UNIVERSITY OF CAPE COAST

LEVEL OF FORMALIN IN SOME FISH SPECIES ALONG THE COAST OF CENTRAL REGION

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DECLARATION

Candidate's Declaration

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

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

Name: Rita Boahemaa Okyere.

Supervisor's Declaration

I hereby declare that the preparation and presentation of the dissertation were supervised by the guidelines on supervision of the dissertation laid down by the University of Cape Coast.

Supervisor's Signature: …………………… Date ………………...

Name: Prof. (Mrs) Sarah Darkwa.

ABSTRACT

Fish is the most widely consumed seafood and the basic diet for most people worldwide, with Ghana consuming over 154 million tonnes annually. However, certain chemicals (formalin) used by some fishermen to preserve fish for transit, may cause food contamination and subsequently health hazards. This study sought to examine and ascertain formalin levels present in commonly eaten fish species caught from the central coast of Ghana. Fresh fish samples were conveniently collected and paid for from various fishmongers and fishermen in Anomabo, Biriwa, Moree, and Elmina. The fish were immediately kept in ice filled in an ice chest and transported to the chemistry laboratory University Cape Coast for further analysis. At the Laboratory, purification of fat was carried out using the Soxhlet Extraction Clean-up method. Findings show that, formalin levels in Bluntnose Lizard fish (Akoteakote) caught at Elmina were considerably high, (59.180 ± 0.611 ppm). However, herrings, also caught from Elmina recorded lower formalin concentration measured at 0.871 ± 0.812 ppm implying that different fishes accumulate different levels of formalin. Also, fish caught from Elmina and Moree exhibited similar formalin levels, with a correlation value of 0.983. The high levels of formalin found in some fish samples raises a concern for health authorities to put measures in place to protect aquatic and human health. It was thus recommended that standardized preservation protocols, increased monitoring and regulation, and public awareness campaigns on fish preservation should be implemented by the government and other regulatory bodies.

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DEDICATION

To my family.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

Fishing is an ancient human activity that has existed for a long time. It is considerably older than agriculture and is likely to be crucial to our species' survival (Russell, 2017). However, algae, among other poisons, may build up in marine fishes, poisoning these crucial seafoods. When fish are exposed to sunlight, a chemical reaction occurs due to using chemicals such as formalin, washing powder, and other hazardous agents used to capture and preserve fish (Hoque et al., 2016). Toxins and algae are frequently studied across Europe, North America, Japan, and some other developing nations (Denutsui, 2019). Most African countries, including Ghana, have little or no information on toxin-causing chemicals found in fish (Denutsui, 2019). It is with this background that, this study sought to examine the possible toxic substances in fish caught along the coast of the central region in Ghana.

Background to the Study

Water is an important component of the ecology. Water resources encourage socio-economic development, particularly for industry, agriculture, and residential usage (Adiyahba, 2014). Jobs in fishing and fisheries sustain Ghana's coastal communities (Freduah et al., 2019). These enterprises provide cash for the local community, the nation, and exports (Vincent, 2014). The Ghanaian fishing industry produces 430,000 tonnes of fish yearly from big and important fish reserves (Afoakwah et al., 2018). Thus, fishing remains a key source of employment, income, and a way of life for native and international fisher folks in Ghana.

However, overfishing has occurred due to surplus fishing capacity (number of boats) and increased fishermen. Since the mid-1990s, no fisherman can claim a bumper catch (Earth Journalism Network, 2018). To keep up with the latest advances, light fishing has become increasingly popular in Ghana's Exclusive Economic Zone (Earth Journalism Network, 2018). Light attracts fish for easier catch (Afoakwah et al., 2018). However, certain species may elude light fishing, rendering it ineffective. Other unlawful techniques of killing or immobilizing fish may also be useful (Zailina et al., 2013).

Fishermen utilize pesticides, Dichlorodiphenyltrichloroethane (DDT), Carbide, formalin, and explosives like dynamite (Mathew, Raman, Parameswaran& Rajan, 2019). All these, kill or disable the fish, making capture easier. Formalin (Formaldehyde), the most basic aldehyde family member, is the most reactive (Noordiana et al., 2011). Formalin is a solution consisting of 37% formaldehyde (H-CHO) dissolved in water, often used as a preservation, embalming agent, and sterilizing agent in scientific settings. Formalin has been documented as a therapeutic agent for treating protozoal and fungal fish diseases, as reported by Udin et al. (2011).

Formalin has been authorized by the United States Food and Drug Administration (US FDA) as a parasiticide and fungicide within aquaculture. The use of this substance in aquaculture has been prohibited in Europe and Japan due to its association with the development of cancer and tumour formation, as reported by Udin et al. (2011). Despite the hazards of illicit fishing and its prohibition, the activity is widespread throughout Ghana. Several causes encourage and/or affect illicit fishing in Ghana. These include weak government enforcement of laws on fishing, depletion of fish stocks, rising demand for seafood, and the infiltration of private enterprises in the fisheries industry (Afoakwah et al., 2018).

In Ghana, illicit fishing has polluted various water basins, increasing the risk of becoming more toxic and dangerous to eat (Kortei et al., 2020). The amino acids, fat, and water content of fish render them susceptible to biochemical processes and microbes during the post-harvest period (Noordiana, et al., 2011). A chemical reaction occurs in water when formalin, washing powder, and other harmful ingredients are used to capture and preserve fish. When swallowed, these chemical reactions produce toxins that are dangerous to aquatic life and people (Hoque, et al., 2016). Although beneficial in many parts of life, molecules like formalin and related substances may harm health (Sibirny et., 2011). There have been reports on fish sellers sometimes adding or spraying formalin on the fish during shipment to enhance shelf life and avoid rotting (Yeasmin et al., 2010)

Environmental contamination caused by harmful chemicals has recently increased ecological and public health concerns. According to Rajeshkumr et al. (2018), when determined, levels of toxins in fish reflect the levels in water and the length of exposure of aquatic life to toxins. Several laboratory and field tests have demonstrated that the level of toxin accumulation in fish tissues depends on parameters such as tissue and water chemistry. Age, sex, swimming habits, reproductive cycle, and geographic location contribute to fish bioaccumulation. The constant development of toxicology data pushed several global and regional regulatory organizations to designate the acceptable range for toxins like heavy metals in various foods.

Many heavy metals have maximum acceptable values determined by the World Health Organisation (WHO) and the European Food Safety Authority (EFSA). According to Zhang et al. (2015), the World Health Organization (WHO) has established a permissible daily reference dose (RfD) of 0.15 mg/kg body weight per day for formaldehyde. Similarly, Zailina et al. (2013) state that the United States Environmental Protection Agency has defined a daily reference dose (RfD) of 0.2 mg/kg body weight per day for the same substance. Malaysian Food and Regulation (MFR) also established a daily FA limit of 5 mg/kg body weight for fish and fish products (Uddin et al., 2011).

In a study conducted by Resma et al. (2020), it was determined that the levels of hazardous metals (namely Zn, Cu, As, Cr, and Cd) detected in fish samples were found to be below the permissible thresholds established by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). The potential adverse effects of metal ingestion on human health resulting from the consumption of the examined fish specimens were assessed by the application of several hazard indicators, including the daily intake of metals (DIM), target hazard quotient (THQ), hazard index (HI), and target risk (TR). It was determined that the values obtained for these parameters all fall within the permissible limits set by relevant regulatory standards. The predicted total concentration range (TR) for the elements As, Cr, and Cd was found to be (106-105), falling within the hazardous range of 106-104 as defined by the United States Environmental Protection Agency (US-EPA).

Plaster of Paris (POPs), radioactive compounds, toxic heavy metals, extractive industry residues, diseases, trash, and debris are among the principal contaminants identified in fish and aquatic bodies, according to Ye et al., (2012). The issue of heavy metal pollution is a significant concern due to its hazardous nature, inability to degrade naturally, prolonged biological half-life, and tendency to accumulate in living organisms (Ye, Huang, Zhang, & Tian, 2012). In their study, Gbogbo et al. (2018) used Atomic Absorption Spectrometry as a method for the identification of toxins present in *Chrysichthys nigrodigitatus* and *Botryostrobus auritus* specimens obtained from the Weija Dam and the Tema Fishing Habour, both located in Ghana. The concentrations of Lead and Cadmium were determined to be below the detection limit in all samples, except for *Botryostrobus auritus*. The concentrations of the other elements in fish were within the limits set by the Food and Agriculture Organization/World Health Organization (FAO/WHO). The researchers found that *Chrysichthys nigrodigitatus* exhibited an Estimated Weekly Intake (EWI) that exceeded the Provisional Tolerable Weekly Intake (PTWI) established by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO).

It can be inferred from the above discussion that very few studies have examined the presence of toxic substances such as formalin and washing powder in fish along the coast of Ghana. Most empirical studies have focused on heavy metals amongst other toxins in fishes. Studies conducted in Ghana focus mainly on heavy metals concerning existing literature except for the work of Afoakwa et al. (2018), who recommended a forensic investigation be done on fish caught with formalin. Hence, this study sought to determine the concentration of formalin that may be present in fish.

Statement of the Problem

Fish are the most widely consumed seafood (Afoakwah et at., 2018). Fish is a basic diet for most people worldwide, with Ghana consuming over 154 million tonnes annually (FAO Fisheries and Aquaculture, 2016). Fish is a great source of protein and other essential nutrients including omega-3 fatty acids, minerals, and vitamins (Joshi et al., 2015). However, certain chemicals some fishermen use, such as formalin to preserve fish for transit, may cause food contamination (Afoakwah et al., 2018). Formaldehyde has been classified as a Group 1 human carcinogen by the International Agency for Research on Cancer. According to Noordiana et al. (2011), the Environmental Protection Agency (EPA) has established a maximum daily dose reference (RfD) of 0.2 g/g body weight per day for formaldehyde. According to Hossain (2011), prolonged exposure to formalin can result in visual impairment, respiratory conditions such as asthma, and potentially developing lung cancer.

