UNIVERSITY OF CAPE COAST

CADMIUM, LEAD AND COPPER LEVELS IN TEN COMMON SPICES SOLD IN CAPE COAST

WINNIFRED PEACE MENSAH

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BY

WINNIFRED PEACE MENSAH

Thesis submitted to the Department of Vocational and Technical Education of the Faculty of Science and Technology Education, College of Education Studies, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Home Economics.

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DECLARATION

Candidate's Declaration

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

Candidate's Signature …… Date ……

Name: Winnifred Peace Mensah

Supervisor's Declaration

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

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

Name: Prof. Mrs. Sarah Darkwa

ABSTRACT

Spices are used as diet ingredients often to enhance aroma, colour, palatability and acceptability of food. Thus, the contamination of spices by heavy metals may result in the accumulation of these metals in the body organs through consumption of these spices. The purpose of this study was to determine the concentrations of Pb, Cu and Cd in common spices available on Cape Coast markets. A total of 60 samples of 10 different spices from Abura and Kotokoraba markets in the Cape Coast Metropolis were analyzed for Pb, Cu and Cd concentrations using Atomic Absorption Spectrophotometer after acid digestion. However, the spices were selected based on a preliminary study of the market that sought the opinions of both buyers and sellers of natural spices on the kinds of spices which are frequently purchased by consumers using an interview guide. Hence, the study adopted the exploratory sequential mixed method design. Results from the study indicated total mean concentrations of Pb (77.33mg/kg), followed by Cu (31.18mg/kg), though Cd was not detected in any of the samples. Mean concentrations for Pb ranged between 4.50mg/kg to 208.04mg/kg in bay leaf and chilli pepper from Abura market, whereas Cu recorded 12.44mg/kg to 139.92mg/kg in rosemary and ginger from Kotokoraba market. However, total mean concentration for Pb and Cu in all samples ranged between 20.07mg/kg in negro pepper to 119.54mg/kg in chilli pepper and 12.85mg/kg in negro pepper to 87.70mg/kg in ginger. It was further revealed that 80% and 5% of all samples exceeded WHO (2007) permissible limits of 10mg/kg and 50mg/kg for Pb and Cu respectively. Attention should be paid to the study of spices and harmful substances they may probably contain by the FDA due to their frequent use in Ghana.

KEYWORDS

Cadmium

Concentrations

Copper

Heavy metals

Lead

Spices

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DEDICATION

To the blessed memory of my beloved father – J. K. Sawn

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LIST OF ACRONYMS

FAO	Food and Agriculture Organization
WHO	World Health Organization
EFSA	European Food Safety Authority
GFDA	Ghana Food and Drugs Authority
GSA	Ghana Standards Authority
EHPA	Environmental Health Protection Agency
CAC	Codex Alimentarius Commission
ISO	International Standards Organization
FDA	Foods and Drugs Authority
ISB	Indian Spice Board
IPC	International Pepper Community
UHF	University of Horticulture and Forestry
UC	University of California
IL-1β	Interleukine-1beta
COX	Cyclooxygenase
NF-kB	Neutral factor-kappa B
iNOS	Inducible nitric oxide synthase
ACE	Angiotensin I converting enzyme
MPL	Maximum permissible limits
AAS	Atomic absorption spectrophotometer
GSS	Ghana Statistical Service
ICP-MS	Inductively coupled-plasma mass spectrometry
PTWI	Provisional tolerable weekly intake
TWI	Tolerable weekly intake

HCl	Hydrochloric acid
HNO_3	Nitric acid
ANOVA	Analysis of variance
CVD	Cardiovascular disease
T2DM	Type 2 diabetes mellitus
UTI	Urinary tract infection

CHAPTER ONE

INTRODUCTION

Background to the Study

Spices, according to Aberie, Sallilh and Tarekegn (2021), are dried parts of plants which have been used as dietary components of food often to improve the colour, aroma, palatability and acceptability of the food. Sharma (2006), also defines spices as natural plants or vegetable products, or mixtures thereof, in whole or ground form which are used for seasoning and imparti ng flavour, aroma and pungency to food. Ogbunugafor, Ugochukwu and Kyrian-Ogbanna, (2017) also define spices as plant-derived seasonings used for culinary purposes. They further add that a spice may be for example, the bud (clove), bark (cinnamon), root (ginger), aromatic seed (cumin), and flower stigma (saffron) among many others. Thus, spices occur in a variety of flavours, colours, and aroma and contribute a wide range of nutrients to food. They also enhance and complement the flavour in food with no detrimental effect on the organoleptic quality of the food. Spices are also known to make food tasty but may not be delicious themselves, with many of them possessing marked pharmacological and medicinal properties, hence their widespread usage in medicine, pharmacology, cosmetology among many others (Aberie et al., 2021; Reinholds, Pugajeva, Bavrins, Kuckovska and Bartkevics 2017).

The medicinal properties of spices are due to their anti-oxidant, anti-microbial and anti-inflammatory action owing to the fact that they contain bioactive substances such as polyphenols, quinines, flavanols/flavonoids, alkaloids, polypeptides among many others. They have also been documented to possess antidiabetic, anti-inflammatory, anti-carcinogenic and anti-

hypertensive potentials (Nordin & Selamat, 2013; Krejpcio, Krol & Sionkowski, 2007). Their antimicrobial and anti-inflammatory properties may explain why they are mostly used in warmer climates where infectious diseases are prevalent (Aberie et al., 2021). Jiang (2019), reports of a cross-sectional survey study in the United States where out of 703 adults whose perceptions about spices were documented, about 51% of them were willing to use spices as complementary and alternative medicine therapies whiles 54% of them were already using one or more spices on daily basis and believed that ginger (64%), garlic (58%) and cinnamon (56%) could promote good health and wellness. Jiang (2019) further reports that in paediatric populations, more than 1/10 of infants and children were given spices to remedy minor ailments such as stomach complications, coughs and colds.

The use of spices for culinary purposes predates recorded history and is said to have been an integral part of local dishes in south Asia and the Middle East as far back as 2000 BCE. Thus, spices have played an important role in the history of civilization, exploration and commerce as they had a universal acceptance as condiments and flavourings in human diet as well as the treatment of many common ailments. Hence there are evidences of them being used by major players of ancient civilization including the Indians, the Egyptians, the Babylonians, the Persians, the Jews, the Chinese, the Greeks and the Romans. Thus, it has been recorded that, the legendary Christopher Columbus' explorations in 1492 were in search of spices. They further add that, spices have been revered since time immemorial for their potential health attributes as they are reported to have positive effects in the treatment of

numerous diseases, especially chronic ones such as cancer, diabetes, and cardiovascular diseases (Ogbunugafor et al. 2017; Oladoye and Jegede, 2016).

It is important, however, to note that, though often perceived as being natural and therefore safe, culinary spices may contain probable contaminants such as heavy metals from the environment where they are produced, processed and stored (Ogbunugafor et al., 2017; Krejpcio et al., 2007; Oladoye & Jegede, 2016). Reinholds et al. (2017) report that, research studies have shown that heavy metals could be present in spices. For instance, a research study in Nigeria by Olayinka and Ipeaiyeda (2011) revealed that red chilli peppers grown by roadside farmlands around high traffic density areas of Ibadan presented higher concentrations of chromium (Cr) and lead (Pb) compared to the corresponding levels in control farms. It was documented that the differences in concentrations were attributed to exhaust from automobiles as the primary source of Pb contamination of roadside-grown peppers in addition to the concentrations derived from the soil.

Reinholds et al. (2017), claim that metal ions of high or moderate toxicity such as copper (Cu), zinc (Zn), iron (Fe), arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb) and mercury (Hg) are among the common contaminants found in agricultural produce. This arising from improper waste management, rapid industrialization and urbanization of agricultural regions. As a result, causing the accumulation of metal ions in cultivated produce of which spices are not exempted, through water, soil and air. Nkwunonwo, Odika and Onyia (2020) further argue that, the availability and accessibility of these metals and metalloids through natural and anthropogenic pathways remain a major concern in the ecosystem. They further add that natural

sources include metal-bearing parent rocks and metallic minerals whereas agricultural practices (fertilizer and pesticide application), metallurgic activities (mining, smelting etc.), energy production (power plants, leaded gasoline) and sewage disposal constitute anthropogenic sources of heavy metal pathways. This is evident in a study that was reported by Akutei (2019) in Ghana. The study which assessed levels of some heavy metals in leachates, and crops grown around four waste dumpsites in the Sekondi-Takoradi Metropolis revealed that the mean levels in leachates ranged from 0.03mg/L to 0.10 mg/L, 0.20mg/L to 5.48 mg/L, 4.97 mg/L to 5.35mg/L, 0.38mg/L to 0.55 mg/L and 0.17mg/L to 0.90mg/L for Cd, Zn, Pb, Cr and Cu respectively, with the mean values for chromium and cadmium exceeding the permissible limits set by joint committee of Food and Agricultural Organization/ World Health Organization (FAO/WHO). Again, the highest mean levels for Zn and Cu were 5.48mg/L and 0.90mg/L in the crops analyzed also exceeded limits by the FAO/WHO.

From Hawkes' work 'What is a heavy metal?', Nkwunonwo et al., (2020) reported that, heavy metals are the block of metals and metalloids found in Groups 3 to 16 and in Periods 4 and greater of the chemistry periodic table. They further argued that, it makes sense to conclude then that, a metal is heavy not necessarily because of its density rather its chemistry. Ali and Khan (as cited in Nkwunonwo et al., 2020), further added that, heavy metals are naturally occurring metals having an atomic number greater than 20 and an elemental density greater than $5g/cm^{3.}$ Thus, common examples found in literature include Pb, Cd, Hg, Zn, Cr, vanadium (V), cobalt (Co), nickel (Ni), manganese (Mn), tin (Sn), and many others. Literature has it that, the most

toxic elements on the chemistry period table are heavy metals, especially arsenic (As), cadmium (Cd), mercury (Hg) and lead (Pb), which have no known biological roles in any living species, and hence are regarded as non-essential. Thus, it is documented that these toxic metals have great potential that include a wide range of toxic effects such as developmental abnormalities. Furthermore, they are known to possess the ability to disrupt metabolic activities and genetic makeup, while others affect embryonic or foetal development, which have been linked to Alzheimer's and Parkinson's diseases, autism and cancer. They are also known to cause developmental and neurological disorders, and behavioural changes often found in children. Adults may also experience high blood pressure, fatigue, kidney and neurological disorders. (Reinholds et al., 2017; Nkwunonwo et al., 2020; Oladoye & Jegede, 2016; Akutei, 2019).

Zinc is a co-factor of over 200 enzymes involved in metabolic pathways but its high levels in the human body can interfere with Cu metabolism. On the other hand, Cu plays a role in the oxidative defense system and its toxicity results in severe poisoning with associated health risks. However, others such as Cr, Hg, Pb, Cd and As are toxic even at very low concentrations as these have caused considerable concern of their potential harmful effects, which are known to cause various health risks such as cancer, mutations and miscarriages. A number of diseases, especially cardiovascular, renal, neurological and bone diseases are associated with excess Pb and Cd concentrations in food, in addition to their implication in causing mutagenesis, teratogenesis and carcinogenesis. (Nkansah & Opoku Amoako, 2010; Al-Dalain et al., 2021; Nordin & Selamat, 2013; Kowalska, 2021; Krejpcio et al.,

2007). Thus, the addition of spices that may be contaminated with trace and heavy metals to food as a habit may result in accumulation of these metals in human organs and lead to diverse health troubles in later years (Nkansah & Opoku Amoako, 2010). Reinholds et al. (2017) claim that the regulations of tolerable concentration levels for contaminants may vary depending on the country. However, the majority of regulations are attributed to the European Food Safety Authority (EFSA), the World Health Organization, the US Food and Drugs Authority as well as the Codex Alimentarius Commission (CAC).

Statement of the Problem

Culinary spices, though have several benefits, unfortunately may become potential sources of hazard to health when they become contaminated with heavy metals. Thus, the presence of heavy metals in spices has been reported from several geographical locations though literature on them remains limited in Ghana (Senanayake, Perera, Liyanaarachchi & Dassanayake, 2013; Darko, Ayim & Voegborlo, 2014). Recent studies by several authors have indicated a common occurrence of heavy metal contamination in commercial spices indicating the need for proper multi-contaminant control to mitigate the potential risks to human health. For instance, Gaya and Ikechukwu (2016), reported on a study that was conducted in Egypt which revealed that spices commonly consumed in the country contain alarming levels of Fe, Pb, Cd, Cr, Sn, Mn, Zn, Co, Cu, and Ni. In the same vein, a variety of selected spices from Nigeria were also analyzed for heavy metal content and the study showed most of the spices analyzed contained higher levels of heavy metals compared to the provisional maximum tolerable intake set by FAO/WHO.

Spices are used enormously among the people of Ghana for a wide array of purposes. Thus, monitoring the levels of heavy metal toxicity in these food additives would help ascertain the potential health impact of continued usage of these spices, and provide relevant data whiles augmenting the limited data available in the country. Moreover, the Ghana Food and Drugs Authority would be aided and informed of the safety or otherwise of these spices in circulation (Nkansah & Opoku Amoako, 2010; Mubeen, Naeem, Taskeen & Saddiqe, 2009). It is in view of the above that the study sought to determine heavy metals in common spices from selected markets in Cape Coast.

Purpose of the Study

The purpose of the study was to determine the levels of some heavy metals in common spices from selected markets in Cape Coast.

Objectives of the Study

The specific objectives of the study were to:

1. identify commonly bought spices on markets in Cape Coast.
2. identify the purposes for which these common spices were bought.
3. determine the levels of cadmium, lead and copper in ten common spices in Cape Coast.

Research Hypothesis

H_0**1:** There is no statistically significant difference in the mean levels of copper and lead in all the ten spices from Abura Market.

$H_0$2: There is no statistically significant difference in the mean levels of copper and lead in all the ten spices from Kotokoraba Market.

$H_0$3: There is no interaction between the mean levels of lead and copper in all the ten spices from both markets.

Significance of the Study

Culinary spices are used extensively in Ghana for varied reasons, especially for enhancing the organoleptic qualities of food and sometimes for medicinal purposes. However, there is little data on their contamination with heavy metals in the Ghanaian context. Hence it is believed that findings from this study will help to bridge the information gap that exists in the country.

It is also hoped that information from the study may be useful to regulatory bodies such as the Ghana Foods and Drugs Authority (G-FDA), the Ghana Standards Authority (GSA) and the Environmental Health Protection Agency (EHPA).

Additionally, it is generally believed that natural spices are safe and hence there is no need to bother about their safety. However, recent studies on spices from other geographical locations have revealed that these 'so-called' natural spices could be a source of hazard to health of consumers. It is therefore hoped that findings from this study will provide valuable information to the general public on the heavy metal content of commonly used spices found on Cape Coast markets.

Delimitation

The study was delimited to the determination of cadmium, lead and copper in ten selected spices from two markets in Cape Coast. The study was delimited to lead and cadmium due to their toxic nature even in their minutest quantities, and as a result, research has proven they are among the top most toxic heavy metals found in nature. Again, the use of these metals in some agricultural materials such as pesticides and fertilizers for the cultivation of agricultural produce, for instance, Cu and Pb are components of fertilizers

used for agricultural purposes, which are likely to impact the heavy metal content of the soil and the agricultural produce. Additionally, the researcher's choice of the spices is based on the information obtained from the first phase of the study, which is a market survey involving interviewing both sellers and buyers of natural spices on those spices which are frequently patronized by consumers.

Limitations

Sellers of the spices did not want to participate in the interviews with the reason that they may be reported to the authorities for selling contaminated food additives and hence may affect their business. In the same vein, some of the buyers also were reluctant to participate as they complained of being in a hurry to get home and hence saw the exercise as time wasting for them. In view of that, most of them were not cooperative in giving out enough responses to the questions that were posed at them which is believed could affect the outcome of the study. Again, it was observed that the public had limited knowledge on the purposes of spices, especially the health purposes and this could also affect the results of the study.

Definition of Terms

Spices are dried parts of plants which are used to improve colour, aroma, palatability and acceptability of food.

Heavy metals refer to a group of metals that are located in group 3 to 16 and in period 4 and above on the chemistry periodic table.

Concentration refers to the strength of a solution, especially the amount of dissolved substance in a given volume of solvent.

Bioaccumulation is the process by which a chemical move from the external environment into an organism from all possible exposure routes such water, air and diet.

Toxicity is the degree to which a chemical substance can damage an organism.

Anthropogenic describes changes in nature caused by human activities.

Periodic table, also known as the periodic table of elements, is a tabular display of the chemical elements in accordance with their increasing atomic number and recurring chemical properties.

Leachate is defined as any contaminated liquid that is generated from water percolating through a solid waste disposal site, accumulating contaminants, and moving into subsurface areas.

Organoleptic properties are the aspects of food, water or other substances that create an individual experience via the senses-including taste, sight, smell and touch.

Biodegradable refers to the ability of substances to get disintegrated or decomposed by the action of microorganisms such as bacteria or fungi while getting assimilated into the natural environment.

Metallurgic is a term that pertains to metallurgy, or the art of working metals.

Carcinogenesis also called oncogenesis or tumourigenesis**,** is the uncontrolled replication of tissue cells with a monoclonal character, implying origin from a single cell mutation.

Culinary means having to do with cooking or the kitchen.

Mutagenesis is the process by which an organism's deoxyribonucleic acids (DNA) change, resulting in a gene mutation.

Aril, also called arillus, is a specialized outgrowth from a seed that partly or completely covers the seed.

Rhizome, also known as rootstocks is a type of plant stem situated either at the soil surface or underground that contains nodes from which roots and shoots originate.

Pungent implies a strong odour that stings the nose, said especially of acidic or spicy substances.

Liming is the application of mineral calcium and magnesium compounds, mainly carbonates, oxides, hydroxides, or a mixture of them and, more rarely, silicates into acidic soils to decrease the concentration of protons.

Sewage sludge is the residue resulting from the treatment of wastewater released from various sources, including homes, industries, medical facilities, street runoff and businesses.

Pathogen is usually defined as a microorganism that causes, or can cause, disease.

Osteoporosis is a bone disease that develops when bone mineral density and bone mass decreases, or when the structure and strength of bone changes. This is characterized by weak and fragile bones.

Osteoarthritis is a degenerative joint disease, in which the tissues in the joints break down over time.

Atherosclerosis is the thickening or hardening of the arteries cause by building up plaque in the inner lining of an artery.

Smelting is a process by which a metal is extracted, either as a simple compound, from it ore by heating beyond the melting point, ordinarily in the presence of oxidizing agent, such as air, or reducing agents, such as coke.

Organization of the Study

The study is organized into five chapters. Chapter One is the introduction which covers the background of the study, statement of the problem, purpose of the study as well as research objectives and hypothesis. It also presents the significance of the study, delimitation and limitations of the study. The second chapter looks into the review of relevant related literature, discussing relevant concepts and previous work done on the subject. Chapter Three describes the methodology used for the study. Chapter Four presents the results and discussions of the study. Chapter Five summarizes the findings and draws conclusions for the study based on the findings. It also presents relevant recommendations and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter reviews literature relevant to the study. The review covers the concept of spices, classification of spices, and functions of spices. Other concepts included are heavy metals, sources of heavy metals in the environment and toxic effects of heavy metals on human health. Furthermore, a review of the purposes of spices in literature as well as empirical evidences on determination of heavy metals in spices.

Conceptual Review

Spices

According to the Codex Alimentarius Commission, as (cited in Bua, Annuario, Albergama, Cicero & Dugo, 2016), spices are dried components or mixtures of dried plants used in foods for flavouring, colouring, and imparting aroma. Raghavan (2007) reports that, the word "spices" came from the Latin word "species," meaning specific kind. Thus, the name reflects the fact that all parts of the plant have been grown for their fragrance, aromatic, pungent or any other desirable properties including the seeds (aniseed, coriander, caraway, cumin), leaves (bay, parsley, mint), berry (allspice, juniper, black pepper), bark (cinnamon, cassia), kernel (nutmeg), stem (chives), aril (mace), rhizome (ginger, turmeric), root (lovage, horseradish), flower (saffron), bulb (garlic), fruits (star anise, cardamon, chilli pepper), and flower bud (cloves). Thus, according to the International Standards Organization (ISO), spices are defined as "vegetable products used for flavouring, seasoning, and imparting aroma to foods." The US Food and Drugs Administration (US-FDA), also

defines spices as "any aromatic vegetable substances in whole, broken, or ground form, except for those substances traditionally regarded as food, such as onions, garlic, and celery, whose significant function in food is seasoning rather than nutritional; that is true to name; and from which no portion of any volatile oil or other flavouring principle has been removed" (Raghavan, 2007).

