish spoilage due to material losses, operational losses, discards of by-catch and fragmentation are among the post-harvest losses in fisheries (Ames, 1990). Cheke & Ward, (1998) outlined a rather more practicable categorization of fish loss into 4 categories; nutritional loss, quality loss, physical loss and market force loss. A thorough analysis of case studies in fish post-harvest losses from different African countries indicates that, there have been significant losses of fishery products in terms of both quality (particularly due to downgrading) and quantity (physical or material losses) (FAO, 2008). Post-harvest losses of fish total about 10 - 20 million tonnes each year due to spoilage (Gyan *et al*., 2020). Additionally, there are losses in quality as a results of stale fish losing its appeal to the consumer and losses in the nutritional benefit when fish provides less of a nutritional boost to consumers' diets than it otherwise would (FAO, 1981) There are various stages of post-harvest losses, from catch through sale, and the degree of the losses could be severe in particular fisheries (Nellemann & MacDevette, 2009). Post-harvest losses in undeveloped countries

as estimated by (FAO, 1981) account for about 50% of the fish produced domestically. One common cause of fish post-harvest losses is biochemical and microbiological degradation that occurs in fish after death. Live fish have in-built defenses that keeps them from rotting, however, when a fish dies, its defense mechanisms are shut down, and quality degradation is brought on by enzymatic, oxidative, and microbiological decomposition (Diei-Ouadi & Mgawe, 2011).

**Fish spoilage**

For a variety of species, fish and fish-related commodities represent growth media, emanating from the aquatic environment, handling, processing, and storage. Fish as a commodity is highly susceptible to deterioration. Fish spoilage commences immediately the fish dies. Fish spoils quiet quickly after a few hours of landing in tropical conditions. All changes occurring in fish after it dies is caused by rigor mortis. Within a few hours of death, fish lose flexibility because its muscles stiffen up after a few hours of death (Prabhakar *et al*., 2020). The degradation process is brought on by all of the enzymes involved in digestion, microorganisms on surfaces that cause spoilage, complete and partial oxidation (Olayemi *et al*., 2012). During the fish spoilage, chemicals are simultaneously broken down and created. Fish spoilage can be categorized in three modes; enzymatic spoilage, chemical spoilage and microbial spoilage (Odeyemi *et al*., 2018). Due to the natural defensive mechanisms in the living cell, enzymes and bacteria do not bring about any deteriorative modifications. However, enzymes play a role in autolytic changes in dead fish, bacteria can get within the muscle of the fish and thrive there. The gut of the fish has a high concentration of proteolytic enzymes, it decomposes the gut and belly region

which makes it very soft in dead fish. When a fish dies, bacteria on its surface, gills, and stomach penetrate it, degrade the tissue, and cause undesired changes. The obvious indicators of spoilage include off flavours and odours, slime, gas production, discolouration, and soft texture. Lipids, nucleotides, sugars and other nitrogen-containing non-protein molecules are among the substances implicated in the deterioration process. Lowering the temperature will slow the pace of rotting because it is temperature-dependent.

**Autolytic (enzymatic) spoilage**

Enzymatic breakdown causes a number of chemical and physical changes after the fish dies. Autolytic enzymes like ATPase and ADPase lower the textural quality during the beginning stages of spoilage, however, it does not produce off-odours and off-flavours (Hultmann & Rustad, 2004). These enzymes work on the fish muscle during rigor mortis to significantly alter its physicochemical characteristics. (Prabhakar *et al*., 2019). Glycolysis, the step-by-step hydrolysis of glycogen to form lactic acids is the initial enzymatic alteration in fish muscle. After the death of fish, blood circulation is halted and cells nourishment of cells with oxygen ceases. Consequently, conversion of glycogen into carbon dioxide and water in contrary to the case of living cells. Glycolysis takes place through the anaerobic pathway with its product being lactic acid during the postmortem period. The pH of the fish's muscle falls as lactic acid increases. This process continues in fish until the glycogen supplied is completely used up. The pH is reduced from 7.2 to 6.2 to 6.5 by the lactic acid produced. The resulting pH will range from 5.8 to 5.6 in some species. Significant enzymatic alterations are the ones which affect flavour. In fish muscle, nucleotide breakdown results in the production of numerous flavour-

rich substances. A sequence of dephosphorylation and deamination events break ATP (adenosine triphosphate) into these molecules.

**Chemical spoilage**

Fish lipid undergoes oxidative changes because of enough of polyunsaturated fatty acids within it. Turchini *et al.* (2009) noted that fish with a high oil and fat content, such as mackerel and pelagic species, are susceptible to lipid oxidation. The perception of objectionable flavours and odours in food refers to oxidative rancidity caused by the reaction of atmospheric oxygen and chains of unsaturated fatty acids. Because this process occurs spontaneously, it is often called autoxidation. The process occurs in a range of complex reactions resulting in the production of a wide array of volatile and non-volatile compounds (Velasco *et al.*, 2010). Not only does lipid oxidation affect food quality with undesirable odours and flavours but it also leads to the loss of important nutrients including vitamins, fatty acids as well as changes its colour and texture. A decrease in the food's shelf life is the primary effect of the initial event of lipid oxidation. Furthermore, as oxidation proceeds, the creation of flavours substantially impairs the sensory appeal till the food gets to a point where it is unacceptable to the consumer. Due to increased lipid peroxidation being shown in vivo in a number of degenerative and chronic diseases, namely cancer and cardiovascular disorders, oxidized lipids have received a great deal of attention in previous decades. Additionally, in vivo and in vitro investigations on a range of lipid oxidation products found in food have demonstrated toxicity (Kristensen *et al.*, 2002). However, it is still unknown how much lipid oxidation in meals accounts for the emergence of diseases.

One of the main causes is the scarcity of knowledge concerning the composition and structure of oxidation in food products. This reactive species mechanism that causes polyunsaturated fatty acids to oxidatively deteriorate occurs in free radical mechanism in three independent stages involving: initiation as the first stage, propagation as the second and termination as the last stage (Frankel, 1985). The first stage, initiation, through catalysts involving metal ions radiation and heat entails the development of lipid-free radicals. There is the formation of peroxyl radicals after the reaction involving free radicals and oxygen. Propagation involves the reaction between peroxyl radicals and other lipid molecules forming new radical and hydroperoxides (Fraser & Sumar, 1998). A concentration of radicals interacting to form non-radical products is termed as termination which is the last stage. Lipid oxidation involves numerous factors. Because several factors function simultaneously and are even related to one another, typically, assessing the impact a particular factor has on the entire oxidation process is difficult. In general, the primary factors can be broken down into two categories: intrinsic and external. Inherent factors including lipid composition including the degree of metal traces, antioxidants, free fatty acids, unsaturation, etc., physical characteristics and composition of the food. External factors include oxygen concentration, temperature, light, and others (Velasco *et al*., 2010).

**Fish preservation methods**

Fish is usually perceived as unstable culinary commodity because of its susceptibility to spoilage. A number of variables significantly influence quality of fish preservation (Rumape *et al*., 2022). With respect to increasing world population, storing and transporting food from one place to another has become

a great necessity. To solve the problem of food wastage in developing nations, proper food preservation must be carried out. Food preservation methods look for ways to prevent or slow down spoilage. Fish preservation is done not only to control the factors that contribute to its spoilage but also to consider measures to prevent mechanical loss (Joardder & Masud, 2019). A number of methods are adapted in fish preservation. The nature of fish, as well as the impact of preservation techniques on the fish should be considered in the preservation of fish (Adeyeye *et al*., 2019). The chemical, physical, and nutritional components of fish vary depending on how they are processed (Akinneye *et al*., 2010). Due to its severe perishability, fish must be processed to some extent to preserve it, prolong its shelf life, and enable wider distribution as well as marketing prospects (FAO, 2016c). The method of preservation may include minimizing the temperature, applying heat treatment such as smoking, boiling and frying) to reduce the amount of water available for microbial attack and change the storage environment.

**Fish quality assessment**

A product's quality is not constant but varies according to the perspective of the consumer. The expectations of the consumer must be satisfied for a product to be considered to be of high quality. Quality lacks definite position in time and space, neither is it a physical entity. Thus, it is conveniently forgotten or ignored in literature regarding food science (Bremner, 2000). There is a major concern regarding fish and fishery products' quality in the world's fisheries sector (Teklemariam *et al*., 2015). To optimize fish value and boost the acceptability of its product, the quality must be preserved and the methods used in its assessment must be understood (FAO, 2013). Fundamentally,

assessment of the quality of fish is done to; prevent consumption of spoilt food, analyse the nutritional composition contained in food by looking for biological, physical and chemical dangers ass, as well as ultimately determine safety of the consumer (Huss *et al.*, 2004). Sensory and instrumental methods are both employed in fish safety assessment (Hassoun & Karoui, 2017).

In the fisheries industry, sensory evaluation is one of the most crucial techniques for determining quality (Moosavi-Nasab *et al*., 2019). Sensory evaluation of food is the methods used by science to measure and understand changes in the characteristics of food (the odour, the taste, tactile, appearance and aroma) by using the senses of humans (Sharif *et al*., 2017). When performed well, sensory methods are a quick and precise way of providing unique and specific information about the food product (Yang & Lee, 2019). Fish is among the commodities in which sensory evaluation can be applied in two (2) distinct ways but not exclusive approaches to measure sensory quality.

First, as part of national and international regulatory programs, specialists grade products during the production process to determine if they correspond to specific product requirements. Secondly, the study of fish and fishery products for a number of reasons including development of fish, the impacts of processing methods on fish quality and shelf life (York & Sereda, 1994).

Instrumental methods involve the usage or mechanical devices or instruments for a number of variables including fat content, moisture content, colour, degree of spoilage, pH, texture/firmness etc. Instrumental methods should provide the same results irrespective of where they are adopted whereas sensory evaluation is dependent on the personal assessment of the respondent to the fish being assessed. Instrumental methods are widely employed in

international trade which requires numerical limits. In comparison to instrumental methods, sensory methods are more likely to predict the consumer's response since they use the same senses that the consumer uses to determine whether a piece of fish is good to eat (Krishna, 2012). Compared to sensory approaches, instrumental methods may seem to be more objective and reliable, although this should not be the case (Lougovois & Kyrana, 2014). However, each test presents a set of drawbacks when used independently. To evaluate a fish quality, a combination of chemical, biological, and organoleptic studies would be the most effective method.

**Fish smoking**

Fish smoking involves the preservation of fish as a result of being exposed to smoke from smoldering plant materials or wood, and it involves salting, drying, heating, and a series of smoking procedures that take place in a smoking chamber (Codex alimentarius, 2016). Not only does fish smoking give the product a special taste, flavour, colour and aroma but prolongs its shelf life because of the drying, antibacterial also the antioxidant effects of smoke (Adeyeye, 2019). Ighodaro & Abolagba, (2010) stated that, fish smoking decreases the amount of water in fish to a degree that inhibits growth of spoilage microbes Compounds like aldehydes, carboxylic acid and phenols contained in smoke that is deposited on the fish also slow down rancidity development (Cieślik et al., 2018). Fish smoking preserves fish by reducing the amount of water in it and keeping protein value (Akinwumi, 2014). Denaturation of proteins occurs based on the extent of heating and temperature throughout the fish smoking process. Also, heating causes the characteristic features of protein structures or complexes to breakdown, exposing their reactive groups.

A number of proteins compounds are susceptible to quality and quantity changes when heated (Abraha et al., 2018). To create high-quality smoked fish products with consistent market demand and a gain for processors, good-quality raw materials are required (Asamoah, 2018). Depending on the smoke delivery system, the species of fish to be used for smoking, uses and the duration of storage (Alhassan et al., 2014), fish products can be wet or dry smoked. Both smoking methods are employed in affluent and developing countries, although these are out under regulated conditions in affluent countries compared to the ones listed as developing.

Wet smoking involves treating fish with smoke at a duration and temperature that does not produce considerable coagulation of the proteins in the flesh but does reduce water activity whereas the latter involves smoking fish at the right temperature and for the right amount of time to cause complete coagulation of the proteins in the flesh (Codex alimentarius, 2016). With respect to wet smoking, it produces a product with a shelf life of about 3 days and the time for smoking is around 1- 3 hrs with a percentage moisture of around 40%-50%. Hot smoking procedure produces a product with a shelf life of 9 month , about 18 hrs of smokinga smoking and moisture of about 10%-15% (Anon, 2007).

**Fish smoking in Ghana**

One of the popular traditional fish processing techniques used in the country to preserve the large amount of fish harvested during the season of glut is fish smoking (Sakyi *et al*., 2019). In Ghana, fish smoking as by other countries in Africa such as Nigeria is mostly carried out by women who live in coastal communities and at the margins of inland waterways (Adeyeye &

Oyewole, 2016). Due to its delicacy and flavour, Ghanaians prefer to consume fish in smoked form with about 70-80% of local fish consumption being smoked (Asiedu, Failler, et al., 2018). One of the major nations in West Africa, Ghana, consumes a lot of smoked fish and exports it to international markets (Failler *et al.*, 2014). In the fish smoking process, the wood used generates enough heat that lowers the amount of moisture , the chemicals in the fires contain chemicals that enhance the flavour and lengthen the shelf life of the fish (Sirra, 2000). Both frozen and fresh fish (imported and local) can be utilized in fish smoking with the frozen generally being used during the dry season (Entee, 2015d). If there are any scales on the fish when they are brought home, they are removed before being washed and placed on smoking trays. The smoker with the trays place on it is turned on, and the firewood is lighted to start burning. Occasionally, the trays may be switched around (bottom tray goes up, top tray down) to enhance equal distribution of ensure of heat. When smoking is finished, the trays are removed from the smoker so the fish can cool. Ankyin, Begyewoba, Papia, and Essia are the four main types of firewood utilized as a fuel source(Entee, 2015c)

**Quality and Safety Regulations of Fish Smoking**

In order to ensure food safety, regulations and fish food security, it is crucial to analyze changes in Ghana's smoked fishing industry as fish consumers become more conscious of fish safety issues. All imported smoked fish must comply to food safety regulations before they can be exported to international markets. An authorized Competent Authority (CA), either public or private organization in the country where the fish was smoked must conduct formal inspections of the smoked fish production chain and give a trustworthy Health

Certificate. Fish processing centers must receive approval from Competent Authority, Ghana Standards Authority (Failler *et al*., 2014). They ensure that operations are compliant with fish smoking safety rules and regulations (Asiedu *et al*., 2018).

**Fish smoking ovens**

Fish smoking in Ghana was done with a metal drum and cylindrical or rectangular smoking ovens constructed of clay or metal until the end of the 1960s. These ovens had a variety of issues, including being low capacity in terms of output ,inefficient with regard to fuel (Avega & Tibu, 2017) and frequent fish handling while smoking. The fish smokers suffered burns and excessive smoke exposure during the fish smoking process (Asamoah, 2018; Bomfeh *et al*., 2019). The drawbacks associated with the ovens resulted in the creation of Chokor oven. In partnership with the Food Research Institute of the Council of Scientific and Industrial Research (CSIR, Ghana), the Food and Agriculture Organization (FAO) of the United Nations created this oven in 1969. (UNDP/TCDC, 2001). The Chorkor oven takes its name from a little fishing community in Accra. It is cheap to make, easy to use in terms of monetary value, with high capacity, low firewood consumption and less smoking times as compared to the traditional ovens used before its development.

Based on the increase in the world population, the quantity of fish landed and advancement in knowledge, there was the need for the development of new ovens. According to (Ford et al., 2020), fish smoked with Chokor oven has been recorded to contain high levels of polycyclic aromatic compounds (PAH), a carcinogenic substance, the smoker uses a lot of fuel wood and generates high

amount of smoke in its operation. It does not meet the requirement of Energising Development (EnDev) of a potential 40% fuel savings (Okyere-Nyarko et al., 2015). The challenges posed by the Chorkor oven resulted in the creation of other improved fish smoking ovens such as Morrison oven, Association of Women for Environment Project (AWEP) oven, Tullow oven, KOSMOS oven FAO-Thiaroye Fish Processing Technology (FTT). These technologies did not solve these issues to enough satisfaction, this led to the creation of the Ahotor fish smoking oven.

The Ahotor, created and made available to fish smokers by SNV Netherlands Development Organisation Ghana, for use in August 2017 (Owusu, 2019), consists of a central combustion chamber attached to an exterior structure, with trays for processing of fish positioned on it as in a typical conventional fish smoker. A fat collecting tray is installed above the combustion chamber, allowing hot air to circulate around the fish while stopping fat that drips into the open fire. To ensure even heating and air circulation in the smoking chamber, the secondary air inlet, which is situated above the opening for fuelwood allows cool air to enter the chamber, mixing with the heat from the chamber. (Avega, 2015).

**Chorkor oven**

A number of ovens is used in fish smoking which forms the majority of fish processing in Ghana (Asiedu, Failler, et al., 2018). Chorkor oven is one of the common fish smoking technique used in Ghana (Owusu, 2019). This oven created and implemented in Ghana by the United Nation's Food and Agriculture Organization (FAO) in collaboration with the Council of Scientific and Industrial Research (CSIR, Ghana), Food Research Institute in 1969 (Wahaga,

2021). The oven named after Chorkor, a fishing community of the capital of the country, where the Chorkor oven first became popular following its development in the country. The Chorkor oven is usually built in rectangular shape with cement blocks ensuring that it has a large smoking chamber. It can either be built with only one combustion chamber or double chambered. The oven is built with a large front loading which allows enough firewood to be used during smoking and has a large opening on top where trays used in fish smoking rest on. There is no interlocking mechanism for the trays that rest on the combustion chamber. The oven is designed without a chimney and it holds about 8 trays with 0.95 $m^2$ a wire mesh surface area (Entee, 2015a). The oven has a dimension of 120 × 150 × 59cm (L × B × H) and a width of 13cm ( Asamoah *et al.*, 2021).

**Ahotor oven**

In August 2017, a new oven was created and made accessible to fish smokers in Ghana by SNV Netherlands Development Organisation Ghana (Owusu, 2019). To improve upon the Chorkor oven, the oven was developed. This oven was created to help solve issues such as low energy efficient, high amount of smoke generated during its operation and the low quality of its product among others posed by the traditional oven (Asamoah, 2019). According to (Avega & Tibu, 2017), the Ahotor oven comparatively produces much cleaner smoke in lower quantities and is 32% less fuel than the Chorkor oven. The Ahotor oven is constructed with concrete blocks and burnt bricks. The oven is mainly constructed with two combustion chambers attached to an exterior shell. The exterior shell is constructed with concrete blocks and the combustion chamber is constructed with burnt bricks. Above the chamber

where the combustion takes place is installed a tray to collect fat which separates the fish being smoked from getting direct contact with the fire. The fat collecting tray also prevents fat and other fluids such as blood that drips off from falling into the fire. CSIR *et al*., (2016) stated that, the PAH levels of fish increases when high amounts of fat and other fluids drop into the fire during fish smoking.

**Effects of smoking on fish quality**

Fish smoking presents a variety of effects that affect the quality of fish smoked. The major effects on fish has to do with the formation of colour, aroma, flavour and the enhancement in the shelf life of the smoked fish (Belichovska *et al*., 2019). The raw material used for fish smoking largely influences quality of the smoked fish product. Quality raw material utilized will results in a product of high quality ensuring a consistent market demand and good financial gains for the fish smoker (Cardinal et al., 2001). Smoking causes the final product to lose weight as a result of dehydration and the loss of lipids from the muscle of the fish. The weight loss is also dependent on the material used being lean or fat fish, the attributes of the finished product, the technique used for smoking, and the fish's size and shape (Arason et al., 2014). The pH of the fish's muscle reduces during smoking due to the loss of water, the intake of acid and the reaction involving phenols, carbonyl compounds and polyphenols from smoke and protein constituents. Smoke fish's shelf life varies depending on a variety of factors, such as the species of fish used, the amount of brimming, the degree of drying, the type of smoke used, the storage temperature, and the packaging and material.