In their study, Adaagoam et al. (2018) investigated the extent of formaldehyde exposure in the Ghanaian population residing in the Kumasi Metropolis by the use of 3-Methyl-2-Benzothiazoline Hydrazone as an extracting agent during fish consumption analysis. The study's results revealed the presence of formaldehyde in all sixty species of both local and foreign fish that were examined, with concentrations ranging from 0.174 to 3.710 ugg^{-1}. The recorded readings remained lower than the maximum limit of 5 $mgkg^{-1}$ for formaldehyde in fish, as the Malaysian Food Act and Regulation stipulated. The amount consumed was below the daily intake recommendations of 0.15 $mgkg^{-1}$ and 0.2 $mgkg^{-1}$ BW/day set by the World Health Organization and the United States Environmental Protection Agency for formaldehyde ingestion, respectively. Once again, it is observed that the danger quotient for all species examined was found to be below 1, suggesting that the presence of formaldehyde in the fish is improbable to result in any detrimental health effects for consumers.

The work of Adaagoam et al. (2018) although insightful, focused on the Kumasi Metropolis, which is a non-fishing metropolis. Also, the study focused on using fish stored in cold stores relative to fresh fish, which may provide a more accurate analysis of the situation. Finally, the use of foreign fish species implies that the data covered fishes that might not be indigenous to Ghanaian waters and thus covered a narrow scope of research.

According to research conducted by Uddin et al. (2011), Bangladesh imports fish and fish products from neighbouring countries to fulfil their domestic demand. Several studies show that fish caught in waters in Bangladesh contain formalin, a very toxic and carcinogenic toxin. The level of formalin usage in Dhaka fish was investigated. Five varieties of fish were obtained from five local markets and analysed using a Bangladesh Council of Scientific and Industrial Research designed “formalin detection kit in fish” (BCSIR). The investigation found formalin in 70% of Rui fish and over 50% of other fish samples. The work of Uddin et al. provides the level of contamination in fish by formalin. However, the geographical scope of the study, Bangladesh, endears it to further empirical and laboratory inspection as the level of contamination of fish with formalin may not be the same in the Ghanaian context.

Alewy et al. (2020) analysed 17 dorsal meat samples for heavy metals using Inductively Coupled Plasma Optical Emission Spectrometry. Cadmium was found in all samples, although the levels were below the detectable limit.

The average values of the detected toxins were 0.030.016, 0.020.03, 0.070.08, 0.100.08, 0.030.03, and 2.903.33 $mgkg^{-1}$. One sample had lead (5.88 %) in addition to the toxin. On the other hand, all samples contained modest levels of mercury (0.140.07). All heavy metals tested were within FAO/WHO permitted levels. The scientists report that consuming such fish poses minimal dangers to human health due to the discovered quantities of heavy metals. Although insightful, Alewy et al. (2020) focused mainly on detecting toxins of metal origin and made little effort to detect other forms of toxins including formalin. This limitation may be due to the geographical scope of the study, Iraq; as the environmental and social conditions of that country and Ghana are significantly different.

Given the existing empirical limitations in research, particularly in terms of contextual and geographical factors, the primary objective of this study was to address the empirical gap on the scarcity of literature investigating the presence of formalin in fish. The investigation into the presence of toxins of metal origin has been widely researched. Thus, this study sought to investigate (scientifically) or determine the presence of formalin in local breeds of fish consumed in Ghanaian markets using Anomabo, Biriwa, Moree, and Elmina fishing towns as case studies.

Purpose of the Study

The primary objective of this research was to examine and ascertain formalin present in commonly eaten fish species within some Coastal Region of Ghana.

Research Objectives

This study focused on achieving the following objectives;

1. examine formalin in commonly caught fish from Anomabo, Biriwa, Moree, and Elmina.
2. determine the concentration of formalin in common species of fish caught in Anomabo, Biriwa, Moree, and Elmina.
3. compare the concentration of formalin in the fish samples to the European Food Safety Authority (EFSA).

Research Questions

The research sought to provide answers to the following research questions;

1. Was formalin present in common species of fish caught in Anomabo, Biriwa, Moree, and Elmina?

2. What are the concentration levels of formalin found in common species of fish caught in Anomabo, Biriwa, Moree, and Elmina?

3. How did the concentration of formalin in common fish species in Elmina Anomabo, Biriwa, Moree, and Elmina compare with the EFSA?

Significance of the Study

Numerous fish samples from diverse locations around the globe have shown the presence of ubiquitous pollutants, including heavy metals. This study aimed to examine and ascertain potential toxic compounds present in commonly eaten fish species in the Anomabo, Biriwa, Moree, and Elmina regions, as well as their surrounding areas. Moreover, this research offers empirical evidence to assist governmental and non-profit entities in making crucial strategic choices on many aspects of the fishing business in Ghana. Primarily, it functions as a substantiated and dependable framework for formulating effective strategies to generate and provide value to stakeholders, attaining sustainable and ecologically sound fishing methods that promote the expansion of the fishing sector and the nutritional quality of locally traded fish. Additionally, it facilitates the establishment of enduring and mutually advantageous initiatives and policies that benefit fishermen and the nation.

The findings and outcomes of the research may be used to inform the development of governmental policies to improve regulatory effectiveness in the fishing communities located along the coastal area of Ghana. The study's findings may contribute to the limited knowledge of the many hazardous substances in fish often sold in Ghanaian marketplaces. This document will be a valuable resource for future scholars engaged in research within the same or interconnected fields of study.

Limitations of the Study

Like any research endeavour, this study is subject to intrinsic limitations, such as time limits and the scope of the effort. The thesis will prioritize three specific goals due to the efficiency of laboratory testing, result acquisition, data coding, analysis, and presentation.

Delimitation of the Study

The study was delimited to four towns in the coastal region of Ghana; specifically, Anomabo, Biriwa, Moree, and Elmina in the central region of Ghana. These towns were selected based on convenience, proximity, and ease of access. Contextually, the study considered common fish species consumed in Ghana including Salmon, Tilapia amongst other species to test for the presence of toxins.

Organisation of the Study

The thesis is made up of five distinct chapters. The first chapter serves as an introductory chapter. The introductory chapter of the study has several components, including the background, issue statement, aims, research questions, significance, scope, and constraints. The second chapter of this research includes a comprehensive evaluation of the relevant literature. The literature review included the presentation of the empirical, conceptual, and theoretical frameworks. Chapter three of this research provides a comprehensive overview of the methodologies and analyses used in the study. It covers several aspects such as the research design, population, sampling approaches, data gathering instruments, data collection processes, and data analysis methods. Chapter Four provides the findings and analysis of the research outcomes. Chapter Five of the research provides a comprehensive overview of the main findings, draws logical deductions based on the results, offers practical recommendations, and proposes potential avenues for further investigation.

CHAPTER TWO

LITERATURE REVIEW

This chapter deals with a review of relevant literature related to possible toxins found in fish. The literature review covers an empirical review, a conceptual framework, and a conceptual review. The key arguments in this study were proposed based on the empirical gaps and provisions from various conceptual dispensations considered in the study.

Conceptual Review

This literature review section focused on key terms relevant to understanding the subject matter being investigated.

Presence of Chemicals in Fishing

The presence of various chemicals in fish has been a global concern, with studies from diverse regions showing that fish are exposed to a broad spectrum of harmful substances. Globally, pollutants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), dioxins, heavy metals, and pesticides are widely distributed in both freshwater and marine ecosystems. For example, in the United States, fish in the Great Lakes have been found to contain high levels of PCBs and dioxins due to industrial pollution, affecting both fish health and human consumers (Jackson et al., 2015). In Europe, particularly in Scandinavia, research has revealed that fish from the Baltic Sea have accumulated high levels of persistent organic pollutants (POPs) like dioxins and PCBs, resulting in strict fish consumption guidelines for certain populations (Axelsson et al., 2019).

In African countries, the situation is similarly alarming. In Nigeria, studies show that fishes from the Lagos Lagoon contain high concentrations of heavy metals such as lead, cadmium, and mercury, primarily due to effluent discharges from nearby industries (Olaifa et al., 2017). In Ghana, a study conducted by Darko et al., (2018) on fish from the Volta Lake revealed elevated levels of DDT and other organochlorine pesticides (OCPs), posing significant health risks to consumers who rely on these fish as a primary source of protein. One chemical of particular concern is formalin, which is frequently used as a preservative for fish in many parts of the world despite being illegal in numerous countries. Formalin is a solution of formaldehyde in water, commonly used in aquaculture to control parasites and pathogens but often misused to prolong the shelf life of fish products in the market (Chinabut et al., 2021). This illegal practice has been documented in Southeast Asia, including in India and Bangladesh, where fish markets have been found selling formalin-preserved fish (Shahjalal et al., 2018). In Ghana, although there is limited data on the prevalence of formalin use in fish preservation, anecdotal reports suggest that this illegal practice occurs in some markets, especially in urban centres (Obodai, 2020).

Concentration of Toxins in Fish Species

The concentration of toxins in fish varies widely depending on the species, the environment they inhabit, and the level of pollution in those environments. Several studies have highlighted the bioaccumulation of toxins such as heavy metals, organochlorine pesticides (OCPs), and polychlorinated biphenyls (PCBs) in different fish species across the world. In the Mediterranean Sea, for instance, the bluefin tuna (*Thunnus thynnus*) has been found to contain high concentrations of mercury, a heavy metal that poses significant risks to both marine life and human consumers (Romeo et al., 2019).

Similar studies conducted in Southeast Asia show that tilapia (*Oreochromis spp*.), a widely consumed freshwater fish, often contains residues of heavy metals like arsenic, cadmium, and lead, particularly in polluted rivers and lakes (Tanwir et al., 2017).

In Ghana, fish from the coastal and inland waters also show evidence of toxin accumulation. A study by Donkor et al., (2016) examined fish from the Korle Lagoon in Accra and found dangerously high levels of heavy metals such as cadmium, lead, and mercury. These metals originate from industrial effluents and municipal waste entering the water system. Similarly, fish from Lake Volta, the largest man-made lake in the world, have been reported to accumulate pesticides such as DDT and lindane, which are commonly used in agriculture around the lake (Darko et al., 2018). These substances bioaccumulate in fish tissues, reaching concentrations far above acceptable limits, posing serious health risks to the local populations that rely on these fish as their primary source of protein.