However, Raghavan (2007), claims that the above definitions are outdated and limited in today's knowledgeable and sophisticated society, with the reason being that chili peppers, mace, nutmeg, and star anise which are fruits or parts of a fruit which impart flavour to food should not be defined as 'vegetable products.' She further argues that, dehydrated garlic, chives, onions and shallots which are basically flavour enhancers should be included in the definition of spices. Again, gone are the days when the leaves from aromatic plants were known to be herbs, whiles spices referred to all parts of the aromatic plants with the exception of the leaves. This definition of spices however changed overtime to include the edible herbs (leafy spices) since many edible herbs have been used since time immemorial to impart flavour of food and beverages; hence herbs should not be considered a separate category from spices.

Raghavan (2007) clarifies that, spices should, thus include "all parts of a plant that provide flavour, colour, and even texture", since all parts of a spice plant including the leaves, seeds, bark, buds, roots, rhizome, and stalks are used. Raghavan, thus concludes that, definitions that appear to be up to date include that of the Indian Spice Board (ISB) and the International Pepper Community (IPC). Thus, the ISB defines spices as various forms of the plant; fresh, ripe, dried, broken, powdered among others that contribute aroma, taste,

flavour, colour and pungency to food, whereas the IPC defines spices as various parts of aromatic plants and relates to dried components or mixtures thereof, used in foods for flavouring, seasoning, and imparting aroma. Thus, spices come in many forms such as fresh, dried and in the extractives.

Classification of Spices

Many classifications exist, however, for the sake of this work, that of Chhetri, Vijayan, Bhat, Gudade and Bora (2018), and the University of Horticulture and Forestry (UHF) {2011} have been merged as follows:

Classification based on plant part used

Seed: Spices produced from the seeds of aromatic plants include cumin, fenugreek, coriander, fennel, poppy, anise, mustard, and ajowan among many others.

Leaf: Leafy spices include mint, curry leaf, bay leaf, chive, rosemary, savory, parsley etc.

Bulb: Onions, garlic, leeks and shallot fall within the bulbous spices.

Bark: Cinnamon and cassia are produced from the bark of spicy trees.

Fruit: Allspice, cardamon, chilli and kokam are fruit spices.

Rhizome: Ginger, turmeric and galangal fall under this category.

Kernel: Nutmeg is obtained from the kernel enclosed in a pod of the nutmeg fruit.

Aril: mace and anardana are obtained from the aril that surrounds the nutmeg kernel.

Bud: clove and caper are produced from unopened flower buds.

Flower: Saffron, majoram, savory, caper, are produced from the flowers of spice trees.

Classification Based on Climatic Requirement

Spices can be grouped into three major categories based on suitable climatic conditions such as temperature, sunlight, humidity and air of a particular climatic zone.

Tropical spices

Spices that fall in this category require high temperature, and abundant humidity and easily get destroyed by low temperature. Spices in this category include ginger, turmeric, cinnamon, black pepper, clove and small cardamon.

Sub-tropical spices

Sub-tropical climate is characterized by three distinct seasons: winter, summer and monsoon. Low temperature occurs in winter and high temperature during summer. Spices found in this category usually require relatively low temperature during their vegetative or early growth stage and high temperature in their reproductive stage. Those grown during winter include cumin, fennel, coriander, fenugreek, onion and garlic whereas summer spices include ginger and turmeric.

Temperate spices

Spices in this category can survive in low temperature and frosty weather but are easily damaged by hot weather. They include spices such as thyme, savory, saffron, caraway seed etc.

Classification Based on Season of Growth

Annual spices

These are spices which complete their life cycle in one growing season. They include coriander, cumin, fennel, fenugreek, ajowan and black cumin.

Biennial spices

This category of spices requires two growing seasons to complete their life cycle, and includes onion and parsley.

Perennial spices

These are the kind of spices which live for more than two years. They include cardamon, turmeric, ginger, black pepper, saffron, clove, nutmeg and cinnamon.

Classification Based on Origin and Flavour

Aromatic spices

These include cardamon, aniseed, celery, cumin, coriander, fenugreek, cassia, nutmeg and cinnamon.

Pungent spices

These include ginger, chilli, black pepper, mustard, onions, oregano, garlic etc.

Phenolic spices

They include cloves and allspice.

Coloured spices

They include turmeric, saffron, annatto and paprika.

Functions of Spices

Flavour, taste, aroma and texture

According to Raghavan (2007), the effectiveness of a spice in a recipe or formula is determined by the overall taste, flavour, texture or colour it contributes to food or a beverage. Spices possess chemical components that are responsible for these sensual qualities. Thus, the characteristic flavour profile of a spice is as a result of balance of these chemical components. Six

basic taste perceptions are given by spices, namely; hot, sour, bitter, salty, spicy, and sweet. Other descriptive terms including pungent, unami (brothy, MSG, or soy-sauce-like), cooling, and floral, earthy, woody or green also do exist. Most spices possess combined flavour profile. For instance, cardamon has woody and sweet notes, whereas fennel has both sweet and bitter notes. In terms of textural qualities, spices are described based on their specific physical characteristics, techniques used in its preparation as well as the form in which it is used in a recipe, be it ground or whole. Literature has it that, most textural qualities of spices are obtained through preparation and cooking techniques of spices.

Colouring

According to Peter (2006), the food industry is presently following a trend back towards the use of natural colourants because of changes it is encountering in legislation and consumer preference, as food colourants from synthetic sources have been linked to health hazards such as asthma, cancer, allergy, thyroidism and hyperacidity. However, the poor stability to changes in pH, oxygen, heat and light, low solubility, low tinctorial power and high cost, place limits on the use of natural colourants. Thus, Raghavan (2007) asserts that, aside the flavour imparting qualities of spices, some others also provide colour to various foods and beverages. Typical colour-imparting spices include saffron, annatto, parsley, turmeric, curry and paprika. The components contained in spices which are responsible for the colour imparting abilities include curcumin, crocin, carotenoids, capsanthin, and bixin found in turmeric, saffron, paprika, chili pepper and annatto respectively.

Spices as anti-microbial agents

According to Raghavan (2007), before the days of refrigeration, people of the medieval times used spices either alone or in combination with salting, smoking and pickling to inhibit the factors that promote food spoilage in order to preserve food. For instance, fish sauce was preserved with mint, dill and savory whereas meats and sausages with cumin and coriander by the Romans. Presently, natives of India, Africa, Indonesia and Thailand still use spices to preserve food. A study that was undertaken by Cornell University reported that spices such as onion, garlic, oregano, and allspice can kill all kinds of bacteria; thyme tarragon, cinnamon, and cumin can destroy up to 80% of bacteria; chilli up to 75% of bacteria; and black and white pepper, ginger, celery seeds and aniseeds up to 25%.

It is therefore recommended that for a more effective preservative effects, spices should be combined rather than using only a single spice. Bioactive principles that make spices effective against microbes include eugenol in cloves and cinnamon, carvacrol in oregano, thymol in thyme, allicin in garlic and linalool in coriander, capsaicin in red pepper, gingerol in ginger and piperine in black pepper, and anetol in anise (Raghavan, 2007).

Spices as antioxidants

Raghavan (2007) claims that, through food, spices can be used to help fight toxins created in the human body. Radiation, tobacco smoke, alcohol, ultraviolet light for instance, are responsible for initiating the production and growth of free radicals in the human body which cause damages to our body cells and limit the ability to resist cancer cells formation, delay aging, and prevent memory loss. Thus, many known spices have components that have

the capacity to protect cells from damages caused by free radicals by acting as antioxidants, however, a synergist effect is achieved when spices are combined with other spices or antioxidants- such as tocopherols and ascorbic acids. Rosmanol, myristphenone, eugenol, thymol, caffeic acid, curcumin, and sesaminol in rosemary, clove, thyme, oregano, ginger, turmeric, nutmeg, sage and sesame seed respectively are found to exhibit effective antioxidant properties.

Spices as medicine

Spices have been used since time immemorial for their medicinal benefits to relieve ailments and to prevent illnesses. With great strides in research into their medicinal benefits in recent years, consumers all over the world are becoming attracted to spices not only for creating tasty low-fat or low-salt foods, but also as natural way of improving health and promoting wellness, as such it has also been speculated that more people are using spices as medicine compared to using pharmaceuticals prescriptions (Li, 2006). The active compounds in spices such as phenolic acids, flavonoids, coumarins, capsacinoids, triterpenoids, sterols, monoterpenes, polyacetylenes, phthalides, are effective components for promoting physical and emotional wellness. These chemical components are known to possess therapeutic values such as antiseptic, antioxidants activities, singlet oxygen quenching, enzyme inducers, reducing induction and advancement of cancer cell development (Raghavan, 2007).

Table 1: Therapeutic effects of some spices

Spice	Chemical components	Medicinal value
Chilli pepper	Capsaicin	Prevents blood clotting, enhances circulation
Garlic	Allicin, glutamyl peptides, diallyl sulfide, S-allyl cysteine	Breaks down blood clots, prevents heart attacks, prevents gastric cancer, treats cough, lowers blood pressure and blood cholesterol, inhibits platelet aggregation, hypertension
Ginger	Gingerol, gingeberane Shogaol	Digestive and anti-tumour, aids digestion, stomach aches and stomach ulcers, prevents bloating, inhibits cholesterol synthesis.
Star anise	Trans-anethole, 1,4-cineole, safrole, estragole	Anti-rheumatic, antiseptic, carminative, stimulant, vermifuge
Thyme	Thymol, tannins, carvacrol, saponins	Anti-oxidant, anti-spasmodic, anti-tussive, relieves cough
Cloves	Eugenol, sitosterols, stigmasterols, campesterol	Abdominal problems, cancer, cough, diarrhoea, gastritis, hernia, nausea, sores.
Bay leaf	Cineole, linalool, eucalyptol	Indigestion, astringent, carminative, stimulant
Tumeric	Curcumin, curcumoids	Anti-inflammator, anti-tumour, anti-oxidant, carminative, improve liver function

Source: Raghavan, 2007

Selected Spices

Chilli pepper

According to Raghavan, (2007), the 'mother chilli is believed to have originated from the Andean region of Bolivia, Peru, and Ecuador, however, it became widely cultivated when the Spanish first landed in the Americas. Thus, they are indigenous to the South and Central America, Mexico and the Caribbean but presently grown in India, China, United States of America, Japan, Africa and Southeast Asia. The fruits of chillis are used ripe and unripe, fresh, smoked or dried. They can be sweet, floral, fruity, earthy, hot and smoky with varying levels of heat (Madala & Nutakki, 2020; Saleh, Omer & Teweldemedhin, 2018).

Scientifically, chilli pepper is known within the genus as *Capsicum(C)*, which originates from the Latin terminology *capsa*, meaning box or chest due to the nature in which the seeds are neatly enclosed in the fruit (Raghavan, 2007), or the Greek word *kapsimo*, which means to bite or burn (Pandit, Pandit & Bairagi, 2020; Mandala & Nutakki, 2020). There are about thirty-one species within the genus *Capsicum* (Raghavan, 2007), however, only five of them are domesticated and therefore cultivated, namely; *Capsicum annum, Capsicum chinense, Capsicum frutescens, Capsicum baccatum, and Capsicum pubescens*, with *C. annum* being the most widely cultivated species. Common names of chilli pepper include, spaanse peper (Dutch), piment (French), roter Pfeffer (German) and ata (Yoruba, West Africa) (Saleh et al., 2018; Pandit et al., 2020; Kumar, Kumar and Singh, 2006).

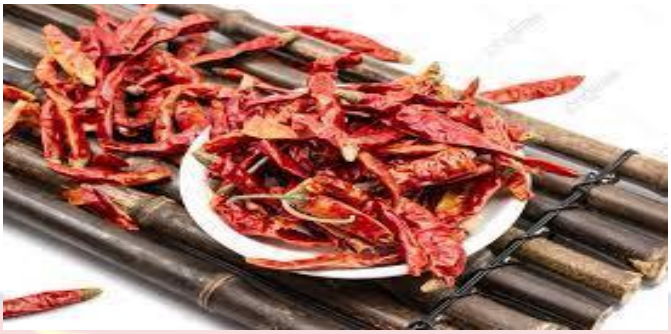

Figure 1: Chilli pepper

Rosemary

According to Raghavan (2007), Rosemary is an evergreen perennial dicot shrub that is native to the Mediterranean region, Asia Minor and North Africa. During the medieval times, the name *Rosmarinus,* which is a Latin word meaning 'dew of the sea', was changed to *Rosa Maria* or 'Rosemary' in honour of 'Mary', the mother of Jesus. Scientifically, rosemary is known as *Rosmarinus officinalis* and belongs to the family *Lamiaceae.* Hamidpour, Hamidpour & Grant (2017) and Labban (2014), further add that rosemary can be used fresh or dried, chopped, whole or ground. The spice is small, narrow and needlelike with the fresh leaves being leathery, shiny and dark green in colour, while the dried ones are curved with dark green to brownish green colour.

Rosemary contains essential oils with principles mainly 1,8-cineol (30%) giving it a cool eucalyptus aroma, borneol (16% to 20%), camphor (15% to 25%), bornyl acetate (2% to 7%) and α-pinene (25%) with the different varieties possessing varied flavours based on their constituents (Kunnumakkara, Dey, Bicer & Aggarwal, 2009). Rosemary has vitamin C, vitamin A, potassium, sodium, calcium, magnesium, iron, and phosphorus. Rosemary does not lose it flavour with long cooking, however it should be

used sparingly due to its strong aroma. Literature further claims that, it contains active phenolic compounds such as carnosic acid, rosmanol, carnosol, isorosmanol,rosmadial and caffeic acid which have shown substantial antioxidant activity with in vitro studies (Parthasaranthy, Rethinam & Kandiannan, 2008; Malvezzi de Macedo et al., 2020).

Figure 2: Rosemary

Anise/ Aniseed

Aniseed is an herbaceous annual plant that is native to the Mediterranean region. The spice is believed to be an indigenous to Greece, Egypt, Crete, Turkey and Lebanon, though it is also cultivated in Mexico, Chile, Argentina, Syria, Spain, Italy, India, Pakistan, China, Russia, Japan and Germany (Raghavan 2007). Aniseed belongs to the family of *Apiaceae* and is known as *Pimpinella anisum* in botany. Sun, Shahrajaban & Cheng (2019), postulate that, the spice is a small, oval, greenish-gray to yellow brown dried seed, with a ridged surface. The spice is mainly sold whole or ground. It is known to lose its flavour quickly when milled into powder.

Aniseed has a fruity, camphoraceous, warm and sweet licorice-like taste, with its flavour having a resemblance to that of star anise and fennel. Aniseed has 1.5% to 6% essential oil, with its major constituents being trans-anethole (80% to 90%). Other components of its essential oil include methyl

chavicol (10% to 15%), iso anethole (2%), ketone and anis-aldehyde. Aniseed is known to contain iron, potassium, phosphorus and calcium (Anwar, 2017).

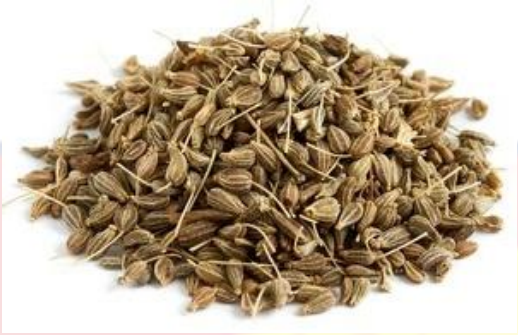

Figure 3: Aniseed

Clove

Clove is a spice that is native to the Moluccas (Spice Island), Indonesia, but now widely cultivated in Brazil, Pemba, Madagascar, Malaysia, Sri Lanka, Zanzibar, Sumantra, Grenada and Jamaica. The name of the spice is derived from 'clavus', 'clavo' and 'clou', which are Latin, Spanish and French words respectively, meaning 'nail' due to its striking resemblance to a nail's shape. From the family of *Myrtaceae*, clove is known as *Syzygium aromaticum* (formerly *Eugenia caryophyllata* or *Eugenia aromaticus)* in botany (Raghavan, 2007). Clove is obtained from dried unopened flower buds, and is sold ground or whole and the buds are picked just before opening. It is characterized by a spicy, woody, burning, sweet and musty aroma with a sharp, pungent, and bitter taste and numbing feeling (Thakur et al., 2021; Kunnumakkara et al., (2009).).

According to Thakur et al., (2021), the clove bud has about 5% to 20% essential oils mainly composed of eugenol (81%), the major bioactive compound, which is responsible for its characteristic pleasant and burning flavour. Other constituents of its essential oils include eugenyl acetate,

caryophyllene, humulene, with traces of chavicol and benzaldehyde. Clove also has some tannins and fixed oils. Clove contains vitamin C, vitamin A, manganese, potassium and magnesium. The spice is a major source of phenolic compounds such as flavonoids, gallic acids, tannins, hydroxicinamic acids, hydroxibenzoic acids, and hydroxiphnyl propens (Cortes-Rojas, Fernandez de Souza & Oliveira, 2014). Others include caffeic, ferulic, elagic, and salicylic acids (Pulikottil & Nath, 2015).

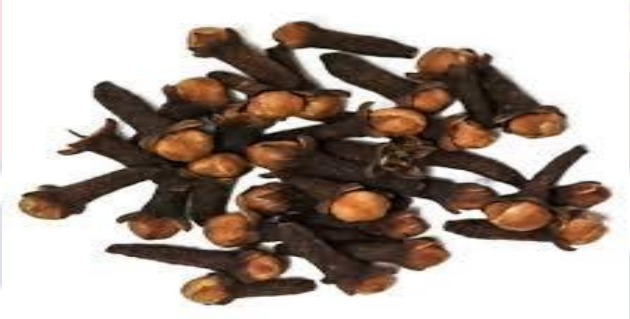

Figure 4: Cloves

Negro pepper

Negro pepper, also known as 'Moor pepper' or 'kien' in West African regions is a popular spice used from Ethiopia, northeast Africa to Ghana, southwest Africa. It is a long slender bean pod in which are enclosed kidney-shaped seeds that has got a mixture of cubeb and mace-like notes. It is scientifically known as *Xylopia aethiopica* and belongs to the family *Annonaceae* (Raghavan, 2007). The spice is commonly known as grains of Selim, Ethiopian pepper, Moor pepper, Senegal pepper or Kani pepper. The aroma the spice imparts is dependent on the essential oils it contains whereas non-volatiles (piperine) provide the pungency or bite (Ezekwesili, Nwodo, Eneh & Ogbunugafor, 2010).

Negro pepper contains about 2% to 4.2 % essential oils, chief among them being β -pinene, γ-cineol, α -terpineol, paradol, linalool, β -ocimene and other terpenes with vanillin traces. The spice also has pharmaceutical active constituents such as alkaloids, tannins and flavonoids which account for its anti-inflammatory and anti-oxidant properties in treating diverse ailments (Oso & Oladiji; 2019; Ogbonna, Nozaki & Yaima, 2013).

Figure 5: Negro pepper

Grains of paradise

Scientifically known as *Afromomum melegueta* or *Afromomum grana paradisi*, grains of paradise belong to the family *Zingiberaceae* (ginger family). Other common names of the spice include, alligator pepper, Melegueta pepper, guinea grains or guinea pepper. The plant is a perennial deciduous herb native to the tropics and grows mainly on the swampy habitats of the coasts of West Africa. It produces trumpet-shaped, purple - coloured flowers which develop into long pods which contain reddish-brown seeds (Raghavan, 2007).

The West African country known to be a chief cultivator of the spice is Ghana and it is endemic in the Atiwa range in the Eastern Region, though others such as Ivory Coast, Benin, Nigeria, Sierra Leone, Ethiopia, Togo and Guinea also contribute significantly to its production in the region (Sarpong, 2018). According to Ogbunugafor et al., (2017), grains of Paradise are small

dried, reddish brown, pyramid-shaped seeds with a shiny exterior, enclosed in a large pod. The seeds are either sold ground or whole, with the ground seeds having a greyish colour. With a whitish interior and a reddish-brown exterior, the seeds have a mild-pungent peppery taste with an accompanying bitter note and a faint cardamon-like odour. The spice has 0.5% to 1% yellow-coloured essential oil which contains chief principles such as humulene and caryophyllene. Shogaol, gingerol, paradol, and diarylheptanoids account for the mild pungency-peppery taste of the seeds (Toh, Lim, Ling, Chye & Koh, 2019; Osuntokun, 2020;).

Figure 6: Grains of Paradise

Garlic

According to Raghavan (2007), garlic is one of the world's well-known spices used extensively across the globe. Tesfaye (2021) claims that, the spice is the second most used *Allium* after onion. The spice's name is derived from the term *garleac*, an Anglo-Saxon word which means 'spear plant'. Scientifically known as *Allium sativum*, garlic is a member of the onion family *Alliaceae*. Garlic is a spice which is indigenous to Central Asia. However, it is now cultivated in the United States, Asia, Europe, the United Kingdom, Mexico, Taiwan and Hungary, with China being both the largest

consumer and producer of the spice of the world's output. It is on record that, there are about 200 different varieties of garlic with varying sizes, shapes, colours, and flavours, however, only two cultivated varieties exist (i.e. hardneck and softneck varieties). Within each garlic bulb is a plump and succulent egg-shapesd bulblets known as cloves, enclosed in an outer skin that is rose, buff, white or purple, depending on the variety. The spice comes in either the dried or fresh forms (Worku & Mehari, 2018; Fesseha & Goa, 2019).