**Polycyclic Aromatic Hydrocarbon in smoked fish**

PAHs are ubiquitous ecological carbon-based chemicals made of rings of benzene fused and clustered or linearly arranged (Abdel-Shafy & Mansour, 2016). As a result of environmental pollution of water bodies, the presence of PAHs in freshly caught fish or in smoked fish is due to the phenolic decomposition of biofuel with firewood. (Codex Alimentarius Commission, 2009). The United States Environmental Protection Agency (USEPA), the European Community (EC), the International Agency for Research on Cancer (IARC), and the Agency of Toxic Substances and Disease Register (ATSDR) have all listed PAHs as priority contaminants of health threats due to their disruptive and carcinogenic effects (Kafeelah *et al*., 2015). PAHs can be acquired in humans through direct contact with the skin, ingestion of the chemical or inhalation (Li *et al*., 2016).

**Atlantic Chub Mackerel (*Scomber colias)***

The middle-sized pelagic fish known as the Atlantic chub mackerel, *Scomber colias* (Allaya *et al*., 2016), is a member of the Genus Scomber and Family Scombridae. It has a wide distribution in eastern Atlantic moving from the Canary and Azores Islands to the Bay of Biscay. Their distribution coincides in the northeast Atlantic; however, *S. colias* also inhabits waters further south. The Atlantic chub mackerel produce offsprings in successive cycles such as annual or seasonal cycles, individuals of this species have one of at least two distinct sexes exhibits a reproductive strategy and it is oviparous like the majority of marine fish species of commercial importance. Up until recently, *S. japonicus* rather than *S. colias* has been used in all researches undertaken within the Atlantic, Mediterranean, and Black Seas. The presence of two different

species, *S. colias* in the Atlantic and *S. japonicus* in Indo-Pacific, however, is supported by morphological and genetic data (Infante et al., 2007). Atlantic chub mackerel is oily and has a rich, distinct flavor. It turns beige when cooked, from off-white. This fish has a soft and flaky texture. In addition to being a significant source of omega-3 fatty acids, it also contains selenium, niacin, vitamins B6 and B12. Atlantic chub mackerel can either be smoked whole, in the fillet form gutted with or without the head.

**Chapter Summary**

Literature on fisheries in Africa and particularly Ghana have been reviewed. Issues regarding post-harvest fish loss and some information on fish preservation were also reviewed in this chapter. Fish smoking as a preservation method, some of the traditional and improved technologies used in fish smoking and issues of fish spoilage were also reviewed in this chapter.

# CHAPTER THREE

# MATERIALS AND METHOD

This chapter provides an overview of the procedures used to carry out this study. The materials used as part of the methods are also described. The study sites are described extensively, while appropriate illustrations are provided, where needed, to give further clarifications on the methods employed.

**Sampling and selection of fish smoking centres**

Following a thorough reconnaissance survey of selected districts of the Coastal Savannah Zones of Ghana on the 14th and 15th November 2021 with staffs and fellow research colleagues of the Power to the Fishers Project, Winneba and Shama-Kesewokan, fishing communities were selected as sampling and smoking locations for this research. Their selection was based on the following criteria:

- These communities were focal communities of the European Union funded Power to the Fishers project, the project that partially funded this study
- This work involved a comparison of the quality of Chorkor (traditional oven) and Ahotor ovens (improved oven) smoked fish samples and both types of ovens can be found at these locations.
- Fish smoking is the major activity carried in these two communities and, hence the availability of experienced persons for this research.
- The selected communities have close proximity to large markets whose major activities involve buying and selling of smoked fish.

**Winneba**

Winneba is one of the numerous coastal communities along the shores of Ghana. The town is located 60 km west of Ghana's capital, Accra. Precisely, between 5° 20′ N and 0° 37′ W along Gulf of Guinea (Fig 1). Winneba is the Effutu Municipal District's capital with its history forming part of the rich history of Ghana. The name of the town is traditionally known as Simpa, adopted from the name of a one-time great leader of the town, "Osimpa". Winneba as of 2013 had a total population of approximately 60,331 with its main industries being fishing and services (Entee, 2015c). Winneba is located in Ghana's arid equatorial climate zone. There is inconsistency in precipitation patterns in the community.

The town experiences two major rainfall seasons. The bigger rainfall begins from April through July, whereas the smaller rainfall starts from the month of September ending in November. The average lowest temperature in the day is below 13 °C with high transportation of sediments to the shore during the season of high precipitation. Nonetheless, the air temperature exceeds 32 °C and sedimentation decreases during the dry season (Ankrah, 2018).

The town is prominent in fishing and it is one of the towns that hosts a major fishing port. There are three (3) landing sites in the town namely Ofunyiem, Warabeba and Yepemso. These sites serve as the main source of fish and it serves a number of fish processors within and beyond the community (Entee, 2015b). Occasionally, the fish processors travel to other areas specifically Tema harbour to purchase fish.

Fish smoking forms the majority of fish processing activities in the community and this is undertaken in individual homes (Entee, 2015b).

However, there is one fish smoking association in the community called Nsuekyir Warabeba Boafo Yenna Group (Entee, 2015b). Winneba is one of the communities where the Ahotor oven has been adopted and being used (Avega & Tibu, 2017).

**Shama-Kesewokan**

Major emphasis on the description area will be based on Shama district in which Shama-Kesewokan fishing community is part of. This is because fish smoked in this community serves the whole district. Shama-Kesewokan is one of the communities in the Shama district where the Ahotor oven has been adopted and being used (Affel & Smith, 2018).

Shama-Kesewokan, is a small fishing community located within Shama District found in the Western region of Ghana. Formerly a part of the Shama Ahanta East Metropolitan Assembly, the Shama district was separated in December 2007, becoming one of the 14 districts of Western Region. Locally called Esima, Shama district is found 15 km east of the Western Regional Capital, Sekondi. It lies between 5.0370° N, 1.6566° W, 1º 63’ E and 48º 40’W, on the global positioning system (Fig 1). The district is located in one of the nation's low-lying regions, with the majority of its territory having an elevation of less than 80 meters above sea level. With a mean annual rainfall of roughly 138mm, the district has two rainy seasons, occurring between May and July and between September and November.

As at 2021, the population of the district stood at 117,224 individuals of which 57,210 are males representing 48.80% and 60,104 representing 51.2% being females (Ghana Statistical Service, 2021). The district’s population constitutes 5.7% of the Western Regionals population.


**Figure 1***:* Map showing the study areas

**Fish sampling**

Atlantic Chub Mackerel (*Scomber colias*) was used as the sample in this research because it is the commonly smoked consumed fish in Ghana (Sakyi *et al*., 2019). In addition, *Scomber colias* is a very important small pelagic species landed in Ghana's artisanal fishery, next in abundance to the Sardinellas and anchovies (Lazar *et al*., 2018). It is usually wet-smoked leading to a product with a limited storage life due its high moisture and fat content, which promotes the growth of microorganisms and rancidification, respectively. The limited storage life of the fish was important to assess the effect of oven smoking type on the shelf life of the fish. Frozen fish obtained from cold stores instead of freshly caught fish from the sea was used in this research because Atlantic Chub Mackerel was out of season.

**Fish smoking**

A total of 230 fish *Scomber colias* specimens were purchased from a cold storage facility in Winneba on 23rd March, 2022 and transported to the Power to the Fishers Project- Fish Processing Centre, Winneba Community to be smoked. The smoking process and other pre-smoking steps were carried out based on the techniques traditionally used by the fish-smokers.

The frozen fish was thawed by placing the packs in bowls of water. The thawed fish were then washed, sorted and salt added to taste, after which they were laid on trays to drain the water, with enough spacing to prevent sticking and stacking of fish during smoking. Fish samples were smoked using the Chorkor and Ahotor ovens at each study site. *Petersianthus macrocarpus* firewood, locally called ‘‘Essia’’ was used for the smoking process in both ovens. The fish were wet smoked in both ovens. The smoking process took about 3 h although the smoking times were unequal for both ovens. It took approximately 85 min for the fish to be smoked using Chorkor oven while the smoking duration for Ahotor oven was about 120 min. Fish samples were allowed to cool at room temperature after smoking. After cooling the smoked fish were arranged in baskets, covered with brown paper, and sent to the Research Laboratory of the Department of Biochemistry, University of Cape Coast for storage and analysis of the samples.

A similar procedure was used in the smoking of fish at Shama-Kesewokan. In this case however, frozen fish were purchased from the Ave Maria cold store in Shama-Inchaban on 24th March, 2022. The pre-smoking steps as well as the smoking process was carried out at the Power to the Fishers Project- Fish Processing Centre, Kesewokan Community.

**Quality analysis of smoked fish**

To be able to assess the influence of oven type and smoking location on smoked fish quality, physicochemical and proximate parameters were measured and recorded for each fish sample. Additionally, sensory evaluation was conducted to assess consumer preferences for the fish samples. Both a hedonic-scale based consumer acceptability and flash profiling were carried out.

**Shelf life analysis of smoked fish**

Shelf life analysis was carried to be able to assess the influence of oven type and smoking location on storage life of the smoked fish. To do this, smoked fish sample from each oven method and smoking location, were divided into two portions. A first portion was stored in the refrigerator maintained at 4 °C, while the second portion was stored at ambient room temperature conditions. Sampling was carried periodically 24 h for the samples stored under ambient room temperature conditions and 48 h for the samples stored in the refrigerator to determine the influence of oven type, smoking method and temperature at storage on the physicochemical quality of the smoked fish. The measured physicochemical qualities include pH, Brix, colour and texture.

**Physicochemical analysis**

**Determination of pH and Brix**

About 10g of smoked fish was mixed with 10 ml of distilled water to determine the pH. The solution was then centrifuged for 10 minutes at a speed of 3000 g using an 800D Centrifuge (JACTERMAC, Germany). The pH of the clear solution was assessed using an InoLab 7310 pH meter. Triplicate determinations were for each sample (Ampofo-Asiama *et al*., 2020).

Droplets of the clear solution was also used in the determination of Brix. Using a Pasteur pipette, 3 drops of the clear solution were transferred to the prism of a refractometer to determine the Brix content. The Brix content was determined using ATAGO Refractometer model PR-101α (Brix 0~45%). Triplicate measures were made in all cases (Ampofo-Asiama & Quaye, 2019).

**Determination of colour and texture**

The colour of each smoked fish was measured using a GRAIGAR portable digital colour meter model CS-10 (8mm). The color was measured using the L*a*b* colorimetric system, where L* denotes lightness, a* denotes the coordinates of red and green, and b* denotes the coordinates of yellow/blue. The colour of the fish sample was measured at three different places namely, the posterior end, anterior end and midsection of the fish. The browning index of the smoked fish was estimated using the measured L*a*b* values (Ampofo-Asiama & Quaye, 2019).

The texture of the fish samples was determined with ALIYIQI texture meter TYD-2 (0~450mm). The texture of the samples was measured at three places on the fish; the anterior section, the mid-section and the posterior section (Ampofo-Asiama & Quaye, 2018).

**Proximate Composition**

Proximate composition of the smoked fish samples was assessed by analysing the moisture, lipid, protein, ash, fibre, dry matter, and carbohydrate content.

**Moisture content determination**

To determine the moisture content, about 10g of the smoked fish samples were weighed in clean crucibles pre-dried in an oven. Samples were then transferred

into an oven and heated at 105 °C for 24 h. To enhance equal distribution of heat, the crucibles were spread evenly across the base of the oven. After heating, samples were taken out of the oven and cooled using a desiccator after which the dry weights were measured. This was done in triplicate for each sample. The moisture content of fish samples was calculated as using equation 1;

$$\text{Percent moisture content} = \frac{Wi - Wf}{Wi} \times 100 \qquad (1)$$

where $W_i$ = Initial weight of sample, $W_f$ = Final weight of sample (AOAC, 2005).

**Determination of Fat**

The fat content of the samples was determined according to Holman *et al. (2019)* with some modifications. Approximately 10g of milled smoked fish sample was weighed into a Soxhlet extraction thimble measuring 50 mm × mm. The extraction thimble was transferred to a 50 ml capacity Soxhlet extractor which was fixed with a condenser. 150 ml of Petroleum ether was measured was added into a 250 ml round bottom flask. The round bottom flask was then connected to the Soxhlet extractor and then placed on a heating mantle (Msuku & Kapute, 2018). The Soxhlet extraction setup was connected to a water chamber containing cold water via the condenser. The setup was switched on and after some minutes, the petroleum ether in the round bottom flask started boiling at a temperature of 60 °C. The petroleum ether that evaporated through the distillation path while boiling was condensed back into the extraction thimble in the Soxhlet extractor, the condensed organic solvent dissolved the sample in the extraction thimble, extracted the fat in it and was siphoned back into the round bottom flask. The extraction continued for 4 h until all the fat in the sample had been extracted. After the 4 h of extraction, the setup was

switched off and the round bottom flask was taken off the heating mantle and dried with its content in an oven at 60 °C for 2 h. Afterwards, the round bottom flask was removed, cooled in a desiccator and weighed (Yaro *et al.*, 2018). The amount of fat in the samples were calculated in percentage using the following the formula;

$$(\%)\ \text{Fat} = \frac{Wf_{(g)}}{Ws_{(g)}} \times 100 \quad (2)$$

Where, $W_{f(g)}$ is the weight of fat, $W_{S(g)}$ is the weight of sample

The weight of the fat was deduced by deducting the round bottom flask's original weight from its final weight

Weight of lipid = $F_{f(g)} - F_{i(g)}$

**Determination of protein**

Food proteins are determined by the proportion of nitrogen concentration (Johnny *et al.*, 2020). The Kjeldahl method (Sáez-Plaza *et al.*, 2013) was adopted to ascertain the amount of protein in the smoked fish samples. This method comprises; digestion of fish samples, followed by neutralising or distillation and titration.

**Digestion**

4.4ml of digestion reagent was added to about 0.2 g of the smoked fish sample in a 100 ml Kjeldahl flask. Samples were digested at 360 °C for 2 h. Samples were transferred into a 50 ml volumetric flask after digestion.

**Distillation**

A 100 ml conical flask was filled with 5 ml boric acid indicator solution and placed underneath a condenser previously flushed distillation unit with the

tip of the condenser entirely submerged in the boric acid solution. The digested smoked fish sample was placed into the reaction chamber. About 10 ml of alkali mixture was added to start the distillation process. After the distillation process, 50 ml of the distillate was collected.

**Titration**

The collected distillate was further titrated 0.1 HCL solution until the solution changed colour from green to win red. Blank titration was done using the same procedure and its titre value subtracted from the smoked fish sample's titre value. The final titre value obtained was used to calculate the amount of nitrogen in the samples. The amount of nitrogen obtained was multiplied by a conversion factor of 6.25 to determine the percentage protein according to equation 3 and 4

$$\%\text{Total Nitrogen (\%N)} = \frac{(\text{Sample titre value} - \text{Blank titre value}) \times 0.1}{\text{sample weight}} \times 100 \quad (3)$$

$$\%\ \text{Protein} = \%N \times 6.25 \quad (4)$$

**Determination of ash**

About 10g of the smoked fish sample was dried in an oven set at 105 °C for an hour. The samples were then heated in a furnace set at 550 °C overnight. The resultant ash was taken out of the furnace, allowed to cool in a desiccator then weighed. The amount of ash collected was used to calculate the ash content as a percentage of the original sample according equation 5 below.

$$\%\ \text{Ash} = \frac{WA_{(g)} - W_s}{W_s} \times 100 \quad (5)$$

Where, $WA_{(g)}$ = Weight of ash, Ws = Weight of Sample

**Determination of crude fibre**

The crude fibre content of the samples was determined according to Luthfi *et al*. (2018) with some modifications. About 100ml of 1.25% sulphuric acid solution was added to 1g of smoked fish sample. The mixture was boiled for 30 min using a boiling flask. The mixture was filtered into a crucible and its residue was transferred back into the boiling flask after boiling. About 100ml of 1.25% NaOH solution was then added to the residue and boiled for 30 min. The mixture was once again filtered, and the residue washed with methanol and boiling water. The crucible which contained the filtrate was dried in at oven set at 105 °C overnight and weighed. The crucible was placed in a furnace set at 500 °C for about 4 h. The crucible was taken out of the furnace and was slowly cooled to room temperature in a desiccator and weighed. The percentage crude fibre content of the smoked fish sample was determined according to equation 6

$$\% \text{ Crude fibre} = \frac{\text{weight loss through ashing}}{\text{Sample weight}} \times 100 \qquad (6)$$

**Determination of dry matter and carbohydrate content**

Percentage dry matter was determined through calculation (Chukwu and Shaba, 2009). The percentage moisture content obtained was subtracted from 100%.

$$\text{Percentage dry matter} = 100\ \% - \text{Moisture}\%$$

Also, the percentage carbohydrate for each sample was determined by calculation. The sum of ash, protein, oil/ and crude fibre contents was deducted from 100% to give the percentage carbohydrate according to equation 6

$$\% \text{ Carbohydrate} = 100\ \% - (\%\text{ash} + \%\text{ protein} + \%\text{oil} + \%\text{ crude fibre}) \quad (6)$$

**Sensory evaluation**

Sensory evaluation for the samples was conducted in two different ways: Consumer preference and flash profiling (Folmer, 2017). Consumer preference was performed to assess the overall acceptability of the products while flash profiling was performed to assess the attributes of the different the samples.

**Consumer preference**

The colour, taste, aroma, texture, appearance and acceptability of each sample were assessed on a 7-point hedonic scale as described by (Mondo *et al*., 2020). The scale was classified as 1 = Dislike Extremely, 2 = Dislike, 3 = Dislike Slightly, 4 = Neither Like nor Dislike, 5 = Like Slightly, 6 = Like, 7 = Like Extremely (Ünlüsayın *et al*., 2007). These characteristics were assessed by an 80-member panelist to evaluate the overall acceptability of respective samples. The 80-member panelist are consumers of smoked fish who were sampled purposively on the criteria that they consume smoked fish more than 4 days a week. The panelist was each presented with a questionnaire containing the different characteristic of the sample and the hedonic scoring. Each member was also presented with each sample cut into pieces and in full as well as cookies to be eaten before each test to establish a baseline throughout sensory evaluation to make sure that perception is not changed due to residual sensations. The average value for the characteristic of each sample was calculated to assess the consumer preference of the individual sample.

**Flash Profiling**

The attributes of the smoked fish samples were evaluated by a 12-member panel according to He and Chung, (2019) with some modifications. The panelist generated a spectrum of characteristics based on the colour, taste, texture, aroma and appearance (Kizzie-Hayford *et al*., 2016). The panelist assessed the intensity of each attribute based on a scale of 1-10, where 1 represent the least intensity of a characteristic and 10 the highest.

**Fish Quality Indices**

**Determination of Peroxide Value**

To get a saturated solution of iodine for the peroxide value determination, 2ml of distilled water was measured into a test tube. Enough iodine crystal was added until the solution became saturated (Ritter *et al*., 2013).

**Preparation of stock solutions**

Potassium iodide solution was prepared by measuring 2 ml distilled water into a test tube and adding enough iodine crystal until the solution became saturated. Acetic acid–chloroform solution was prepared by mixing 90 ml acetic acid with 60 ml chloroform. Starch indicator solution (1 %) was prepared by heating 50 ml distilled water in a beaker on a heating mantle to boil and adding 0.5g starch. The mixture was stirred using a stirrer until the starch completely dissolved in the water. Sodium thiosulfate (0.01 N) was prepared by dissolving 0.25 g sodium thiosulfate in 80 ml distilled water. The obtained solution was transfer into a 100 ml volumetric flask and distilled water added to the mark (Saju *et al.,* 2022).