Furthermore, studies from around the world have highlighted the issue of illegal formalin use. Research from Bangladesh showed that formaldehyde concentrations in some fish species exceeded safety limits, leading to severe health risks, including carcinogenic effects (Li et al., 2017). Formaldehyde is also naturally produced in fish post-mortem, but its levels are significantly increased by human adulteration practices. In Ghana, although formaldehyde adulteration is not well-documented in academic literature, the use of formalin as a fish preservative has been reported in informal sectors, particularly in densely populated urban areas where fish preservation is challenging (Obodai, 2020).

Ecotoxicity of Toxins

In addition to the specific risks posed by formalin, heavy metals, pesticides, and washing powder residues, the broader ecotoxicity of chemicals like polycyclic aromatic hydrocarbons (PAHs) and organochlorine pesticides (OCPs) is also well-established. PAHs, which are by-products of the combustion of fossil fuels, have been found in elevated levels in fish from industrialized areas worldwide. For instance, fish from the Niger Delta in Nigeria, a heavily polluted region due to oil extraction activities, have been reported to contain high levels of PAHs (Abdel-Shafy et al., 2016).

In Ghana, similar issues are emerging, particularly around industrial hubs. Studies indicate that fish from the Tema Harbour area, a major industrial zone, are exposed to PAHs from nearby oil refineries and shipping activities (Olaifa et al., 2017). Organophosphorus pesticides (OPPs) and organochlorine pesticides (OCPs), commonly used in agriculture, are also prevalent in water bodies in agricultural regions, leading to contamination of local fish populations (Hussein El-Mekkawi et al., 2019).

Fisheries in Ghana

The fisheries business in Ghana has two main sectors: capture fisheries and aquaculture, often known as culture fisheries (Paintsil, 2010). Nevertheless, aquaculture in Ghana is still restricted to fish rearing. Within the realm of capture fisheries, two primary categories can be identified: coastal and inland. The fisheries along the coast, which comprise three divisions, namely artisanal fisheries (also called small-scale fisheries), and a significant industrial fishing fleet, contribute approximately 80% of the overall fish production. Notably, artisanal fishers alone capture over two-thirds of Ghana's marine fish catch

(Afoakwah et al., 2018). The fishermen in Ghana currently coexist with the emerging oil sector within the country's marine territory. This sector has generated expectations of substantial economic growth for Ghana but has also raised worries regarding possible environmental and social consequences. The fishing industry in Ghana comprises two main sectors: the semi-industrial fishery, also referred to as the inshore fishery, and the industrial fishery, commonly known as the distant water fleet (Perry, 2010). This study focused on the culture fisheries, specifically the industry centred around Elmina, to achieve the study's objectives. This study primarily examined two types of fisheries in Ghanaian coastal waters, namely the artisanal and semi-industrial fisheries, due to their established presence and significance (Nunoo, 2013).

The Artisanal Sector – The artisanal fishery predominantly employs various types of watercrafts, including motorized and non-motorized dug-out canoes and a diverse array of fishing equipment, to harvest fish within coastal regions. One of the techniques for fishing employed in Ghana is the beach seine, a gear commonly utilized on the sandy coastlines of the country (Nunoo, 2017). The primary focus of the artisanal fishery is the exploitation of tiny pelagic fish species (Mohammed et al., 2013). The beach seine fishing holds significant socioeconomic significance for numerous coastal communities within the country and constitutes 12% of the overall production of artisanal fisheries (Nunoo, et al., 2016). The small- and medium- fishery sector is crucial in various aspects such as food production, employment generation, and wealth building in remote regions. Another noteworthy element of small-scale fisheries is a flourishing post-harvest industry, primarily comprised of women engaged in fish processing, wholesaling, and retailing activities (Ministry of Fisheries, 2008).

Artisanal fishing, also known as subsistence fishing, encompasses a range of fishing operations characterized by their small-scale nature, utilization of low-technology methods, and limited capital investment. Individual fishing households typically carry out these activities. Many of these households consist of ethnic groups residing in coastal or island regions (Voegborlo et al., 2010). These households engage in brief fishing excursions that typically do not extend overnight and are conducted near the shoreline. Their agricultural products are typically unprocessed and mostly intended for regional consumption. Artisanal fishing employs conventional fishing methods, including beach seine, hook and line, cast nets, and small conventional fishing vessels (Tue et al., 2015). Artisanal fishing can be pursued for both commercial and subsistence purposes.

In comparison to contemporary industrial fishing methods, small-scale fishing practices exhibit notable distinctions as they tend to be characterized by reduced wastage and diminished stress on fish populations. The comprehensive documentation of artisanal fishing, including its complete volume and economic impact, is lacking due to its diffuse character. However, it is estimated that the overall magnitude and economic benefit of artisanal fishing could be roughly equivalent to that of industrial fishing.

The characterization of "artisanal" fishing exhibits considerable variability, yet the Food and Agriculture Organization (FAO) defines traditional fisheries conducted by fishing households rather than commercial enterprises. These activities involve utilising relatively modest amounts of capital and energy, employing relatively small boats, if any, and undertaking brief fishing expeditions close to the shoreline. The primary objective of such endeavours is the local consumption of the catch. The definition of the term "practice" exhibits variation across different countries. For instance, it might encompass gleaning or using a single-person canoe in low-income developing nations. At the same time, in wealthy countries, it may refer to the deployment of trawlers, seiners, or long-liners measuring over 20 meters long. Artisanal fisheries encompass subsistence and commercial fishing activities, catering to local consumption or facilitating exportation. These fisheries are occasionally denoted as small-scale fisheries. The distinction between artisanal and industrial production can often be ambiguous, necessitating a nuanced perspective that acknowledges a continuum rather than a rigid dichotomy (Wittsiepe et al., 2015). By conducting a comparative analysis of the dimensions of the boats employed and the level of financial resources allocated per individual on board, it becomes more discernible to identify these distinctions.

This implies that a wooden canoe of considerable size, propelled by human effort and employing rudimentary tools, can be classified as artisanal owing to its little technical input. A diminutive watercraft outfitted with cutting-edge GPS systems, downriggers, and sonar technology may yet meet the criteria for being classified as industrial. The primary distinguishing factor between industrial and artisanal fishing lies in their respective objectives within the fishing realm.

The primary objective of an industrial fishery is to maximize the capture of fish to generate economic profits. This fishing method entails certain inherent risks, such as the potential for overexploitation of fish populations leading to fisheries collapse, along with various other associated hazards. While artisanal fishers do have the option to sell a portion of their catch at marketplaces, their main focus is on subsistence fishing. In this context, individuals engage in fishing with the primary objective of procuring an adequate quantity of sustenance to support their households, while capitalizing on the opportunity to generate income by selling surplus catches. The pursuit of smaller-scale and ecologically sustainable objectives entails a reduced likelihood of jeopardizing fish populations. However, it is important to note that not all artisanal fisheries may be universally deemed superior to industrial fisheries. The impact of artisanal fisheries on various ecosystems and marine organisms is insignificant. The eco-friendliness of an artisanal fishery is frequently determined by the specific technology utilized, how it is implemented, and the overall management practices followed within the fishery. The artisanal fishery often employs several types of fishing gear, such as purse seines ("poli/watsa"), beach seines, drift gill nets, and surface set nets. Artisanal fishers also utilize a range of bottom-set nets and apply the method of hook and line, commonly referred to as "lagas". Fishing vessels often employ either drift gill nets or hook-and-line methods in areas characterized by water depths over 50 meters. In particular, individuals engaged in hook and line fishing, commonly called "lagas," typically carry essential supplies such as ice, provisions, and fishing equipment including fish finders and Global Positioning System (GPS) devices. Approximately 80 percent of the annual marine fish catch by volume is attributed to artisanal marine fishing.

The semi-industrial fishery comprises a fleet of 230 vessels produced domestically (MOFI, 2008). These vessels operate from eight landing sites across the country, one of which is the Tema inshore landing location.

According to the study conducted by MOFI in 2008, it was found that the semi-industrial fleet is responsible for around 2% of the overall marine fish production. The semi-industrial fishery exploits pelagic and demersal species, including scombrids, sciaenids, sea breams, snappers, and cuttlefish. A varied assemblage of many species characterizes the fisheries of Ghana. The Semi-industrial (inshore) fishery involves the utilization of indigenously constructed wooden vessels with dimensions ranging from 9 to 12 meters. These boats have engines with power output ranging from 30 to 90 horsepower. The primary objective of this fishery is to exploit the available fisheries resources. Most vessels have a dual-purpose capability, enabling them to employ trawls and purse seines effectively. These maritime vessels are active during upwelling periods, employing purse seines mostly in the nearshore regions at depths ranging from 30 to 50 meters. In these areas, they encounter competition from the artisanal fishing fleet. They capture around 2 percent of the overall marine production during their activities.

Species of Fishes and Fish Resources in Ghana

According to data from the Ministry of Environment and Science in 2012, a comprehensive inventory has identified 347 distinct marine fish species, classified into 82 taxonomic groups. Kwei and Ofori-Adu (2015) conducted a comprehensive study documenting the many fish species inhabiting the coastal waters of Ghana. Their research findings indicated the presence of 127 distinct species belonging to 53 taxonomic classes. In a study by Nunoo (2013), a comprehensive assessment of fish species near marine settings in Sakumono, Accra was conducted. The study identified a total of 75 fish species, which were classified into 35 taxonomically distinct families.

Similarly, Aggrey-Fynn et al., (2012) conducted a study in the central coastal waters of Ghana, where they recorded 56 fish species belonging to 30 taxonomic families. Several taxonomic families that can be identified include *Carangidae, Clupeidae, Polynemidae, Pomadasydae, Scianidae, and Scombridae*. Species like *Sardinella sp*., anchovies, and mackerels are commonly linked to periods of upwelling, during which they are taken in substantial volumes. Koranteng (2011) asserts that investigations into fish communities have revealed that both natural and anthropogenic causes have the potential to influence alterations in the composition of assemblages and the variety of species. Consequently, these changes can have implications for fishery resources' overall health and sustainability.