Jiang (2019) adds that fresh whole garlic is odourless, however, when it is cut or bruised, it gives off a strong aroma as a result of the production of allicin, which occurs due to the action of the enzyme alliinase on alliin. When garlic cloves are crushed, cut or rehydrated, about 0.1% to 0.25% essential oil is formed enzymatically. Principles found in the spice's essential oils are sulphur compounds, chiefly, 60% diallylsulphide, 20% diallyl trisulphide, 6% allyl propyl disulphide and diallyl sulphide (Raghavan, 2007; Worku & Mehari, 2018; University of Carlifonia, 2016).

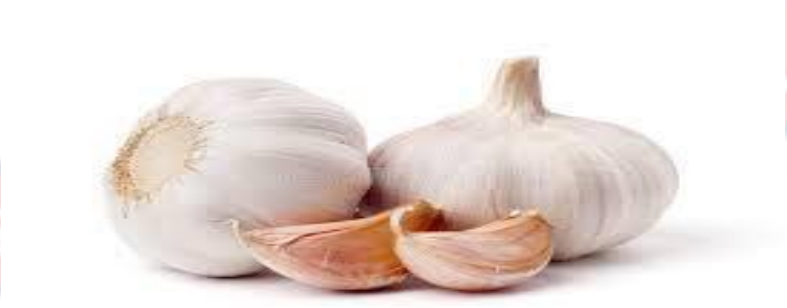

Figure 7: Garlic

Ginger

According to Raghavan (2007), ginger remains the most treasured spice in Asia as it is highly esteemed for its therapeutic effects and flavour. In

botany, ginger is known as *Zingiber officinale* and belongs to the family *Zingiberaceae.* The spice obtained its name from the term *shringavera,* a Sankrit word which means 'shaped like the deer's antlers. Thus, different varieties of ginger exist, including Jamaican, Indian (cochin and Calicut), Chinese and African. Though it is an indigenous spice to southern India and Southeast Asia, major cultivating countries of ginger include Fiji, Hawaii, Sierra Leone, Nigeria, Jamaica, Japan, Mexico, Ghana, Costa Rica, among many others. Ginger is a rhizome, that is, a thick root-like underground stem which is available in many forms; fresh, dried, black, preserved, crystallized and pickled (Zadeh & Kor, 2014; Jahkribettu et al., 2017).

Bhatt, Waly, Essa & Ali (2013) further add that, the properties of ginger such as colour and flavour vary depending on its form, origin, harvesting, storage and processing conditions. Fresh ginger has got a refreshing, juicy, spicy with slightly sweet, lemon-like aroma, strong bite and more aromatic. On the other hand, dried ginger is more fibrous with less pungency compared to fresh ginger. With respect to origin, Jamaican ginger has got a light tan colour with a delicate aroma and more pungency with fine-textured powder when likened to that of African origin, which has a darker colour with a weak aroma but a harsh flavour. Ginger originating from India has strong, aromatic, pungent qualities with a lemon-like aroma unlike Chinese and Japanese ginger which tend to have weak pungency and aroma, with the former being whiter in colour and fibrous, with slight bitter notes (Raghavan 2007; Jahkribettu et al., 2017; Zachariah, 2008).

Ginger contains 1% to 4% essential oils, known as sesquiterpenes, which are responsible for ginger's characteristic aroma; however, its bite or

pungency is attributed to non-volatiles such as gingerol, shogoal, zingerone and paradol (Zadeh & Kor, 2014). Chief constituents contributing to ginger's aroma comprises zingiberene, curcumene, α-pinene, sabinene, limonene, boneol, linolool, farnesene, and citrol. Dried ginger has less pungency due to the conversion of gingerol in fresh ginger to shogaol, zingerone and paradol (Jiang, 2019; Bhatt et al., 2013).

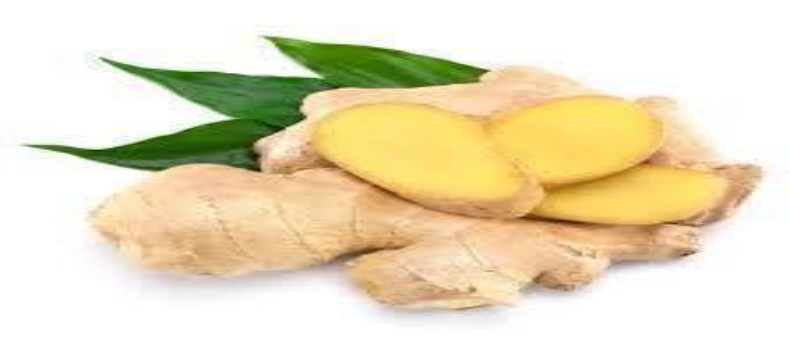

Figure 8: Ginger

Bay leaf

According to Raghavan (2007), Greek history has reported that, many centuries ago, a beautiful nymph known as Daphne was turned into an evergreen laurel tree by the gods when she was fleeing from Apollo's love, hence the name daphnee in Greek for bay leaf. Thus, the Romans have since the ancient times used wreaths made with laurel leaves to honour their god (Apollo), and continue to use the leaves in their cuisines till date. The spice is native to the Mediterranean regions, the sub-tropics and Eastern Asia, as well as South and North America, Asia Minor and the Balkans.

Raghavan (2007) further add that, scientifically, bay leaf is known as *Laurus nobilis*, and it is an evergreen perennial shrub that belongs to the family *Lauraceae.* It is also known as sweet bay, true bay, Grecian bay or bay laurel. The leaf of the laurel tree, is thick, leathery, and aromatic with a bright-

green upper surface and a pale green colour beneath. Bay leaf is used whole, crushed in the fresh or dried form. The leaf has got a strong, spicy, bitter, yet pungent and cooling undertones. Bay leaf contains 0.8% to 3% essential oil with chief principles such as 1,8-cineole, α-terpineol, and σ-pinene. Others include cinnamic acid, eugenol, sabinene, methyl-eugenol, and methyl esters (Al-Hashimi & Mahmood, 2016; Batool, Khera, Hanif and Ayub, 2020).

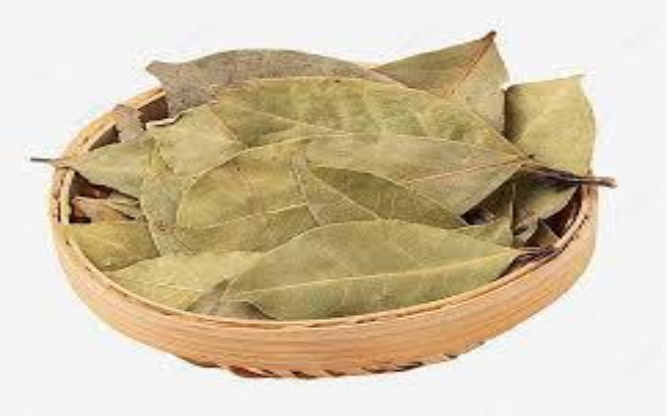

Figure 9: Bay leaves

African nutmeg

In other words, known as calabash nutmeg or Jamaican nutmeg, African nutmeg belongs to the family *Annonaceae*, and scientifically called *Monodora myristica*. It is native to Central, West and East Africa, spanning from Sierra Leaone to Uganda, Congo, Kenya and Angola, though it is widely distributed from Africa to Asia, Central and South America and Australia Enabulele, Oboh & Uwadiae, (2014). It is documented that, the fruit which is a berry measures about 18cm to 20cm in diameter, and has a sub-spherical, smooth appearance. The fruit is green and turns brown upon maturity. Inside each fruit are the oblong, pale brown seeds which are about 1.5 cm long, embedded in a whitish sweet-smelling pulp (Eli, 2015).

It is further asserted that, the seeds possess a pungent, peppery taste which is attributed to the presence of aromatic ketones such as gingerol and paradol (Agiriga & Siwela, 2017). The seeds also possess important pharmacological compounds such as vitamins A and E, alkaloids, flavonoids as well as several significant lipids. Essential oils contained in the seeds have chief principles such as eugenol, limomene, mycene, and thujene. The seeds are also rich sources of flavonoids, saponins, steroids, tannins and glycocides (Adewole et al., 2013; Ekeanyanwu, Ogu & Nwachukwu, 2010).

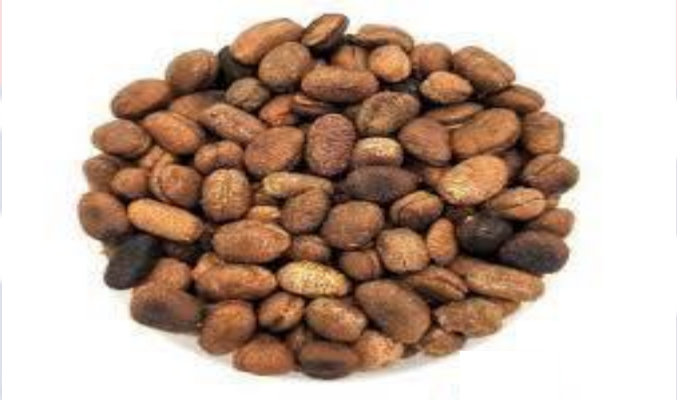

Figure 10: Africa nutmeg

Heavy Metals

Lente et al. (as cited in Akutei, 2019) claim that, there have been many definitions which have been proposed by many writers, some based on atomic weight, some on density and others on chemical properties or toxicity. According to Morais, Garcia e Costa and de Lourde Pereira (2012), heavy metal is a generic term for all the metallic elements having an atomic weight higher than 40.04 (the atomic mass of Ca). Sharma and Agrawal (2005) however postulate that, the term 'heavy metal' is often not rigidly defined, though it commonly refers to those metals with specific weights more than $5g/cm^3$. Heavy metals are found in the soil and aquatic ecosystems in large

proportions in the biosphere but in relatively smaller proportions as particulate or vapour in the atmosphere (Sharma & Agrawal, 2005).

Jovic et al. (as cited in Akutei, 2019) assert that, heavy metals can be classified as essential and non-essential based on their roles in biological systems. Thus, essential heavy metals are those which perform important roles in living organisms and may be required in quite low concentrations in the body. Specific examples of such essential trace nutrients include Cu and Zn, serving as either co-factors or activators of enzyme reactions. Thus, they partake in redox reactions, electron transfer, and structural functions in nucleic acid metabolism. Regarding the non-essential heavy metals, they have no known biological roles in living organisms and includes Cd, Pb, As and Hg which are toxic even in minute concentrations. Thus, they are highly poisonous to metal sensitive enzymes resulting in growth inhibition and death of organisms (Akutei, 2019; Sharma & Agrawal, 2005).

Sources of Heavy Metals in the Environment

Natural sources

An important natural source of heavy metal is geologic parent material or rock outcroppings. It has been established that heavy metals originate within the earth's crust and therefore their occurrence in the soil is as a result of weathering of the parent rock that contain them. Thus, the type of rock as well as environmental factors activating the weathering process determine the composition and concentration of heavy metals. Literature claims that, geologic parent material tends to contain high levels of metals such as Cr, Co, Mn, Ni, Cd, Sn, Hg and Pb which eventually impart the soil.

Furthermore, literature asserts that volcanoes are also reported to emit high amounts of heavy metals such as Mn, Al, Cu, Hg and Pb along with poisonous gas into the ecosystem. Additionally, volatile heavy metals such Hg and Se are emitted as part of carbonaceous matter into the atmosphere through forest and prairie fires. Again, dust carried from desert areas such as the Sahara contain significant amount of Fe and lesser amounts of Mn, Cr, Ni and Pb, all contributing to the total amount of heavy metals concentration in the ecosystem (Sharma & Agrawal, 2005; Nkwunonwo et al., 2020).

Anthropogenic sources

Agricultural sources of heavy metals

The application of organic and inorganic fertilizers in agriculture is one of the major sources of heavy metal contribution to the soil. Research has proven that inorganic fertilizers such as the phosphate fertilizers have significant levels of Cd, Cr, Ni, Pb and In, so are nitrate fertilizers, which invariably contribute to the total heavy metal content of the soil in a quest to replenish soil fertility. Sewage sludge is also known to be rich in In, Cr, Pb, Ni, Cd and Cu, contributing to the heavy metal content of the soil to which it is applied. Liming is said to increase soil heavy metal content more than nitrate fertilizers and compost refuse. Agricultural soils also get contaminated through the application of heavy metal-based pesticides which are used in controlling diseases of fruit crops and grains. For instance, a pesticide such as lead arsenate which was used on Canadian orchards for more than six decades were later found to be a source of In, Pb and As to the soil on which the orchards were cultivated (Sharma & Agrawal, 2005; Nkwunonwo et al., 2020).

Organic sources such as animal manure and compost refuse applied to agricultural soils remain significant sources of concern as these contribute good amounts of Mn, In, Cu and Co. The continued irrigation of agricultural lands for farming purposes with water from deep wells, rivers, lakes and irrigation canals has also proven to be a source of heavy metal contamination to the soil due to presence of Pb and Cd. Sharma and Agrawal (2005) further claim that, the contamination of agricultural soils by heavy metals is dependent on factors such as the rate of application of these contributors with their elemental concentration, as well as the soil characteristics.

Industrial sources of heavy metals

Mining activities, transport of ores and metal refining processes such as smelting, recycling of metals and metal finishing constitute industrial sources of heavy metals in the environment. Mining activities are known to emit a variety of heavy metals into the environment depending on the kind of mining. Thus, the mining of coal is known to be associated with the emission of heavy metals such Fe, Cd and As, which directly or indirectly enrich and consequently contaminate the soil around the coalfield. Additionally, the high temperature processing of metals such as casting and smelting also emit metals in the form of vapour or particulate into the atmosphere. These metal vapours combine with water in the atmosphere to form aerosols which get dispersed by wind (dry deposition) or precipitated in rainfall (wet deposition) and thus contaminate water bodies and the soil. Several other processes also contribute to heavy metal (Se, B, Cd, Cu, In, Cs, and Ni) contamination of soil including energy supplying power stations such as coal burning power plants, petroleum combustion, nuclear power stations. Other industrial processes such

as plastic processing, textile production, wood preservation, and paper processing all contribute to heavy metals contamination of the environment (Sharma & Agrawal, 2005, Nkwunonwo et al., 2020).

Transportation as a source of heavy metals

Transport vehicles also emit Ni and In from the tires as well as Cd and Cu from diesel engines. Lubricants used in various parts of vehicles as anti-wear protection also emit heavy metals such as Cd, Cr, Hg, Ni, Pb and In, especially when the vehicle's engine is inefficient. The burning of leaded gasoline has also contributed significant amount of Pb to the environment which has been a global challenge for several decades, though many nations have banned the use of such type of gasoline by their populace (Sharma & Agrawal, 2005).

Selected Heavy Metals

Cadmium

Cadmium is a silvery-white, soft, ductile, metal found at low concentrations in nature, mainly with the sulphide ores of Zn, Pb and Cu. It is one of the heavy metals that have got no physiological functions in humans alongside Pb, As, Cr and Hg. On the chemistry periodic table, cadmium belongs to group 12, period 5 and the d-block of metals. Cadmium has an atomic number of 48, atomic weight of 112.41µ and a density of 8.65g/cm^3 at 20° C. It has melting and boiling points of 321.07°C and 763°C respectively (Genchi, Sinicropi, Lauria, Carocci & Catalano, 2020; Sharma, Rawal & Mathew, 2015). The German chemist, Strohmeyer discovered it in 1817 as a component of smithsonite. Cadmium pollution in the environment is attributed to increase in anthropogenic activities such as combustion of fossil fuels,

leachates from landfill sites and mining wastes, particularly from Pb and Zn mine fields, use of phosphate fertilizers in agriculture among others (Genchi, et al., 2020; Sharma et al., 2015).

Health effects of cadmium

Cadmium and its compounds are known human carcinogens, where normal epithelial cells transform to malignant cells and thus, inhibit the biosynthesis of DNA, RNA and proteins (Martin and Griswold, 2009). It has been established that people who smoke are at a higher risk than those who do not as tobacco cigarette are known to contain significant levels of the metal. Thus, breathing in high levels of cadmium may cause severe damage to the lungs. Ingesting high doses through food and water may also cause irritations of the gastrointestinal tissues, leading to diarrhoea and vomiting (Akutei, 2019).

Additionally, the kidneys are the main target organs in exposed populations. Thus, irreversible damage to the renal tract occurs as a result of relatively long- term accumulation of cadmium in the human kidneys (Dghaim, Al-Khatib, Rasool & Khan, 2015). Other target organs which are affected include the liver, vascular and immune systems. Fragile bones, reduced birth weight in newly-born infants may also occur due to cadmium toxicity. Sperm production is also affected, hence causing problems with reproduction and consequently leading to impotence and infertility. Low dose exposures may also cause musculoskeletal diseases such as rheumatoid arthritis, osteoarthritis and osteoporosis (Sharma et al., 2015; Genchi et al., 2020).

Lead

Lead is a silvery blue-white, soft and cubic crystal found among the p-block metals. On the chemistry periodic table, it is situated in period 6 and group 14. The metal has an atomic mass of 207.2 and atomic number of 82, with a density of 11.4g/$cm^{3.}$ It has a melting point of 601 K and boiling point of 2013 K. Lead also occurs naturally and is found as a mineral in combination with other elements including sulphur (PbS, $PbSO_4$) and oxygen ($PbCO_{3).}$ Waste incineration remains one of the major contributors of lead in the environment in urban areas (Akutei, 2019). Other human activities which have increased lead and its compounds in the environment (air, soil and water) include use of leaded gasoline in vehicles, fossil fuel burning, mining, and manufacturing of the many products in which lead is used (Martin & Griswold, 2009).

Health effects of lead

Lead is also known to be among the most toxic environmental contaminants posing varied adverse effects on the human body. Lead exposures affect the blood, immune, renal, nervous, skeletal, muscular, reproductive and cardiovascular systems causing poor muscle coordination, gastrointestinal symptoms, brain and kidney damage, hearing and vision impairments and reproductive defects (Dghaim et al., 2015). Slowed cognitive development and learning deficits may also occur in children due to early childhood and prenatal exposures. Additionally, sperm production is affected as the organs responsible are damaged due to high levels of lead. Death may eventually occur as a result of severe damage to the brain and kidneys.

Pregnant women may also experience miscarriages due to exposure to high levels of lead (Martin & Griswold, 2009; Achparaki, 2012).

Copper

Copper is one of the transition metals located in group 11 and period 4. It is a reddish brown, cubic crystal among the d-block metals. Copper was derived from the word Kyprios, which is the Greek name for Cyprus, an ancient island that was a hub of many copper mines. As a non-toxic element, the metal has an atomic mass of 63, atomic number of 29 with a density of 8.96g/cm$^{3.}$ Copper has 1357 K and 2840 K as melting and boiling points respectively (Akutei, 2019). Copper exists in rocks, air, water, soil, animals and plants. It is also an essential micronutrient needed in plants, animals and humans. In humans, copper is required for the synthesis of blood haemoglobin whereas plants need it for diseases resistance, water regulation and seed production. Copper is mostly released into air through the combustion of fossil fuels. It remains in air for a considerable amount of time until it settles on the earth as part of rain, hence end up in the soil and eventually get absorbed by plants. (Anant, Inchulkar & Bhagat, 2018).

Health effects of copper

Copper is one of the essential trace elements required for the synthesis of many enzymes. It does not get bio-accumulated in the food chain, though large doses of the metal can cause severe anaemia as high blood copper levels contribute to iron deficiency (Akutei, 2019). It is also associated with irritations to the stomach and intestines, bone fractures, neurological problems, hypertension, as well as liver and kidney dysfunction (Araya, Olivares & Pizarro, 2007). Excessive large doses of the metal may also cause severe

irritations and corrosion of the mucous membrane inducing nausea, vomiting and diarrhea, damage to the capillaries and the central nervous system. Additionally, elevated copper levels in the human body may give rise to acne, breakdown of all protein structures including hair and nails, migraines and headaches. Chronic exposures may also lead to Wilson disease, which is an autosomic, recessive genetic condition which is characterized by swelling, fatigue, abdominal pain, poorly coordinated movements and others (Sharma & Agrawal, 2005; Anant et al., 2018;).

Empirical Review

This part of the report presents an empirical review of the purposes of spices as well as the heavy metals concentrations in spices reported from various geographical locations.

Purposes of Spices

From literature, the information obtained on the purposes of spices have been grouped under the following broad themes as; culinary, health, industrial applications, preservative, and religious and spiritual.