**Titration**

After extracting oil from the smoked fish using the Soxhlet apparatus, 0.5g of the oil was weighed in a 250 ml Erlenmeyer flask. , Acetic acid–chloroform solution (30 ml) was added to the oil sample, as well as 0.5 ml of potassium iodide solution (Bako *et al*., 2017) . The new solution was kept in the dark for 1 min with occasional shaking and 30 ml of distilled water added (Dermiş *et al*., 2012). Starch solution indicator (0.5 ml) was added and the solution changed colour to blue black and this was then titrated against 0.01 N sodium thiosulfate with vigorous shaking to release all the $I_2$ from the chloroform layer until the blue black colour completely disappeared (Amri et al., 2021). A blank titration was determined without the oil sample following same procedure. The peroxide value was expressed as millequivalent of peroxide oxygen per kg of sample (meq/kg) according to equation 7 (AOAC, 2005).

$$\text{Peroxide value} = \frac{T \times N \times 1000}{W_s} \qquad (7)$$

Where; T = Titre value of titrant (sodium thiosulfate), N = Normality of sodium thiosulfate, Ws = Weight of sample (oil)

$$I_2 + \text{starch} + 2Na_2S_2O_3(\text{blue}) \rightarrow 2NaI + \text{starch} + Na_2S_4O_6(\text{colourless}) \qquad (8)$$

**Determination of Total Volatile Basic Nitrogen**

Total volatile basic nitrogen value was determined by steam distillation method as described by Socaciu *et al.* (2021) with some modifications. About 10 g of the smoked fish sample was minced and then mixed with 90 ml of 0.6 M perchloric acid. The solution was then centrifuged using 800D Centrifuge

(JACTERMAC, GERMANY) at a speed of 3000 g for 10 min. After centrifugation, the clear solution was made alkaline by adding 50 ml of 30 % sodium hydroxide (NaOH) which was then distilled for 5 min. The distillate was then transferred into a conical flask with 50 ml of boric acid solution with a mixed indicator solution of 0.1 g each of methyl red and bromocresol green prepared with 100 ml of 95 % ethanol. The solution was then titrated with 0.01 M hydrochloric acid (HCl). A blank titration was determined without the smoked fish sample. The TVB-N value was measured and expressed as mg N/100 g fish muscle according to the consumption of hydrochloric acid. The concentration of TVB-N was calculated using equation 9.

$$\text{TVB−N (mg N/100 g fish sample)} = \frac{(V_f - V_0)\ x\ 0.1\ x\ 100}{W_s} \quad (9)$$

Where; $V_f$ is the volume (ml) of 0.01 N hydrochloric acid solution consumed during titration involving fish sample solution at endpoint, $V_0$ is the volume (ml) of 0.01 N hydrochloric acid solution consumed during blank at endpoint

$W_S$ is the weight of the fish sample.

**Determination of Histamine**

The histamine content of the smoked fish samples was determined following methods developed by Hardy and Smith, (1976). Extracts of fish samples were prepared by blending 10 g of fish with 100 ml of 2.5 % trichloroacetic acid (TCA) solution for 2 min. The resulting mixture was filtered to obtain the extracts. Using thin layer chromatography, the histamine content of the extracts was determined calorimetrically by coupling with a diazonium salt. As other components react with the diazonium salt, the histamine components of the extract were separated using an ion-exchange column.

A slurry of 1 g of Amberlite Resin in 10 ml 0.2 N buffer solution was poured into the chromatography column. An aliquot of 75 ml of the TCA extract was the neutralized to pH 7 with potassium hydroxide and added to the column. Other interfering substances were removed by washing with 150 ml of buffer solution and the absorbed histamine eluted with 25 ml 0.2 N hydrochloric acid. The absorption of histamine was measured at 495 nm using distilled water as a reference. Extracts with known aliquots of histamine content was also treated in the same procedure as standard. A calibration curve was then determined for the histamine absorption of the fish samples against the standard extract to determine the histamine content of the fish samples.

**Determination of Polycyclic Aromatic Hydrocarbon (PAH)**

The PAH contents of smoked fish samples were determined using a gas chromatography-mass spectrometry (GC/MS) as described by (Conde *et al*., 2004) with some modifications. Extracts of the fish samples were obtained by weighing 3 g of the samples into a 50 ml centrifuge tube. Acetonitrile (15 ml) was then added and vortexed for a minute and centrifuged at 4000 rpm for 5 min.

An aliquot (6 ml) of the acetonitrile layer was the transferred into a 15 ml centrifuge tube containing 150 mg Primary Secondary Amine (PSA), 150 mg C18 and 900 mg magnesium sulphate. The tube was closed and shook vigorously for 30 seconds and centrifuged at 4000 rpm for 5 min. The cleaned extract (4 ml) was then transferred into a round bottom flask while concentrating the filtrate below 40 °C on rotary evaporator to dryness. The filtrate was redissolved in 1 ml acetyl acetate and transferred into a 2 ml standard opening vial for quantification of the PAH content by GC-MS.

Polycyclic Aromatic Hydrocarbons were analyzed with Agilent 7890B Gas Chromatography GC equipped with Agilent Technologies GC sampler 80 (Agilent Technologies, Santa Clara, CA, USA). A micro syringe was used to deliver 2 ml of the concentrated sample into the column through a rubber septum. Following injection, the gas chromatography (GC) was set to the optimum temperature and operated normally. PAHs quantification were carried out by CLARITY-GC interfaced software.

The initial oven temperature was 70 °C for 2 min. The temperature was allowed to rise to 150 °C and finally held at 280 °C for 13.133 min. and the injector temperature for samples was 280 °C. After samples were injected, the temperature rose at a gradient rate of 8 °C/min. Helium was the carrier gas. Nitrogen was used as the collision gas. Septum purge was at 30 mL/min at 0.75 min at pressure of 27.5 psi. The segment start time was 4 min and ended at 45 min.

**Data Analysis**

Data analysis was conducted in Microsoft Excel (MS Excel) 2019 using "data analysis" and "real statistics" (Real Statistics Resource Pack software, Release 7.6) add-ins. Results of laboratory measurements and tests were recorded and arranged in MS Excel. Post hoc analysis for the physicochemical and proximate composition which had significant difference were computed using Statistical Package for Social Sciences software version 26. Prior to analysis, the data was tested for normality using Shapiro-wilks normality test.

**Evaluating the sensorial difference in quality of smoked fish**

The frequency of the responses per the responses were used to draw a bar chart to visualise the differences in consumer preference of fish samples for each parameter that was assessed. To determine whether there was a difference in responses for each of the parameters, a single factor analysis of variance (ANOVA) was used. Where the differences were significant, Tukey HSD post-hoc test was conducted to determine the differences in responses for pairwise comparison of each fish sample. To visualize the differences in the flash profiling results of the smoked fish samples, a principal component analysis was employed.

**Difference in physicochemical properties of smoked fish**

The average values of physicochemical properties of fish samples were recorded for each day. Using line charts, the trends of changes in physicochemical properties of the fish samples during the period of storage were visualised. This was done for storage at both room temperature and refrigeration temperature. Differences in the average values of each of the physicochemical parameters were investigated using a single factor ANOVA. Where the difference was significant, Tukey HSD post-hoc test was conducted to determine the differences in responses for pairwise comparison of each fish sample.

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**Differences in proximate composition of smoked fish**

Differences in proximate values between the fish samples smoked with the two ovens at each of the study sites were tested using one-way analysis of variance (ANOVA). Where the differences were significant, Tukey HSD post-hoc test was carried to determine the differences for pairwise comparison of the fish samples.

# CHAPTER FOUR

## RESULTS

The outcome of the research and the results of data analysis are outlined in this chapter. The findings are presented based on the categories of comparative assessments that were conducted on the fish samples smoked using the two oven types in each of the study sites. Findings are summarized in tables and graphs for visualizing the differences or similarities observed between the samples. Results of statistical tests are also presented where necessary.

### Quality indices

Quality indices determined to assess the quality of the fish samples include Peroxide Value (PV), Total Volatile Basic Nitrogen (TVB-N) and Histamine. In the two study sites, he Chorkor samples had a higher PV than the Ahotor samples (Table 1). PV values recorded for Winneba Ahotor and Winneba Chorkor samples were 10.09 meq/kg and 13.2 meq/kg respectively. PV value of 18.09 meq/kg was recorded in Shama Ahotor samples while a value of 30.71 was recorded for Shama Chorkor sample.

TVB-N values recorded in the Chorkor samples were higher than those recorded in the Ahotor samples at both study sites. A value of 31.6 mN/100g TVB-N was recorded for Winneba Ahotor samples, 42 mN/100g for the Winneba Chorkor samples. A value of 16.61 mN/100g and 10.28 mN/100g TVBN was recorded for the Shama Chorkor and Shama Ahotor samples respectively. Like the PV and TVB-N values, Histamine values recorded in samples smoked using Chorkor oven were higher than in Ahotor samples. Histamine values of 10.2mg/kg, 12.06mg/kg, 10.28 mg/kg and 16.61 mg/kg

were recorded for the Winneba Ahotor, Winneba Chorkor, Shama Ahotor, Shama Chorkor samples respectively (Table 1).

**Table 1:** ***Quality Indices of Fish Samples Smoked Using Two Kinds of Ovens in Two Fishing Communities in Ghana***

| Quality Indices | Winneba: Ahotor | Winneba: Chorkor | Shama Ahotor | Shama: Chorkor |
|---|---|---|---|---|
| Peroxide Value (meq/kg) | 10.09 | 13.2 | 18.09 | 30.71 |
| Total Volatile Basic Nitrogen (mN/100g) | 31.6 | 42 | 57.4 | 119 |
| Histamine (mg/kg) | 10.2 | 12.06 | 10.28 | 16.61 |

Values were determined once hence no statistical analysis was performed.

**PAH analysis**

A total of 16 PAHs were determined in the smoked fish samples using Chorkor oven and Ahotor oven at each study site. Table 2 presents the individual PAHs concentrations (µg/kg) determined in the smoked fish samples. The concentration of Benzo(a)anthracene in Winneba Chorkor sample recorded was 18.98 µg/kg with Winneba Ahotor samples recording 13.18 µg/kg while Shama Chorkor samples recorded 20.27 µg/kg and 12.77 µg/kg in Shama Ahotor (Table 2). The concentration of Chrysene (CHR) was 30.02 µg/kg, 25.31 µg/kg in Winneba Chorkor and Winneba Ahotor samples respectively. The concentration of Chrysene (CHR) recorded in Shama Chorkor sample (33.57 µg/kg) was higher than in Winneba Chorkor sample (30.02 µg/kg). The concentration of Chrysene (CHR) in Shama Ahotor sample (24.9 µg/kg) was lower than in Winneba Ahotor sample (25.31 µg/kg). The concentration of Benzo(a)pyrene (BAP) in Winneba Ahotor sample (12.27 µg/kg) was lower as compared to Winneba Chorkor sample (15.9 µg/kg). This was the same for Shama Ahotor sample (9.86 µg/kg) lower than Shama Chorkor sample (18.06 µg/kg). The concentration Benzo(b)fluoranthene was higher in Winneba Chorkor sample (19.9 µg/kg) than in Winneba Ahotor sample (14.21 µg/kg). Benzo(b)fluoranthene concentration in Shama Ahotor sample (15.29 µg/kg) was lower than in Shama Chorkor sample (21.36 µg/kg). The concentration of Benzo(a)pyrene in Ahotor oven in Winneba and Shama were different, its concentration in Winneba sample was higher than in Shama sample.

**Table 2:** ***Concentrations of PAHS (µg/kg) in Fish Samples Smoked Using Two Kinds of Ovens in Two Fishing Communities in Ghana***

| PAH (µg/kg) | Winneba: Chorkor | Winneba: Ahotor | Shama: Chorkor | Shama: Ahotor | EU MRL (µg/kg) |
|---|---|---|---|---|---|
| (NAP) Napthalene | 23.52 | 24.11 | 22.98 | 6.14 | |
| (ACA) Acenaphthylene | 50.7 | 37.35 | 52.39 | 11.52 | |
| (ACE) Acenaphthene | 2.95 | 14.52 | 3.26 | 17.22 | |
| (FLU) Fluorene | 33.6 | 23.77 | 35.29 | 7.18 | |
| (ANT) Anthracene | 34.32 | 27.21 | 27.7 | 10.47 | |
| (PHE) Phenanthrene | 70.04 | 58.54 | 70.64 | 31.35 | |
| (FLT) Fluorathene | 42.45 | 27.81 | 41.98 | 19.1 | |
| (PYR) Pyrene | 35.63 | 23.73 | 37.74 | 18.04 | |
| (BAA) Benzo(a)anthracene | 18.98 | 13.18 | 20.27 | 12.77 | |
| (CHR) Chrysene | 30.02 | 25.31 | 33.57 | 24.9 | |
| (BAP) Benzo(a)pyrene | 15.9 | 12.27 | 18.06 | 9.86 | |
| (BBF) Benzo(b)fluoranthene | 19.9 | 14.21 | 21.36 | 15.29 | |
| (BFK) Benzo(k)fluoranthene | 16.64 | 11.28 | 17.56 | 12.74 | |
| (IND) Indenol (1,2,3-c,d)pyrene | 12 | 7.09 | 11.45 | 7.55 | |
| (DAA) Dibenzo(a,h)anthracene | 2.45 | 2.61 | 3.61 | 4.61 | |
| (BGP) Benzo(g,h,i)perylene | 11.25 | 8.28 | 13.88 | 2.42 | |
| Total PAH | 420.35 | 331.27 | 431.74 | 211.16 | |
| Total (BAP) Benzo(a)pyrene | 15.9 | 12.27 | 18.06 | 9.86 | 2 |
| Total PAH4 | 82.46 | 63.07 | 90.55 | 62.79 | 12 |

Values were determined once hence no statistical analysis was performed on them.

PAH4 is the summation of (CHR) Chrysene, (BAP) Benzo(a)pyrene, (BBF) Benzo(b)fluoranthene and (BFK) Benzo(k)fluoranthene.

**Shelf life analysis**

Physicochemical parameters of fish samples measured in this study for the determination of shelf life included the pH, brix, and texture. These parameters were assessed for fish samples smoked using the two oven types (Chorkor and Ahotor) from each of the study sites stored at ambient temperature (25-30ºC) and refrigeration temperatures (4ºC). Parameters for the fish samples stored at ambient temperature were measured on daily basis until visible signs of spoilage were seen on the samples and those stored at refrigeration temperature measured every two days until visible signs of spoilage detected on them. Parameters for fish samples stored at ambient temperature were recorded for 3 days while that of fish samples stored at refrigeration temperature was recorded for 18 days.

**pH**

Generally, the pH of samples ranged between 5.0 and 6.5. These values fluctuated over the duration of measurement for fish samples stored at refrigeration temperature (4ºC) (Figure 2 A). Shama Ahotor samples recorded a lower pH compared to its initial pH on the 2nd and 4th day but increased after that. There was a decrease in the pH of Winneba Chorkor samples on the fourth (4th) day of storage. The pH of all the samples within the 18 days of storage were all within the range of 5.0 to 6.5. For samples stored at ambient temperature, pH increased with time but begun to decrease after a day of storage for Shama samples, and after 2 days for Winneba samples. pH recorded for Winneba Ahotor samples for the three days storage period at ambient temperature were all within 5.7 to 5.9 (Figure 2 B). pH of fish samples differed significantly between the two oven types from the study sites. pH of fish samples stored at ambient temperature were significant for all the days (day 0, 1, 2 and 3) of measurement. pH of fish samples stored at 4ºC was also significant for all the days of measurement except on day 14. Pairwise post-hoc test showed no significant difference between the pH of fish samples stored at refrigeration temperature ($p > 0.05$). A significant difference was however observed between Winneba Chorkor and Shama Ahotor samples ($p = 0.004$) as well as between Shama Chorkor and Shama Ahotor ($p = 0.0039$) fish samples stored at ambient temperature.

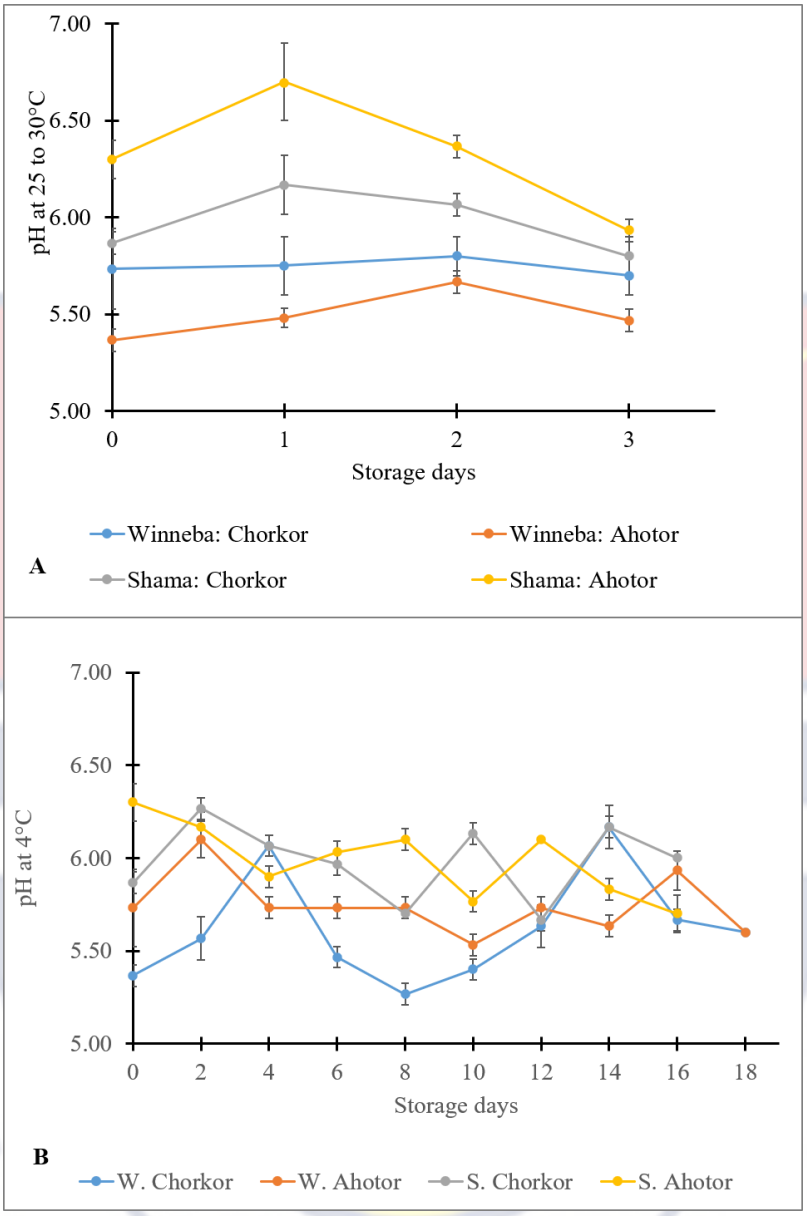


**Figure 2**: pH of fish samples from the two oven types from each of the study sites stored at refrigeration temperature (4ºC) (A) and at ambient temperature (25 - 30°C) (B).