According to a study conducted by Gordon, Pulis, and Owusu-Adjei (2011), there has been a notable alteration in the biological and physical aspects of the marine environment in the Gulf of Guinea during the past thirty years. This transformation may potentially impact the collections of species within the sub-region. Prominent documented alterations encompass the decrease and subsequent resurgence of the round sardinella (*Sardinella aurita*), the increasing number and resulting decrease of the grey triggerfish (*Balistes capriscus*), and the augmentation in quantity of cuttlefish (*Sepia officinalis*) and globefish (*Lagocephalus laevigatus*).

According to the Food and Agriculture Organisation of the United Nations (2021), the predominant fish species captured in Ghana's waters are the tiny pelagics, including mackerel, horse mackerel, chub mackerel, sardines, and anchovies. Additionally, there exist fisheries targeting demersal species belonging to the *Sparidae, Lutjamdae, Mullidae, Pomadasydae, Serranidae,* *Polynidae, and Penaedae* families (FAO, 2021). According to Nzeve (2015), the small pelagic species constitute around 70 percent of Ghana's overall marine fish harvest.

Tilapia

Tilapia, scientifically classified as *Oreochromis niloticus*, is a member of the family *Cichlidae* and belongs to the family *Actinopterygii*. The fish in question exhibits a robust physique, characterized by scales and a distinct silvery hue. In addition to its characteristic silvery hue, the organism exhibits either black or grey body bars that enhance its overall appearance. When exposed to smoke, tilapia undergoes a transformation in which it acquires a dark brown hue, enabling it to remain unspoiled for an extended period. The average body length of this fish is 20 cm, with a maximum length of 62cm and a maximum weight of 3.65 kg. Tilapia, a species inhabiting freshwater environments, prefers to reside in stagnant, shallow waters adjacent to lakes and rivers that are abundant in vegetation (Watanabe et al., 2012).

Mudfish

Clarias anguillaris, commonly referred to as Mudfish is a species of freshwater fish typically encountered in regions of lakes or lagoons with significant water inundation. Their primary diet consists of other fish, molluscs, crabs, and benthic animals in the pond's substrate. The organism possesses a substantial cranial region that exhibits a concave morphology, typically connected to a lengthened anatomical structure. Additionally, the organism displays diminutive ocular organs situated inside the cranial region. The mudfish species is characterized by possessing a significantly large mouth and elongated dorsal fins.

The mudfish often exhibits a length ranging from 22 to 24 centimetres, with a maximum weight reaching 7 kilograms. The pigmentation of mudfish exhibits a range of hues, spanning from sandy-yellow to grey and extending to olive, accompanied by distinct dark greenish-brown patterns. According to Azeroual et al. (2010), the colour of the substance changes to black when it is smoked.

Tuna

Thunnus albacores, generally called Tuna, is a type of fish that exhibits a substantial size and primarily inhabits marine environments such as seas and oceans. Tuna has elongated second-dorsal and anal fins, beside a swim bladder lacking striations on the ventral surface of the liver. The spawning period of tuna occurs year-round, with notable surges in spawning activity throughout the summer. Tuna exhibits a black metallic hue with dark blue undertones, which remains perceptible even after the first smoking process on the first day. Upon further examination, it has been shown that the colour of smoked tuna transforms, becoming a darker shade of black and brown. This process leads to decreased water content and a significant extension of its shelf-life (Collett et al., 1983).

Salmon

The scientific nomenclature for salmon is *Oncorhynchus* species. It lives in inhabits aquatic environments such as seas and oceans. The salmon's body structure elongates throughout time, gradually becoming more prominent. The front portion of the upper jaw of *Oncorhynchus* species extends posteriorly beyond the eye. In contrast, male individuals' snout and lower jaw undergo a pronounced curvature during the spawning season. In their marine habitat, these organisms consume smaller fish, squids, pteropods, and insects as a source of sustenance. Salmon has the potential to reach a maximum length of roughly 75 cm and correspondingly weigh around 5 kg. During spawning, adult individuals typically exhibit a length ranging from 40 to 56 centimetres. Each exhibits the formation of conspicuous melanin-rich pigmented areas on its cranial region, upper lateral body surfaces, and posterior fin. Fresh salmon exhibits a silvery hue, but once undergoing smoking preservation, it acquires a golden-brown coloration, with its dorsal region emitting a black hue (Collette & Nauen, 1983).

The Small Pelagic Resource – The tiny pelagic resources exhibit substantial fluctuations in their biomes. According to Quansah (2014), an estimation suggests that the small pelagic fishery can support a maximum catch of 180,000 tons. The landings of *Sardinella* exhibit significant fluctuations, with certain years like 1973 and 1978 seeing near collapse. However, starting from the 1980s, there was a notable surge in landings, culminating in a record-breaking 140,000 metric tons in 1992 (Mensah et al., 2011). Since then, there has been a fall in landings, with a decrease to 64,000 metric tons in 1997. Quansah (2014) asserts that the quantity of chub mackerel (*S. japonicus*) exhibits considerable variability on an annual basis, rendering its predictability nearly impracticable. Comparably, the quantities of anchovy landings exhibited variations, ranging from 19,000 metric tons (mt) in 1986 to 82,700 mt in 1996, reaching a peak of 93,000 mt in 1987 (ibid). The FAO (2021) asserts that these fluctuations may be related to periods of decline commonly observed in pelagic populations globally, which are linked, among other factors, to alterations in the marine environment (FAO, 2012).

The Large Pelagic Resource – According to Mensah et al. (2013), the primary tuna species found in the waters of Ghana are the yellowfin (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*), and bigeye (*Thunnus obesus*). According to the Food and Agriculture Organization (FAO) in 2012, the Government of Ghana established a Tuna Task Force which proposed an increase in the country's yearly tuna production from an average of approximately 36,000 metric tons to 60,000 metric tons. According to Mensah et al. (2013), the overall capture in 1999 exceeded 83,000 metric tons. However, the average arrival from 2010 to 2012 was 9,400 metric tons.

The Demersal Resources – According to the Food and Agriculture Organization (FAO) in 2012, assessments of biomass surveys indicate that the estimated annual potential output of demersal biomass in Ghana's continental shelf ranges from 36,000 to 55,000 metric tons, with an average of approximately 43,000 metric tons. Nevertheless, in the previous decade, the yearly landings of approximately 50,000 metric tons surpassed the possible output, indicating the significant strain under which the fishery has been functioning.

Shrimp Resources – Despite dedicated shrimp fisheries in Ghana, shrimp are captured by other fleets, excluding tuna fishing vessels, primarily in low-lying waters around estuaries (Mensah et al., 2013). Shrimp of little economic value, typically in their juvenile stage, are mostly captured by artisanal operators using beach seines (FAO, 2021). According to the Food and Agriculture Organization (FAO, 2012), estimating shrimps' maximum sustainable yield (MSY) using a modelling technique suggests an annual production of 350 metric tons, not accounting for catches made by artisanal fishers. Despite never surpassing the maximum sustainable yield (MSY), the fishing industry has exhibited indications of a decrease over the past six years (Mensah et al., 2013). Even though shrimps are a frequent type of fish that may be found in Ghana, for the sake of this study, shrimps were included. Instead, the research primarily concentrated on the demersal and small and big pelagic resource species of fish.

Empirical Review

This section of the review examined scholarly works conducted on the topic. Based on the inherent gaps found in the review of similar areas, various arguments in the study were proposed and presented.

A study by Uddin et al (2011) indicated that Bangladesh imports fish and fish products from adjacent countries to fulfil or meet local demand. Several studies show that Bangladeshi fish contain formalin, a very toxic and carcinogenic toxin. The level of formalin usage in Dhaka fish was investigated. Five varieties of fish were obtained from five local markets and formalin was discovered using a Bangladesh Council of Scientific and Industrial Research designed “formalin detection kit in fish” (BCSIR). The investigation found formalin in 70% of Rui fish and over 50% of fish samples. The work of Udin et al. provides the degree of contamination of fish by formalin. However, the geographical scope of the study, Bangladesh, endears it to further empirical and laboratory inspection as the level of contamination of fish with formalin may not be the same in the Ghanaian context.

Gasu (2019) conducted a study on the presence of Polycyclic Aromatic Hydrocarbons (PAHs) and Organochlorine pesticides (OCPs) in salted, smoked, and sundried fish. The study involved the collection of six commonly consumed salted, smoked, and sundried fish samples from nine markets located in three coastal regions of Southern Ghana. The objective was to assess the contamination levels of seven PAHs and eight OCPs in these fish samples. The analysis utilised a gas chromatographic-mass spectrophotometer, with a detection limit of 1.0 parts per billion. The study revealed that the average levels of polycyclic aromatic hydrocarbons (PAHs) in smoked fish samples not irradiated ranged from 11.75 to 39.37 micrograms per kilogram (μgkg^{-1}). In contrast, the non-irradiated sun-dried fish samples exhibited PAH values ranging from 5.76 to 47.68 μgkg^{-1}. Furthermore, the degradation of PAHs in sun-dried fish due to gamma irradiation was observed to range between 0.32 and 29.73 μgkg^{-1} at a dose of 7.5 kiloGrays (kGy), and in smoked fish, the range was found to be 7.54 to 22.30 μgkg^{-1} at the same dose of 7.5 kGy. The concentration of benzo(b)fluoranthene (B(b)F) in smoked fish decreased from 33.55 – 22.30 micrograms per kilogram ($p \geq 0.05$) when exposed to a radiation dose of 7.5 kGy. The concentrations of pesticides and organochlorine pesticides (OCPs) in the non-irradiated samples varied between 0.1 and 93 $mgkg^{-1}$. However, after gamma irradiation, the concentrations decreased and ranged from non-detectable levels to 29.73 $mgkg^{-1}$ ($p = 0.001$) in sun-dried fish samples.