Culinary purposes

Chilli pepper

According to Saleh et al. (2018), chilli pepper remains the most widely used and consumed spice globally as it is greatly priced for its pungency and potential to add a unique flavour to many cuisines. Thus, the Eritreans used it as a dye to impart the colour of their cuisines, and their sauces and the green ones are also eaten raw as an appetizer or in salads. Today, chillis do not only provide heat to dishes, but also colour, flavour and visual appeal. Folks of the Mediterranean region used the fresh chillis as vegetables and the dried and

smoked forms as a spice in their ethnic cuisines. Chillis are made into hot sauces, spice blends, pickled or pureed and used as table condiments. The spice is also used in whole cuts in snacks, chutneys, and curries by the Sri Lankans and South Indians.

Aniseed

Raghavan (2007) reports that, special cakes which were eaten as dessert by the Romans to aid digestion had aniseed added to it as a flavouring agent. The Europeans also garnished their fruits salads, and flavoured their fish soups and cream sauces with the spice. The spice is also used as a flavouring in cakes, cookies, apple sauces, rye bread, pancakes, sweet rolls, cheeses, beef stews, salad dressings, marinated meat among many other dishes by the Portuguese, Germans, French, Italians and Scandinavians. Leela and Vipin (2008) added that, natives of Thailand used the spice to flavour teas, and in the production of alcoholic beverages in the Middle East.

Rosemary

Raghavan (2007) claims that, rosemary is a common spice in most Mediterranean ethnic cuisines. The Europeans thus, use it in their fruit-based desserts, breads, stews, soup, stocks and in cold beverages to flavour them. The Italians for instance use the spice in their wine, roasted lamb, goat and fish dishes. Rosemary flowers are used in salads, whereas the stems are used as aromatic skewers for barbecues.

Clove

Raghavan (2007) reports that, clove is one of the ancient spices used extensively in meat curries. It is further asserted that, the ground form of the spice is used in the United States for all kinds of meat dishes, salad dressings,

fruit cakes, desserts and puddings and also a significant contributor to the flavour of Worcestershire sauce and ketchups. Furthermore, the Europeans prefer to use the spice in their sweet dishes such as apple tarts, whereas the Asian ethnic folks use it extensively in their pickles, soups, sauces, meat, fish and pork dishes (Bhowmik et al., 2012). Leela and Sapna (2008) further add that, the spice is used a flavour enhancers in all manner of food products including meats, sausages, candies, confectionery, pickles, rice dishes (especially the *biriyanis* of the Indians), and also in curry powders and masalas.

Negro pepper

Negro pepper is an important ingredient in most West African cooking especially in soups and sauces (Raghavan, 2007). Onyebuagu, Kiridi & Aloamaka (2015) support the above saying that, the spice is an indispensable ingredient in a special soup known as 'pepper soup' in southeastern Nigeria. Ikrang and Anyanwu (2019) further opine that, the spice is a useful flavoruing in many assorted dishes such as soups, yam pottage, stews, sauces, and meat and fish.

Grains of paradise

Different African cultures use the seeds as a spice for culinary purposes. Natives of the Northern African countries use the ground seeds to create aromatic stews, and flavour their coffee in combination with other spices. The Morroccans, for instance, use the spice as an important ingredient in their spice blends known a *ras-el-hanout*, which is an ideal part of their tangines, couscous, and lamb dishes. The Tunisians, likewise, use the spice in their five-spice blend called the *galat-dagga* to flavour vegetable and lamb

dishes (Raghavan, 2007). Inegbenebor, Ebomoyi, Onyia, Amadi and Aigbiremolen (2009) claim that, *Afromomum melegueta* is a common ingredient in pepper soup, a spicy delicacy in many parts of West Africa. Obike, Ezejindo, Akinboye and Ezejindo (2014); Young and Markmanuel (2019), posit that, the spice is used for culinary reasons, due to its aromatic flavour and pungent taste. Hence, it is commonly used as a seasoning in food products. Toh et al., (2019) add that, the spice is a common condiment in most African cuisines including meats, sauces and soups.

Garlic

According to Raghavan (2007), garlic is an important component of many spice blends used by the Asians for enhancing the flavour of soups, stews and curries. For instance, it is a must in combination with ginger or onions in the pickles, curries, stir-fries and barbecues of the Chinese and Indians. The Vietnamese use the spice in their spring rolls, noodle soups and marinades. In the Mediterranean regions, garlic is useful part of condiments and seasonings such as adobo, and in sauces, stews and soup. Worku and Mehari (2018) also opine that, garlic is a flavouring agent in a majority of dishes in many countries including soups, stir-fries and stews.

Ginger

According to Bhatt et al. (2013), ginger has been used globally as a spice, garnish, flavouring agent and food preservative. Parthasarathy et al., 2008; Zachariah (2008) add that the spice is a common condiment in both food and beverages. Raghavan (2007) claims that, ginger is an indispensable spice in many Asian cuisines as its spicy-sweet flavours complements and enhance their curries, stir-fries, soups and marinades, rice porridges(congee),

meat and vegetable dishes, sauces among many others. Powdered dried ginger on the other hand is used in seasoning spice blends, curry blends, and also as a flavouring in snacks, teas, desserts. Ground ginger also blends well in cold and hot beverages such as ginger tea, coffee, ginger beer, ginger ale, ginger wine, pickles, cordials, baked goods and confectionery, ginger bread, ginger cake, ginger snaps, biscuits, puddings, cookies, pies, ice creams, jams, marmalades. It is also used in soft drinks as a flavouring agent (Partharasathy et al., 2008; Zachariah, 2008; Bhatt et al., 2013).

Bay leaf

Balasaserikha (2014) claims that, bay leaf is one of the most popular spices in the Western countries. Batool et al. (2020) assert that, bay leaf is useful in the preparation of a wide array of dishes, sauces, stews, soups, stuffing, fish, meats, vegetables, pickles and sausages. It is also important in teas, cheeses and liquors, as it adds flavour to food and beverage. Al-Hashimi and Mahmood (2016) further opine that, the spice has an extensive usage as a seasoning of meat products, fish and soup. Raghavan (2007) posits that, laurel leaf is a peculiar spice in European soups, stews, pickles and stocks. It is also a chief component in *bouquet garni*, *bouillabaisse*, and *bourinide* of the French. Again, it plays a major role in the *tangines* of the Morrocans.

African nutmeg

Monodora myristica seeds, when milled into powder is used as a spice for culinary purposes to flavour soup, stew, sauces, and as a substitute for nutmeg in cakes and desserts (Agiriga & Siwela, 2017; Fovo et al., 2017; Enabulele et al., 2014; Ekeanyanwu, Ogu & Nwachukwu, 2010). Adewole et al. (2013); Eli (2015) add that, the spice is a popular condiment in both

African and continental cuisines in Nigeria. One of such cuisines being a popular Nigerian delicacy known as 'pepper soup'.

Health purposes

Chilli pepper

Many cultures around the world have long recognized chilli peppers for their medicinal qualities. Thus, the Pre-Columbian Indians used chilli pepper to treat sore throat, arthritis, coughs, and earaches by mixing it with other ingredients. This is possible due to the anti-inflammatory characteristics of its chief principle-capsaicin (Raghavan, 2007). It is believed that, chillis helps to improve circulation and reduces blood clotting and helps with rheumatic pain, cold, asthma, chest congestion, headaches, treats infected wounds and mouth sores. It has also been established that, endorphins (the pleasure producing hormone) are released when chillis are eaten, as capsaicin in chillis stimulate the release of the hormone, and this accounts for the pain relieving properties of the spice (Balasasirekha, 2014; Pandit et al., 2020).

Saleh et al. (2018) explains that, the ability of capsaicin to treat pain and aches lie in its capacity of depleting nerves of their supply of subsistence P-the neuropeptide responsible for sending signals of pain to the brain, thereby preventing transmission of the feeling of pain. Balasasirekha (2014) adds that, chillis also helps with diabetes, as capsaicin affects the breakdown of carbohydrates which helps in controlling the fluctuations of sugar levels after meals have been eaten.

Aniseed

Literature claims that, aniseed played a key role in European traditional treatment of epilepsy. The spice was also used in making tea which

was used to relieve cough, and to dispel gas from the stomach by the Aztecs due to its carminative properties and also an aid to new mothers to boost breast milk production. It is also believed that the spice possesses properties that aid digestion, improve appetite, alleviate cramps, and nausea and soothe colic in infants. It is also served after meals by the Indians to freshen breath and to aid digestion. Its essential oil is also used in the treatment of lice and scabies. (Sun et al., 2019; Balasasirekha, 2014; Parthasarathy et al., 2008).

Rosemary

The Romans used rosemary to treat insect bites, as the Arabs used it as a memory refresher. The French also used it for the sanitation of the air in their hospitals whereas the Greeks treated jaundice with rosemary. The spice is a major constituent in the treatment of whooping cough, panic attacks, irritability, aching joints, fluid retention, poor circulation, migraine, jaundice and mental fatigue. In Germany, rosemary leaf is licensed as a standard medicinal tea for internal and external use (Raghavan, 2007). Internally, it is taken as a carminative or stomachic component of gastrointestinal medicines in aqueous infusions, tinctures, and medicinal wine. The aqueous infusions and essential oil are used in external preparations for rheumatic diseases and circulatory problems (Kunnumakkara et al., 2009; Parthasarathy et al., 2008). Malvezzi de Macedo et al., (2020) added that, rosemary oil is proven to inhibit hair loss caused by alopecia.

Clove

The Chinese court officials chewed clove to refresh their breath before they appeared in the presence of the emperor (Raghavan, 2007). It is documented that clove has anti-bacterial and anti-fungal properties due to its

eugenol content. Thus, physicians of old used the spice to aid indigestion and to promote circulation due to its warming qualities. The Indians also made aphrodisiac for men by combining clove, nutmeg and black pepper. Clove is believed to be a pain reliever; hence it is used as a mild anesthetic for toothache (Raghavan, 2007). It is further reported that clove possesses carminative properties hence when consumed has the potential to increase hydrochloric acid in the stomach and improve peristalsis. Other reported medicinal properties include the spice's ability to treat impotence and clear vaginal discharges when combined in formulas. In pregnancy, clove can control morning sickness together with ginseng and patchouli.

Pulikkoti and Nath (2015) reported that, essential oils in clove have anti-cancer potentials and the ability to inhibit *C albicans* due to its anti-fungal properties, whereas Bhowmik et al., (2012) opined that, clove is an immune booster as well as blood detoxifier. It was reported by a research team at Chittaranjan and National Cancer Institute, Kolkata, India, that clove has got the potential to prevent lung cancer, as it may inhibit the growth of abnormal cells in the lungs and reduce the abnormal crowding of cells in particular spots in lung tissues by more than 85% (Raghavan, 2007; Kunnumakkara et al., 2009; Balasasirekha, 2014; Parthasarathy et al., 2008). Cortes-Rojas et al., (2014), reported that, clove exhibited analgesic properties by activating Ca^{2+} and Cl^{-} channels and its alopecia-inhibiting potential from their studies (Shahtalebi, Hosseini & Saaeian, 2016).

Negro pepper

The Indians and Chinese, in recent times use all kinds of pepper to improve circulation, to treat coughs, asthma, kidney inflammation and pains in

the joints (Raghavan, 2007). Ogbonna, Nokazi and Yajima (2013), also add that, with its variety of chemical compounds, *Xylopia aethiopica* is a medicinal plant with great reputation in West Africa, as almost every part of the plant is utilized in traditional medicine in managing varying number of ailments including, candidiasis, skin infections, cough, fever and dyspepsia. Onyebuagu et al., (2015), postulate that, as part of traditional practices in south-eastern Nigeria, the spice is added to the preparation of a special soup known as 'pepper soup' which is served to new mothers to aid quick recovery from after-birth wounds, stimulate postpartum appetite, reduce pain, and aid in lactation.

Ikrang and Anyanwu (2019), also support the argument by saying that, data from several studies has revealed that, negro pepper possesses laxative, anti-oxidizing, carminative, and anti-microbial properties and therefore used either alone or mixed with garlic or ginger, and other ingredients for making herbal teas for the treatment of gastrointestinal problems, menstrual problems, respiratory problems, rheumatism, coughs, fever, flu and cold. Adeoye, Joel, Ifunnu, Arise and Maloma (2021) reported of negro pepper having anit-hypertensive potential due to its xylopic and kaurenoic acids. Usman, Usman and Mainassara (2015) posited that, the spice is able to inhibit *E. coli* with its many phenolic compounds, hence treats urinary tract infections caused by the organism. Ogbonna et al., (2013) and, Ikrang and Anyanwu (2019) reported that negro pepper has expectorant qualities hence helps with cough and flu. It also treats skin boils and it is known to get rid of chest pains as it has been confirmed in Ivoirian folk medicine for ages (Ebuete, Ebuete & Berezi, 2022).

Grains of paradise

Afromomum melegueta, is one of the many spice seeds available to mankind with endless benefits. Traditionally, West African cultures use the spice chiefly to cure fever, as an aphrodisiac and pain reliever (Raghavan, 2007). Ogbungafor et al. (2017), add that, the seeds are used as local remedy for the treatment of stomach ache, snake bites, cardiovascular diseases, diabetes, diarrhoea, dysentery and inflammations. They further add that, natives of Eastern Nigeria, use the ground seeds in the preparation of yam pottage to increase appetite and to minimize the risk of puerperal infections in new mothers. Toh et al. (2019) also posit that, the spice is mixed with other herbs in the treatment of body pains, sore throat, diarrhoea, rheumatism catarrh and congestion due to its natural decongesting qualities. The seeds are also reported to enhance potency in males as they have aphrodisiac properties. It is further posited that, recent studies on the pharmacological effects of the seeds have revealed that, the seeds have anti-ulcer, anti-microbial and cytoprotective effects, with these effects being attributed to the presence of 6-shogoal and 6-pardol (Young and Markmanual, 2019; Sarpong, 2018).

Osuntokun (2020), further reported that, recent studies on the pharmacological potentials of the spice indicate that, *Afromomum melegueta* possesses anti-cancer ability which is attributed to flavonoids and paradol. Again, extract from the spice has also proven its worth in combating metabolic disorders such as type 1 and 2 diabetes as several compounds in the seeds exert an anti-diabetic effect by inhibiting enzymes (α-amylase and α-glucosidase) that are responsible for digestion of carbohydrates into simple sugars which raise blood sugar. It also helps with soothing inflamed mucous

membrane. Toh et el. (2018) reported of the anti-inflammatory functions of the spice in inhibiting the expression of IL-1β (interleukine-1beta).

Garlic

Kunnumakkara et al., (2009) posited that, garlic has been used as folk medicine for the treatment of a varying number of ailments including intestinal disorders, diabetes and inflammation, bronchitis, liver disorders, tuberculosis, intestinal worms, dysentery, rheumatism, colic, high blood pressure, flatulence and facial paralysis and fevers due to its anti-pyretic potentials. Raghavan (2007) further report that, the spice was used by the ancient Greeks in the treatment of coughs and colds. The Greeks also used it to kill intestinal parasites and to stimulate blood flow in the body. Furthermore, Raghavan (2007) and Fesseha and Goa (2019) claim that, being referred to as the 'Russian penicillin', garlic was used in diverse ways to treat varying ailments due to its wide spread use as a topical and systematic antimicrobial agent. It is further documented that, ancient Egyptians used garlic to treat virtually everything from insect bites to tumours and heart disease, and also helps in poor digestion as it stimulates the digestive system, lowers blood pressure and helps with blood circulation**.**

Kunnumakkara et al., (2009) emphasize that, recent studies on garlic are focused on its fibrinolytic activities and its role in lowering cholesterol. Thus, Balasasirekha (2014) has pointed out in support of the above that, the use of garlic supplementation in human studies revealed that vascular calcification was inhibited in patients with high blood cholesterol. Balasasirekha (2014) further claims that, garlic, like any other Allium species is a rich source of many phytonutrients, and hence its effectiveness in the

treatment and prevention of many diseases such as cardiovascular diseases, cancer, hypercholesterolemia, obesity, type 2 diabetes, cataract, hypertension and gastrointestinal disorders with the above activities being attributed to the thiosulphites, that is, the volatile sulphur-compounds in garlic.

Thus Raghavan (2007), is in synch with the above by saying that, recent studies on garlic have focused on garlic curative potentials in relation to cancers, heart diseases, immune system and memory enhancement as well as its role in decreasing cholesterol and blood pressure. Shang et al., (2019) reported that garlic has immunomodulatory functions due to its active compounds. Jiang (2019) reported of the blood glucose reducing functions of garlic which helps in controlling diabetes as well as the anti-inflammatory functions as it is able to inhibit the expression of inflammatory genes such as cyclooxygenase-2 (COX-2), NF-$_k$B (Neutral factor-kappaB), iNOS (inducible nitric oxide synthase). Jiang (2019) further reports of garlic's potential to slow the development of atherosclerosis- a condition that lead to heart attacks and stroke. It is also reported that, the spice possesses anti-platelet potentials due to its ability to reduce COX activity as well as anti-bacterial and anti-fungal properties as it is able to inhibit microbes that cause vaginitis and vaginal discomfort.

Ginger

Being one of the oldest and most popular medicinal spices worldwide, Raghavan (2007) postulates that, the therapeutic uses of ginger are wide and many across the globe. With its soothing effect on the stomach, the Greeks and the Chinese prescribed it for stomach ailments, and as an antidote to poisons as it neutralizes toxins, and also potent against motion sickness and

nausea. It also discharges phlegm, relieves pains, increases blood circulation, soothes digestion and decreases acidity in the gastrointestinal tract. The Indians however, used it as a bowel cleanser to detoxify the kidneys and to enhance blood circulation. In traditional medicine, it has been proven to be effective against sore throats, diarrhoea, gingivitis, arthritis, bronchitis, muscle pains, sprains, asthmatic respiratory diseases, constipation, stroke, diabetes among many others. It also eases menstrual cramps and bloating by drinking teas in which ginger has been brewed. In contemporary times, studies revealed that ginger possesses strong anti-oxidant properties against cancers, tumours, and gastrointestinal disorders and to reduce cholesterol.

Kunnumankkara et al., (2009) emphasize that, ginger has been used in Ayurvedic and traditional Chinese medicine for the treatment of gastrointestinal disorders, especially nausea and vomiting associated with pregnancy, abdominal spasms, respiratory and rheumatic disorders, dyspepsia, flatulence (due to its carminative role). Bhatt et al., (2013) reported of ginger having immunomodulatory effects on the immune system as well as anti-inflammatory functions as its inhibits the expression of COX-1 and 2, hence strengthening the immune system to fight infections. They further reported of the hypoglycemic functions of ginger which helps in managing diabetes and its ability in inhibiting the performance of angiostensin I converting enzyme (ACE) related to hypertension. It is further added that ginger is a cough suppressant. Kaushal et al,.(2017) adds that, ginger helps with respiratory disorders due to its rich phenolic compounds. Bhatt et al., (2013) add that, gingerol and shogaol in ginger make the spice an effective suppressor of asthmatic synptoms. Shabanian, Khalili, Lorigooini, Malepor and Heidari-

Soureshjani (2017) reported that terpenoids in ginger make it effective in combating *Candida albicans,* the organism that causes vaginal thrush and its associated discomfort.

Bay leaf

Literature asserts that the therapeutic values of bay leaves are innumerable. Notable among them include relieving pain in the joints, chest, womb and stomach, stimulating gastric secretion and easing earaches and cramps. Data from recent studies has revealed that, bay leaves have got anti-ulcer potentials as well as hypoglycemic function. It has also been documented to possess high anti-microbial potentials against pathogens found in the gastrointestinal tract (Raghavan, 2007). Balasasirekha (2014) adds that, bay leaves have both herbal and pharmacological activities such as anti- bacterial, anti- fungal, anti- diabetic and anti- inflammatory effects.

African nutmeg

In traditional medicine, the spice is used as a stimulant and a stomachic to relieve constipation. In women who had just given birth, the spice is used to control uterine heamorrhage, when used in pepper soup for them. It is further documented that, due to the rich alkaloid content of the seeds, they can be used in the treatment of headache. (Fovo et al., 2014; Enabulele et al., 2014). Akise, Fasakin and Adeparusi (2020) add that, the seeds are effective in treating high levels of cholesterol due to the presence of alkaloids, flavonoids, vitamin A, vitamin E and other several significant lipids. Additionally, the seeds are effective in the treatment of wounds caused by guinea worms, hypertension, toothache, dysentery, rheumatism, chest pains, stomach aches, diabetes mellitus, malaria, anaemia, sexual weakness, body aches, candidiasis,

and in the management of pain. The seeds can be roasted, ground and chewed, and then spat into the palm and rubbed on the forehead to relieve headaches or rubbed on the skin to treat skin diseases. They may also be chewed and used as worm expeller. (Agariga and Siwela, 2017).