**Brix**

Brix fluctuated with time with values of Winneba Ahotor, Winneba Chorkor and Shama Chokor decreasing after 14 days of storage at refrigeration (4ºC) (Figure 3 A). At ambient temperature, Brix of Shama samples decreased after a day of storage however Brix of Winneba Chorkor and Winneba Ahotor decreased and increased respectively after 2 days of storage (Figure 3 B). Generally, Brix of samples ranged between 1.5-2.5. The differences in Brix of samples were significant for storage at refrigeration temperature and at room temperature. A significant difference was also observed between Brix of fish samples stored at room temperature on each of the storage days. Similarly, Brix of fish samples stored at 4ºC was also significant for all the days of measurement. Post Hoc test however showed a significant difference only between Winneba Chorkor and Shama Chokor samples ($p$ = 0.0067) at 4 ºC and between the following; Winneba Ahotor and Shama Ahotor ($p$ = 0.005), Winneba Ahotor and Shama Chorkor ($p$ = 0.001) at room temperature.

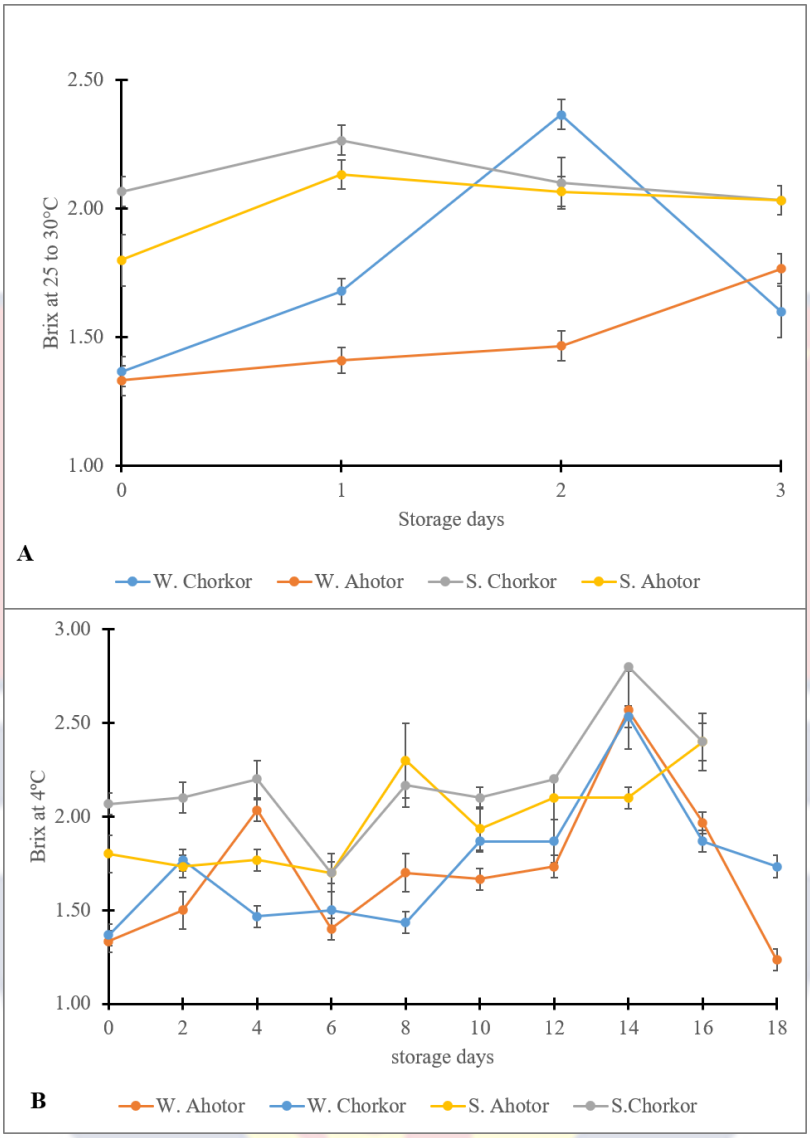


**Figure 3**: Brix of fish samples from the two oven types from each of the study sites stored at refrigeration temperature (4ºC) (A) and ambient temperature (25 - 30°C) (B).

**Texture**

The texture of all samples increased with time at room temperature except for Winneba Chorkor samples which decreased with time but increased after 2 days of storage (Figure 4 A). The differences in the texture of the fish samples were significant at both refrigeration temperature and room temperature. Pairwise post-hoc test however, showed significant differences in the texture of Winneba Ahotor and Winneba Chorkor ($p$ = 0.005), Winneba Ahotor and Shama Ahotor ($p$ = 0.003) and between Winneba Ahotor and Shama Chorkor ($p$ = 5.92 x $10^{-5}$) smoked fish samples at 4ºC. At room temperature (Figure 4 B), significant differences in texture were not observed between the samples.

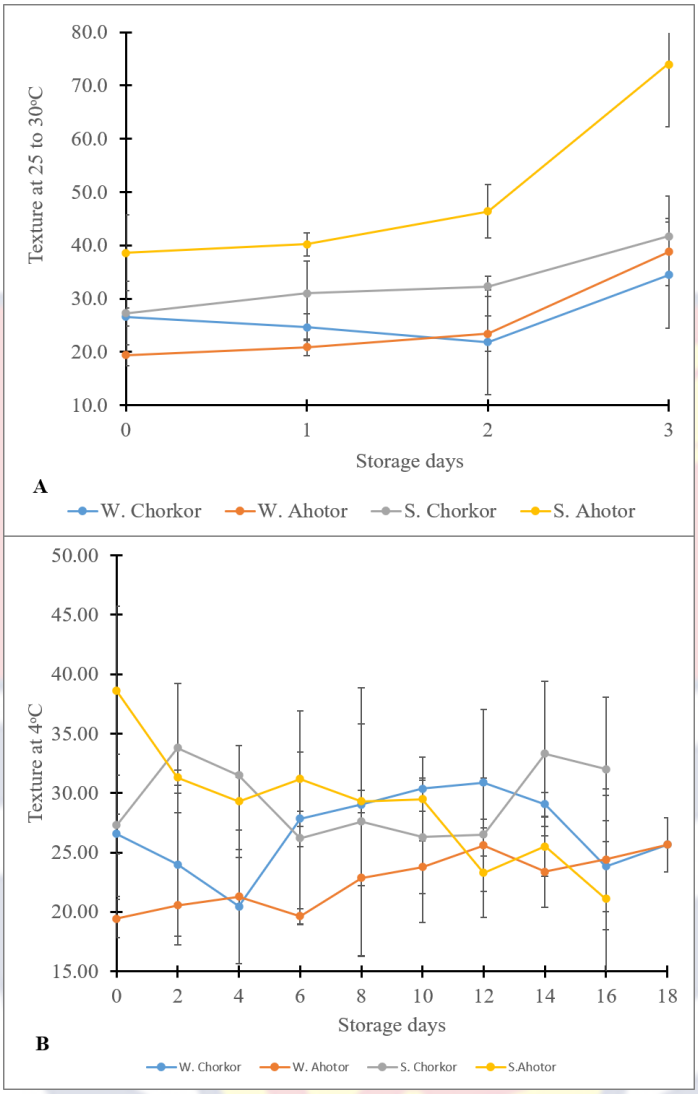


**Figure 4:** Texture of fish samples from the two oven types from each of the study sites stored at refrigeration temperature (4ºC) (A) and at ambient temperature (25 - 30°C) (B).

**Proximate composition**

The percentage moisture, protein, oil, dry matter, ash, fibre, as well as the carbohydrate contents were evaluated as proximate measures of the fish samples.

**Moisture Content**

It was observed that, the average moisture content of the Ahotor oven samples were relatively higher than that of the Chorkor samples in both study sites (Figure 5). There was a significant difference in the moisture content of the smoked fish samples. Post Hoc test showed a significant difference between Winneba Ahotor samples and Winneba Chorkor samples ($p$ = 0.001)) and between Winneba Chorkor samples and Shama Chorkor samples ($p = 0.023$).

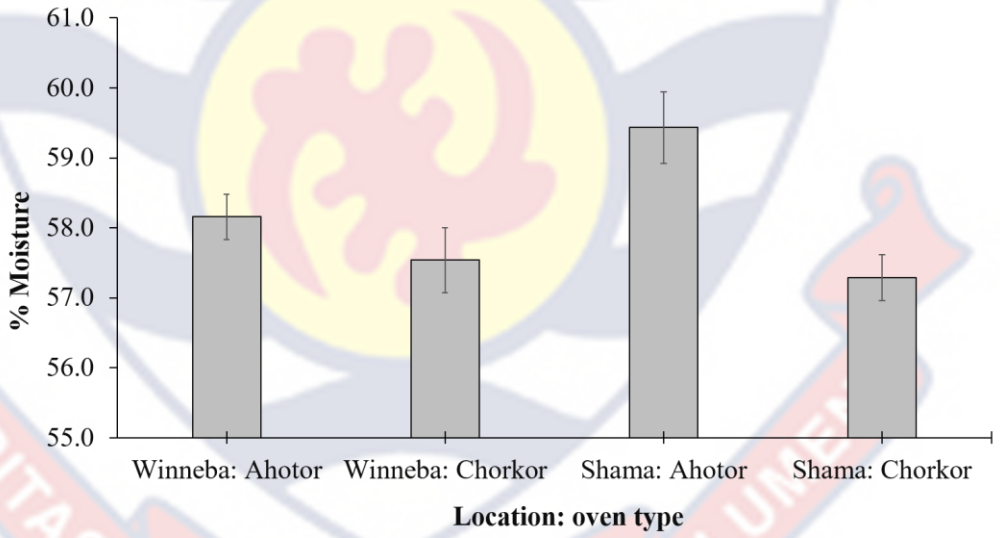


**Figure 5**: Percentage moisture (±SD) of fish smoked using the two ovens at the two study sites from two different study sites

**Protein Content**

The protein content of the fish samples also varied significantly between the two oven types. Samples from Shama recorded relatively higher protein content as compared to samples from Winneba (Figure 6). However, there was no significant difference between the protein content of samples from Shama. A significant difference in protein content was observed between the Winneba Ahotor and Shama Ahotor samples ($p = 0.001$).

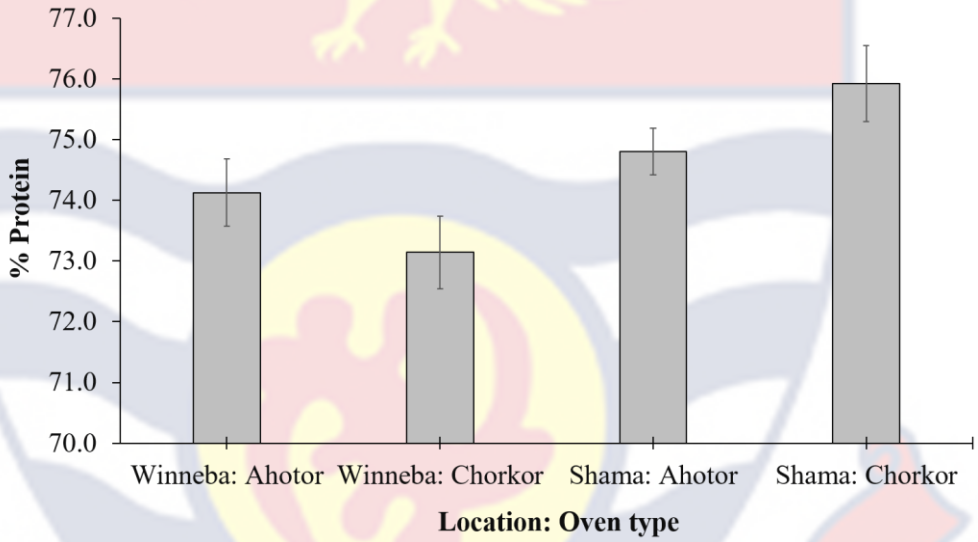


**Figure 6**: Percentage protein (±SD) of fish smoked using the two ovens at the two study sites from two different study sites

**Oil Content**

The oil content of the smoked fish samples showed significant variations. The oil content of samples from Winneba were significantly higher than samples from Shama (Figure 10). Pairwise comparisons of the samples after post hoc test showed significant differences between Winneba Ahotor and Shama Ahotor, and between Winneba Chorkor and Shama Chorkor. However, there was a significant different in the oil content of fish samples from Shama Ahotor and Shama Chorkor.

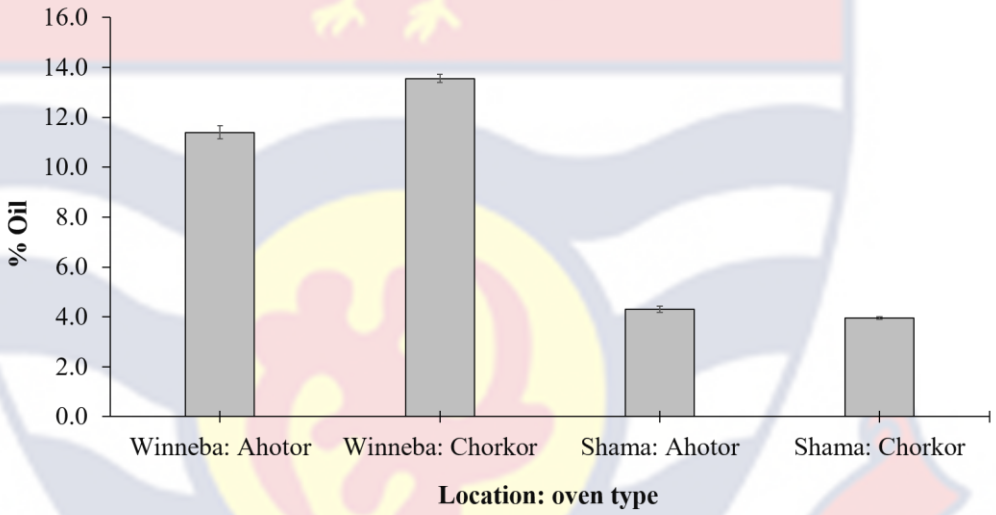


**Figure 7**: Percentage oil (±SD) of fish smoked using the two ovens at the two study sites from two different study sites

**Dry Matter, Fibre and Carbohydrate Contents**

The dry matter of fish samples smoked with the Chorkor oven were relatively higher as compared to samples smoked using the Ahotor Oven in both study sites (Figure 8, 9, 10). There was a significant difference in the dry matter content of fish samples from Winneba, and also among the Chorkor smoked. Unlike dry matter content, the fibre content of the Ahotor oven samples were relatively higher as compared to those smoked using Chorkor oven (Figure 4.2.5). However, there was no significant difference in percentage fibre of the samples. The carbohydrate content of the samples from Shama were relatively higher than the samples from Winneba (Figure 4.2.6). The difference in the carbohydrate was significant. There was a significant difference between samples Winneba Ahotor and Shama Ahotor, and between Winneba Chorkor and Shama Ahotor.

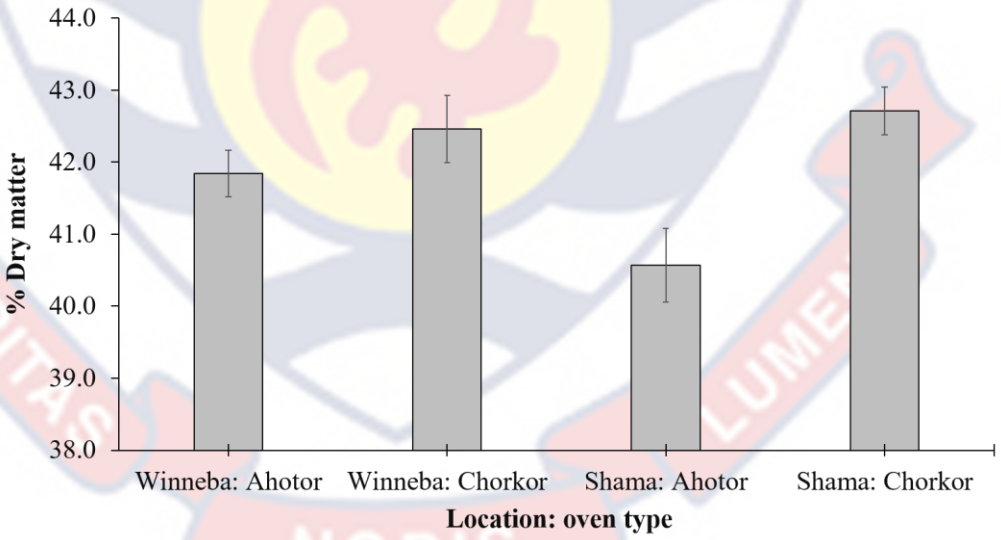


**Figure 8:** Percentage dry matter (±SD) of fish smoked using the two ovens at the two study sites from two different study sites

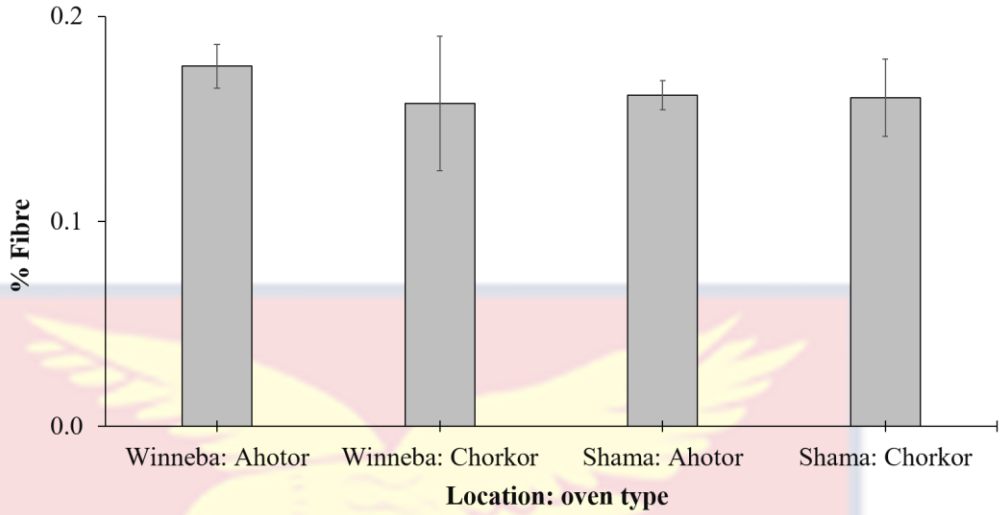


**Figure 9**: Percentage fibre (±SD) of fish smoked using the two ovens at the two study sites from two different study sites

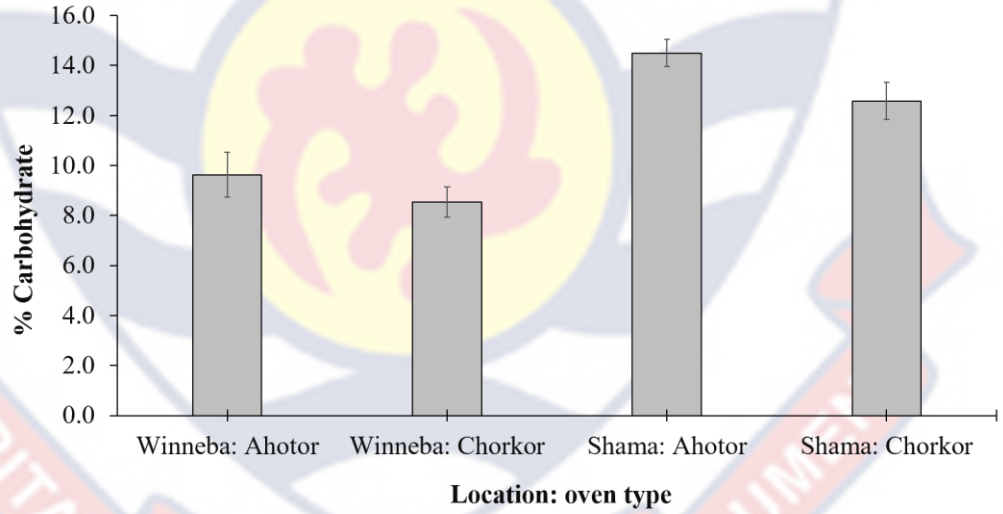


**Figure 10**: Percentage carbohydrate (±SD) of fish smoked using the two ovens are the two study sites from two different study sites

## Sensory Evaluation

### Consumer preference

To assess the preference of consumers, the colour, taste, aroma, texture, appearance and acceptability were evaluated by an 80-member panel. The average responses for each attribute were evaluated according to Asmara & Windasari, (2022) with some modifications.