Although insightful, the work of Gasu was limited contextually as it focused on only processed fish (thus, sundried fish and smoked fish). Also, the study narrowed its scope to focus on only pesticide contamination and PAHs. Hence, these limitations endear his research to further investigation by broadening the scope of the definition of toxins in fish.

Alewy et al. (2020) analysed 17 dorsal meat samples for metals using Inductively Coupled Plasma Optical Emission Spectrometry. There was cadmium in all samples, although it was below the detectable limit. The average values of the detected toxins were 0.03, 0.016, 0.02, 0.03, 0.07, 0.08, 0.10, 0.08, 0.03, 0.03, and 2.90, 3.33 $mgkg^{-1}$. One sample had Lead (5.88 percent). On the other hand, all samples had modest levels of mercury (0.140.07). All heavy metals tested were within FAO/WHO permitted levels. The scientists claim that consuming such fish poses no dangers to humans due to the discovered quantities of heavy metals. Although insightful, the work of Alewy et al. (2020) focused mainly on detecting metal toxins and made little effort to detect other forms of toxins including formalin and washing powder. This limitation may be due to the geographical scope of the study, Iraq; as the environmental and social conditions of the country and Ghana are significantly different.

In their study, Narayan et al. (2019) sought to ascertain the presence or lack of formaldehyde in three distinct retail fish markets in Mumbai. The researchers collected samples from four separate Bungalows for analysis. The presence of formaldehyde was assessed in Rohu (*Labeo rohita*), Catla (*Catla catla*), Boyal (*Wallago attu*), Indian Mackerel (*Rastrelliger kanagurta*), and Bombay duck (*Harpodon nehereus*). The Catla fish exhibited a formaldehyde concentration of 2.76 μgg^{-1}, whereas the fish from the Andheri fish market displayed a formaldehyde concentration of 2.88 μgg^{-1}. The Rohu fish and Andheri fish market had formaldehyde The boyal fish samples' formaldehyde concentration was 2.38 and 2.22 μgg^{-1}, respectively. The formaldehyde content of Bombay duck fish was measured to be 1.48, 1.71, and 2.08 μgg^{-1}, while Indian Mackerel fish exhibited formaldehyde levels of 1.81, 2.27, and 2.35 μgg^{-}

[1]. The presence of formaldehyde has been observed in the flesh of both marine and freshwater fishes. Although marine fish may produce formaldehyde as part of their natural processes, the formaldehyde produced is often lower than freshwater fish. This difference may be attributed to potential adulteration in the marketing chain, as suggested by many authors.

The work of Narayan et al., (2019) is limited geographically and contextually as the work was conducted in Asia where concentrations of formalin and the uses for fish preservation may be significantly different from how it is used in Sub-Saharan Africa and therefore Ghana. Also, using only three species of fish for the tests narrowed the contextual scope of the study as a larger sample size could have led to much more robust findings. Finally, the type of laboratory test used to conduct his analysis is unclear, which makes the work insufficient for conclusive analysis. This endears their work for further empirical investigation into the degree of formalin concentration in fresh fish.

Adaagoam et al., (2018) conducted a study to investigate the extent of exposure to formaldehyde in the Ghanaian population residing in the Kumasi Metropolis through the consumption of fish. In their research, they utilized 3-methyl-2-benzothiazoline Hydrazone as an extracting agent. Formaldehyde was detected in all sixty species of both indigenous and non-indigenous fish examined, with concentrations ranging from 0.174 to 3.710 μgg^{-1}. The recorded measurements remained within the permissible threshold of 5 $mgkg^{-1}$ for formaldehyde in fish, as stipulated by the Malaysian Food Act and Regulation. The amount consumed was below the acceptable daily intake of 0.15 and 0.2 $mgkg^{-1}$ BW/day as advised by the World Health Organization and the United States Environmental Protection Agency for the ingestion of formaldehyde, correspondingly. Once more, it is observed that the danger quotient for all species examined was found to be below one. This finding suggests that the presence of formaldehyde in the fish is improbable to result in any adverse health effects for consumers.

Although insightful, Asare-Donkor et al.'s work focused on the Kumasi Metropolis, which is a non-fishing metropolis. Also, the study focused on using fish in cold stores relative to fresh fish which may provide a more accurate analysis of the situation. Finally, the use of foreign fish species implies that the data covered fishes that are not indigenous to Ghana and thus require narrowing the scope of the research.

In a study conducted by Noordiana et al., (2011), the objective was to assess the formaldehyde content and quality parameters of fish and seafood from wet markets. The findings revealed that the amount of formaldehyde in the fish samples ranged from 0.38 to 15.75 μgg^{-1}. All samples analysed in this study exhibited the presence of three distinct biogenic amines, namely histamine, putrescine, and cadaverine. The histamine level ranged from 0.25 to 1.97 μgg^{-1}, putrescine level ranged from 0.33 to 9.09 μgg^{-1}, and cadaverine level ranged from 0.34 to 5.81 μgg^{-1}. Regarding microbiological studies, the total plate counts for all fish kinds exhibited a range of 5.68 to 7.13 log cfu g-1, while the proteolytic counts varied from 5.12 to 6.91 log cfu g-1. The samples were analysed to determine the presence of bacteria capable of making putrescine, cadaverine, and histamine. The bacterial counts observed in the samples ranged from 3.50 to 6.52 log cfu g-1. The researcher also discovered that no statistically significant variation ($p>0.05$) was observed in the fish samples obtained from several wet markets.

Conceptual Framework

Based on the research objectives, a conceptual framework was proposed for the study. Figure 1 displays the conceptual framework.

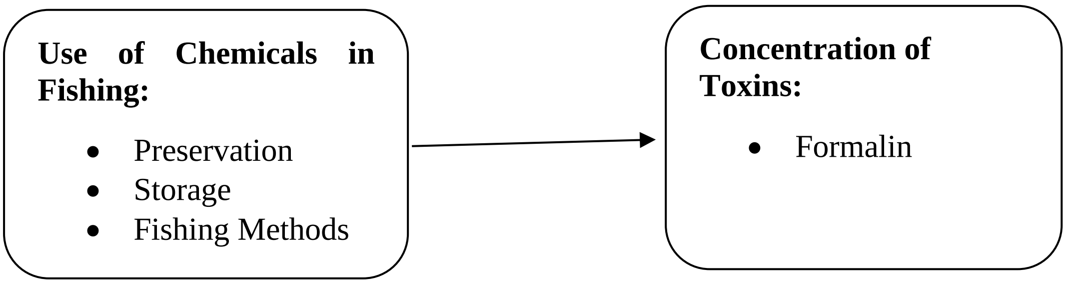

Figure 1: Conceptual Framework

From the conceptual framework, the use of chemicals in fishermen's fishing practices, including fishing methods and perceived preservation and storage methods, is expected to be associated with the volume of concentration of formalin in fish along the central coast of Ghana.

CHAPTER THREE

RESEARCH METHODS

Introduction

The study sought to examine possible formalin available in fishes caught along the Coast of Ghana, with a particular interest in the Elmina, Anomabo, Biriwa, and Moree fishing centres of the Central Region of Ghana. This chapter therefore discusses the methodology used for the study. This chapter provides a detailed discussion of the research approach, research design, study population, sample size and sampling methodologies, data collection instruments, and method used for data analysis.

Research Design

The study was conducted in accordance with positivism, a philosophical paradigm that upholds the idea that only information derived from observation and the senses – including measurement – is reliable (Zyphur & Pierides, 2020). This philosophy was used because the study involves scientific experiments which revealed objective facts. Based on the philosophy, the study adopted quantitative research approach and experimental research design. Before sampling, relevant literature was thoroughly reviewed to ensure a comprehensive understanding of the methodologies and potential challenges. Reagents, including Trichloroacetic acid (TCA), Nash reagent, Ammonium acetate, Ethyl acetone, Acetic acid, and distilled water were acquired for the reactions. Essential tools, such as zip-lock bags, ice chests, and GPS coordinates of the sampling areas were obtained from the Geography Department of the University of Cape Coast well before the sampling period. Analytical methods were carefully planned to ensure the precision and accuracy of sample analysis.

The sampling sites were strategically selected, focusing primarily on major fishing areas known for their high use of different fish preservation approaches. A cross-sectional sampling approach was employed to capture a representative snapshot of the environmental conditions.

Research Population

Marzcyk, DeMatteo, and Festinger (2005) define the population of a study as the comprehensive and pertinent quantity of objects that fall inside the contextual and geographical boundaries of a research investigation. Therefore, a population refers to a set of variables a study aims to conclude about through inference. The study encompasses the entire fish population residing along the coastal regions of Ghana. This study encompasses the entirety of 347 marine fish species, which are classified into 82 taxonomic groups, as documented by the Ministry of Environment and Science (MoES, 2012). The target population consists of 474 marine and coastal fishes as identified by these authorities.

Sample and Sampling Procedure

This researcher sampled from Anomabo, Biriwa, Moree and Elmina. The sites were purposely selected because of their largest landing and trade shores in the central coast of Ghana. The fish samples were selected conveniently because they were the type of fishes the fishermen had caught at the time the researcher visited. A structured and standardized sample collection protocol was followed to assess formalin contamination across various fish species from different coastal locations in Ghana. Each fish species was collected from each of these locations for a comparative analysis of the formalin levels across the species and their respective geographical areas. The following outlines the sample collection and handling procedures to ensure accuracy, consistency, and scientific rigor in this study. The sampling sites included four coastal fishing communities in the central coast of Ghana-Biriwa, Anomabo, Moree, and Elmina-known for their active fishing markets. At each location, local fishermen and market vendors were engaged by the researcher to obtain freshly caught fish samples using convenience sampling technique. This collaborative approach ensured access to high-quality samples collected directly from the landing site, thereby reducing potential degradation or contamination associated with prolonged storage. The study targeted thirteen fish species commonly found in the central coast of Ghanaian waters: Redfish, West African goatfish (Kokodudu), Bluntnose Lizard fish (Akoteakote), Lesser African threadfin (Sukwei), Salmon, Herrings, Boe drum (Ebue Akoa), Club mackerel Kyerkyerwere, Flying gurnard (Pampamsere), Bullet tuna (Apoku), Bogue (Oto), West African Spanish mackerel (Saforo), and Grey Trigger fish (Ewurefua). Each species was chosen based on the availability at the time the researcher visited the shores. To maintain consistency in species identification, experts in fisheries thus the African Centre of Excellence in the university of Cape Coast (ACECOR) assisted in accurately mentioning the English names of the fish samples before analysis. A total of five per species were conveniently collected from each location, resulting in a substantial dataset for statistical comparison. Consistent fish size was sought for each species to control for size-related variability in formalin levels. Specimens were measured and recorded for both weight and length to maintain a uniform sample size across locations.