Industrial applications

Pandit et al., (2020) reported that capsaicin in chilli pepper finds its usefulness in many pharmaceutical preparations such as counter-irritant balms and ointments for external applications (Kumar et al., 2006). The Koreans have also used capsicum plaster, which contains powdered capsicum and tincture in hand acupuncture to treat many ailments (Kunnumakkara et al., 2009; Balasasirekha, 2014). It is further reported that, oleoresins extracted from chillis are used in the cosmetic, food and beverage industry to produce value added products. For instance, the colour of ketchup is improved by the use of these oleoresins (Pandit et al., 2020; Kumar et al., 2006). According to Parthasarathy et al. (2008), rosemary is used in the formulation of a wide array of compounded oils used for flavouring sauces, meats, condiments and other food products, and also as an ingredient in vinegar and some oil-based marinades, and to flavour vodkas, herbal wines, mead and beer (Pawlowska, Janda-Milczarek and Jakubczyk, 2020). Sun et al., (2019) reported that, the numerous natural antioxidants in aniseed makes it an ideal additive in foods as well as a component of cough syrups and lozenges due to its mild expectorant qualities.

In the flavouring industries, clove is employed as fragrance in perfumes, artificial vanilla (Kunumakkara et al., 2009) and a constituent in ice cream, whisky, baked goods, and candies, chewing gums, tooth pastes,

cosmetics, perfumes, mouth washes and for making filler for dental cavities (Pulikkoti and Nath, 2015). Eugenol present in the spices also acts like menthol to reduce the harshness of tobacco in cigarettes (Thakur et al., 2021; Pulikottil & Nath, 2015). Durodola, Ogunmuyiwa, Olasoju, Salami and Ogunsina (2021) opine that the essential oils of *A. melegueta* have been reported to have industrial applications as fragrances and flavourings in the perfumery and pharmaceutical industries. Udosen, Esenwo and Sam (2015) also reported that, oils from the seeds can be used for industrial purposes as a flavouring in corn spirit, beer, wine, and gin, ice cream, and confectionery products (Oboh and Imafidon, 2018). The Europeans also used the spice to flavour their wine and beer, but in recent times use it in vinegars and liquors (Raghavan, 2007).

Pandey (2012) posited that, garlic has several industrial applications for the production of garlic powder, garlic salts, garlic vinegar and garlic oil which is used in a variety of food products such as sauces, canned foods and meat preparation, mayonnaise, ketchup and salad dressings. Ginger on the other hand is also used in many value-added products such candies, preserves, vitaminized effervescent ginger powder, tinctures, jam, cookies, and beverages such as cordials, ginger cocktails, ginger brandy, ginger ale, and wine, as well as carbonated drinks. It is also used in essences, pickles, marmalades, chutneys, and salted ginger (30% and 1% citric acid), ginger bread, ginger appetized flakes, ginger paste (8% common salt and citric acid), ginger starch (a white, tasteless and odourless powder which contains amylase and amylopectin) for use in the plastic, paper, pharmaceutical, textile and food industries. (UHF, 2011; Kaushal et al., 2017).

Batool et al., (2020) reported that, bay essential oils contain useful bioactive constituents used in the cosmetic industry in perfumes and soaps, in dental preparations, and in hair lotions due to their anti-dandruff activity. Literature asserts that, African nutmeg contains a variety of active compounds which makes is useful in many industrial applications. For instance, stearic acid, which is found in its essential oil is useful as a binding agent in various food and cosmetic products such as vanilla and butter flavourings, chewing gum, butter and fruit waxes, soaps, lotions, deodorants and candles. Eucalyptus a-phellandrene and eucalyptus are used in yoghurt, baked goods and in cough suppressants and mouthwashes, insecticides and insect repellants (Agiriga & Siwela, 2017; Adewole et al., 2013).

Preservative purposes

Parthasarathy et al., (2008) and Raghavan (2007) reported that, rosemary was used in the preservation of meat in the ancient days due to its anti-microbial potentials against some gram-positive and gram-negative bacteria. Oleoresins from the spice are also used on commercial basis to preserve the colour of meat. Hamidpour et al., (2017) claim that, rosemary has since antiquity been used as a food preservative due to its anti-fungal, anti-bacterial and anti-oxidant properties as a major inhibitor of food spoilage pathogens, with its anti-oxidant properties being attributed to phenolic compounds such as phenolic acids and flavonoids, which are able to provide defense against free radicals. Pawloska et al., (2020) support the above claiming that, E392-an extract from rosemary has been approved by the European Commission for its use as an anti-oxidant in food products with fat content in the food industry.

In the ancient days, negro pepper was primarily used to preserve meat to inhibit factors that cause spoilage (Raghavan, 2007), and is still being used as a preservative agent in meat Ikrang and Anyawu (2019), as the ethanolic extracts in the spice have been proposed to have preservative properties against spoilage agents, Oso and Oladiji (2019), and this is attributed to its active constituents such as terpene compounds which are microbistatic or microbicidal (Ogbonna et al., 2013). Adesola et al. (2019) further assert that, negro pepper is a natural anti-oxidant and as such is potent in prolonging the shelf life of food by preventing rancidity. Agiriga and Siwela (2017) tested the efficacy of methanolic extracts and powders of African nutmeg in its capacity to stabilize crude soyabean oil during storage due to its potent anti-oxidants that are able to stabilize oils and prevent them from going rancid.

Spiritual / religious purposes

Pandit et al., (2020) reported that, chillis were used as war artifacts and in religious rituals in the ancient times. Kumar et al., (2006) further reported that, traditionally, dried fruits of chillis are stringed on a thread together with lime by Indians and hanged at the entrances of homes with the belief of driving away evil whereas the Mexican did same as a sign of hospitality. Some cultures around the world also use them to ward off spells, evil, as charm to prevent nightmares and in offerings to appease their gods as the plant is perceived as holy. The ancient Greeks believed that rosemary had the ability to strengthen the human memory and rejuvenate the spirit, hence their students wore garlands made from rosemary during examinations in order to retain knowledge and to excel. The spice was widely used as a symbol of protection against evil during religious ceremonies, weddings, and funerals (Raghavan,

2007). Dafni et al. (2019) support the above by adding that, ancient Greeks garlanded the statutes of their gods with rosemary plants as part of their religious rites, whereas others also consecrated rosemary to the *Lares*-deities for protection. It is also used in funeral rites with the belief that, it leads the departed souls in the hereafter and, in the circumcision rites of new born infants, as they believe it protects the children from evil eyes. In Europe, rosemary was and is still worn by brides during weddings or used in their bouquets as a sign of virginity.

Raghavan (2007) claims that, in Indonesian traditional practices demand that clove trees be planted when a child is born. It is believed that, as the tree grows straight and strong, so will the child be. Again, traditional custom dictated that clove necklaces be made and put around the necks of children to protect them from illnesses. Jayashree, Gawande and Sheihk (2018) also added that, clove is believed to contain magical powers hence its usage in the practice of magic. It is believed to be used to banish negative forces, protect lives from evil and gain what its users seek in life. Inegbenebor et al. (2009) further posit that, members of the Iyay (Faith) Society of Nigeria serve the seeds of *A. melegueta* as communion during their worship while some diviners invoke spirits with the seeds of the spice. Garlic is known in many cultures as the 'stinking rose', and hence was used and still being used by such cultures to drive away evil spirits (Raghavan, 2007), for fortification in the practice of white magic and to ward of vampires, imps, and werewolves (Worku and Mehari, 2018). The ancient Greeks also revered bay leaf as holy and as such used it in their religious ceremonies (Raghavan, 2007). It is also believed that, the seeds of African nutmeg have magical powers and hence

their usage as rosary beads (Fovo et al., 2014). Batool et al., (2020) reported that bay leaves are believed to possess protective powers and hence its users' are able to get their wishes come through for them.

Heavy Metals in Spices

This section presents a review of literature on the presence of heavy metals in spices from various geographical locations. Fadhil, Noori, Al-Samarraie and Mohamed (2021) estimated the content of Cu, Cd, Ni, and Pb in ten different spices available on local markets of Tikrit, Iraq using Atomic Absorption Spectrometry. Findings from the study revealed that maximum concentrations of the metals were recorded in turmeric, kebbah, curry, mixed spices and curry for Cu, Cd, Fe, Ni and Pb respectively. It was concluded that, most of the investigated metal concentrations were within the permissible limits and therefore were safe for human consumption when results were compared with the permissible limits stipulated by FAO/WHO.

Oladoye and Jegede (2016) also assessed the levels of Fe, Cu, Cd and Pb in some common natural and processed spices available in Odo-Ori market, Iwo, Osun State, Nigeria using Atomic Absorption Spectrophotometry. The study revealed that, Fe and Cu concentrations were below the maximum permissible limits (MPLs) set by the WHO whereas Cd levels exceeded the MPL. Lead was not detected in any of the natural spices that were analyzed, possibly because it fell below the detection limit.

Mubeen, Naeem, Taskeem, and Saddiqe (2009) investigated the concentrations of Fe, Cu, Cr, Pb, Cd and Co in two commonly used spice brands in Pakistan using Atomic Absorption Spectrometry. Results indicated that, daily intake limits for Cr and Pb in all samples exceeded the minimum

risk level (MRL) for all spice samples given by the Agency for Toxic Substances and Disease Registry (ATSDR) {2001}. It was then concluded that, continual intake of these spice brands could cause the accumulation of these hazardous metals - Cr and Pb in the human body and hence expose individuals to diverse health complications.

Krejpcio, Krol and Sionkowski (2006) also evaluated Pb, Cd, Zn and Cu contents in 113 groups of herbs and spices available on Polish markets. Findings from the study indicated that, excessive levels of Pb and Cd were present as 8% and 6% respectively, whereas Zn and Cu concentrations were within the MPLs set by WHO.

Bua, Annuario, Albergamo, Cicero, and Dugo (2016) determined the content of Cd, Hg, As and Pb in common spices collected from different origins that traded in Italian markets using inductively coupled-plasma-mass spectrometry (ICP-MS). Findings from the study indicated that, metal concentrations in the spices were within the maximum limits set by national and international standards except for a few which recorded values above the provisional tolerable weekly intake (PTWL), tolerable weekly intake (TWI) which therefore need attention considering consumers' health.

Nordin and Selamat (2013) also analyzed commonly consumed herbs and spices in Malaysia for As, Cd, Pb and Hg. Findings from the study revealed that, Cd, Pb and Hg found in the analyzed spice samples exceeded the MPLs. Thus it was suggested that, further monitoring should be done for Cd, Pb and Hg on the daily consumption of herbs and spices and its toxicological implications for consumers since only As concentrations fell within the permitted levels.

Gaya and Ikechukwu (2016) further investigated Cd, Cr, Cu, Co, Fe, Mn, Ni, Mo, Pb and Zn in 22 spices from major markets in Northern Nigeria using Atomic Absorption Spectrometry. Findings from the study indicated that, all the spices contained excessive levels of Co and Cu, with maximum concentrations being recorded in ginger and African nutmeg respectively. Some of the samples recorded values above the provisional tolerable intake (PTI) by FAO/WHO hence it was concluded that priority be given to such spices as their consumption can lead to the accumulation of toxic metals with potential risk to human health.

Soliman (2015) investigated the content of As, Cu, Fe and Zn in 10 popular herbs and spices used in Egyptian cuisine. Findings from the study indicated that As and Cu levels in all the samples fell within the WHO limits. However, some samples recorded concentrations levels which were above thee WHO limits. Soliman concluded that, routine checks on foodstuffs should be carried out to ensure the safety of consumers so far as metal contamination is concerned.

Darko et al. (2014) also investigated a total of 22 samples of unmixed and mixed spices from the Kumasi Metropolis, Ghana, using Flame Atomic Absorption Spectrometry for Fe, Zn, Cu, Cd and Pb. Results indicated that, Fe, Zn and Cu recorded mean concentration values below the permissible limits whiles Pb and Cd recorded values above the permissible limits.

Senanayake et al., (2013) also investigated Pb exposure in samples of commonly used spices from seven provinces of Sri-Lanka using atomic absorption spectrometry. Results indicated that, all samples analyzed

contained Pb concentrations which fell well below the USA/FDA action level of 5µg/g with chilli pepper recording the maximum concentration of the metal.

Finally, Nkansah and Opoku Amoako (2010) determined the content of Pb, Zn, Ni, Cu, Fe and Hg in 15 common spices available at the local markets in the Kumasi metropolis, Ghana, using atomic absorption spectrometry. Results from the study indicated that, all analyzed metals fell below the standard threshold except Pb which recorded concentrations above the threshold in ginger, cinnamon and negro pepper. They concluded that, spices available on the local markets generally contained safe levels of trace metals.

Chapter Summary

Spices have been known to mankind since time immemorial not only for culinary purposes, but also for medicinal purposes due to their therapeutic values. Though they may not be used in significant quantities for the above-mentioned purposes, research has proven that, their continued usage for relatively long period of time may become a probable source of hazard to the health of consumers when they become contaminated by heavy metals through natural, and mainly anthropogenic sources. Hence to ensure the safety of our everyday spices used for food, beverages and medicine, testing their heavy metal concentrations will provide relevant data on them to which will help to safeguard the health of consumers and curtail any future health-related-toxicity-complications.

CHAPTER THREE

RESEARCH METHODS

Introduction

This chapter discusses the methodology, processes, tools, materials and methods used to collect and analyze data for the study. Specifically, the chapter comprises the study area and research design. Other areas of concern include population and sampling, materials and methods, instrument for data collection, how data were collected, analyzed and interpreted, reliability and validity of instrument as well as ethical considerations.

Research Design

This study adopted the exploratory sequential mixed method design. Creswell (2014) explains that, this type of mixed method approach is a design in which the researcher first begins by exploring with qualitative data and analysis, and then uses the findings in a second quantitative phase. The study made use of this design because the researcher first needed a qualitative insight into spices and heavy metals and further quantitative exploration of the quantitative data in the second phase of the study.

The researcher therefore went to Abura and Kotokoraba markets to conduct a market survey to seek the views and opinions of both buyers and sellers of natural spices on the kinds of spices that are available for sale at the markets and the ones which are frequently patronized by buyers using an interview guide. Through the interviews, data obtained were ranked by the researcher and the first 10 spices on top of the list were selected as the frequently patronized and hence used for the heavy metal analysis. The ranking of the spices in order to obtain the top 10 was to provide a basis for

decision making should these spices be contaminated by the heavy metals under consideration in this study.

Study Area

The research study focused on the Cape Coast Metropolis. This is an area located in the Central Region of Ghana and is the regional capital. It is a coastal city with land size of nearly 122km^2. It has an estimated population size of 169,800 (Ghana Statistical Service, 2013; Danso, Ma, Adjakloe & Addo, 2020). Central Region is one of the regions in Ghana rich in cultural and historical heritage. In terms of educational purposes, it has some of the best schools and institutions in the country. It also has a diverse market system with the main commercial activities being fishing and trading. Others include services in commerce, education and tourism. Two vibrant market centres within the Metropolis (Kotokoraba and Abura markets) were used for the study.

Phase One of the Study

Population

The population for the first phase of the study included all sellers and buyers of spices in Cape Coast markets. However, with regards to sellers, the target population comprised all sellers of natural spices in the Abura and Kotokoraba markets in Cape Coast, which were 16 and 11 respectively. Hence, any of such sellers who were present at the market on the days of data collection and were willing to be interviewed were included. With regards to the buyers, the nature of the participants made it impossible to determine the target population. Participants in these two markets were used because these markets are included in the major markets in terms of size in the Metropolis,

hence the researcher believed that valuable data could be obtained from these markets to help address the research objectives one and two.

Sampling Procedures

The sample sizes for the sellers from Abura and Kotokoraba markets were therefore 14 and 10 respectively, which are acceptable for the populations 16 and 11 according to Krejcie and Morgan (1970). However, with regards to the buyers, 12 respondents each were selected from each of the two selected markets. The researcher's choice of 12 respondents from each market was based on an assertion by Guest, Bunce and Johnson (2006). They proposed that for a qualitative study with an unknown population size, 12 is ideal for a sample size. This is supported by their study which was based on saturation of themes. In this study, Guest et al., (2006) observed that saturation of themes was reached by the twelfth interview and therefore there were repetition of responses, hence no new information was needed in addressing their research questions, hence their conclusion on using 12 as sample size for an unknown population size in a qualitative study.

Each of these participants was chosen as part of the sample size using the purposive sampling procedure. According to Tongco (2007), the purposive sampling is a non- random technique in which the researcher decides what needs to be known and sets out to find people who can and are willing to provide the information by virtue of knowledge or experience. The researcher believed that this technique was suited for the study to provide the needed information to address the objectives of the study.

Research Instrument

The research instrument consisted of self-developed interview guides which are shown in appendices A and B. They were used to collect data from the respondents (sellers and buyers of natural spices) in the markets for the first phase of the study. The interview guides were designed to solicit information on the kinds of spices available on markets in Cape Coast and the spices which were mostly bought by consumers as well as the purposes for which they bought the spices. The data collection instruments were designed to consist of three open-ended questions each in order to give respondents the opportunity to express their views on issues where necessary. Again, the instruments were designed to cover two sections, that is theme A and theme B, consisting of questions suited to address the first two objectives of the study. The researcher's choice of the instrument was based on the fact that they best suited for collecting qualitative data and also capable of providing enough and necessary information to address research objectives though they are time consuming and tiring to conduct interviews.

Validity and Reliability of Instrument

The face validity of the interview guide was determined with the help of the researcher's Supervisor. All typographical errors and elements of ambiguity in the instrument were corrected by the help of the Supervisor before it was used. The content validity of the interview guide was done by the supervisor and the researcher together with other lecturers in the University of Cape Coast who are experts in the field. The reliability of the interview guide was checked by conducting a pilot test was conducted using 'Yawda Guam', one of the oldest and well-known markets in Cape Coast aside the two

selected for the study. The questions were tried on participants (buyers and sellers of spices) from that market. Ambiguities, confusion and problems regarding the wording of the questions were looked at and corrected after the pilot test.

Data Collection Procedures

In research methodology, procedure is critical since without it, reaching valid conclusions becomes a challenge. Before the conduct of the study, a research proposal was approved by the Vocational and Technical Education Department of the University of Cape Coast. Furthermore, an ethical clearance was obtained from the Institutional Review Board (UCCIRB/CES/2022/62) of the University of Cape Coast. Introductory letters were also obtained from the Department of Vocational and Technical Education and presented to the Research and Teaching Farm, School of Agriculture and the School of Physical Sciences, Department of Chemistry, both of the University of Cape Coast for assistance in the data collection.

In the first phase of the study, the researcher approached both buyers and sellers of natural spices in the two markets for a face-to-face interview to seek their consent before the interview sessions were recorded using an audio device. Respondents were informed that the exercise was purely academic and that their responses would be highly confidential. The researcher expressed gratitude to the respondents concerned at the end of each interview session. For the sellers, the researcher walked to a stall and spoke to the seller concerning the research, if the seller accepted to be interviewed, the researcher proceeded with the interview. However, if the seller declined to grant the interview due to inconveniences that may be created for her as she sold, the

researcher thanked her and moved to another seller, until the required number of respondents was attained.

Regarding that of the buyers the researcher waited at vantage points closer to some of the sellers so that buyers could easily be identified and approached. At any particular moment, any buyer who approached a spice seller to buy was requested to participate after she is done with her purchases, and the aim of the research was explained to her. Those who agreed to participate in the interview were finally thanked for their time. In the same vein, any buyer who was unwilling to participate was allowed to go without her participation. This same procedure was followed until the required number of buyers (respondents) was achieved.

Phase Two of the Study

Materials and Methods

Samples collection and classification

A total of 60 samples (3 of each kind) of 10 different spices were collected from different sellers at the Kotokoraba and Abura markets and classified according to the plant part used, scientific, family and local names Table 2. The samples were purchased after preliminary study of the two markets indicated that they were the most purchased, consumed and hence frequently patronized spices in the Metropolis. The samples were collected in sterilized zip lock bags, labelled with codes for easy identification and then transported to the laboratory. Codes given to the spices are presented in the Table 3.