### Aroma

The average responses of the consumers for the aroma of the fish samples showed higher preference for Shama Ahotor samples (5.74), followed by the Shama Chorkor samples (5.68) than for Winneba Ahotor (5.175) and Winneba Chorkor samples (5.09) (Figure 11). A significant difference ($p$ = 0.04) was observed between the responses of respondents in terms of the aroma of the smoked fish. Post-hoc test showed significant difference between the responses for Winneba Chorkor and Shama Ahotor samples ($p$ = 0.02) and between Winneba Chorkor and Shama Chorkor samples ($p$ = 0.04).

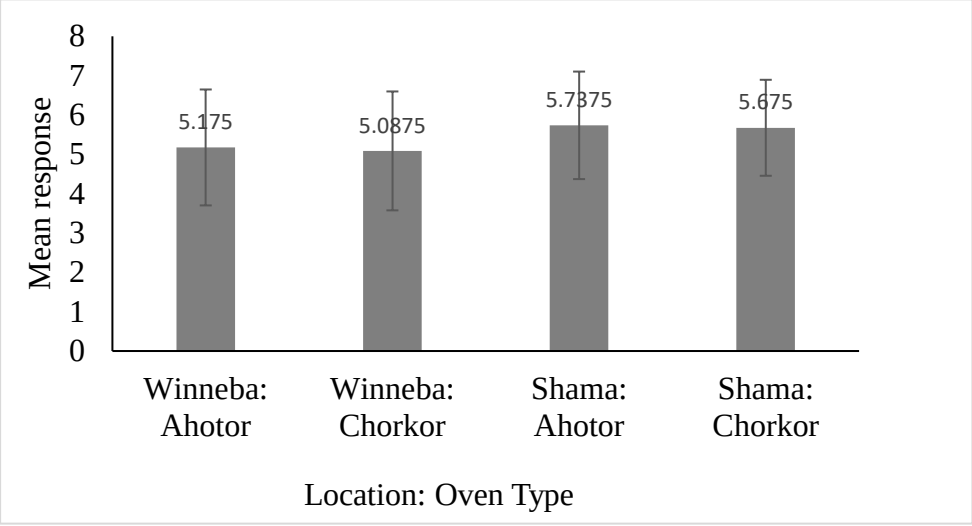


**Figure 11**: Mean response (±SD) indicating the consumer preference of the aroma of fish samples smoked using the two ovens at the two study sites

**Appearance**

The average responses for the appearance of the fish samples varied between the oven types at each study sites (Figure 12). Respondents preferred the appearance of samples smoked with Chorkor oven (5.61) more than those smoked in Ahotor oven (5.32) in Winneba. Respondents preferred the Shama samples smoked with Ahotor oven (5.51) more than fish smoked with Chorkor oven (5.39). However, the differences observed were not statistically significant ($p$ = 0.54).

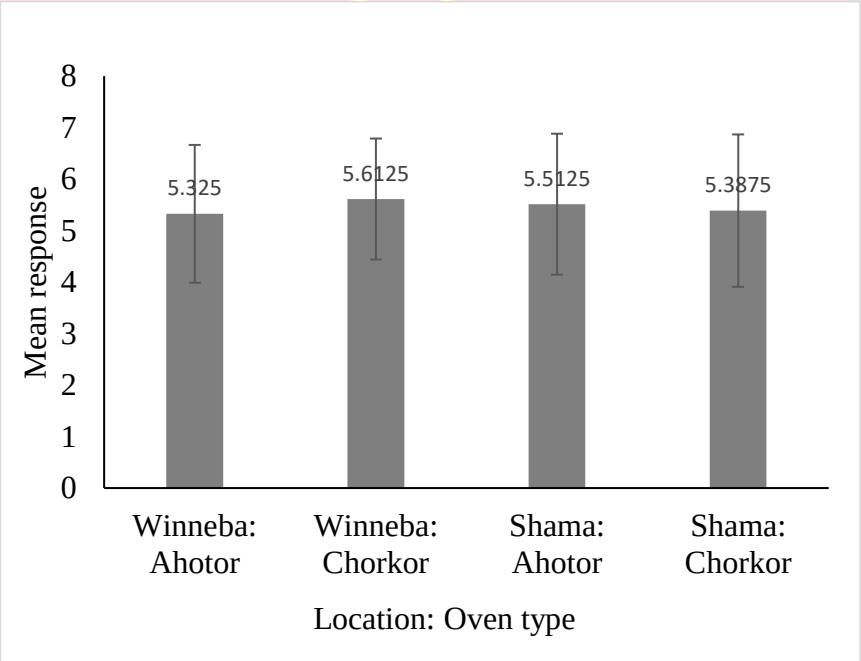


**Figure 12**: Mean response (±SD) indicating the consumer preference of the appearance of fish samples smoked using the two ovens at the two study sites

**Texture**

The preference of respondents to the texture of the fish samples varied significantly between the oven types from each of the study sites (Figure 13). Respondents on average preferred samples from Chorkor oven as compared to Ahotor oven from Winneba. This was the same situation for the samples smoked with Chorkor oven and Ahotor oven at Shama. A significant difference was observed between the texture of fish samples ($p$ = 0.01). After post-hoc test, a significant difference was found between Winneba Ahotor samples and Winneba Chorkor samples ($p$ = 0.03).

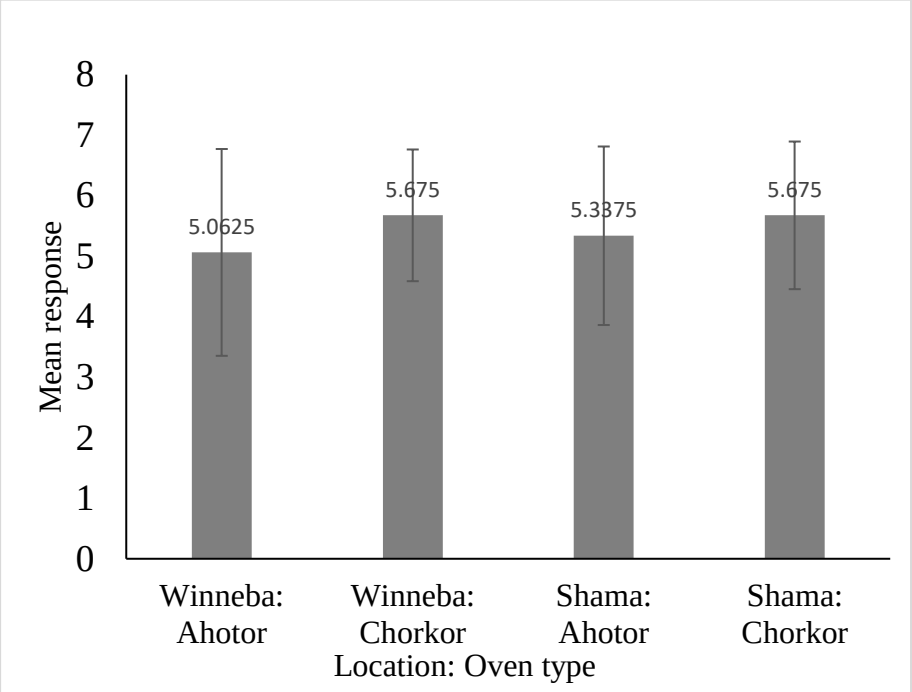


**Figure 13**: Mean response (±SD) indicating the consumer preferences of the texture of fish samples smoked using the two ovens at the two study sites

**Taste**

Responses for the taste of the fish samples varied between the oven types at each study site (Figure 14). Respondents preferred the appearance of samples smoked with Chorkor oven (5.49) more than those smoked in Ahotor oven (5.13) in Winneba, respondents preferred samples smoked with Chorkor oven (5.13) more than those smoked with Ahotor oven (5.49) at Shama. The differences in the responses were not significant ($p$ = 0.23).

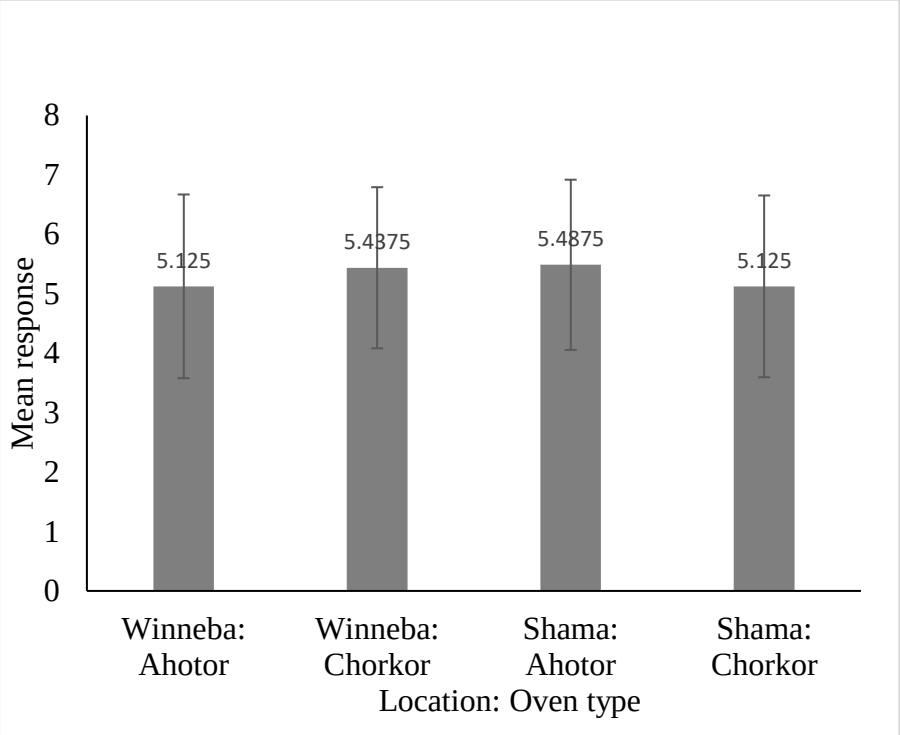


**Figure 14**: Mean response (±SD) indicating the consumer preference of the taste of fish samples smoked using the two ovens at the two study sites

**Acceptability**

The average responses of the respondents also showed higher acceptability of the Ahotor oven samples than the Chorkor samples (Figure 15). The average response of respondents pertaining the acceptability of Winneba Ahotor sample was 5.38, 5.75 for Winneba Chorkor samples, 5.8 for Shama Ahotor samples and 5.44 for Shama Chorkor samples, the difference was statistically significant ($p$ = 0.07).

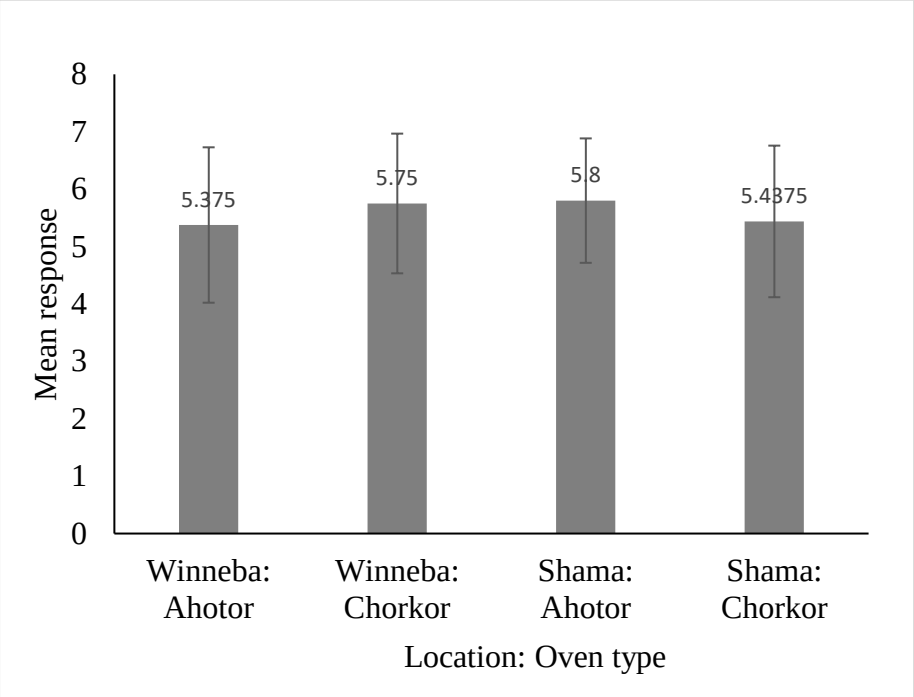


**Figure 15**: Mean response (±SD) indicating the consumer preferences of the acceptability of fish samples smoked using the two ovens at the two study sites

**Flash profiling**

In addition to the consumer preference conducted on the attributes of the fish samples, 12 panellists evaluated the colour taste, texture, aroma and appearance and generated 97 product attributes after evaluation for the fish samples. Different key attributes emerged for each sample evaluated. Key attributes for Winneba Chorkor samples were smoky, burnt, brown, dry and sour. Emerging attributes for Winneba Ahotor samples were soft, sour, oily and smoky. Similar attributes also emerged for Shama Ahotor samples, with musty, metallic, petroleum, bitter and burnt emerging as key attributes for Shama Chorkor samples.

Principal component analysis showed that Winneba Chorkor and Shama Chorkor samples were similar in attributes as compared to the other samples hence they were grouped together on the same axis of the graph (Figure 16). The Ahotor samples from both Winneba and Shama were group at the same side of the graph but they were not as close as the samples smoked with Chorkor oven at both study site.

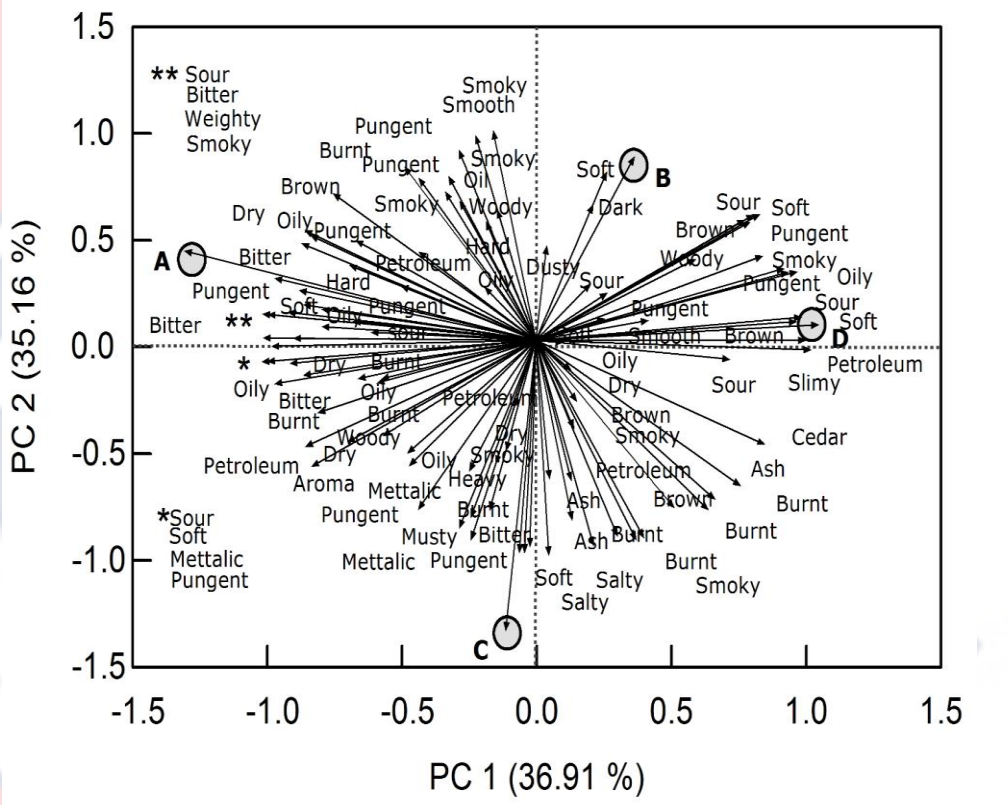


Figure 16: Principal component analysis showing the 97 product attributes generated for fish samples. A – Winneba: Chorkor, B – Winneba: Ahotor, C – Shama: Chorkor, D – Shama: Ahotor.

**Physicochemical analysis**

Physicochemical parameters of fish samples measured in this study included the pH, brix, colour and texture. These parameters were assessed for fish samples smoked using the two oven types (Chorkor and Ahotor) from each of the study sites (Winneba and Shama).

Shama Ahotor samples recorded the highest pH concentration followed by Winneba Ahotor samples, Shama Chorkor and Winneba Chorkor samples respectively. On average, the Ahotor samples recorded high pH values in both study sites. There was a significant difference in the pH of the samples.

The highest brix content was measured in Shama Chorkor samples, followed by Shama Ahotor samples, Winneba Chorkor samples while Winneba Ahotor samples recorded the least brix content. There was a significant difference in the brix content of the samples. A significant difference was found between Winneba Ahotor and Shama Ahotor samples, between Winneba Ahotor samples and Shama Chorkor samples, between Winneba Chorkor and Shama Ahotor samples and between Winneba Chorkor and Shama Chorkor samples after a post hoc test.

There was a variation in texture values measured between the two ovens at the two study sites. Shama Ahotor samples recorded higher texture value than the Shama Chorkor samples while higher texture value was recorded in Winneba Chorkor samples than Winneba Ahotor samples (Table 3). There was a significant difference in the texture of the fish samples. After a post hoc test, a significant difference was found between Winneba Ahotor and Shama Ahotor samples.

**Table 3:** ***Mean (±standard deviation) of Parameters Assessed for Physicochemical Analysis of Fish Samples from Two Kinds of Ovens in Two Fishing Communities in Ghana (* indicate significant difference between fish samples; values with same letters indicate significant difference after post-hoc test)***

| Parameter | Winneba: Ahotor | Winneba: Chorkor | Shama: Ahotor | Shama: Chorkor |
|---|---|---|---|---|
| pH* | $5.7 \pm 0.2^{ab}$ | $5.4 \pm 0.1^{acd}$ | $6.3 \pm 0.1^{bc}$ | $5.9 \pm 0.1^{d}$ |
| Brix* | $1.3 \pm 0.1^{ab}$ | $1.4 \pm 0.1^{cd}$ | $1.8 \pm 0.1^{ac}$ | $2.1 \pm 0.1^{bd}$ |
| Texture* | $19.4 \pm 2.0^{a}$ | $26.6 \pm 1.7$ | $32.8 \pm 1.8^{a}$ | $27.3 \pm 2.1$ |
| Browning Index | 192.3 | 210.0 | 203.7 | 226.8 |

# CHAPTER FIVE

## DISCUSSION

The reasons for the findings recorded in this study are presented in this chapter. Findings of this study are compared with published literature to ascertain similarities and differences between this study and other published works.