For each sample, a detailed record was maintained, documenting the species name, location of collection (Biriwa, Anomabo, Moree, or Elmina), date and time of collection, source (e.g., fishermen or local markets), and specific physical metrics (weight and length). Each fish was assigned a unique sample identification code (e.g., "BIR-RF-01" for the first Redfish specimen from Biriwa), allowing for precise tracking throughout the study. This labelling system facilitated seamless sample management and minimized the risk of misidentification during laboratory processing.

Immediately following collection, each fish specimen was placed in a sterile, individually labelled zip-lock plastic bag to prevent any cross-contamination. Specimens were then stored in coolers with ice packs to maintain a temperature of approximately 4°C, thus preserving the fish sample integrity during transport. All samples were transported to the laboratory within 24 hours; in instances where immediate analysis was not feasible, samples were frozen at -20°C to inhibit any biochemical changes or degradation of formalin content.

Reagents

Trichloroacetic acid (TCA), Nash reagent, Ammonium acetate, Ethyl acetone, Acetic acid, distilled water.

Preparation of Nash Reagent. (Nash, 1953)

15 g of ammonium acetate was weighed and transferred in a 100 ml volumetric flask. 0.3 ml acetyl acetone and 0.2 ml of acetic acid was added. This was diluted with distilled water to the mark. This prepared Nash's reagent was kept in a dark-glass bottle covered with Aluminium foil because it is light sensitive.

Preparation of Trichloroacetic Acid

15 g of trichloroacetic acid was measured and transferred into a 250 ml volumetric flask and was diluted with distilled water to the mark.

Preparation of standards (Formaldehyde)

Working Formaldehyde Standard with Concentrations 0.1ppm, 0.5ppm, 1ppm, 2ppm and 5ppm were prepared by diluting 10ppm stock solution of formaldehyde and subsequently added 2 ml of Nash's reagent to each of the prepared solution in separate 25ml flasks. These solutions were then heated in a water bath for 30mins at 60°C. The volume was brought up to the 25 ml mark by adding distilled water in order to make a desired solution. The absorbance of each standard formaldehyde prepared was determined by measuring the absorbance at 415 nm using a UV-Vis spectrophotometer and a calibration curve was plotted from the data.

Extraction Procedure

Each sample was thawed and cut into small pieces. The samples were then blended and homogenized. 30 g of each sample was measured and transferred into a beaker. 60 ml of 6% w/v of prepared trichloroacetic acid was added. The mixture was then filtered with a Whatman filter paper and 5 mL of each filtrate (two for each sample) was collected into two different test tubes. The extract was then stored in a freezer for 30 mins. After, 2 mL of the Nash reagent was added to the 5 mL of the extract. The sample was then heated in a water bath at 60°C for 30 mins. Finally, the absorbance of formaldehyde by the extract was measured immediately at 415 nm using a UV Spectrometer.

Sample Analysis

The samples were analysed using a UV Spectrophotometer (Thermo Fisher Scientific, Waltham, MA) at a wavelength of 415nm. At first, a standard formaldehyde solution was analysed in different fractions and the readings were recorded from the UV Spectrophotometer. The concentrations and the absorbance of the standard solutions were used to prepare a standard curve. The formaldehyde concentration of the different fish samples was measured and compared with those in the standard curve in order to determine the concentrations of formaldehyde in the samples.

Quality Control

Quality control methods were implemented during the study to validate the obtained data's accuracy. In each analytical batch, the samples underwent multiple analyses to ascertain the analysis' precision and accuracy. During the analysis, we additionally used standard reagents and blanks to guarantee accuracy.

Data Analysis

The data obtained were examined, characterised, organised, and coded into an Excel Worksheet and the results were exported to the Statistical Package for Social Sciences (SPSS) version 22.1 pack was used as the main tool for analysis. Some analyses conducted were descriptive, using means, standard deviations, and frequencies. Presentation of data using graphs was done where feasible using tables and charts. For the comparisons of concentrations of toxins with world averages, One-way ANOVA was used.

Ethical Considerations

To obtain ethical clearance to undertake the study, an introductory letter was obtained from the VOTEC Department to show official proof of studentship. An application form for clearance was also filled, submitted to Institutional Review Board, UCC. This was reviewed by the board and clearance provided prior to data collection. The researcher visited the various fishing sites along the central coast of Ghana-Moree, Biriwa, Anomabo, and Elmina, and every fisherman or fishmonger who sold fish. Some fish were bought, packaged well and conveyed to the laboratory for storage prior to conducting the analyses.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

Chapter 4 delves into the quantified concentrations of formalin found in various fish types from Ghana's coastal sites, juxtaposing these findings against the broader backdrop of global research and concerns about food safety. This chapter outlines the results and subsequently discusses their implications with existing literature. The overarching goal was to elucidate the current formalin contamination in Ghana's fish supply, offering insights crucial for consumers, stakeholders, and policymakers in public health and food safety.

To validate the analytical methods for the quantitative determination of formalin in the fish samples, some characteristics, including linearity, the minimum detection limit, the minimum limit of quantification, repeatability, and accuracy, were taken into account and assessed.

Quality Control Results

Research Question

1. Was formalin present in common species of fish caught in Anomabo, Biriwa, Moree, and Elmina?

   Formalin was present in fish samples with Bluntnose Lizard fish (Akoteakote) caught at Elmina were considerably high, 59.180 ± 0.611 ppm and herrings, also caught from Elmina recorded lower formalin concentration measured at 0.871 ± 0.812 ppm.

Research Question

2. **What are the concentration levels of formalin found in common species of fish caught in Anomabo, Biriwa, Moree, and Elmina?**

The analytical procedure was validated to assess the comprehensive efficacy of the analytical technique utilized in the investigation, including the extraction process, purification, and instrumentation. This involved employing a Calibration Solution derived from a 37% formaldehyde standard and subjecting it to analysis employing a UV-spectrophotometer. The calibration solutions were utilized to establish calibration curves in the form of y = ax + b, where y represents the signal strength and x denotes the concentration of the analyte in the calibration solution. The acceptability of the linearity of the calibration curve depicted in Figure 2 was determined based on the regression coefficient R^2, which was reported to be 0.963 in the study conducted by Voica et al. (2012).

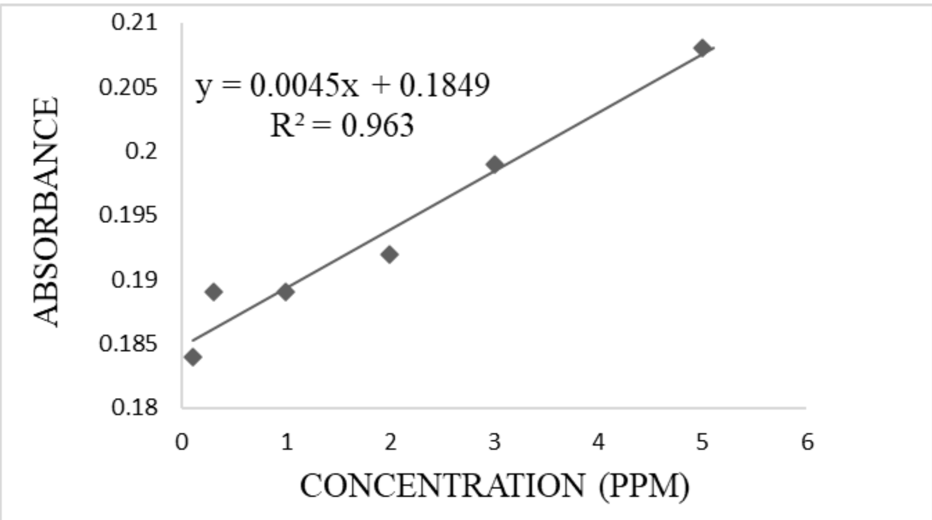

Figure 2: Standard curve for formalin concentration in fish
Source: Okyere (2023)

The limit of detection (LOD) was determined by multiplying the standard deviation of the concentrations by a factor of three and afterward dividing it by the slope of the calibration curve. Similarly, the limit of quantification (LOQ) was determined by multiplication of the standard deviation by a factor of ten, followed by division by the slope of the calibration curve. The limit of detection (LOD) and limit of quantification (LOQ) for each element were calculated using Equations 1 and 2, respectively.

$$\mathrm{LOD} = \frac{3 \times SD}{m} \quad (1)$$

$$\mathrm{LOQ} = \frac{10 \times SD}{m} \quad (2)$$

Where SD stands for the standard deviation of the data and m is the gradient of the calibration curve for each different species of fish.

Table 1: Limit of Detection and Limit of Quantification for Formalin

Element	Gradient	LOD	LOQ
Redfish	0.1849	0.502	1.674
West African goatfish	0.1849	0.917	3.056
Bluntnose Lizard fish	0.1849	0.155	0.517
Lesser African threadfin	0.1849	1.213	4.044
Salmon	0.1849	0.241	0.803
Herrings	0.1849	1.743	5.810
Boe drum	0.1849	1.698	5.661
Club mackerel	0.1849	0.133	0.444
Flying gurnard	0.1849	0.658	2.194
Bullet tuna	0.1849	0.446	1.488
Bogue	0.1849	0.138	0.460
West African Spanish mackerel	0.1849	0.127	0.425
Grey Trigger fish	0.1849	0.339	1.130

SD = Standard Deviation

Source: Okyere (2023)

Table 2 presents the varying thresholds across fish types at which formalin can be reliably detected and quantified, highlighting the importance of considering species-specific variations when monitoring formalin levels.