Table 2: Classification of selected spices according to scientific, plant part used, family and local names

Spice	Scientific Name	Family	Local Name	Part Used
Chilli pepper	*Capsicum annum*	*Solonaceae*	Muoko(*Fante*), Meko(*Twi*), shito *(Ga*), Barkono(*Hausa)*	Fruit
Rosemary	*Rosmarinus officinalis*	*Lamiaceae*	Rosemary	Twigs/ terminal shoot
Anise seed/Anise	*Pimpinella anisum*	*Apiaceae*	Nkitsinkitsi (*Fante*), Nketenkete(*Twi*), Osukor*(Ga*), Nketenkete(*Hausa*).	Seeds
Cloves	*Eugenia carylophyllata*	*Myrtaceae*	Mpregowamba *(Fante*), Dadoamba/Pepre (*Twi*), Pepple*(Ga*), Kanumfari(*Hausa*)	Unopened flower buds
Negro pepper	*Xylopia aethiopica*	*Annonaceae*	Hwentsia*(Fante),* Hwentiaa*(Twi),* Soh*(Ga),*Kimba *(Hausa).*	Fruits and seeds
Ginger	*Zinginber officinale*	*Zingiberaceae*	Tsintsimber (*Fante*), Akakaduro (*Twi*), Kakatsofa (*Ga*), Citta *(Hausa).*	Rhizome
Garlic	*Allium sativum*	*Alliaceae*	*Garlic(Fante/Twi/ Ga),* Tafarnuwa (*Hausa*)	Bulb
African nutmeg	*Monodora myristica*	*Annonaceae*	Ayerewamba (Fante), Wediaba/Ayerewa (Twi), Ayerewamba (Fante), Maalai(Ga), Gyadar Kanshi (Hausa)	Seeds
Grains of paradise	*Afromomum melegueta*	*Zingiberaceae*	Famu wusa(Fante), Efom wisa(Twi), Tsuruin(Ga),Yaagyi (Hausa)	Seeds
Bay leaf	*Laurus nobilis*	*Lauraceae*	Bay leaf	Leaf

Source: Darkwa, 2013;Raghavan, 2007;Peter, 2006

Table 3: Codes Assigned to Spice Samples

Spice sample	Abura Code	Kotokoraba Code
Ginger	A-GI	K-GI
Garlic	A-G	K-G
Rosemary	A-RM	K-RM
Aniseed	A-AS	K-AS
Grains of paradise	A-GP	K-GP
Negro pepper	A-NP	K-NP
Bay leaf	A-BL	K-BL
Clove	A-C	K-C
African nutmeg	A-AN	K-AN
Chilli pepper	A-CP	K-CP

Source: Mensah, 2023

Preparation of Samples

Fresh samples such as ginger and garlic were cleaned, washed and grated for easy and even drying. All the samples were then dried in the oven at 60°C overnight in order to get rid of any moisture, cooled and stored in the zip-lock bags. They were then milled into powder using a stainless steel laboratory beater mill. The milled samples were stored in the refrigerator in zip-lock bags prior to analysis.

Instruments and Apparatus

Polyethylene bags (sterilized zip lock bags) were used for handling and transporting the collected samples. The laboratory beater mill was used in pulverizing the dried samples and the digital analytical balance used in weighing samples. The beaker, hot plate and the Esco Laboratory fume hood were used for the digestion of the samples. The refrigerator was used for keeping the milled and digested samples. Others included the pipette, filter paper and volumetric flask. Finally, SHIMADZU AA-7000 atomic absorption spectrophotometer (AAS) was used to analyze the samples for heavy metals.

Chemicals and Reagents

All chemicals and reagents used in the study were of analytical grade. They included 37% hydrochloric acid (BDH Prolabo, France), 69% nitric acid (BDH Prolabo, France), and standard solutions purchased from Waters ERA, Colorado, USA, and distilled water.

Cleaning of Glassware

All apparatus and glassware were initially washed with detergent and then soaked in 10% nitric acid overnight then washed thoroughly with distilled water. They were then rinsed with aqua regia, followed by tap water and finally with distilled water. The glassware was dried in hot oven at 105°C.

Digestion of Spice Samples

Aqua regia (i.e. a solution 3:1 of HCl and HNO_3) wet digestion was employed. Approximately 0.5g of the sample was transferred into a digestion flask and moistened with 2-3ml distilled water. 7.5ml concentrated HCl and 2.5ml concentrated HNO_3 were then added to the sample. The digestion flask was covered with a watch glass and allowed to react under a fume hood

overnight (minimum 12 hours). The sample was heated and boiled under reflux for 2 hours and then allowed to cool. The extract was then filtered with an acid-resistant filter paper into a 100ml volumetric flask. The sample was allowed to cool and diluted to 100ml mark with the 2M nitric acid solution (Verloo & Demeyer, 1997).

Preparation of Working Standards

From a stock solution of 100ppm, working standard solution of Cd and Pb were prepared. Standards were prepared in 25ml volumetric flask. For instance, 0.05ppm Cd in 25ml of volumetric flask was prepared by adding 12.5µl of the 100ppm Cd standard using a micro-pipette in 10ml of distilled water in the volumetric flask and topped up to 25ml. The same procedure with the same dilution was done for the other working standards for various concentrations. Hence for Cd, the following volumes 12.5µl, 25µl, 125µl, 250µl, 500µl gave a concentration range of 0.05ppm, 0.1ppm, 0.5ppm, 1ppm and 2ppm respectively. That of Pb were as follows; 125µl, 250µl, 500µl, 1250µl, 2500µl for a concentration range 0.5ppm, 1ppm, 2ppm, 5ppm and 10ppm and finally that of Cu with volumes of 25µl,125µl, 250µl, 500µl and 1250µl for a concentration range of 0.1ppm, 0.5ppm, 1ppm, 2ppm and 5ppm. In the same way, blank solutions from only reagents (i.e. a mixture of HNO3 and HCl), were prepared and digested for each metal for comparison using the same procedure as the sample.

Heavy Metal Analysis in Spice Samples

The filtrate resulting from wet digestion was subsequently analyzed for Pb, Cd and Cu using atomic absorption spectrophotometer (SHIMADZU AA-7000). Measurements were made using the hollow cathode lamps for Cd, Pb

and Cu at the proper wavelength, and the slit width was adjusted using air acetylene flame. Thus, light is generated from the hollow cathode lamp at wavelength characteristic of each analyte. Each analyte is then atomized using an atomizer to create free atoms from the samples (Aberie, et al., 2021; Akutei, 2019).

The air-acetylene gas was used as the source of energy for the production of free atoms for the elements. The sample was then introduced as an aerosol into the flames where light was absorbed. The light was then directed into a monochromator which then isolated the specific analytical wavelength of the light emitted by the hollow cathode lamp from the non-analyte sensitive light detector then measures the light and translates the response into an analytical measurement. Replicates of three determinations were carried out for each sample and the same procedure was employed for the determination of elements in digested blank solutions and for the spiked samples. Concentration of metals in the spice samples was calculated by using the following formula;

$$\text{Final conc. (mg/L or mg/kg)} = \frac{\text{Conc. (analytical measurement)} \times \text{Nominal volume}}{\text{Sample weight in gram}}$$

Where Conc. = instrumental measurement

Nominal volume = final volume of digest sample solution

Conc. (mg/kg) = concentration of metals in spices (Akutei, 2019).

Table 4: Instrumentation conditions for AAS

Element	Wavelength (nm)	Slit width (nm)	Detection limit (ppm)	Lamp current (mA)	Flame Type
Cd	228.8	0.7	0.004	8	Air-C_2H_2
Cu	324.8	0.7	0.03	8	Air-C_2H_2
Pb	283.3	0.7	0.04	10	Air-C_2H_2

Source: Mensah, 2023

Quality Control and Quality Assurance

Precautions were taken to ensure the reliability of results. The samples were carefully handled to avoid any external influences that could interfere with the integrity of the result. Blank and replicate samples were analyzed and compared to actual values obtained. Before the analysis, equipment was calibrated using appropriate standards. Triplicate determination of the samples was made and data presented as mean. All glassware and plastic bottles were soaked overnight in nitric acid and rinsed with distilled water and dried before use. Distilled water was used in the preparation of samples while deionized water was used in the preparation of reagents. The digestion method and atomic absorption spectrophotometry analysis were validated by the recovery method. About 25% of the total samples were spiked.

Data Processing and Analysis

Data collected from the survey through the interviews were analyzed thematically. Hence, responses from the respondents were transcribed then grouped under themes for analysis and discussion in order to address research objectives 1 and 2. Furthermore, quantitative data collected was analyzed

using Microsoft excel and Statistical Package for Solutions and Services (SPSS version 20). Results were then expressed as means and standards deviation for the heavy metal concentrations. The One-Way Analysis of Variance (ANOVA) was used to compare the means to determine statistical significance among the groups of spices from the two markets with statistical significance being set at $p<0.05$. The data was presented in Tables for discussion.

Ethical Considerations

Ethical protocols for the general conduct of research as well as those pertaining to the University of Cape Coast were adhered to. Hence, before the collection of data, ethical clearance was sought from the UCC Institutional Review Board for the permission to be granted for data collection. Again, introductory letters were sought from the researcher's department to be taken to the Research and Teaching Farms of the School of Agriculture and the Department of Chemistry for assistance in the data collection process.

The names of the two selected markets for the study were kept anonymous, but were given codes such as 'Market A' and 'Market K' for purposes of easy identification. In the same vein, sellers and buyers were given unique codes such as AS1 to AS12 for Abura Sellers, AB1 to AB12 for Abura buyers and then KS1 to KS12, KB1 to KB12 for Kotokoraba sellers and buyers respectively. Confidentiality, anonymity and privacy of both sellers and buyers of natural spices used as respondents for the study was also ensured. Their informed consent was sought before being asked to partake in the interviews.

Chapter Summary

This chapter presented methods that were employed for data collection and analysis. The study adopted a mixed method approach, specifically the exploratory sequential design. The qualitative aspect of the study's methodology dealt with the population, sample size and sampling procedure with the main research instrument being an interview guide. However, the quantitative aspect of the study dealt with how the spice samples were collected and prepared for heavy metal analysis. The data collection for quantitative part used the Atomic Absorption Spectrophotometry to determine the levels of Cd, Pb and Cu in the spices. Data analysis procedures were also discussed here, where ANOVA was used in analyzing the quantitative data and to check if there exist any significant differences in the heavy metal concentrations in the spices from the two selected markets, whereas the qualitative data was thematically analyzed for discussion.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter presents the findings of the study which have been organized into tables, followed by explanations and discussions. Thus, these findings have further been presented to reflect the research objectives addressed in this study. Furthermore, presentations and discussions were done from the perspectives of the respondents (sellers and buyers of spices) of the study. The major themes which were addressed based on the objectives of the study included:

1. Common spices available on Cape Coast markets (Abura and Kotokoraba)
2. Purposes of using spices
3. Heavy metal (Cu, Pb, Cd) concentrations in spices.

Sellers

In this subsequent section, the issues that were considered were to explore the spices that sellers put out there for sale at the selected markets as well as those spices that consumers frequently purchased from the sellers' point of view. The study also sought the views of the sellers on the purposes of the spices. The responses from the sellers on the three issues have been presented in Table 5.

Table 5: Responses collated from the sellers using the interview guide.

Question	Response
Q1. What natural spices do you sell?	AS1: *"I sell pepper, star anise, rosemary, aniseed, coriander, fennel seeds, fenugreek, cloves, bay leaf, ginger, garlic and negro pepper."* AS2: *"I have ginger, garlic, grains of paradise, pepper, African black pepper, African nutmeg, bay leaves, rosemary, aniseed and white pepper."* AS3: *"For me, I sell pepper, ginger, garlic, rosemary, aniseed, cloves, cumin, nutmeg and negro pepper."* AS4: *"I have in here, garlic, ginger, African nutmeg, cloves, negro pepper, rosemary, basil, cinnamon and African black pepper."* AS5: *"I sell grains of paradise, basil, coriander, fennel seeds, thyme, parsley, turmeric, mint, cinnamon and bay leaf."* AS6: *"I have nutmeg, parsley, ginger, garlic, cinnamon, basil, mint, thyme, rosemary and aniseed."* AS7: *"I have in here pepper, garlic, ginger, nutmeg, rosemary, aniseed, grains of paradise, cloves, negro pepper and star anise."* AS8: *"I sell ginger, garlic, rosemary, cinnamon, tumeric, parsley, negro pepper, aniseed, cloves and grains of paradise."* AS9: *"I have ginger, garlic, tumeric, African black*

pepper, African nutmeg, coriander, fennel seeds, aniseed, rosemary, cinnamon, and mint.

AS10: *"I also sell pepper, garlic, ginger, rosemary, aniseed, coriander, grains of paradise, negro pepper and cloves.*

AS11*: "I have ginger, garlic, cloves, negro pepper, African nutmeg, grains of paradise, and nutmeg."*

AS12: *"I have in here, thyme, parsley, rosemary, basil, sage, mint, aniseed, cumin, coriander, cinnamon and tumeric."*

AS13: *"I have ginger, garlic, star anise, aniseed, cloves, negro pepper, pepper, coriander, fennel seeds, and nutmeg.*

AS14: *"I have ginger, negro pepper, cloves, grains of paradise, star anise, garlic, aniseed, rosemary, white pepper, pepper and ginger.*

KS1: *"In here, I have garlic, ginger, bay leaves, pepper, white pepper, rosemary, cinnamon, turmeric, aniseed and cumin."*

KS2: *"I sell sage, parsley, cinnamon, tumeric, thyme, star anise, aniseed, rosemary, mint and nutmeg."*

KS3: *"I sell pepper, garlic, ginger, cinnamon, bay leaf, grains of paradise, negro pepper, cloves and tumeric."*

KS4: *"I have nutmeg, cinnamon, tumeric, ginger, garlic, African nutmeg and African black pepper."*

	KS5: *I have in here, pepper, garlic, ginger, coriander, fennel seeds, star anise, rosemary, parsley, nutmeg, African nutmeg and pepper."*
	KS6: *"I have ginger, rosemary, aniseed, thyme, cinnamon, star anise, garlic, cloves, negro pepper, African nutmeg, grains of paradise, and nutmeg."*
	KS7: *"I sell ginger, garlic, thyme, parsley, rosemary, basil, sage, mint, aniseed, cumin, coriander, cinnamon and turmeric."*
	KS8: *"I have ginger, garlic, star anise, aniseed, cloves, negro pepper, pepper, coriander, fennel seeds, African nutmeg and nutmeg.*
	KS9: *"I have ginger, negro pepper, cloves, grains of paradise, star anise, garlic, aniseed, rosemary, pepper and ginger.*
	KS10: *" In here, I have ginger, grains of paradise, African black pepper, African nutmeg, cloves, negro pepper, rosemary and aniseed.*
Q2. Which of the spices do consumers purchase the most?	AS1: *"My customers often buy pepper, ginger, and garlic."*
	AS2: *"Pepper, rosemary, aniseed, ginger, garlic, cloves and negro pepper are the ones my customers mostly buy."*
	AS3: *"Pepper, ginger, garlic, rosemary, and aniseed are the ones my customers like to buy often."*
	AS4*: "Customers mostly buy pepper, garlic, negro pepper,*

African nutmeg, bay leaf, rosemary, aniseed and white pepper."

AS5: *"Ginger, pepper, garlic, rosemary, cloves, aniseed, grains of paradise and African nutmeg are the spices people mostly buy."*

AS6: *"Customers mostly buy garlic, pepper, ginger, bay leaf, star anise, cloves, white pepper, aniseed and rosemary."*

AS7*: "People mostly buy ginger, garlic, grains of paradise, African black pepper, negro pepper, African nutmeg and cloves."*

AS8: *"My customers buy ginger, garlic, African nutmeg, African black pepper, negro pepper, and cloves."*

AS9: *"People like to buy ginger, pepper, negro pepper, white pepper, rosemary, aniseed and cloves."*

AS10: *"Ginger, pepper, cloves, negro pepper, African nutmeg, African black pepper, bay leaf are the spices people mostly buy."*

AS11: *"People mostly prefer to buy pepper, aniseed, ginger, garlic, rosemary, African nutmeg, bay leaf and grains of paradise."*

AS12: "Ginger, pepper, garlic, rosemary, cloves, white pepper, aniseed, grains of paradise and African nutmeg are the spices people mostly buy."

AS13: *"Customers mostly buy pepper, aniseed, garlic,*

ginger, bay leaf, star anise, negro pepper, white pepper and rosemary."

AS14: *"People mostly buy pepper, cloves, negro pepper, grains of paradise, African black pepper, African nutmeg and cloves."*

KS1: *"Most people often buy rosemary, pepper, ginger, garlic, and aniseed."*

KS2: *"Most of the time people buy pepper, rosemary, aniseed, grains of paradise, African nutmeg, cloves, and negro pepper."*

KS3: *"Basically, people mostly buy pepper, ginger, star anise, garlic, bay leaf, and white pepper."*

KS4: *"My customers only like to buy pepper, rosemary, aniseed, negro pepper, pepper, African nutmeg, and cloves."*

KS5: *"My customers always prefer to buy pepper, ginger, rosemary, aniseed, cloves, negro pepper, star anise, and garlic."*

KS6: *"Most of the time my customers always buy pepper, grains of paradise, African nutmeg, garlic and ginger."*

KS7: *"People often purchase ginger, pepper, garlic, African nutmeg, grains of paradise, rosemary and aniseed."*

KS8: *"Consumers always love to buy pepper, ginger, garlic, white pepper, aniseed, and rosemary."*

	KS9: *"People always prefer to buy ginger, grains of paradise, bay leaf, cloves, negro pepper, pepper, and garlic."*
	KS10: *"Consumers prefer to buy pepper, ginger, cloves, negro pepper, aniseed, rosemary and garlic."*
Q3: What are the purposes of the specific spices mentioned in question 2 above?	AS1: *"I know pepper, ginger, garlic, rosemary, aniseed are used for making stews, soups, gravy to give them a nice flavour and aroma."*
	AS2: *"I also know that pepper, ginger, negro pepper, cloves and sometimes African nutmeg are used in making 'sobolo', 'lamugene', 'zomkom' and ginger drink."*
	AS3: *"I know ginger for instance is used for ginger toffee, and also heard it is used for cakes and biscuits. As for ginger biscuits I have eaten some before but not the cake."*
	AS4: *"I also know that ginger, negro pepper, cloves give millet a nice flavour and aroma in 'hausa kooko'. Again, I know that ginger is also good for our hearts because it helps blood to flow easily."*
	AS5: "*I have heard that women soak cloves and sometimes negro pepper in water and drink or wash down there with the water to get rid of 'white', itching and discharges from the vagina."*
	AS6: *"I also know that grains of paradise can be ground into paste and applied on painful body part to get relief. I also heard again that it can be soaked in water and the*

water used to wash down there to get rid of 'white'."

AS7: *"I also know that, native traditional doctors use grains of paradise and sometimes pepper in combination with herbs to treat bone fractures."*

AS8: *"I can testify that when you are coughing and you chew ginger, garlic or negro pepper, you can get rid of the cough and its accompanying sore throat very quickly."*

AS9: *"I also heard some women crush ginger and with the help of a piece of cotton wool, pick some of the juice and clean the private part with it because they believe it helps to get rid of white."*

AS10: *"I have also heard that we should try and eat plenty garlic since it is good for our heart and helps the blood to flow easily. The spice also protects us from evil spirits, so personally I chew it a lot of the time."*

AS11: *"I also know that grains of paradise can be ground into a paste and smeared on a swollen body part to get rid of the swelling in few days. It also removes the pain that was associated with the swelling."*

AS12: *"Our sisters who sell salted beef also preserve the raw beef using salt and spices such as rosemary, aniseed, bay leaf etc."*

AS13: *"As for me, what I can say it that, when you put garlic under your pillow to sleep evil spirits don't come near you, that's what I have hear people say. I also know*

that, ginger, lime juice and honey can be combined to treat cough."

AS14: *"I also know that, people soak garlic in honey for the treatment of cough. In the same vein, garlic is used by so many people because they believe it protects them."*

KS1: *"I know that African nutmeg is good traditional medicine for men with fertility issues when combined with other herbs. They are ground together and used for enema."*

KS2: *"I know ginger, garlic, cloves, and negro pepper are good for the treatment of cough when chewed alone or combined with honey, and lime juice. As you do that it helps to remove all the phlegm in your body."*

KS3: *"As for ginger, cloves and negro pepper, I know people use it for 'sobolo', 'lamugene', and other drinks to add flavour to those drinks."*

KS4: *"Rosemary, aniseed, cloves, ginger, garlic and African nutmeg give stews, soups, jollof, shito, gravies nice flavour and aroma*."