### Sensorial differences in quality of smoked fish from Chorkor and Ahotor oven.

Sensory analysis of food products is one of the fastest and easiest, yet reliable method of assessing the quality of food. The method uses the key human senses to assess the level of acceptance of food among consumers (Yu *et al.*, 2017). Several factors influence smoked fish's quality. These include; raw material, smoking technology, and the composition of smoke (Doe, 1998; Olukayode Amos & Paulina, 2017; Onyia *et a*l., 2011). Texture, flavour, colour and taste of fish samples play major roles in consumer acceptance of fish and are also influenced by chemical and enzymatic changes that take place during the smoking of fish as well as during fish spoilage (Arason, Nguyen, and Thorarinsdottir, 2014). As such, sensory analysis was conducted to assess consumer preference for fish samples smoked using the Ahotor and Chorkor ovens in Winneba and Shama.

Texture (Sutikno *et al*., 2019), aroma and colour (Nollet and Toldrá, 2009) among other attributes have been shown to influence consumers to either accept or reject a fish product. Findings of the study showed varying responses for consumer preference for colour, taste, aroma, texture, appearance and acceptability by the respondents.

The results of the study did not show clear differences between the sensory properties based on the consumer preferences of Ahotor smoked samples and Chorkor smoked samples however, it appears the study area had more influence on the sensorial properties of the fish samples rather than the oven type. Taking differences in consumer preferences at each study site, it was observed that using the same oven at the different sites did not reveal similar sensory properties for the fish samples.

Also, only texture showed significant differences between the two oven samples at each of the study sites. The similarities observed for the taste, aroma and appearance of the fish samples may be explained by the firewood used for the smoking of fish samples (Essia - *Petersianthus macrocarpus*). Differences in flavour, taste and aroma of smoked fish are mostly attributed to the different woods used for smoking because several volatile compounds are absorbed from the smoke by the fish samples (Rana *et al.*, 2021). The influence of firewood on the sensory properties of fish has been reported by other studies (Baten *et al*., 2020; Küçükgülmez *et al*., 2010; Mohibbullah *et al*., 2018).

The differences in texture of the fish samples however may be an indicator of possible effect of the influence of the oven types on the consumer preference of fish samples. The texture of fish, as shown by Oz *et al*. (2015) is important in determining consumer preference for fish products. Taking the texture of fish samples, it can be said that Chorkor ovens produce better samples than Ahotor oven. Texture of fish samples is affected by the amount of heat used during smoking. Akande *et al*. (2001) observed that the texture of smoked fish is greatly influenced by the loss of moisture and the denaturation of proteins. Chorkor ovens use more firewood and high heat as compared to the

Ahotor oven, hence the expectation was that the texture of the fish samples would be improved by the Ahotor oven but the preference of the respondents as shown in this study showed otherwise.

The differences in the overall acceptability of the Chorkor and Ahotor smoked fish was not significant. Perhaps, Ahotor oven does not improve the sensorial qualities of the fish samples as compared to the Chorkor oven. Results of flash profiling indicates that, when told what to look out for in the samples, respondents were able to distinguish samples smoked with Ahotor oven from Chorkor oven.

**Physicochemical Analysis of fish samples**

Physicochemical properties of fish are affected by changes that occur during fish processing techniques. Smoking requires the application of heat which causes changes in the physicochemical properties of fish samples (Abraha *et al*., 2018). pH of mackerel fish is known to decrease after death to values below 6.0 and a further decrease as time after death progresses (Sone *et al*., 2019). The goal of smoking therefore is to minimise rate of decline in pH of fish samples after death. As such, the measurement of pH can be used as an indicator of the quality of fish (Kayim & Can, 2010). The pH of fish samples in this study, were recorded below 6.5. Changes in pH of fish samples is due to post mortem changes that occur after death. Higher pH is however associated with high quality fish (Gregory *et al*., 1994). Specifically, a pH of about 6.2 or below at initial storage indicates higher nutritional quality (Abbas *et al*., 2008; Sutikno *et al*., 2019). The pH of samples smoked in Shama were relatively higher than pH of samples from Winneba irrespective of oven type.

Texture, just like all other attributes, is influenced by smoking. The water holding capacity of the fish muscle is decreased by smoking thereby causing it to lose its tenderness (Dhanapal *et al*., 2013). The texture of fish samples from Shama were not different from that of Winneba, indicating a similar influence of the oven types on the texture of the fish samples. Perhaps, the oven type has an influence on the texture of the fish samples however the processes of smoking at each of the study sites may have masked the effects.

Similar to the physicochemical properties of fish samples, Proximate composition, which quantifies the macromolecules of fish samples, has also been observed to undergo changes during fish processing, particularly with methods that use heat (Abraha *et al*., 2018). Proximate composition of fish samples recorded in this study differed from findings of other studies. Moisture content of fish samples recorded in this study was lower as compared to findings by (Stamatis & Arkoudelos, 2007), however higher values for protein, fat, and ash content were recorded in this study.

The moisture content of fish is known to be reduced by smoking due to the evaporation of water in fish samples caused by the use of higher temperatures (Magawata & Musa, 2015). In line with the moisture content, the dry matter of samples smoked with the Chorkor oven were higher as compared to samples smoked with the Ahotor oven. Although the design of Chorkor oven require the use of more firewood, as such more heat is produced as compared to the Ahotor oven which requires the use of little firewood and a partition that prevents fish samples from directly coming into contact with fire used for smoking, no effect of oven type was observed with respect to moisture content.

This shows that the oven type does not influence the amount of water loss in fish during smoking

According to Aliya *et al*. (2012), as moisture content decreases, protein content increases. Similar findings were made by Goulas & Kontominas (2005) who showed that smoking of fish results in the concentration of nutrients however, protein content of fish samples measured in this study did not show a similar relationship with corresponding moisture content. Despite reports on the significant effect of smoking on fish, the overall differences between the protein content of fish samples smoked with the Ahotor and Chorkor ovens was not significant, showing similar influence of the ovens on protein content.

The differences in ash content of fish samples were also significant but these differences were not distinct between samples of Ahotor and Chorkor oven. Significant differences were observed between Ahotor samples at Winneba and Shama. The inconsistency in the differences between the two oven types may be due to factors present at each of the study site rather than the oven. It has also been shown that differences in biological properties of fish samples may influence their ash content as shown in Gilthead sea bream (Bilgin *et al*., 2008). This may also explain the differences in the fat and carbohydrate content of the fish samples after smoking. Clear differences were not observed between the effects of the type of oven on these parameters. For fat content for instance, significant differences were observed between the oven types. Given that the design of the ovens is the same, differences could only arise if there are differences in the fish samples or there are variations introduced by the smoker.

Fish quality indices were assessed for each sample to ascertain the impact of the oven type used for fish smoking on the quality of fish samples

after smoking. Total volatile base nitrogen (TVBN), which evaluates the suitability of fish items for human consumption (Asamoah, 2018), were measured for each fish sample. According to an EU Directive (2008) and Özoğul & Özoğul (2000), the accepted limits for TVBN of smoked fish is 100 – 200 mg N/100g. From the results of the study, the TVBN of fish samples were below this limit after smoking, however, the TVBN of Shama Chorkor fish samples exceeded the acceptable limit. This raises concerns for the fitness of consumption of fish products smoked with the Chorkor oven at Shama. Given that TVBN of fish samples smoked with the Chorkor oven at Winneba were below the acceptable limits, it is possible there may be other location related factors that contributed to the high levels of TVBN of the fish samples. Overall, the TVBN values of fish samples smoked in Shama were higher than that smoked in Winneba.

The peroxide value (PV) determines the level of primary oxidation which has occurred in the lipids present in foods (Salaudeen, 2014). PV between 20 – 40 meq $0_2$/kg indicates presence of high oxidation and spoilage of a product (Daramola *et al*., 2007). PV of all fish samples were within the accepted limit after smoking. It must be noted that at each location, fish smoked with Chorkor ovens had values higher than fish smoked with Ahotor oven. Perhaps, if location specific factors are accounted for, the rate of spoilage of Ahotor samples, as indicated by their PV values, would be slower than Chorkor samples.

The presence of histamine in fish has potential toxicity on consumers and also serves as an indicator of the freshness of fish (Karovicova & Kohajoda, 2005). Histamine is produced during fish storage as such fish processing methods, storage mechanisms and duration of storage are important factors that

influence the presence of histamine in fish samples (Hungerford, 2021; McLauchlin *et al*., 2006). The histamine levels of fish samples from this study were however within the acceptable limits for consumption (100 mg/kg) (Pawul-Gruba *et al*., 2014), however the histamine levels in Chorkor samples were higher than Ahotor..

Polycyclic aromatic hydrocarbons of different types and concentrations were recorded in this study. The overall concentration of PAHs was higher in Chorkor oven samples than for Ahotor oven samples. Similar findings were also made by Asamoah (2019) who recorded higher concentrations of PAHs for fish samples smoked with Chorkor oven as compared to two other improved smoking ovens. Essumang *et al*. (2014) recorded higher levels of total PAHs in Chorkor smoked sardine, cigar minnows, tuna and mackerel using three different fuel sources (acacia, sugarcane bagasse and mangrove). PAH of fish samples recorded may be due to the use of wood for smoking. The presence of lignin in wood causes them to burn thereby releasing PAHs which is deposited in the fish samples. The use of the Chorkor oven requires the use of more firewood as compared to the Ahotor oven which requires the use of less firewood. This may explain the higher PAH concentrations in Chorkor samples as compared to Ahotor samples.

With respect to specific hydrocarbons, the maximum amount of benzo(a)pyrene allowed in smoked fish is 2 ug/kg (European Commission, 2011). Benzo(a)pyrene in all the smoked fish using both Chorkor and Ahotor oven at each other the study sites exceeded the maximum residual limit by the European Union. The higher concentration of benzo(a)pyrene in the samples smoke with Chorkor oven is in line with Essumang *et al*. (2012) and Nunoo *et*

*al*. (2019) who reported higher amount of benzo(a)pyrene (BAP) in fish smoked with traditional oven. The concentration of BAP in the Ahotor smoked samples were lower as compared to that of the Chorkor smoked samples, however, they were still higher than the maximum residual limit of 2 ug/kg by the European Union. This observation is in agreement with CSIR et al., (2016) who reported 5.9 µg/kg as the concentration of BAP for Ahotor smoked fish samples. The total concentration of PAH4 which is the addition of (BAA) Benzo(a)anthracene, (CHR) Chrysene, (BAP) Benzo(a)pyrene and (BBF) Benzo(b)fluoranthene in the Chorkor smoked samples was higher than the European Union maximum residua limit of 12 µg/kg at both study sites. This observation agrees with the findings of Nunoo *et al*. (2019) who observed higher PAH4 for fish smoked with traditional ovens. However, the concentration of PAH4 in Ahotor oven recorded at both study sites were above EU MRL. This agrees with findings of CSIR *et al*. (2016) who also recorded higher PAH4 than the EU MRL in fish smoked with Ahotor oven.

**Shelf life analysis of fish samples**

The shelf life of the fish samples was analyzed to determine the extent to which the quality of fish can be maintained after smoking with the two oven types. Smoking of fish samples affects the physicochemical properties of the fish (Abraha *et al*., 2018) and the extent of changes in the fish samples goes a long way to determine the extent to which the quality of the fish sample can be maintained. The method of fish storage of fish samples after smoking is also important in determining the shelf life of fish. Refrigeration for instance, slows the biological, chemical, and physical deterioration of food, degradation of food quality (colour, texture, lipid oxidation, enzymatic activity) (Dawson *et al*.,

2018; Zhu *et al*., 2021). As such, storage at cold temperature is preferred as a better storage of fish rather than storage at room temperature. The findings of this study showed that for samples stored at refrigeration temperature, shelf-life indicators could be recorded for each sample for about 3 weeks before observed signs of spoilage. Samples stored at ambient temperature had a relatively shorter shelf life of 3 days before signs of spoilage was observed. These observations were the same for both samples smoked with Chorkor oven and Ahotor oven.

Despite the differences in chemical and biological process that take place in storage of fish at ambient temperature and refrigeration temperature, clear differences in physicochemical properties between the different were not observed in this study.

pH of fish samples was recorded for storage at ambient temperature and at refrigeration temperature. pH of mackerel fish is known to decrease after death to values below 6.0 and a further decrease as time after death progresses (Sone *et al*., 2019). Similar observations were made in this study when fish samples were stored at room temperature but at refrigeration temperature, not all samples decreased over time. The overall decline in pH of the samples could be associated with post mortem changes that occur in fish after death (Sone et al., 2019). According to Gregory *et al*. (1994), higher pH is associated with shorter shelf life but quality fish. Specifically, a pH of about 6.2 or below at initial storage stages indicates higher nutritional quality (Abbas *et al*., 2008; Sutikno *et al*., 2019). Differences in pH of fish samples stored at ambient temperature may be due to the methods used in the smoking process at the two study sites rather than the type of oven used for smoking.

Even though differences were observed between the effect of the oven type on the Brix content, these differences were not significant. Significant differences were between the study sites rather than within a study site suggesting that method of smoking may have contributed to the differences. Texture, just like all other attributes, is influenced by smoking. Smoking decreases the water holding capacity of the fish muscle thereby causing it to lose its tenderness (Dhanapal *et al*., 2013). The texture of fish samples from Shama recorded higher values as compared to fish samples from Winneba however the differences were not significant for samples stored at ambient temperature indicating a similar influence of the oven types on the texture of the fish samples. At refrigeration temperature however, the change in texture was significant between samples smoked using Ahotor oven at the different study sites but the Chorkor oven showed a similar effect on the texture of the fish samples from the two study sites.

# CHAPTER SIX

# SUMMARY, CONCLUSION, RECOMMENDATION

## Summary

This research aimed to comparatively assess the quality and the shelf-life of fish smoked using Chorkor oven and Ahotor oven. Fish were smoked using both smoking technologies and later collected and transported to the laboratory for further analysis. To carry out fish quality analysis, sensory evaluation, physicochemical parameters, proximate composition, peroxide value, total volatile basic nitrogen, histamine and polycyclic aromatic hydrocarbon were analyzed. To perform shelf-life analysis, the smoked samples from each sampling sites were stored at two different temperature conditions; at ambient temperature (25 – 30℃) and refrigeration temperature (4℃). One portion of the samples smoked with Chokor oven and Ahotor oven at each study site was stored in a refrigerator whose temperature was maintained at 4°C. Observations were recorded at a 2-day interval for the samples that were stored in refrigeration temperature and at a 24-hour interval for the samples that were stored under ambient temperature conditions. pH, brix, colour and texture were the sampled parameters until visible signs of spoilage were detected on the fish samples.

From the results obtained, it was generally found out that the differences in both quality and shelf life of fish samples smoked with traditional (Chorkor) oven and those smoked with improved (Ahotor) oven were not statistically significant. Nevertheless, a number of quality parameters such as PAHs which have health implications on both consumers and processors, were slightly lower in samples smoked with Ahotor oven than those smoked with Chorkor oven.

This indicates that Ahotor ovens are comparatively better than Chorkor ovens on a number of aspects and their usage by the fishing communities should be encouraged.

**Conclusion**

Several indicators were measured and evaluated between Chorkor oven smoked and Ahotor oven smoked fish samples to compare the differences in the fish's quality and shelf life of samples smoked using these two ovens. These indicators included sensory analysis, physicochemical properties of the samples and their proximate composition as well as the Total Volatile Base Nitrogen, Histamine and Polycyclic Aromatic Hydrocarbons present in the fish samples produced by the Chorkor and Ahotor oven.

There was no statistical difference in the quality and shelf life between Chorkor smoked fish samples and the Ahotor smoked fish samples for most of the indicators that were assessed. Few indicators did show a distinction between the properties of fish smoked by the two ovens. For sensory analysis, a clear preference for the acceptance and taste of Ahotor smoked fish samples was observed but the difference was not significant. For proximate analysis, the differences in moisture content and dry matter were clear between the Ahotor oven and Chorkor oven and it was observed that the Chorkor oven caused a greater reduction of the moisture content of the fish samples thereby leading to an increased dry matter.

For fish quality indices, the TVB-N and PV values as well as histamine values recorded were within acceptable limits for the two ovens, however, the values recorded for the samples smoked with Chorkor oven were higher than those smoked with Ahotor oven. Although the PAHs of Chorkor smoked fish

samples were higher than that of the samples smoked with Ahotor oven, they were both above the acceptable limits set by the European Union.

Based on these findings, it can be concluded that;

1. Fish smoked using the two oven types are similar in their sensory properties and this may not influence consumer purchase or perception about the fish products.

2. There is no clear difference between the physicochemical properties and the proximate composition of fish samples smoked with the two oven types.

3. Ahotor oven may however produce more quality fish than Chorkor oven due to the reduced levels of Histamine, PAH, TVB-N and PV of the fish samples.

4. There may be other factors that could have contributed to the observed differences in the quality of fish samples rather than the oven type that was used. It is possible that even though the design of the oven types is not the same, the process of smoking at different locations may contribute to the quality and the duration of the shelf life of the fish samples in terms on the parameters measured.

**Recommendation**

Based on results obtained in this study, it is recommended that

Further studies should be carried out using different fish species and at more fish smoking locations to offset the effect of the type of raw material on the quality and shelf life of fish smoked using Chorkor oven and Ahotor oven.

The findings of this study showed that using the same oven at different locations produced different results, therefore, there is the need for introduction and implementation of standard practices that should guide fish smoking.

## REFERENCES

Abbas, K. A., Mohamed, A., Jamilah, B., & Ebrahimian, M. (2008). A review on correlations between fish freshness and pH during cold storage. *American Journal of Biochemistry and Biotechnology*, *4*(4), 416–421. https://doi.org/10.3844/ajbbsp.2008.416.421

Abdel-Shafy, H. I., & Mansour, M. S. M. (2016). A review on polycyclic aromatic hydrocarbons: Source, environmental impact, effect on human health and remediation. *Egyptian Journal of Petroleum*, *25*(1), 107–123. https://doi.org/10.1016/j.ejpe.2015.03.011

Abraha, B., Admassu, H., Mahmud, A., Tsighe, N., Shui, X. W., & Fang, Y. (2018). Effect of processing methods on nutritional and physico-chemical composition of fish: a review. *MOJ Food Processing & Technology*, *6*(4), 376–382. https://doi.org/10.15406/mojfpt.2018.06.00191

Adei, D., Braimah, I., & Mensah, J. V. (2019). Occupational Health and Safety Practices Among Fish Processors in Kumasi Metropolitan Area. Ghana. *Occupational Health Science*, *3*(1), 83–102. https://doi.org/10.1007/s41542-019-00038-0

Adeyeye, S. A. O. (2019). Smoking of fish: a critical review. *Journal of Culinary Science and Technology*, *17*(6), 559–575. https://doi.org/10.1080/15428052.2018.1495590

Adeyeye, S. A. O., Fayemi, O. E., & Adebayo-Oyetoro, A. O. (2019). Amino acid, vitamin and mineral profiles of smoked fish as affected by smoking methods and fish types. *Journal of Culinary Science and Technology*, *17*(3), 195–208. https://doi.org/10.1080/15428052.2017.1418693

Adeyeye, S. A. O., & Oyewole, O. B. (2016). An Overview of Traditional Fish Smoking In Africa An Overview of Traditional Fish Smoking In Africa. *Journal of Culinary Science & Technology*, *14*(3), 198–215. https://doi.org/10.1080/15428052.2015.1102785

Affel, R., & Smith, N. (2018). Training on the Use and Maintenance Of New Improved Oven. *The USAID/Ghana Sustainable Fisheries Management Project (SFMP). Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island*, 20.