Formalin Concentration in Fish

The study aimed to quantify the mean concentrations of formalin across various fish types sampled from four different coastal sites in Ghana: Anomabo, Biriwa, Elmina, and Moree. The data provides insight into the variance of formalin concentrations in fish types, including Redfish, Kokodudu, Akoteakote, Sukwei, Salmon, and Herrings.

Research Question

3. **How did the concentration of formalin in common fish species in Elmina Anomabo, Biriwa, Moree, and Elmina compare with the EFSA?**

Table 2: Mean concentrations (ppm) of formalin in fish at sample sites

	Concentration of formalin in fish (Mean ± Standard deviation)				Permissible level
Fish Type	**Anomabo**	**Biriwa**	**Elmina**	**Moree**	
Redfish	15.899 ± 4.595	21.133 ± 4.183	24.094 ± 1.142	21.911 ± 3.614	
West African goatfish	38.868 ± 3.305	23.716 ± 0.718	21.353 ± 1.451	22.911 ± 3.143	
Bluntnose Lizard fish	53.132 ± 7.434	58.919 ± 1.154	59.180 ± 0.611	59.133 ± 1.257	
Lesser African threadfin	7.241 ± 0.552	14.786 ± 3.629	6.659 ± 4.900	14.000 ± 0.283	
Salmon	12.122 ± 1.407	14.137 ± 0.377	12.138 ± 0.645	13.689 ± 0.786	
Herrings	3.690 ± 3.347	3.024 ± 0.315	0.871 ± 0.812	1.467 ± 0.157	
Boe drum	10.356 ± 1.100	20.356 ± 2.671	42.578 ± 0.471	43.689 ± 2.043	100ppm
Club mackerel	12.244 ± 0.629	12.244 ± 0.629	13.356 ± 0.943	12.244 ± 0.629	
Flying gurnard	13.911 ± 1.100	11.689 ± 1.100	8.356 ± 0.471	13.911 ± 1.100	
Bullet tuna	6.911 ± 0.314	6.911 ± 0.314	9.133 ± 0.314	6.911 ± 0.314	
Bogue	11.800 ± 0.314	11.800 ± 0.314	12.911 ± 1.886	11.800 ± 0.314	
West African Spanish mackerel	12.800 ± 0.157	12.800 ± 0.157	13.911 ± 1.728	12.800 ± 0.157	
Grey Trigger fish	15.578 ± 0.314	15.578 ± 0.314	12.244 ± 1.886	15.578 ± 0.314	

Source: Okyere (2023)

Table 2 delineates the mean formalin concentrations across various fish species from four sampling locales: Anomabo, Biriwa, Elmina, and Moree. These concentrations, expressed in ppm, compares the amount of formalin in same fish species across the sites. The 'Akoteakote' species emerges as an outlier, with formalin concentration consistently across sampling sites, most notably peaking at Elmina with 59.180 ± 0.611 ppm. Conversely, herrings from Elmina manifest one of the most attenuated formalin concentrations at 0.871 ± 0.812 ppm, suggesting a potential differential in exposure or preservation methodologies among districts Furthermore, 'Ebue Akoa' showcases marked fluctuations, with its concentration at Anomabo being 10.356 ± 1.100 ppm, which escalates drastically in Elmina and Moree.

In contrast, species such as 'Kyerkyerwere' and 'Oto' exhibited a remarkable homogeneity in formalin concentrations across sites, suggesting a potential uniformity in exposure or preservation practices. Kyerkyerwere's readings oscillate around 12.244 ± 0.629 ppm and Oto's around 11.800 ± 0.314 ppm. Notably, 'Redfish' and 'Kokodudu', both integral to culinary preferences, present elevated formalin metrics across most sites, with the former's concentration notably surpassing the permissible threshold at Elmina. Collectively, the data underscores the imperative for rigorous scrutiny of formalin concentrations in aquatic consumables, particularly discerning the underlying causative factors for such disparities.

Table 3: Correlation of formalin concentration in fish across sample sites

	Anomabo	Biriwa	Elmina	Moree
Anomabo	1			
Biriwa	.902**	1		
Elmina	.734**	.897**	1	
Moree	.738**	.909**	.983**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Okyere (2023)

Table 3 elucidated the correlation coefficients encapsulating the interrelations of formalin concentrations among four sampling locations: Anomabo, Biriwa, Elmina, and Moree. Manifesting significant correlations at the 0.01 level, the matrix underscored pronounced interdependencies in formalin concentrations across sites. Notably, the Biriwa-Moree and Elmina-Moree dyads exhibited exceptionally robust correlations of 0.909 and 0.983 respectively, suggesting nearly concomitant variations in formalin concentrations. Conversely, Anomabo, while maintaining significant correlations with Elmina and Moree at 0.734 and 0.738 respectively, intimates a slightly attenuated linear relationship. Collectively, these findings underscore the presence of pervasive commonalities or practices influencing formalin concentrations across these regions, with certain sites mirroring each other's trends more pronouncedly.

Table 4: One-Sample T-test of the concentrations of formalin found in fish caught from the sample sites

	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Anomabo	-21.732	12	0.000	-83.496	-91.867	-75.125
Biriwa	-21.802	12	0.000	-82.531	-90.779	-74.283
Elmina	-18.427	12	0.000	-81.786	-91.456	-72.115
Moree	-18.657	12	0.000	-80.766	-90.198	-71.334

Source: Okyere (2023)

Table 4 presents a one-sample T-test on the formalin concentrations found in fish caught across four sample sites: Anomabo, Biriwa, Elmina, and Moree. The t-values for all sites were notably negative, with Anomabo and Biriwa demonstrating values of -21.732 and -21.802 respectively, and Elmina and Moree presenting slightly less negative values of -18.427 and -18.657 respectively suggesting that the sample mean is below the permissible level of formalin in fish (100 ppm). Critically, each site's two-tailed significance (Sig.) is 0.000, indicating a statistically significant deviation of the sample mean from a hypothesized population mean (permissible level). These findings suggest that the formalin concentrations found in fish caught at each of the sample sites differ significantly from the pre-established standard or benchmark.

Exploratory Factor Analysis

Table 4 presents the results of exploratory factor analysis (EFA) applied to formalin concentrations across different fish types. Utilizing Principal Component Analysis for data extraction and Varimax with Kaiser Normalization for rotation, two distinct components that seem to influence formalin concentrations emerge.

Table 5: Rotated Component Matrix of formalin concentration in the type of fish

	Component	
Fish type	1	2
Redfish	0.353	0.935
West African goatfish	-0.116	-0.989
Bluntnose Lizard fish	0.027	0.995
Lesser African threadfin	-0.845	0.520
Salmon	-0.802	0.551
Herrings	-0.503	-0.776
Boe drum	0.313	0.825
Club mackerel	0.943	0.326
Flying gurnard	-0.793	-0.443
Bullet tuna	0.943	0.326
Bogue	0.943	0.326
West African Spanish mackerel	0.943	0.326
Grey Trigger fish	-0.943	-0.326

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization.

Source: Okyere (2023)

For Component 1, fish such as Kyerkyerwere, Apoku, Oto, and Saforo display pronounced positive loadings, with values near 0.943, indicating a strong association with this component. Conversely, fish types like Sukwei, Salmon, Pampamsere, and especially Ewurefua (with a loading of -0.943) exhibit significant negative associations, suggesting a deviation from the characteristics of this component. Regarding Component 2, Akoteakote stood out with a notably high positive loading of 0.995, indicating its close alignment with this component. Other fish, including Redfish, Ebue Akoa, and Kyerkyerwere, also show positive associations, though with more moderate loadings. In contrast, Kokodudu, with a loading of -0.989, appears to be the most disassociated from this component. The identification of these two components suggests that underlying factors account for the variability in formalin concentrations among fish types.

Table 6: Component Score Coefficient Matrix for formalin concentration in the type of fish

Fish type	Component	
	1	2
Redfish	-0.002	0.173
West African goatfish	0.045	-0.200
Bluntnose Lizard fish	-0.060	0.207
Lesser African threadfin	-0.172	0.163
Salmon	-0.167	0.167
Herrings	-0.033	-0.130
Boe drum	-0.002	0.153
Club mackerel	0.134	0.008
Flying gurnard	-0.102	-0.042
Bullet tuna	0.134	0.008
Bogue	0.134	0.008
West African Spanish mackerel	0.134	0.008
Grey Trigger fish	-0.134	-0.008

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Source: Okyere (2023)

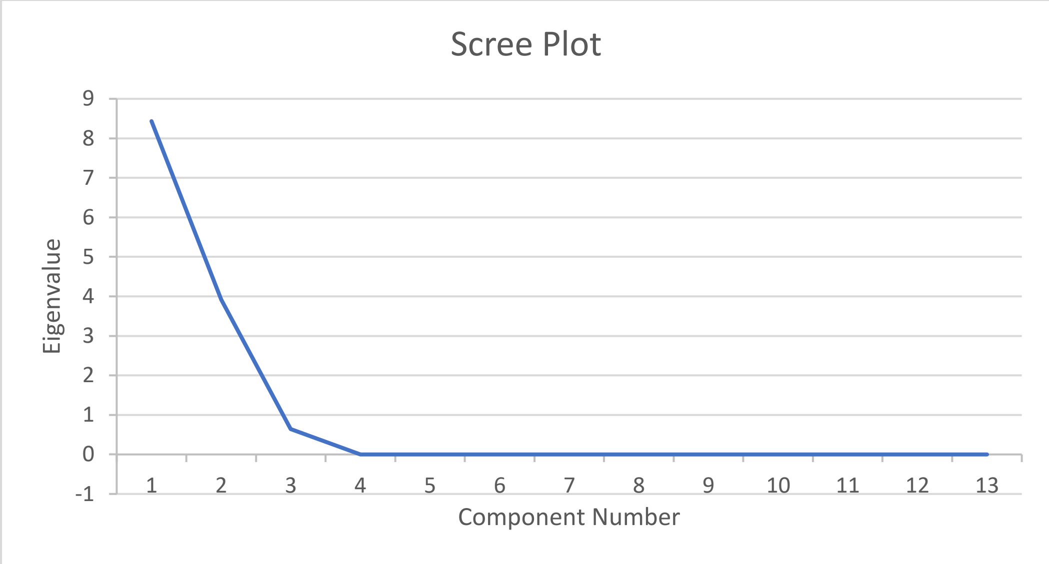

Figure 3: Scree plot of extracted components of formalin concentration in the types of fish
Source: Okyere (2023)

A scree plot is a visual tool utilized predominantly in factor analysis and principal component analysis (PCA) to determine the optimal number of components or factors to retain. In this study, 2 components were extracted.