KS5*: "I know the main spices used for 'hausa kooko', are ginger, dried pepper, cloves and negro pepper. They really make the porridge have a nice aroma and taste."*

KS6: *"To me spices give our food, be it stew, soup, jollof, shito or gravy a nice flavour and aroma. But I know that, garlic protects us from evil spirits."*

KS7: *"I know some women use cloves and negro pepper to treat white. They say the spices are soaked in water and the water is drunk and/or used to wash the private part"*

KS8: *"For me, I have heard some women attach a string to one end of garlic and insert it into the private part overnight. This is repeated for about a week and it helps to treat white. The same garlic also protects us from evil spirits, so I chew it a lot."*

KS9: *"I know that ginger or dried pepper can be added to herbs for enema in treating waist pains and other ailments."*

KS10: *"I know that, people grind grains of paradise into paste and smear on painful joints for relief. And again, garlic is used by some people for spiritual protection."*

Source: Mensah, 2023

Common Spices Available on Cape Coast Markets (Kotokoraba and Abura)

From Table 5, twenty-five different spices were identified to be the common spices sold by the sellers from the two markets. The spices mentioned by the respondents included sage, mint, parsley, African nutmeg, African black pepper, fennel seeds, fenugreek, white pepper, and rosemary. Others included thyme, basil, chilli pepper, negro pepper, ginger, tumeric, cloves, garlic, nutmeg, cinnamon, bay leaf, grains of paradise, aniseed, cumin, coriander and star anise. However, among these spices identified, those ones sold by majority of the sellers from the two selected markets included chilli

pepper, ginger, garlic, rosemary, aniseed, negro pepper, cloves, African nutmeg, grains of paradise and African black pepper. Probably, these spices are patronized more by consumers and thus stocked often by the sellers. Nonetheless, those which were found to be sold by few of the sellers included thyme, tumeric, cinnamon, parsley, mint, basil, sage, fenugreek and fennel seeds. On the other hand, spices that were sold by few sellers could be spices that are less consumed and hence less patronized by the consumers. It could also be that, they are more expensive and above the means of majority of consumers. Based on the above, it could be said that, the most patronized spices may be more profitable to sellers than the less patronized ones.

Again, respondents provided varied views on the issue that sought sellers' opinion on the kinds of spices that are frequently purchased by consumers. From Table 5, thirteen (13) different spices out of the twenty-five spices mentioned earlier were identified as the most frequently bought spices. It was realized that out of 24 sellers who were interviewed from both markets, all of them believed chilli pepper was the most frequently purchased spice. More than half of the total number of the respondents also indicated that, ginger and garlic are the next frequently patronized spices after chilli pepper, followed by rosemary and aniseed. Again, it could also be realized, that white pepper, African black pepper and star anise, though amongst the most frequently patronized spices, only few of the sellers included them in their list of most frequently patronized spices.

Darko et al. (2014) reported from Kumasi Metropolis in Ghana that, commonly consumed unmixed seasonings/spices in the metropolis included rosemary, aniseed, garlic, nutmeg, 'prekese', negro pepper, Ashanti pepper,

chilli pepper (green and red), and ginger. It can be deduced from this that, there are differences in the preferred spices for use even among the same people in the same country but of different regions, and these preferences could be attributed to a plethora of reasons for which these spices are bought. From Darko et al., aniseed, chilli pepper, negro pepper, ginger and garlic were among the most consumed spices from the Kumasi Metropolis. A trend similar to that of Darko et al. was recorded in this study that was conducted in Cape Coast. However, 'Ashanti' pepper, 'prekese', and nutmeg differed from the rest of the spices that were recorded from Cape Coast, as being the most consumed. These were African nutmeg, bay leaf, grains of paradise and cloves.

Purposes of Using Spices

This section presents the views of participants (sellers) concerning the purposes for which consumers purchase the spices they consume. In view of that, respondents gave different reasons to be the possible purposes for which consumers often purchase spices. Table 5 presents the varied views of respondents which have further been discussed under themes and presented as culinary, health, preservative, and spiritual purposes.

Culinary purposes

As seasoning and flavouring agents

From the views of respondents, information gathered revealed that, ginger, cloves, negro pepper, and African nutmeg are such indispensable fragrant spice that imparts the flavour and aroma to both food and beverages. Hence they are used in flavouring both local beverages and fruit drinks, smoothies, and juices, such as 'sobolo', 'zonkom', 'lamugene' as well as the

popular local breakfast cereal dish known as 'hausa kooko' in the Ghanaian local parlance. Again, it was mentioned by majority of the respondents that, the four spices mentioned could be blended with onions, garlic, rosemary, aniseed and used to season meat, fish, chicken and other animal flesh. This is usually done to impart the flavour and aroma of dishes such as soups, stews, savoury sauces, gravies and many others. Raghavan (2007) opined that, the above spices are used in many cuisines around the world as a spice to enhance flavour and aroma of such dishes and drinks. This helps to enhance the flavour when they are cooked. Chilli pepper and grains of paradise provide some amount of spiciness in dishes such as soups, 'shito', stews, and hence, respondents revealed that these two spices enhance the flavour of other spices used in dishes. This confirms Raghavan's (2007) assertion that, chilli peppers provide heat and background note to other spices and flavourings apart from enhancing the flavour and aroma of dishes. Toh et al., (2019); Inegbenebor et al. (2014) earlier reported that grains of paradise is a popular spice used in most West African dishes such as the popular 'pepper soup' prepared by both Nigerians and Ghanaians due to its unique pungent taste it imparts.

As ingredients in the confectionery industry

Respondents also revealed that ginger is also used in making candies, popularly known in Ghana as 'amuduro' or 'ginger toffee'. The findings from the respondents are similar to that of Kaushal et al. (2017) that, ginger is useful in cookies, candies among many others. Furthermore, ginger is used in making cakes (gingerbread) and biscuits (ginger snaps) among several others according to Raghavan (2007).

Health purposes

Majority of the participants' revealed that spices, apart from their culinary benefits, also have a myriad of health benefits. Thus, this section presents the purposes of which consumers purchase spices from the sellers' point of view, pertaining to health.

Effects on the circulatory system

Among the participants that were interviewed, about 50% of them agreed to the fact that, ginger has the potential to inhibit or help in the management of cardiovascular diseases (CVDs). Some of the respondents also pointed out that, garlic and ginger are blood thinners hence ensures proper blood circulation in the human system, helping to prevent or inhibit and blockages in blood vessels. Raghavan (2007) affirms the above with the assertion that, garlic and ginger stimulate blood flow and hence enhance blood circulation in the body. Balesasirekha (2014) explains that, garlic is able to perform the above functions due to its rich content of thiosulfites.

Effects on the respiratory system

A portion of the respondents were also of the view that, ginger and garlic are effective in the treatment of asthmatic symptoms such as cough and other flu symptoms such as runny nose etc. It was further indicated that, the spices are efficient in discharging phlegm from the human system. Raghavan (2007) and Kunnumakkara (2009) affirmed the findings of this study that ginger and garlic are effective phlegm dischargers and help with respiratory disorders and asthmatic conditions, whereas garlic was used by the Greeks to treat coughs and colds.

Effects on the reproductive system

The sellers also brought to light that, garlic is also used in the treatment of candidiasis or what is popularly known as 'white' in women. Thus, a clean thread is attached to one end of a clove of garlic and inserted into the vagina overnight according to the sellers' report. Fesseha et al. (2019) reported of the anti-fungal properties of *Allium sativum* against *Candida albicans* as allicin in garlic has exhibited strong inhibition against *albicans* due to the enhancement of AmB (Amphotericin B-a fungizone). It was further reported by the respondents that, ginger also controls itching, and other related symptoms of candidiasis. A little ginger that is crushed and the juice applied at the vulva with a piece of cotton wool also helps with the same ailment. Bhatt et al. (2013) affirmed this by saying that, ginger possess anti-microbial and anti-fungal properties which make it effective against *Candida*.

Again, respondents were of the view that, Negro pepper can treat candidiasis when it is used in combination with cloves. The two are soaked in water and orally administered for the treatment of candidiasis and it related symptoms. Others reported that, grains of paradise can be soaked in water together with other spices such as cloves and negro pepper to treat vaginal itching and its related symptoms. Raghavan (2007) made an assertion that, cloves and negro pepper possess anti-fungal and anti-bacterial properties, thus could explain why it helps to reduce itching in the vagina and clear vaginal discharges, whereas negro pepper is effective in treating candidiasis due to its anti-microbial properties. A seller revealed that, African nutmeg is an effective treatment for male impotency when added to some traditional medicine and

used for enema. A study by Akise et al. (2020) assert that the spice is used traditionally to enhance sexual weakness in men.

Effects on joints and bone inflammations

Respondents expressed that, grains of paradise are ground into paste and applied tropically, either alone or in combination with other traditional medicine to treat bone fractures and dislocations. This supports an earlier assertion by Raghavan (2007) that, grains of paradise are used in by the Chinese to treat all manner of ailments including joint pains. Ikrang and Anyanwu (2019) added that, negro pepper is effective in the management and treatment of diverse illnesses including rheumatism due to its anti-oxidizing properties.

Preservative purposes

Data from the respondents revealed that, cloves, aniseed, bay leaf rosemary and negro pepper are often used in the preservation of meat, especially beef. The sellers indicated that, most of their colleagues who sell salted beef in the market mostly purchase these spices together with salt to preserve the beef, which can stay for months without deterioration. Parathasaranthy et al., (2008) and Raghavan (2007) assert that, rosemary and negro pepper have active compounds which are able to inhibit the factors that cause food spoilage, hence their usage since antiquity in the preservation of food.

Spiritual purposes

A significant number of the respondents were of the view that garlic also has some spiritual benefits. They indicated that, when garlic is used in the house, it protects the occupants of a household from spiritual attacks that are

perpetuated by evil spirits. Worku and Mehari (2018) assert that, garlic has been used since antiquity in folklore to drive away evil spirits.

In summary, findings from the study as recorded from the perspective of the respondents (sellers) indicated that, there are about twenty-five different common spices that are available for sale at the two selected markets used for the study. It was further revealed that, out of the 25 spices, thirteen of them fell within the most frequently purchased spices of which chilli pepper constituted the most patronized spice, followed closely by garlic and ginger, and then rosemary and aniseed. Again, respondents indicated that the purposes of the spices were enormous varying from culinary, health, spiritual to preservative which constituted the themes for discussion. Among the culinary purposes, notable ones discussed included the use of spices as seasonings and flavouring agents and as ingredients in the confectionery industry.

Regarding the health purposes, three main purposes that were identified were the positive effects spices have on the circulatory system, the reproductive system as well as on the joints and bones helping to alleviate inflammations. With respect to the preservative purposes, respondents revealed that some spices possess anti-oxidative and anti-microbial properties which help to preserve food together with salt or vinegar. Finally, on the spiritual purposes, some spices such as garlic is believed to protect people from evil spirits.

Further observations made from the study indicated people generally have limited knowledge when it comes to the uses of spices. Though efforts were made on the culinary purposes of spices, it was still limited comparing it to what literature has indicated. Again, extremely little efforts were made on

the other purposes of the spices in question, and this shows how limited the knowledge of the respondents was on the health, spiritual, and preservative purposes of the spices.

Buyers

This section presents the discussion of the data obtained from the second group of respondents (buyers of spices) in the two selected markets. Issues of concern that sought the opinion and views of the respondents were the kinds of spices that were available for sale at the two selected markets, those spices they were frequently bought as well as the purposes of buying these spices. Thus, Table 6 presents these views and opinions of the buyers from the two selected markets using interview.

Table 6: Responses obtained from buyers of spices from the two selected markets

Question	Response
Q1. What natural spices do you find available for sale at the market?	AB1: *"I find pepper, rosemary, ginger, garlic, aniseed, grains of paradise, cloves, and negro pepper."* AB2: *"At the market I find coriander, white pepper, negro pepper, aniseed, pepper, tumeric and cinnamon."* AB3: *I always get to see ginger, garlic, rosemary, aniseed, and white pepper, African nutmeg, grains of paradise."* AB4*: "I see a lot of spices but the ones I can mention include garlic, ginger, cloves, pepper, rosemary and aniseed."*

AB5*: "I can mention bay leaf, cloves, negro pepper, parsley, nutmeg, tumeric, cinnamon, African black pepper and basil."*

AB6*: "I get to see pepper, African nutmeg, rosemary, cloves, negro pepper and grains of paradise."*

AB7: *"I always find ginger, garlic*, basil, *rosemary, cloves, negro pepper, pepper, aniseed and African black pepper."*

AB8: *"When I go to the market I get ginger, pepper, bay leaf, rosemary, aniseed, garlic, ginger, African nutmeg, African black pepper, star anise and nutmeg to buy."*

AB9: *"When I go to the market, ginger, rosemary, aniseed, negro pepper, cloves, and African nutmeg are the ones I find".*

AB10: *"I always get garlic, ginger, rosemary, cloves, grains of paradise, nutmeg and negro pepper".*

AB11*: "I find pepper, rosemary, garlic, ginger, aniseed, grains of paradise, cloves, and negro pepper."*

AB12: *"At the market I find fennel seeds, fenugreek, coriander, white pepper, negro pepper, aniseed, pepper, tumeric and cinnamon."*

KB1: *"I find pepper, ginger, garlic, rosemary, fenugreek, aniseed, grains of paradise, cloves, and negro pepper."*

KB2: *"At the market I find coriander, white pepper, negro pepper, aniseed, pepper, tumeric and cinnamon."*

KB3: *"I always get to see fennel seeds, ginger, garlic, rosemary, aniseed, bay leaf, and white pepper."*

KB4: *"I often see garlic, ginger, basil, cloves, pepper, rosemary and aniseed."*

KB5: *"I see bay leaf, mint, ginger, garlic, parsley, nutmeg, tumeric, cinnamon and basil."*

KB6: *"I get to see pepper, ginger, garlic, rosemary, cloves, bay leaf, negro pepper and grains of paradise."*

KB7: *"I always find ginger, garlic, rosemary, coriander, cloves, negro pepper, pepper, aniseed and African black pepper."*

KB8: *"When I go to the market ginger, pepper, nutmeg, bay leaf, rosemary, aniseed, star anise and nutmeg are the spices I get to buy."*

KB9: *"When I go to the market, I get ginger, pepper, rosemary, aniseed, negro pepper, parsley, bay leaf, cloves, and African nutmeg".*

KB10: *"I always get coriander, garlic, ginger, rosemary, cloves, grains of paradise, and negro pepper".*

KB11: *"I mostly find ginger, garlic, bay leaf, white pepper, cloves, negro pepper, African nutmeg, nutmeg,*

	pepper, and rosemary."
	KB12: *"I get to see pepper, ginger, garlic, rosemary, aniseed, bay leaf, African nutmeg and African black pepper."*
Q2. Which of the spices do you mostly buy?	AB1*: "I often buy pepper, ginger, garlic, cloves, rosemary and aniseed."*
	AB2*: "Pepper, rosemary, aniseed, ginger, garlic, cloves and negro pepper are the spices I always buy*."
	AB3: *"Pepper, ginger, garlic, cloves, negro pepper, aniseed and grains of paradise are the ones I mostly buy."*
	AB4: *"I mostly buy garlic, pepper, African nutmeg, bay leaf, rosemary, and white pepper."*
	AB5: *"Ginger, garlic, pepper, rosemary, cloves, white pepper, grains of paradise and African nutmeg are the spices I mostly buy."*
	AB6: *"I mostly buy garlic, pepper, ginger, bay leaf, star anise, cloves, white pepper and rosemary*."
	AB7: *"I often buy ginger, pepper, garlic, grains of paradise, star anise, African nutmeg and cloves."*
	AB8: *"I often buy ginger, garlic, African black pepper, negro pepper, and cloves."*
	AB9: *"Basically, I buy ginger, pepper, garlic, negro pepper, white pepper, and cloves."*
	AB10: *"I often buy ginger, pepper, cloves, negro*

pepper, African nutmeg, African black pepper, and bay leaf."

AB11: *"Pepper, ginger, garlic, rosemary, African black pepper, bay leaf and grains of paradise are the ones I mostly buy."*

AB12: *"Ginger, garlic, rosemary, cloves, white pepper, grains of paradise and African nutmeg are the spices I mostly buy."*

KB1: *"I often buy rosemary, pepper, ginger, garlic, and aniseed."*

KB2: *"Most of the time I buy ginger, pepper, African nutmeg, cloves, and negro pepper."*

KB3: *"Basically, I mostly buy pepper, ginger, garlic, bay leaf, and white pepper."*

KB4: *I only like to buy ginger, pepper, African nutmeg, and garlic most of the time."*

KB5: *"I always prefer to buy pepper, ginger, cloves, negro pepper, and garlic."*

KB6: *"Most of the time I buy pepper, grains of paradise, African nutmeg, ginger and African black pepper."*

KB7: *"I often purchase pepper, ginger, garlic, African nutmeg, rosemary and aniseed."*

KB8: *"I love to buy pepper, ginger, garlic, aniseed, rosemary, cloves and negro pepper all the time."*

KB9: *"I always prefer to buy pepper, ginger, cloves, negro pepper, pepper, star anise and garlic."*

KB10: *"Most of the time, I prefer to buy pepper, ginger, cloves, negro pepper, aniseed, rosemary and garlic."*

KB11: *"I often buy pepper, rosemary, aniseed, ginger and garlic."*

KB12: *"I prefer to buy ginger, pepper, aniseed, rosemary, garlic and African nutmeg all the time."*

Q3. For what purpose do you purchase the spices you mentioned above?	AB1: *"I know that in the olden days, new mothers make paste out of cloves and smear on their body to remove the smell of breast milk and it was like perfume on them."*
	AB2: *"When I get constipated, I crush ginger and brew it in warm water and drink, I'm able to free my bowels easily. Cloves and /or negro pepper can be soaked in water and the water drunk daily to boost immunity, detoxify the body too."*
	AB3: *"Sometimes when I get nauseous or feel bloated after eating something, I only make 'ginger water' and drink or chew or piece of ginger, and I become fine after a while."*
	AB4: *"I know that when babies become feverish, garlic is made into paste and added to shea butter and smeared all over their body for relief. I know that*

'hausa kooko' gets its taste and aroma from spices."

AB5: *"Sometimes when I get stomach aches, I grind some herbs together with a piece of ginger or dried pepper and use for enema, and I become fine. When I feel bloated too, I brew crushed ginger in water and drink and I become fine."*

AB6: "I have personally heard that, cloves can be soaked in water and the water used to wash the hair. It helps with dandruff and hair breakages. Ginger, pepper, cloves and negro pepper also flavors many local drinks such as 'sobolo".

AB7: *"I know that African nutmegs can be roasted and made into paste and put on boils to treat them. Negro pepper also treats boils when ground into paste and put on it."*

AB8: *"I know that long term sinus problems can be treated with grains of paradise together with other herbs. The herbs are ground with one or two seeds of the spice and with the help of a cotton wool, a drop of the juice is dispensed into the nostrils."*

AB9: *"I have heard that, African nutmeg is used together with some other traditional medicine to help men who have fertility issues."*

AB10: *"I also know that, ginger can be chewed alone or together sugar to treat cough and sore throat.*

Ginger, garlic, grains of paradise are also good for relieving painful joints."

AB11: *"Personally, when any of my children get measles, I soak cloves and negro pepper in 'akpeteshie' or water and give to them morning and evening. On the third day they become fine."*

AB12: *"I have also read online that rosemary or cloves can be soaked and the water used to wash natural hair to make the hair soft and stop breakage and treat dandruff."*

KB1: *"For me I know that, garlic is known to repel bad spirits so I really like using it in all my savoury dishes. I sometimes even put a clove under my pillow to sleep."*

KB2: *"Personally when I get catarrh and cold with blocked nostrils, I chew either garlic or ginger and I get so much relief because I'm able to discharge so much phlegm. We managed my mum's high bp with negro pepper and 'prekese' boiled together."*

KB3: *"I use ginger, garlic, rosemary and aniseed to flavour my stews, soups and gravy. I also heard that you can pray over two or three bay leaves on which prayer points have been written. Burn them afterwards for breakthroughs."*

KB4: *"I buy dried pepper, ginger, cloves and negro pepper for my 'sobolo' is sell every day. These spices*

make it nice to taste."

KB5: *"When I am coughing I buy negro pepper or cloves and chew and I get relief from the cough. Women also manage menstrual cramps with ginger or cloves which have been brewed in warm water and drunk. This mixture also helps with weight management and flat tummy."*

KB6: *"As for pepper, I use it for all my dishes including porridges, stews, soups, and even drinks such as 'sobolo' and 'zonkom'."*

KB7: *"I know that, when a woman suffers from white, she can soak cloves and/or negro pepper and drink the water morning and evening as well as use the water to wash the private part for like a week and she will be free."*

KB8: *"I also know that garlic helps us to fight bad spirits from our homes and also treats asthmatic conditions when added to some herbs. It also helps to fight feverishness in babies when made into paste and smeared on them."*

KB9: *"I know that a piece of dried pepper or ginger and sometimes garlic is added to some traditional herbs for enema to enhance their effectiveness in treating various ailments including waist pains."*

KB10: *"Someone also told me that, when you get a cut*

	or a bruise from a rusted metallic object you can put crushed ginger on it kill the poison in it that may lead to tetanus. African nutmeg also treats post-partum wounds of new mothers."
	KB11: *"I also use ginger and garlic in my cooking a lot because I heard they are good as they help to cause your blood move freely in your system. They are also good in treating painful joints."*
	KB12: *"I buy these spices for my mother who sells salted beef. She uses rosemary, cloves, negro pepper and sometimes bay leaf together with salt to preserve the raw beef. They help to prevent spoilage."*

Source: Mensah, 2023

Common Spices Available on Cape Coast markets (Kotokoraba and Abura)

From Table 6, twenty-one different spices were identified by the respondents to be the spices they found available for sale at the markets. The spices that were identified by the buyers were chilli pepper, star anise, rosemary, aniseed, coriander, fennel seeds, fenugreek, cloves and bay leaf. Others that were mentioned by the respondents were ginger, garlic, negro pepper, grains of paradise, African black pepper, African nutmeg, basil, white pepper, cinnamon, turmeric, nutmeg and parsley. These were the ones that were mentioned by the buyers to be what they always find and therefore get to buy because they are available.