Aheto, D. W., Adinortey, C. A. Essumang, D. K., Adjei, J., Ahadzi, E., Kwarteng, E., & Avega, B. (2017). Microbiological and polycyclic aromatic hydrocarbons (PAHs) analysis of fish from selected areas from central and western regions of Ghana. *The USAID/Ghana Sustainable Fisheries Management Project (SFMP).*

Akande, G. R., Ajayi, A. A., Ogunweno, C., & Ash, M. T. (2001). *Comparative proximate composition, physical and sensory evaluation of fish smoked with sawdust and firewood using improved Chorkor oven*.

Akinneye, J. O., Amoo, I. A., & Bakare, O. O. (2010). *Effect of drying methods on the chemical composition of three species of fish ( Bonga spp ., Sardinella spp . and Heterotis niloticus )*. *9*(28), 4369–4373.

Akintola, A. J., & Lawal, O. (2011). Biochemical factors involved in the resistance of some smoked tropical fish samples to insect attack. *Turkish Journal of Biology*, *35*(1), 89–93. https://doi.org/10.3906/biy-0810-8

Akinwumi, F. O. (2014). Effects of Smoking and Freezing on the Nutritive Value of African Mud Catfish, Clarias gariepinus Burchell, 1822. *Journal of Agricultural Science*, *6*(11), 143–149. https://doi.org/10.5539/jas.v6n

11p143

Akpambang, V. O. E., Purcaro, G., Lajide, L., Amoo, I. A., Conte, L. S., Moret, S., Purcaro, G., Lajide, L., Amoo, I. A., & Conte, L. S. (2009). *Determination of polycyclic aromatic hydrocarbons ( PAHs ) in commonly consumed Nigerian smoked / grilled fish and meat*. *0049*. https://doi.org/10.1080/02652030902855406

Alhassan, E., Boateng, V., & Ndaigo, C. (2014). Smoked and frozen fish consumption and marketing channels in the Tamale Metropolis of Ghana. *Ghana Journal of Developement Studies*, 21.

Aliya, G., Humaid, K., Nasser, A., Sami, G., Aziz, K., Nashwa, M., & Ponnerassery, S. S. (2012). Effect of the freshness of starting material on the final productquality of dried salted shark. *Advanced Journal of Food Science and Technology*, *4*(2), 60–63.

Allaya, H., Faleh, A. Ben, Rebaya, M., Zrelli, S., Hajjej, G., Hattour, A., Quignard, J. P., & Trabelsi, M. (2016). Identification of Atlantic chub mackerel Scomber colias population through the analysis of body shape in Tunisian waters. *Cahiers de Biologie Marine*, *57*(3), 195–207.

Ames, G. R. (1990). The kinds and levels of post-harvest losses in African inland fisheries. *Proceedings of the Symposium on Post-Harvest Fish Technology*, 1–10.

Ampofo-Asiama, J., & Quaye, B. (2018). The Effect of Pasteurisation on the Microbiological and Nutritional Quality of Soursop (Annona muricata L.) Juice. *Asian Food Science Journal*, *6*(3), 1–8. https://doi.org/10.9734/afsj/2019/45610

Ampofo-Asiama, J., & Quaye, B. (2019). Effect of storage temperature on the physicochemical, nutritional and microbiological quality of pasteurised soursop (Annona muricata L.) Juice. *African Journal of Food Science*, *13*(2), 38–47. https://doi.org/10.5897/ajfs2018.1767

Ampofo-Asiama, J., Zebede, A. A., Abakah, B., & Quaye, B. (2020). Effect of Different Processing Methods on the Quality of Ackee Fruit Arils. *European Journal of Nutrition & Food Safety*, *12*(2), 79–84. https://doi.org/10.9734/ejnfs/2020/v12i230195

Amri, U., Diharmi, A., & Sukmiwati, M. (2021). Characteristics of catfish oil, red palm oil and shark liver oil as functional foods. *Depik*, *10*(2), 151–160. https://doi.org/10.13170/depik.10.2.19131

Ankrah, J. (2018). Climate change impacts and coastal livelihoods; an analysis of fishers of coastal Winneba, Ghana. *Ocean and Coastal Management*, *161*(April), 141–146. https://doi.org/10.1016/j.ocecoaman.2018.04.029

Anon. (2007). *A summary of fisheries statistics in Ghana*.

AOAC. (2005). *Official Methods of Analysis* (18th ed.). Association of Official Analytical Chemist International.

Arason, S., Nguyen, M. Van, & Thorarinsdottir, K. A. (2014). Preservation of Fish by Curing. In I. S. Boziaris (Ed.), *Seafood Processing; Technology, Quality and Safety* (1st ed., pp. 129–160). John Wiley & Sons. Ltd.

Asamoah, E. (2018). The quality and shelf life of Atlantic mackerel (Scomber scombrus) as influenced by smoking technology, packaging material and storage temperature. Nations University Fisheries Training Programme, Iceland [final project]. *Nations University Fisheries Training Programme, Iceland [Final Project]*.

http://www.unuftp.is/static/fellows/document/eunice16cprf.pdf

Asamoah, E. K. (2019). *Assessing the Efficiency of Two Improved Lesser Known Kilns and Their Effect on the Quality and Shelf Life of Smoked Fish in Ghana* (Issue 10085118). http://ugspace.ug.edu.gh

Asamoah, E. K., Nunoo, F. K. E., Addo, S., Nyarko, J. O., & Hyldig, G. (2021). Polycyclic aromatic hydrocarbons (PAHs) in fish smoked using traditional and improved kilns: Levels and human health risk implications through dietary exposure in Ghana. *Food Control*, *121*(August 2020), 107576. https://doi.org/10.1016/j.foodcont.2020.107576

Asiedu, B., Afriyie, G., & Amponsah, S. K. K. (2018). Overview of Marine Stock Enhancement, Restocking and Sea Ranching in Ghana. *Public Management and Administration*. https://doi.org/10.5772/intechopen.79454

Asiedu, B., Failler, P., & Beygens, Y. (2018). Ensuring food security: An analysis of the industrial smoking fishery sector of Ghana. *Agriculture and Food Security*, *7*(1), 1–11. https://doi.org/10.1186/s40066-018-0187-z

Asmara, S., & Windasari, P. (2022). *Effect of Amount and Type of Fuel on The Smoked Fish Quality*. *01*(02), 77–84.

Assan, D., Akongyuure, D, N., Abarike, E, D., & Guangli, L. (2019). Assessment of Post- Harvest Fish Losses at the Landıng Site and during Transportatıon at Tema Fishing Harbour , Ghana. *International Journal of Oceanography & Aquaculture*. https://doi.org/10.23880/ijoac-16000178

Avega, B. (2015). *Sustainable Fisheries Management Project (SFMP ) Ahotor Oven Construction Manual*.

Avega, B., & Tibu, G. A. (2017). *SUSTAINABLE FISHERIES MANAGEMENT PROJECT (SFMP) Performance Evaluation Survey-(Ahotor oven)*. *June*. http://www.crc.uri.edu/projects_page/ghanasfmp/

Bako, T., Umogbai, V. I., & Awulu, J. O. (2017). Criteria for the extraction of fish oil. *Agricultural Engineering International: CIGR Journal*, *19*(3), 120–132.

Bank of Ghana. (2008). *The Fishing Sub-Sector and Ghana ' S Economy*. Bank of ghana.

Baten, A., Won, N. E., Sohn, J. H., Kim, J. S., Mohibbullah, M., & Choi, J. S. (2020). Improvement of sensorial, physicochemical, microbiological, nutritional and fatty acid attributes and shelf life extension of hot smoked half-dried pacific saury (Cololabis saira). *Foods*, *9*(8), 1–15. https://doi.org/10.3390/foods9081009

Belhabib, D., Lam, V. W. Y., & Cheung, W. W. L. (2016). Overview of West African fisheries under climate change: Impacts, vulnerabilities and adaptive responses of the artisanal and industrial sectors. *Marine Policy*, *71*, 15–28. https://doi.org/10.1016/j.marpol.2016.05.009

Belhabib, D., Sumaila, U. R., & Le Billon, P. (2019). The fisheries of Africa: Exploitation, policy, and maritime security trends. *Marine Policy*, *101*(December 2018), 80–92. https://doi.org/10.1016/j.marpol.2018.12.021

Belhabib, D., Sumaila, U. R., & Pauly, D. (2015). Feeding the poor: Contribution of West African fisheries toemployment and food security. *Ocean and Coastal Management*, *111*, 72–81. https://doi.org/10.1016/j.ocecoaman.2015.04.010

Belichovska, K., Belichovska, D., & Pejkovski, Z. (2019). Smoke and Smoked Fish Production. *Meat Technology*, *60*(1), 37–43. https://doi.org/10.18485/meattech.2019.60.1.6

Belusso, A. C., Nogueira, B. A., Breda, L. S., & Mitterer-Daltoe, M. L. (2016). Check all that apply (CATA) as an instrument for the development of fish products. *Food Science and Technology*, *36*, 275–281.

Bilgin, F., Unlusayin, M., & Gunlu, A. (2008). Determination of the shelf life and somnutritional component of Gilthead seabrem (Sparus aurata L., 1758) after Cold and Hot smoking. *Turkish Journal of Veterinary and Animal Science*, *32*(49–56).

Bomfeh, K., Jacxsens, L., Amoa-Awua, W. K., Tandoh, I., Afoakwa, E. O., Gamarro, E. G., Ouadi, Y. D., & De Meulenaer, B. (2019). Reducing polycyclic aromatic hydrocarbon contamination in smoked fish in the Global South: a case study of an improved kiln in Ghana. *Journal of the Science of Food and Agriculture*, *99*(12), 5417–5423. https://doi.org/10.1002/jsfa.9802

Bremner, H. A. (2000). Toward practical definitions of quality for food science. *Critical Reviews in Food Science and Nutrition*, *40*(1), 83–90. https://doi.org/10.1080/10408690091189284

Cardinal, M., Knockaert, C., Torrissen, O., Sigurgisladottir, S., Morkore, T., Thomassen, M., & Luc Vallet, J. (2001). Relation of smoking parameters to the yield, colour and sensory quality of smoked Atlantic salmon (Salmo salar). *Food Research International*, *34*(6), 537–550. https://doi.org/10.1016/S0963-9969(01)00069-2

CDC. (2009). *Fourth National Report on Human Exposure to Environmental Chemicals (Fourth Report)* ,.

Cheke & Ward. (1998). A model for evaluating interventions designed to reduce post-harvest fish losses. *Fisheries Research*.

Chukwu, O., & Shaba, I. M. (2009). Effects of Drying Methods on Proximate Compositions of Catfish (Clarias gariepinus). *World Journal of Agricultural Sciences*, *5*(1), 114–116.

Cieślik, I., Migdał, W., Topolska, K., Mickowska, B., & Cieślik, E. (2018). Changes of amino acid and fatty acid profile in freshwater fish after smoking. *Journal of Food Processing and Preservation*, *42*(1). https://doi.org/10.1111/jfpp.13357

Codex alimentarius. (2016). *Code of Practice for Fish and Fishery Products Type*.

Codex Alimentarius Commission. (2009). Code of practice for the reduction of contamination of food with polycyclic aromatic hydrocarbons (PAH) from smoking and direct drying processes. CAC/RCP. *CAC/RCP*, *68*.

Conde, F. J., Ayala, J. H., Afonso, A. M., & González, V. (2004). Optimization of a sampling method to determine polycyclic aromatic hydrocarbons in smoke from incomplete biomass combustion. *Analytica Chimica Acta*, *524*(1-2 SPEC. ISS.), 287–294. https://doi.org/10.1016/j.aca.2004.04.063

CSIR, I. for I. R.-, Ghana, S. A., & Kwarteng, E. (2016). *Testing Of Low PAH Improved Fish Smoking Stove (Ahotor Oven)*. http://www.crc.uri.edu/projects_page/ghanasfmp/

Daramola, J. A., Fasakin, E. A., & Adeparusi, E. O. (2007). Changes in physicochemical and sensory characteristics of smoke-dried fish species stored at ambient temperature. *African Journal of Food, Agriculture, Nutrition and Development*, *7*(6), 16.

Dawson, P., Al-Jeddawi, W., & Remington, N. (2018). Effect of Freezing on the Shelf Life of Salmon. *International Journal of Food Science*, *2018*. https://doi.org/10.1155/2018/1686121

de Alba, M., Pérez-Andrés, J. M., Harrison, S. M., Brunton, N. P., Burgess, C. M., & Tiwari, B. K. (2019). High pressure processing on microbial inactivation, quality parameters and nutritional quality indices of mackerel fillets. *Innovative Food Science and Emerging Technologies*, *55*, 80–87. https://doi.org/10.1016/j.ifset.2019.05.010

Dermiş, S., Can, S., & Doru, B. (2012). Determination of peroxide values of some fixed oils by using the mFOX method. *Spectroscopy Letters*, *45*(5), 359–363. https://doi.org/10.1080/00387010.2012.666702

Dhanapal, K., Nayak, B. B., Venkateshwarlu, G., Balasubramanian, A., Reddy, A. D., Basu, S., & District, N. (2013). Changes in Instrumental and Sensory Characteristics of Tilapia Fish Steaks During Cold Blanching and. *The Bioscan*, *8*(3), 887–892.

Diei-Ouadi, M. (2011). Post-harvest fish loss assessment in small-scale fisheries. . . *FAO Fisheries and Aquaculture Technical Paper*.

Doe, P. E. (Ed.). (1998). *Fish drying and smoking: Production and quality*. Taylor & Francis Routledge.

Entee, S. (2015a). *Post-harvest Processing Stove Performance Report. The USAID/Ghana Sustainable Fisheries Management Project (SFMP)*.

https://www.crc.uri.edu/download/GH2014_ACT005_SNV_FIN508.pdf

Entee, S. (2015b). *Post Harvesting Processing Scoping Study Report. The USAID/Ghana Sustainable Fisheries Management Project (SFMP).*

Entee, S. (2015c). *Sustainable Fisheries Management Project ( SFMP )* (Vol. 233, Issue 0).

Entee, S. (2015d). SUSTAINABLE FISHERIES MANAGEMENT PROJECT ( SFMP ) Post Harvest Processing Value Chain Literature Review Report. *The USAID/Ghana Sustainable Fishiries Management Project (SFMP)*, *22*, 48.

Essumang, D. K., Dodoo, D. K., & Adjei, J. K. (2012). Journal of Food Composition and Analysis Polycyclic aromatic hydrocarbon ( PAH ) contamination in smoke-cured fish products. *Journal of Food Composition and Analysis*, *27*(2), 128–138. https://doi.org/10.1016/j.jfca.2012.04.007

Essumang, D. K., Dodoo, D. K., & Adjei, J. K. (2014). Effective reduction of PAH contamination in smoke cured fish products using charcoal filters in a modified traditional kiln. *Food Control*, *35*(1), 85–93. https://doi.org/10.1016/j.foodcont.2013.06.045

EU Directive. (2008). COMMISSION REGULATION (EC) No 1022/2008 of 17 October 2008 amending Regulation (EC) No 2074/2005 as regards the total volatile basic nitrogen (TVB-N) limits. L277/18 EN. *Official Journal the European Union. EU.*

European Commission. (2011). Commission Regulation (EU) No 835/2011 of 19 August 2011 amending Regulation (EC) No 1881/2006 as regards maximum levels for polycyclic aromatic hydrocarbons in foodstuffs. *Official Journal of the European Union (L 215)*, *L 215*, 4–8.

Failler, P., Beyens, Y., & Asiedu, B. (2014). *Value chain analysis of the fishery sector in Ghana with focus on quality , environmental , social , sustainable , food safety ... Value chain analysis of the fishery sector in Ghana with focus on quality, environmental, social,* (Issue May 2015). https://doi.org/10.13140/RG.2.1.2421.5201

FAO. (1981). The prevention of losses in cured fish. *FAO Fisheries Technical Paper No. 219*.

FAO. (2008). Securing regional supply in aquatic products: prospects from the FAO post-harvest loss assessment case studies. *Committee for Inland Fisheries and Aquaculture of Africa, Fifteenth Session*.

FAO. (2013). *Lessons learned note: Improving the quality of fishery products and market chains*. *July 2013*, 21. http://www.fao.org/publications/card/en/c/7047c8fc-f9ac-458b-98af-a56722fce173

FAO. (2016a). *FAOSTAT food balance sheets*.

FAO. (2016b). *Fishery and Aquaculture Country Profiles: the republic of Ghana*. Food and Agriculture Organization. http://www.fao.org/fishery/facp/GHA/en

FAO. (2016c). *The State of World Fisheries and Aquaculture 2016 - Contributing to food security and nutrition for all.*

Folmer, B. (2017). The Craft and Science of Coffee. In *The Craft and Science of Coffee*.

Ford, A., Randrianantoandro, A., & Peñarubia, O. R. (2020). The FAO-Thiaroye processing technique: Facilitating social organization, empowering women, and creating market access opportunities in West Africa. In J. Zelasney, A. Ford, L. Westlund, A. Ward, & O. R. Penarubia

(Eds.), *Securing sustainable small-scale fisheries*. FAO.

Frankel, E. N. (1985). Chemistry of Free Radical and Single Oxidation of Lipids. *Progress Lipid Research*, *23*, 197–221.

Fraser, O., & Sumar, S. (1998). Chemistry of Free Radical and Single Oxidation of Lipids. *Nutrition. Food Science*, *5*, 275–279.

GHANA STATISTICAL SERVICE. (2021). Population of Regions and Districts. In *Ghana 2021 Population and Housing Census* (Vol. 3A).

Gilberg, Y. C. (1966). *Fish handling, preservation and distribution; report to the Government of Malawi.*

Goulas, A. E., & Kontominas, M. G. (2005). Effect of salting and smoking-method on the keeping quality of chub mackerel (Scomber japonicus): Biochemical and sensory attributes. *Food Chemistry*, *93*(3), 511–520. https://doi.org/10.1016/j.foodchem.2004.09.040

Gregory, K. E., Cundiff, L. E., Koch, R. M., Dikeman, M. E., & Koohniaraie, M. (1994). Breed effects and retained heterosis for growth, carcass and meat traits in advanced generations of composite populations of beef cattle. *Journal of Animal Science*, *72*, 833–850.

Gyan, W. R., Alhassan, E. H., Asase, A., Akongyuure, D. N., & Qi-Hui, Y. (2020). Assessment of postharvest fish losses: The case study of Albert Bosomtwi-Sam fishing harbour, Western Region, Ghana. *Marine Policy*, *120*(May), 104120. https://doi.org/10.1016/j.marpol.2020.104120

Hardy, R., & Smith, J. G. M. (1976). Development of Histamine and Rancidity. *The Journal of the Science of Food and Agriculture*, *27*, 595–599.

Hassoun, A., & Karoui, R. (2017). Quality evaluation of fish and other seafood by traditional and nondestructive instrumental methods: Advantages and limitations. *Critical Reviews in Food Science and Nutrition*, *57*(9), 1976–1998. https://doi.org/10.1080/10408398.2015.1047926

He, W., & Chung, H. Y. (2019). Comparison between quantitative descriptive analysis and flash profile in profiling the sensory properties of commercial red sufu (Chinese fermented soybean curd). *Journal of the Science of Food and Agriculture*, *99*(6), 3024–3033. https://doi.org/10.1002/jsfa.9516

Holman, B. W. B., Bailes, K. L., Meyer, R. G., & Hopkins, D. L. (2019). Effect of modified Soxhlet (Soxtec) and Folch extraction method selection on the total lipid determination of aged beef. *Journal of Food Science and Technology*, *56*(8), 3957–3961. https://doi.org/10.1007/s13197-019-03878-4

Hultmann, L., & Rustad, T. (2004). Iced storage of Atlantic salmon (Salmo salar)–effects on endogenous enzymes and their impact on muscle proteins and texture. *Food Chemistry*, *87*(1), 31–41.