Discussion

The level of formalin in the fish sample ranged from 0.871 ± 0.0812 to 59.180 ± 0.611. The formaldehyde concentration in all species of all locations is relatively low with a general mean value of around 17.855 ppm. In a previous investigation conducted by Bianchi et al. (2007), the researchers did not pursue further analysis when the formaldehyde content was below 1 ppm since these lower levels do not pose a health risk. Various varieties of fruits, kinds of meat, and fish species possess varying levels of formaldehyde as a metabolite. In a study by Bianchi et al. (2007), formaldehyde concentration above 5 parts per million (ppm) was discovered in fresh fish samples.

Similarly, Noordiana et al. (2011) reported the presence of formaldehyde ranging from 0.38 to 15.75 parts per million (ppm) in several fish species. The formaldehyde concentrations in the fish samples were somewhat greater than anticipated for certain fish species, such as Akoteakote. However, lower quantities were recorded in herrings, as shown in Table 2. This disparity in the level of formalin concentration suggests that some communities might use formalin deliberately for fishing while others do not. Notably, formaldehyde undergoes production and exhibits a concentration rise of 134% after 6 days, even when subjected to storage conditions at 0°C, as reported by Bianchi et al. (2007). Hence, it is quite probable that the formaldehyde concentration levels would increase during prolonged storage and transportation of fish from sea to market. Simultaneously, the process of cooking leads to a reduction in the concentration of the aforementioned volatile analyte due to the phenomenon of evaporation (Bianchi et al., 2007). The present investigation has uncovered that fish exhibit a notably low level of formaldehyde concentration. Specifically, the observed values in herrings (0.871 ± 0.0812) are significantly below the recommended thresholds set by the Italian Ministry of Health, which are 60 ppm for fish of the *Gadidae* family and 10 ppm for crustaceans. Also, Adaagoam et al, 2018) discovered formaldehyde in all sixty species of local and foreign fish tested, ranging from 0.174 to 3.710 ppm. The readings were still below the Malaysian Food Act and Regulation maximum limit of 5 $mgkg^{-1}$ for formaldehyde in fish. Therefore, there could be minimal risk to the consumer of fish in the central region concerning formalin adulteration.

The variance in formalin concentrations across the selected sites Anomabo, Biriwa, Elmina, and Moree more reminiscent of findings from other coastal regions globally. Such variances reflect the heterogeneity in fishing practices, preservation methods, and even the proximate industrial activities that may influence contamination levels. The substantial correlations between sites, as indicated in the exploratory factor analysis, suggest common underlying factors or practices (such as direct use of formalin as a preservative, runs from agriculture, improper disposal, lack of awareness, lack of regulation as well as accidental spills) that influence these high concentrations. This pattern resonates with studies from other coastal regions where shared fishing or preservation practices lead to similar contamination profiles (Narayan et al., 2019; Gasu, 2019).

These communities are traditionally known for fishing in the central region of Ghana. Most of these fishermen were not educated and were therefore engaged in the direct use of formalin for fishing activities, which directly affects the levels of formalin found in fish, posing a danger to human health after consumption. The implications of these findings are manifold. From a consumer's perspective, the data underscored the need for vigilance in sourcing fish, with certain species and regions such as Elmina, potentially posing higher risks. For stakeholders in the fishing industry, there was a pressing need to re-evaluate and possibly standardize preservation practices to ensure safety. Policymakers, on the other hand, are furnished with empirical evidence to draft or refine regulations on formalin usage in fish preservation. The health implications of prolonged exposure to formalin-contaminated food sources necessitate stringent measures to mitigate risks and safeguard public health. The study offered invaluable insights into the formalin concentrations found in fish from Ghana's coastal regions. When juxtaposed against global research, the findings underscored shared concerns and patterns, emphasizing the universal need for rigorous monitoring and intervention in food safety practices.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Introduction

Drawing from the rigorous data collection and analysis from specified sample sites, the chapter presents a concise summation of key findings, articulates conclusive interpretations regarding the implications of these concentrations on public health and food safety, and, based on the evidence gathered, proffers recommendations directed towards stakeholders to ensure optimal safety standards and practices. The chapter climaxes the study by providing suggestions for future research.

Summary

Key Findings

The study sought to investigate the levels of formalin in different fish samples collected from various sites along the central coast of Ghana. Throughout the research, certain significant variations in formalin concentrations in fish were noticed, which seemed to be influenced by the specific fish type and sample location.

A notable observation was with the Akoteakote fish caught from Elmina. The formalin levels in this particular fish were considerably high, registering at 59.180 ± 0.611 ppm. This stood because it was among the highest concentrations encountered throughout the research. In contrast, when herrings, also from Elmina were analysed, the formalin concentration was much lower, it was measured at 0.871 ± 0.812 ppm. This discrepancy, observed within the same location but across different fish types, led to the belief that the location alone might not be the sole determinant of formalin levels. Other aspects, such as storage methods, handling practices, or even the natural habitats of these fishes, could play pivotal roles.

Further analysis of the data revealed intriguing patterns across different locations. It was found that the fish from Elmina and Moree exhibited strikingly similar formalin levels, with a correlation value of 0.983. This near-identical trend provided that both regions might share common practices or face similar environmental conditions influencing the formalin concentrations in their fish.

Conclusion

This comprehensive study on formalin concentrations in fish from these coastal areas revealed marked variability across different fish types and the sampling sites. Certain species, like Akoteakote from Elmina, exhibited high formalin levels, though not up to the permissible limits stated by Annobi et al., 2023, which contrasted with other species from the same location. Additionally, the remarkable similarity in formalin concentrations between fish from Elmina and Moree suggested shared practices or environmental factors at play. These findings underscored the intricate interplay of various determinants influencing formalin levels, emphasizing the imperative for rigorous monitoring and standardization of fish preservation practices to ensure public health.

Recommendations

Based on the findings of the study, the study recommended the following:

- **Standardized Preservation Protocols**: Given the observed variability in formalin concentrations found across fish types and locations, there's a clear need to establish standardized fish preservation protocols. Authorities (community leaders, the Ministry of Agriculture at the district level, and all stakeholders) should collaborate with local fishery communities to develop and disseminate best practices for fish preservation that minimize the use of harmful chemicals like formalin.

- **Increased Monitoring and Regulation**: Regulatory bodies (Ghana Environmental Protection Agency, Fisheries Commission, and Food and Drugs Authority) should intensify monitoring efforts, especially in regions like Elmina where notably high formalin concentrations were observed. Regular checks and inspections can ensure that fish sold in markets adhere to safe concentration levels, thereby protecting public health.
- **Public Awareness Campaigns**: Considering the health implications of consuming fish with high formalin concentrations, there's a need for public awareness campaigns. The general populace should be educated about the potential risks associated with formalin in fish and how to identify signs of excessive chemical preservation in the fish they purchase.
- **Research on Alternative Preservation Methods**: The Ghana Fisheries Commission should encourage and fund research into safer, alternative methods for preserving fish that do not rely on harmful chemicals. Identifying and promoting such methods can reduce the industry's reliance on formalin, ensuring both the fish's freshness and consumers' safety.

Suggestions for Future Research

Given the disparities in formalin concentrations among fish types and locations, future research should investigate the ecological and commercial factors influencing these levels. This includes examining the specific habitats, feeding habits, and life cycles of the fish species with elevated formalin levels and the commercial practices, supply chains, and preservation techniques employed in different regions. Such a comprehensive study could provide a more holistic understanding of the root causes of formalin variation, paving the way for targeted interventions and improved fishery practices.

Also, I would recommend that further studies be conducted to carefully assess the prevalence of washing powder in fish samples caught from the coastal sites studied since this could not be achieved.

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APPENDICES

APPENDIX A

ETHICAL CLEARANCE

UNIVERSITY OF CAPE COAST

INSTITUTIONAL REVIEW BOARD SECRETARIAT

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20TH FEBRUARY 2023

Ms Rita Boahemaa Okyere
Department of Vocational and Technical Education
University of Cape Coast

Dear Ms Okyere,

ETHICAL CLEARANCE – ID (UCCIRB/CES/2022/91)

The University of Cape Coast Institutional Review Board (UCCIRB) has granted Provisional Approval for the implementation of your research on ***Possible Toxic Substance Found in Fish Along the Coast of Central Region.*** This approval is valid from 20th February 2023 to 19th February 2024. You may apply for a renewal subject to the submission of all the required documents that will be prescribed by the UCCIRB.

Please note that any modification to the project must be submitted to the UCCIRB for review and approval before its implementation. You are required to submit a periodic review of the protocol to the Board and a final full review to the UCCIRB on completion of the research. The UCCIRB may observe or cause to be observed procedures and records of the research during and after implementation.

You are also required to report all serious adverse events related to this study to the UCCIRB within seven days verbally and fourteen days in writing.

Always quote the protocol identification number in all future correspondence with us in relation to this protocol.

Yours faithfully,

Kofi F. Amuquandoh

Ag. UCCIRB Administrator

ADMINISTRATOR
INSTITUTIONAL REVIEW BOARD
UNIVERSITY OF CAPE COAST