Hungerford, J. M. (2021). Histamine and Scombrotoxins. *Toxicon*, *201*(August), 115–126. https://doi.org/10.1016/j.toxicon.2021.08.013

Huss, H, H., Ababouch, L., & Gram, L. (2004). Assessment and management of seafood and quality. *FAO Fisheries Techinical Paper*, 1–6.

Ighodaro, H. E., & Abolagba, O. J. (2010). The acceptance of package smoked-dried fish cured (Clarias gariepinus) in Benin City. *Journal of Field Aquatic Studies*, *4*(1), 32–39.

Infante, C., Blanco, E., Zuasti, E., Crespo, A., & Manchado, M. (2007). Phylogenetic differentiation between Atlantic Scomber colias and Pacific Scomber japonicus based on nuclear DNA sequences. *Genetica*, *130*(1), 1–8. https://doi.org/10.1007/s10709-006-0014-5

Joardder, M. U. H., & Masud, H. M. (2019). Food Preservation Techniques in Developing Countries. In *Food Preservation in Developing Countries: Challenges and Solutions*. Springer Nature. https://doi.org/https://doi.org/10.1007/978-3-030-11530-2_4

Johnny, M. K., Espoir, K. H., & Paul, C. M. (2020). Determination of the Protein Content of Smoked Fish Sold in the Markets of the Town of Mbuji-Mayi (Democratic Republic of the Congo). *OALib*, *07*(10), 1–8. https://doi.org/10.4236/oalib.1106816

Kafeelah, A. Y., Lucy, N. E., Kafayat, A. F., Shehu, L. A., Julius, I. A., & Titus, O. O. (2015). Influence of fish smoking methods on polycyclic aromatic hydrocarbons content and possible risks to human health. *African Journal of Food Science*, *9*(3), 126–135. https://doi.org/10.5897/ajfs2014.1227

Karovicova, J., & Kohajoda, Z. (2005). Biogenic amines in food. *Chemical Papers*, *59*(1), 70–79. https://doi.org/10.1007/s10068-017-0239-3

Kayim, M., & Can, E. (2010). The pH and Total Fat Values of Fish Meat in Different leed Storage Period. *Asian Journal of Animal and Veterinary Advances*, *5*(5), 346–348.

Kizzie-Hayford, N., Jaros, D., Zahn, S., & Rohm, H. (2016). Effects of protein enrichment on the microbiological, physicochemical and sensory properties of fermented tiger nut milk. *LWT - Food Science and Technology*, *74*, 319–324. https://doi.org/10.1016/j.lwt.2016.07.067

Krishna, A. (2012). An integrative review of sensory marketing: Engaging the senses to affect perception, judgment and behavior. *Journal of Consumer Psychology*, *22*(3), 332–351. https://doi.org/10.1016/j.jcps.2011.08.003

Kristensen, D., Andersen, M. L., & Skibsted, L. H. (2002). Prediction of oxidative stability of raw milk using spin trapping electron spin resonance spectroscopy. *Milchwissenschaft*, *57*(5), 255–258.

Küçükgülmez, A., Eslem Kadak, A., & Celik, M. (2010). Fatty acid composition and sensory properties of Wels catfish (Silurus glanis) hot smoked with different sawdust materials. *International Journal of Food Science and Technology*, *45*(12), 2645–2649. https://doi.org/10.1111/j.1365-2621.2010.02440.x

Kumar, D., & Kalita, P. (2017). Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. *Foods*, *6*(1), 1–22. https://doi.org/10.3390/foods6010008

Lauria, V., Das, I., Hazra, S., Cazcarro, I., Arto, I., Kay, S., Ofori-Danson, P., Ahmed, M., Hossain, M. A. R., Barange, M., & Fernandes, J. A. (2018). Importance of fisheries for food security across three climate change vulnerable deltas. *Science of the Total Environment*, *640–641*(May), 1566–1577. https://doi.org/10.1016/j.scitotenv.2018.06.011

Lazar, N., K., Y., Blay, J., Ofori-Danson, P., Markwei, P., Agbogah, K., Bannerman, P., Sotor, M., Yamoah, K. K., & Bilisini, W. B. (2018). Status of Ghana ' s small pelagic stocks and recommendations to achieve sustainable fishing 2017. *Scientific and Technical Working Group. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University*

*of Rhode Island.*, *April*, 22.

Li, J., Dong, H., Li, X., Han, B., Zhu, C., & Zhang, D. (2016). Quantitatively assessing the health risk of exposure to PAHs from intake of smoked meats. *Ecotoxicology and Environmental Safety*, *124*, 91–95. https://doi.org/10.1016/j.ecoenv.2015.10.007

Lougovois, V. P., & Kyrana, V. R. (2014). Freshness Quality and Spoilage of Chill-Stored Fish. In *Food Policy, Control and Research* (Issue January 2005).

Luthfi, N., Restitrisnani, V., & Umar, M. (2018). The Optimation of Crude Fiber Content of Diet for Fattening Madura Beef Cattle to Achieve Good A:P Ratio and Low Methane Production. *IOP Conference Series: Earth and Environmental Science*, *119*(1). https://doi.org/10.1088/1755-1315/119/1/012056

Magawata, I., & Musa, T. (2015). Quality characteristics of three Hot-Smoked fish species using locally fabricated Smoking kiln. *International Journal of Fisheries and Aquatic Studies*, *2*(5), 88–92.

McLauchlin, J., Little, C. L., Grant, K. A., & Mithani, V. (2006). Scombrotoxic fish poisoning. *Journal of Public Health*, *28*(1), 61–62. https://doi.org/10.1093/pubmed/fdi063

MoFAD. (2016). *Republic of Ghana Fisheries and Aquaculture Sector Development Plan*. 1–33.

Mohibbullah, M., Won, N. E., Jeon, J. H., An, J. H., Park, Y., Kim, H., Bashir, K. M. I., Park, S. M., Kim, Y. S., Yoon, S. J., Sohn, J. H., Kim, A., & Choi, J. S. (2018). Effect of superheated steam roasting with hot smoking treatment on improving physicochemical properties of the adductor muscle

of pen shell (Atrina pectinate). *Food Science and Nutrition*, *6*(5), 1317–1327. https://doi.org/10.1002/fsn3.674

Mondo, B. C., Akoll, P., & Margaret, and M. (2020). Water activity, microbial and sensory evaluation of smoked fish (Mormyrus caschive and Oreochromis niloticus) stored at Ambient Temperature, Terekeka-South Sudan. *International Journal of Fisheries and Aquaculture*, *12*(2), 47–60. https://doi.org/10.5897/IJFA2020.0783

Moosavi-Nasab, M., Asgari, F., & Oliyaei, N. (2019). Quality evaluation of surimi and fish nuggets from Queen fish (Scomberoides commersonnianus). *Food Science and Nutrition*, *7*(10), 3206–3215. https://doi.org/10.1002/fsn3.1172

Msuku, L., & Kapute, F. (2018). Effect of smoking and sun drying on proximate composition of diplotaxodon fish species (Ndunduma) from Lake Malawi, Malawi. *African Journal of Food, Agriculture, Nutrition and Development*, *18*(1), 13009–13018. https://doi.org/10.18697/ajfand.81.16960

Nellemann & MacDevette. (2009). *The environmental food crisis: the environment's role in averting future food crises:a UNEP rapid response assessment*.

Nollet, L. M., & Toldrá, F. (Eds.). (2009). *Handbook of seafood and seafood products analysis*. CRC Press.

Nunoo, F. K. E., Tornyeviadzi, E., Asamoah, E. K., & Addo, S. (2019). Effect of two fish smoking ovens on the nutritional composition and PAH content of smoked fish . *J Pub Health Catalog*, *1*(1), 5–10.

Nunoo, Fke, Asiedu, Kombat, Eo, & Samey. (2015). *sustainable fisheries management project (SFMP) Sardinella and other small pelagics value and supply chain of the fishery sector, Ghana*. *September*. http://www.crc.uri.edu/projects_page/ghanasfmp/

Odeyemi, O. A., Burke, C. M., Bolch, C. J., & Stanley, R. (2018). Evaluation of spoilage potential and volatile metabolites production by Shewanella baltica isolated from modified atmosphere packaged live mussels. *Food Research International*, *103*, 415–425.

Okyere-Nyarko, A. A., Aziebor, E., & Robinson, J. (2015). Namhowfo, mangroves and woodlots: a more complete approach to reducing deforestation in Ghana. *Netherlands: SNV Netherlands Development Organisation. Retrieved September*, *9*, 2017.

Olayemi, F. F., Adegbola, J. A., Bamishaiye, E. I., & Awagu, E. F. (2012). Assessment of postharvest losses of some selected crops in eight local government areas of rivers state, Nigeria. *Asian Journal of Rural Development*, *2*(1), 13–23.

Olukayode Amos, S., & Paulina, I. (2017). Assessment of Smoked Fish Quality Using Two Smoking Kilns and Hybrid Solar Dryer on Some Commercial Fish Species in Yola, Nigeria. *Journal of Animal Research and Nutrition*, *02*(01). https://doi.org/10.21767/2572-5459.100026

Onyia, L. U., Sogbesan, O. a, Milam, C., & Joseph, a I. (2011). Microbial Load Analysis of Fresh Mud Catfish (Clarias anguillaris) And Tilapia (Oreochromis niloticus) in Lake Gerio, Adamawa State, Nigeria using Two Different Smoking Kilns. *Journal of Environmental Issues and Agriculture in Developing Countries*, *3*(1), 165–170.

http://www.doaj.org/doaj?func=openurl&issn=21412731&date=2011&volume=3&issue=1&spage=165&genre=article

Owusu, D. (2019). *Final Report on Ahotor Oven Market Development and Financing Outcomes and Lessons Learned. The USAID/Ghana Sustainable Fisheries Management Project (SFMP)*. GH2014_ACT242_ RESONANCE. 24 pp

Oz, A. T., Ulukanli, Z., Bozok, F., & Baktemur, G. (2015). The postharvest quality, sensory and shelf life of agaricus bisporus in active map. *Journal of Food Processing and Preservation*, *39*(1), 100–106. https://doi.org/10.1111/jfpp.12301

Özoğul, F., & Özoğul, Y. (2000). Comparision of methods used for determination of total volatile basic nitrogen (TVB-N) in rainbow trout (Oncorhynchus mykiss). *Turkish Journal of Zoology*, *24*(1), 113–120.

Pawul-Gruba, M., Michalski, M., & Osek, J. (2014). Determination of histamine in fresh and smoked fish commercially available in Poland. *Bulletin of the Veterinary Institute in Pulawy*, *58*(2), 301–304. https://doi.org/10.2478/bvip-2014-0046

Pemberton-Pigott C, Robinson J, Kwarteng E, & Boateng L. (2016). *SUSTAINABLE FISHERIES MANAGEMENT PROJECT (SFMP) Low PAH Improved Fish Smoking Stove Design Development Report*. *September*. http://www.crc.uri.edu/projects_page/ghanasfmp/

Prabhakar, P. K., Srivastav, P. P., & Pathak, S. S. (2019). Kinetics of Total Volatile Basic Nitrogen and Trimethylamine Formation in Stored Rohu (Labeo rohita) Fish. *Journal of Aquatic Food Product Technology*, *28*(5), 452–464. https://doi.org/10.1080/10498850.2019.1604598

Prabhakar, P. K., Vatsa, S., Srivastav, P. P., & Pathak, S. S. (2020). A comprehensive review on freshness of fish and assessment: Analytical methods and recent innovations. *Food Research International*, *133*(March), 109157. https://doi.org/10.1016/j.foodres.2020.109157

Puke, S., & Galoburda, R. (2020). Factors affecting smoked fish quality: A review. *Research for Rural Development*, *35*, 132–139. https://doi.org/10.22616/rrd.26.2020.020

Rana, M. M., Mohibbullah, M., Won, N. E., Baten, M. A., Sohn, J. H., Kim, J. S., & Choi, J. S. (2021). Improved hot smoke processing of chub mackerel (Scomber Japonicus) promotes sensorial, physicochemical and microbiological characteristics. *Applied Sciences (Switzerland)*, *11*(6). https://doi.org/10.3390/app11062629

Ritter, J. C. S., Budge, S. M., & Jovica, F. (2013). Quality analysis of commercial fish oil preparations. *Journal of the Science of Food and Agriculture*, *93*(8), 1935–1939. https://doi.org/10.1002/jsfa.5994

Rosenberg, A.A., Fogarty, M.J., Cooper, A.B., Dickey-Collas, M., Fulton, E.A., Gutiérrez, N.L., Hyde, K.J.W., Kleisner, K.M., Kristiansen, T., Longo, C., Minte- Vera, C., Minto, C., Mosqueira, I., Chato Osio, G., Ovando, D., Selig, E.R., Thorson, J.T. & Y, Y. (2014). *Developing new approaches to global stock status assessment and fishery production potential of the seas*. *1086*(1086), 175. http://www.fao.org/fi/oldsite/eims_search/1_dett.asp?calling=simple_s_result&lang=en&pub_id=314932

Rumape, O., Elveny, M., Suksatan, W., Hatmi, R. U., Voronkova, O. Y., & Bokov, D. O. (2022). Study on the quality of fish products based on different preservation techniques: a review. *Food Science and Technology*,

*42*.

S. Akyeampong, K. Amador, B. N. (2013). *Report on the 2013 Ghana marine canoe frame survey*. http://rhody.crc.uri.edu/gfa/wp-content/uploads/sites/10/2018/04/Ghana-Marine-Canoe-Frame-Survey-2013.pdf

Sáez-Plaza, P., Michałowski, T., Navas, M. J., Asuero, A. G., & Wybraniec, S. (2013). An Overview of the Kjeldahl Method of Nitrogen Determination. Part I. Early History, Chemistry of the Procedure, and Titrimetric Finish. *Critical Reviews in Analytical Chemistry*, *43*(4), 178–223. https://doi.org/10.1080/10408347.2012.751786

Saju, A. K., Blossom, K. L., Thomas, A., Safeena, M. P., Saju, A. K., Blossom, K. L., Thomas, A., Safeena, M. P., Thomas, A., & Safeena, M. P. (2022). " Evaluation of Shelf Life Extension of Vacuum Packed Sardine Marinade Formulated with Leaves of Tamarind ( Tamarindus indica ) and Malabar Tamarind ( Garcinia gummigutta )." " Evaluation of Shelf Life Extension of Vacuum Packed Sardine Marinade Formulate. *Journal of Culinary Science & Technology*, *00*(00), 1–20. https://doi.org/10.1080/15428052.2022.2104771

Sakyi, M. E., Cai, J., Akwasi, A.-Y., & Adele, A. (2019). Fish Smoking in Ghana: A Review. *Journal of FisheriesSciences.Com*, *13*(3), 13–24. https://doi.org/10.36648/1307-234x.13.3.165

Salaudeen, M. M. (2014). *Quality analysis of dried cod (Gadus morhua) heads along the value chain from Iceland to Nigeria*. United Nations University Fisheries Training Programme, Iceland [final project]. http://www.unuftp.is/static/fellows/document/mutiat13prf.pdf

Sharif, M. K., Sharif, H. R., & Nasir, M. (2017). Sensory evaluation and consumer acceptability. *Handbook of Food Science and Technology, October*, 361-386.

Sirra, E. N. (2000). Traditional fish processing and marketing of the Gambia. *Final Project*.

Socaciu, M. I., Fogarasi, M., Simon, E. L., Semeniuc, C. A., Socaci, S. A., Podar, A. S., & Vodnar, D. C. (2021). Effects of whey protein isolate-based film incorporated with tarragon essential oil on the quality and shelf-life of refrigerated brook trout. *Foods*, *10*(2), 1–21. https://doi.org/10.3390/foods10020401

Sone, I., Skåra, T., & Olsen, S. H. (2019). Factors influencing post-mortem quality, safety and storage stability of mackerel species: a review. *European Food Research and Technology*, *245*(4), 775–791. https://doi.org/10.1007/s00217-018-3222-1

Stamatis, N., & Arkoudelos, J. (2007). Quality assessment of Scomber colias japonicus under modified atmosphere and vacuum packaging. *Food Control*, *18*(4), 292–300. https://doi.org/10.1016/j.foodcont.2005.10.009

Sutikno, L. A., Bashir, K. M. I., Kim, H., Park, Y., Won, N. E., An, J. H., Jeon, J. H., Yoon, S. J., Park, S. M., Sohn, J. H., Kim, J. S., & Choi, J. S. (2019). Improvement in Physicochemical, Microbial, and Sensory Properties of Common Squid (Todarodes pacificus Steenstrup) by Superheated Steam Roasting in Combination with Smoking Treatment. *Journal of Food Quality*, *2019*. https://doi.org/10.1155/2019/8721725

Teh, L. C. L., & Sumaila, U. R. (2013). Contribution of marine fisheries to worldwide employment. *Fish and Fisheries*, *14*(1), 77–88. https://doi.org/10.1111/j.1467-2979.2011.00450.x

Teklemariam, A. D., Tessema, F., & Abayneh, T. (2015). Review on Evaluation of Safety of Fish and Fish Products. *International Journal of Fisheries and Aquatic Studies*, *3*(2), 111–117. www.fisheriesjournal.com

Turchini, G. M., Torstensen, B. E., & Ng, W. K. (2009). Fish oil replacement in finfish nutrition. *Reviews in Aquaculture*, *1*(1), 10–57.

UNDP/TCDC. (2001). Examples of successful initiatives in agriculture and rural development in the South. In *Sharing innovative experiences* (5th ed.).

Ünlüsayın, M., Bilgin, Ş., Levent, İ., & Ali, G. (2007). CHEMICAL AND SENSORY ASSESSMENT OF HOT-SMOKED FISH PÂTÉ. *FisheriesSciences.Com*, *1*(1), 20–25. https://doi.org/10.3153/jfscom.2007003

Velasco, J., Dobarganes, C., & Márquez-Ruiz, G. (2010). Oxidative rancidity in foods and food quality. In *Chemical Deterioration and Physical Instability of Food and Beverages*. Woodhead Publishing Limited. https://doi.org/10.1533/9781845699260.1.3

Wahaga, E. (2021). *History of csir-food research institute*.

Yang, J., & Lee, J. (2019). Application of sensory descriptive analysis and consumer studies to investigate traditional and authentic foods: A review. *Foods*, *8*(2), 1–17. https://doi.org/10.3390/foods8020054

Yaro, C. A., Bello, O. Z., & Okpanachi, M. A. (2018). Assessment of the Effect of Processing Methods on the Proximate Composition of Trachurus trachurus ( Mackerel ) Sold in Anyigba Market , Kogi State. *American Journal of Food Science and Technology*, *6*(1), 26–32. https://doi.org/10.12691/ajfst-6-1-5

York, R. K., & Sereda, L. M. (1994). Sensory assessment of quality in fish and seafoods. *Seafoods: Chemistry, Processing Technology and Quality*, 233–262. https://doi.org/10.1007/978-1-4615-2181-5_13

Yu, L. C., Zzaman, W., Akanda, M. J. H., Yang, T. A., & Easa, A. M. (2017). Influence of Superheated Steam Cooking on Proximate, Fatty Acid Profile, and Amino Acid Composition of Catfish (Clarias batrachus) Fillets. *Turkish Journal of Fisheries and Aquatic Sciences*, *17*(1), 936–943. https://doi.org/10.4194/1303-2712-v17_5_09

Zhu, S., Yu, J., Chen, X., Zhang, Q., Cai, X., Ding, Y., Zhou, X., & Wang, S. (2021). Dual cryoprotective strategies for ice-binding and stabilizing of frozen seafood: A review. *Trends in Food Science and Technology*, *111*(August 2020), 223–232. https://doi.org/10.1016/j.tifs.2021.02.069