However, unlike that of the sellers, four spices including thyme, cumin, sage and mint were not found in the list by the buyers possibly because consumers were either not familiar with them or did not know their names even though they could be available for sale. Again, spices such as fenugreek, tumeric, fennel seeds, cinnamon, coriander, white pepper and basil were mentioned by few respondents in their responses. It can be deduced that, those spices which were mentioned by most respondents are the spices which are mostly grown locally and therefore they are familiar with them, and those that respondents are not so familiar with are mostly imported into the country and hence the fewer mentions of those spices.

Again, information gathered from the respondents (buyers) pointed out a number of spices that they mostly purchase. From Table 6, about thirteen different spices were also identified by respondents to be the most frequently purchased spices out of the twenty-one which were initially mentioned to be available for sale at the two selected markets. It was further observed that those spices mostly purchased were chilli pepper, garlic, ginger, cloves, negro pepper, aniseed, rosemary, African nutmeg and bay leaf. The others were grains of paradise, African black pepper, white pepper and star anise. Just as it was recorded from the first group of respondents (sellers), chilli pepper once again topped the list of the most frequently purchased spices from the two markets. This is because almost all of the buyers mentioned chilli pepper in their list of frequently bought spices. However, unlike ginger and garlic which followed closely from the point of view of the sellers, rosemary and aniseed were found to be next in line after chilli pepper from the buyers' perspective.

White pepper, African black pepper and star anise were mentioned by only a few of the buyers though they appeared among the frequently bought spices.

From Kumasi Metropolis, Nkansah and Opoku Amoako (2010) also reported that, aniseed, rosemary, bay leaf, garlic, ginger, galbanum(prekese), chilli pepper, white pepper, West African locust bean, curry powder, African / calabash nutmeg, cinnamon, nutmeg, black pepper, and negro pepper were the commonly consumed spices from the metropolis. Their study also shared some similarities with this present study in terms of the spices that were sampled for investigation. These spices included ginger, garlic, African nutmeg, aniseed, rosemary, bay leaf, negro pepper and chilli pepper. White pepper, African black pepper together star anise though were identified amongst the commonly consumed spices in Cape Coast, did not fall in the first ten when the researcher ranked the spices based on the responses from both sellers and buyers, hence they were not included for analysis.

Purposes of Using Spices

This section explores the views and opinions of respondents concerning the purposes for using spices. From the buyers' point of view, various concerns were raised which have been discussed under the following themes as culinary, health, preservative and spiritual purposes.

Culinary purposes

As a seasoning and flavouring agent

Information gathered from the respondents indicated that, ginger, garlic, clove, aniseed, rosemary, bay leaf and African nutmeg are ideal seasonings when it comes to meat and fish cookery. It was also indicated from the responses that, the above mentioned spices are indispensable to the flavour and aroma of dishes such stews, gravies, soups, sauces (for example, 'shito'). A section of the respondents also added that, ginger, clove, negro pepper, African nutmeg and sometimes chilli peppers are used as flavourings in local drinks such as 'lamugene', 'zonkom' and 'sobolo'. The buyers were also of the view that, chilli pepper is the mother of all spices and hence without it dishes are not complete no matter how palatable and appetizing they look, unless the spice needs to be omitted completely from meals due to health reasons. Thus, chilli pepper complements the flavour of all other spices used in the preparation of dishes, be it stew, soup, gravy or sauce.

It was further revealed that, the distinctive flavour and aroma of millet porridge, popularly known as 'hausa kooko', in Ghana is attributed to negro pepper, ginger, cloves, African nutmeg, chilli pepper which are the chief spices used in the preparation of the breakfast porridge. Many writers have concluded that the above spices impart flavour and aroma to various dishes {Saleh et al., (2018); Raghavan (2007); Bhatt et al., (2013); Ikrang and Anyanwu,(2013)}.

Use as ingredients in confectionery products

Some respondents were of the view that, ginger is also useful in the confectionery industry, hence is used in flavouring products such as cakes

(ginger bread), biscuits (ginger snaps), and candies. Clove and African nutmeg are also added to cakes to enhance flavour and aroma. According to Enabulele et al. (2014) and Kunumakkara (2009) agree to the above saying that, African nutmeg is used in place of nutmeg to flavour cakes and cloves used in the manufacture of artificial vanilla. A particular mention was made of the popular 'ginger toffee' in Ghana.

Health purposes

Effects on the circulatory system

Data from the respondents pointed out that, the consumption of ginger and garlic is helpful in the management of heart diseases and hypertension. Jiang (2019) assert that, human studies have proven that garlic consumption is able to slow the development of atherosclerosis that may subsequently lead to heart attacks and stroke, by reducing fatty streak formation in blood vessels. Bhatt et al. (2013) reported that, ginger has also shown significant performance in the inhibition of ACE (Angiotensin I converting enzyme- an enzyme that catalyzes the constriction of blood vessels and hence blood pressure regulation) in many research studies which is an indication of potential anti-hypertensive activity.

Another respondent, was also of the view that, negro pepper can be effective in combating high blood pressure especially when combined with aridan fruits ('prekese') and boiled, and then administered orally. Adeoye et al., (2021) report that, xylopic and kaurenoic acids isolated form the hexane extracts of *Xylopia aethiopica* in vitro studies significantly decreased systolic blood pressure as these compounds are Ca channel blockers. This ensures that

Ca^{2+} increases whiles $Cl^{-}$and Na^{+} accumulation is prevented in blood serum, and consequently decreases blood pressure.

A section of the respondents was also of the view that, the consumption of garlic and ginger also help to ensure proper blood circulation as garlic is known to be a blood thinner. Tesfaye (2021) affirms that garlic has got anti-platelet effects due to its ability to inhibit platelet aggregation by reducing COX activity and thromboxane A2 production and thus ensuring that, there are no clots in the blood hence free flow of blood in the human system. Bhatt et al. (2013) also report that studies have shown that ginger has circulatory system stimulating qualities due to its natural blood thinning properties and anti-thrombotic effects, ability to lower blood cholesterol levels, cleanse and stimulate blood supply, prevents internal blood clots among many others.

Effects on respiratory system

Data collected from the respondents revealed that, ginger and garlic are effective phlegm dischargers. Raghavan (2007) claim that both spices have active biological chemical compounds that make them effective phlegm dischargers helping to free the human airways. Respondents further claimed that ginger, garlic and negro pepper help in relieving cough by chewing on them or using them in formula. Bhatt et al. (2013) claims that, ginger is a cough suppressant as it increases human bronchial smooth muscle cell migration and proliferation and reverses phthalate ester-mediated airway remodeling. Ogbonna et al. (2013); Ikrang and Anyanwu (2019) also claim that, negro pepper has expectorant qualities that helps with cough, flu, cold and feverishness.

Information gathered from the respondents further revealed that ginger and garlic help with asthmatic disorders. Kaushal et al (2017) made claims that, ginger is effective in treating respiratory disorders due to its rich phenolic compounds content. Bhatt et al., (2013) claim that, gingerol, and shogaols have demonstrated effectiveness in suppressing phthalate ester-mediated airway remodeling indicating that ginger is capable of preventing phthalate ester-associated asthma. It was also recorded from data collected from the respondents that, grains of paradise is a nasal decongestant. In other words, it is effective in the treatment of acute sinusitis, when added to other traditional herbs or medicine. Toh et al. (2019) report that bioactive compounds in *A. melegueta* make the spice an ideal natural decongestant in easing catarrh and congestion. Osutokun (2020) add that, the spice being a rich source of tannins is ideal in treating and soothing inflamed mucous membrane.

Effects on the reproductive system

Some respondents were also of the view that, ginger, garlic and clove can be used as a treatment for candidiasis and vaginal itching and the associated complications. Tesfaye (2021) claim that, garlic has both bactericidal and fungicidal properties making it an effective antibiotic, hence it is able to inhibit microbes that cause vaginitis, bacterial vaginosis and discomfort. Shabanian et al., (2017) reported that, chief active compounds in ginger such as terpenoids exhibited high inhibitory activity on *Candida albicans*, the organism responsible for candidiasis, by stopping various phases of cell division of the microorganism. Pulikotti and Nath (2015) further report of the anti-fungal activity of clove against *C. albicans* because of its fungicidal properties which are attributed to its bioactive compounds such as carvacrol

and eugenol. In controlling vaginal itching, clove is soaked in water and taken orally or used in washing the vulva regularly.

Ginger or clove can also relieve women of menstrual cramps when it is brewed in warm water and taken orally. Bhatt et al. (2013) claim that ginger helps to ease menstrual pain when taken orally, that is if the pain is due to ischemic cramp, that is lack of uterine blood supply. A respondent brought to light that, African nutmeg is also effective in treating the postpartum-placental-wounds of new mothers. Agiriga and Siwela (2017); Adewole et al. (2013) claim that, the spice is effective in controlling passive uterine haemorrhage immediately after child birth and aids in quick recovery.

Effects on the gastrointestinal system

Data from the respondents indicated that garlic and ginger are effective in treating sore throat. Bhatt et al. (2013) report that, ginger is used in treating throat infections and sore throat due to its anti-microbial properties which are attributed to its active compounds such as gingerol and shogaol which makes it an effective expectorant. A respondent was of the view that, ginger is effective in the treatment of ulcers. Bhatt et al., (2013) further reported that, gingerol and its extractives present in ginger have effective inhibitory effects on *Helicobacter pylori*, the organism which is associated with peptic ulcer.

Additionally, respondents opined that, ginger can ease constipation, bloating and helps in relieving the feeling of nausea when it is crushed and brewed in warm water and orally administered early in the morning. Zadeh and Kor (2014) reported that, ginger powder of 250mg was able to relieve pregnant women of the feeling of nausea and associated symptoms of vomiting when it was administered four times over four days. They added that,

the bioactive compounds in ginger helps in easing constipation by increasing the muscular activity of the digestive tract. Bhatt et al. claim (2013) that ginger acts as a purgative that's helps to ease constipation. They further claimed that, ginger is a carminative agent that helps to get rid of intestinal gases, and hence eliminates bloating. Finally, it was brought to light that, ginger and dried chillis can be added to other traditional herbs or medicine in the cleansing of the colon when used for enema, as they enhance the therapeutic effects of those selected herbs on the colon. Raghavan (2007) and Bhatt et al. (2013) claim that ginger is an effective colon cleanser.

Weight management effects

It was noted from the responses that garlic, ginger and bay leaf, clove and negro pepper have weight management abilities. Thus, they could be brewed in warm water or made into herbal teas and administered orally to manage an individual's weight. Jiang (2019) reported that ginger has thermoregulatory activity and fat oxidation properties. Bhatt et al. (2013) claim that, an active component of ginger known as zingerone prevents fats storage in rats in vitro studies by increasing fat burning and reducing fat absorption from the small intestines, hence the ability of ginger to act as a fat and cellulite burner. Shang et al. (2014) reported that, research studies have proven that garlic and its extracts have demonstrated positive effects on obesity by limiting lipogenesis and regulating the metabolism of lipids, hence the ability of garlic to control weight gain. Jung, Ahn, Jeon, Kim and Ha (2012) also reported that, clove extract supplements provided solid evidence that clove is able to exert an anti-obesity effects by regulating the genes

related to lipid metabolism in a manner that resulted in the reduction of lipid accumulation in tissues in vitro studies.

Analgesic and anti-inflammatory effects on the muscular-skeletal system

Respondents opined that, ginger, negro pepper, clove, grains of paradise and garlic are also used in treating bone fractures and dislocations, waist pains, rheumatism and arthritis in traditional medicine due to their inflammatory properties, together with other herbs. They added that, these spices could also be crushed or ground into paste and applied tropically for the above-mentioned purposes. Others suggested, that they could be crushed and added to herbal roots and made into bitters. Jiang (2019) reported that, in vitro studies have demonstrated that, garlic and its sulphur-containing compounds have anti-inflammatory characteristics that inhibit NF-$_K$B (NF-kappaB) activation, iNOS, and COX-2 expression. Thus, it was observed that, garlic supplements significantly improved pain, stiffness, and general function in animal studies.

Jiang (2019) further reported that, *in vitro* studies and human trials have also proven, that ginger is able to reduce cartilage destruction, joint swelling and serum levels of inflammatory cytokines associated with rheumatoid arthritis, joint and muscle pain. Bhatt et al. (2013) support the above by saying that, ginger exhibits such inflammatory properties due to its ability to inhibit the expression of COX-1 and COX-2 as well as leukotriene biosynthesis. Raghavan (2007) further reported that, *A. melegueta and X. aethiopica* are known pain relievers. Toh et al. (2019) buttressed this claim reporting that, the ethanolic extracts of *A. melegueta* has exerted significant pain relief in painful arthritis when it was used in massage oils, and this

activity is attributed to the presence of bioactive compounds such as 6-paradol and 6-shogaol, which are able to inhibit the expression of COX-2 and IL-1β, a pro-inflammatory gene. Clove and African nutmeg also help in relieving general body pains. Cortes-Rojas et al. (2015) reported that, the analgesic effect of clove has been attributed to its eugenol content through the activation of Ca and Cl channels in gangliomar cells.

Effects on blood sugar

Some other respondents were also of the view that garlic and ginger are effective in the management of diabetes. Respondents added that, diabetics are able to control their blood sugar and manage their condition with the consumption of garlic and ginger in their diet. Jiang (2019) reported that, human trials have proven that treatment with time-released garlic product (Allicor) demonstrated significant metabolic control by lowering fasting blood glucose and triglyceride levels. Thus current data has also confirmed a positive and sustained role of garlic in blood glucose and favourable lipoprotein regulation in T2DM (type 2 diabetes mellitus). Bhatt et al. (2013) reported that, ginger exhibits both hypoglycemic and anti-oxidative properties, hence its usefulness as an anti-diabetic agent. They buttress that, ginger may assist in the prevention or progression of T2DM by enhancing insulin sensitivity and decreasing serum glucose, cholesterol and triglycerides levels as were observed in vitro studies.

System detoxification, immune boosting and infections fighting effects

A section of the respondents opined that, garlic, ginger and negro pepper when crushed and brewed in warm water and administered orally, is an effective detoxifier or cleanser of the human system and also an immune

booster. Furthermore, some respondents were also of the opinion that ginger helps to prevent tetanus caused by rusted metals on human and also effective in the treatment of piles. Garlic and ginger also helps to fight infections. Shang et al. (2019) reported that, garlic exerts immunomodulatory effects as it possesses bioactive compounds that enhance the activity of the immune system. Bhatt et al. (2013) further reported that, ginger's bioactive compounds such as gingerol, gingerone, shogaol and paradol confer on it some immunomodulatory functions, hence enhancing the body's immunity via their anti-microbial and free radical scavenging properties.

Some of the respondents also added that, clove helps to fight certain diseases such as cancer and also good for boosting the immune system, and also acts as detoxifier. Pulikkotil and Nath (2015) reported that, clove essential oils, extracts and their derivatives have shown anti-carcinogenic and anti-mutagenic potential as well as cytotoxic action towards human tumour cell lines. Thus, they could inhibit, delay, block or reverse the initiation of and promotional events associated with carcinogenesis. Bhowmik et al. (2012) further opined that, the bioactive compounds present in clove make it an ideal immune system booster by purifying the blood and help to fight against varying number of ailments due to its anti-septic properties.

It was said, that negro pepper helps in infections such as mumps, and chest infections and urinary tract infections. Usman et al., (2015) reported that the phytochemical screening from their study indicated that negro pepper and four other spices showed that the presence of phenolic compounds such as tannins, saponins, flavonoids, steroids and alkaloids demonstrated significant inhibition of *E. coli* and hence could be defined as an anti-biotic to cure

various diseases caused by *E. coli* such as UTIs. Ebuete et al., (2022) reported that negro pepper has been used by the Ivoirians for the treatment of chest pains for many years due to its anti-microbial and analgesic properties.

Dermatological effects

According to the respondents, clove, when soaked in water together with negro pepper and orally administered is effective in the treatment of measles. Other respondents also were of the view that, clove has dermatological properties, hence in times past when perfumes were not so much available, new mothers would grind cloves into paste and apply tropically for smooth skin and to serve as a perfume which helps to remove the nauseating odour associated with excess breast milk production and sweat. It was further indicated that, negro pepper and African nutmeg are also effective in treating boils. The spice is crushed and ground into paste and applied on the boils to treat them. Ebuete et al., (2022**)** reported that negro pepper is also effective in the treatment of skin boils when tropically applied on the skin.

Some of the buyers also revealed that, when clove and rosemary are soaked in water and used to massage the scalp, it helps in hair treatment, especially in controlling dandruff and hair breakage or loss. Malvezzi de Macedo et al. (2020) reported that rosemary oil showed significant growth in hair by inhibiting alopecia (a condition that is characterized by loss of some or all hair) via 5αR enzyme activity which showed strong inhibition of the binding of dihydrotestosterone (DAT) to its receptor. Research has shown that excess testosterone in the blood capillaries is significantly associated with hair loss. Shahtalebi et al., (2016) reported that clove oil in vitro studies

demonstrated its effectiveness in promoting hair growth and inhibiting alopecia.

Febrifugal effects

Respondents also added that, traditionally, garlic thought to help bring relief to infants from feverishness together with shea butter. The two are mixed into a paste and applied tropically on the infants for relief. Kunnumakkara et al., (2009) reported that garlic has been used as an anti-pyretic by 'Unami' physicians to treat varying number of ailments including fevers.

Spiritual purposes

A respondent also opined that, bay leaf has got some spiritual purposes. It was explained that, people who wish to have breakthroughs in life could write their prayer points on the leaves, pray over them and burn them afterwards, they eventually begin to experience some super-natural breakthroughs in their lives. Batool et al., (2020) reported that, bay leaf is believed to aid in wishes of its users coming through for them due to the possession of protective powers and hence prevents misfortunes from coming upon its users.

A good number of the respondents were of the opinion that garlic is capable of driving away evil spirits from people who use the spice. Hence any household or individual who often uses garlic in one way or the other does not experience frequent spiritual attacks. Raghavan (2007); Worku and Mehari (2018) claimed that, garlic is used in folklore to drive away evil spirit. It is further asserted that, a clove of garlic that is put under the pillow of a child whiles sleeping is believed to protect the child from evil.

Preservative purposes

Respondents were of the view that, cloves, negro pepper, bay leaf, rosemary, aniseed are able to inhibit microbes which are responsible for food spoilage, especially in meat. Many writers such as Raghavan (2007); Ogbonna et al., (2013); Ikrang and Anyanwu (2019); Agiriga and Siwela (2017) have claimed that, the anti-microbial (anti-fungal, anti-bacterial) and anti-oxidant characteristics of spices make them agents for preservation as they are able to inhibit the growth of micro-organisms and oxidative rancidity that cause food spoilage.

In summary, twenty-one different spices were identified to be available for sale at the two selected markets according to the respondents (buyers). Out of these twenty-one spices, thirteen of them were noted to be the most frequently purchased ones with chilli pepper topping the list, followed by rosemary and aniseed. Again, pertaining to the purposes of spices, respondents revealed that spices are used for culinary, health, preservative and spiritual purposes. Respondents further pointed out that the culinary purposes include use of spices as seasoning and flavouring agents and their use as ingredients in confectionery products. Regarding the health benefits of spices, respondents revealed that, spices have effects on the circulatory system, respiratory system, the reproductive system and the gastrointestinal system. Other health effects of spices that were mentioned included weight management effects, analgesic and anti-inflammatory effects on the muscular-skeletal system, blood sugar management, dermatological effects as well as febrifugal effects. With regards to the spiritual purposes, respondents revealed that some spices such as garlic and bay leaf have spiritual benefits for their users. And finally, on preservative

purposes, it was revealed that spices have the potential to prolong the shelf life of food due to the anti-oxidant and anti-microbial properties they possess.

Heavy Metal Concentrations in Spices

Heavy metal presence in nature and in food of both humans and animals within the permissible limits stipulated by national and international accredited bodies is acceptable. However, an increased concentration of heavy metals in the human body beyond the permissible threshold may pose undesirable consequences on the health of people due to their bio-accumulative nature and the inability of the human body to easily excrete them. Significant differences were shown in between the heavy metal concentrations studied herein in comparison to the permissible limits outlined by World Health Organization for food additives. Table 7 shows the permissible limits for heavy metals in spices according to WHO (2007) as reported by Oladoye and Jegede (2016); Olusakin and Olaoluwa (2016).

Table 7: Maximum permissible limits of heavy metals in food additives by WHO (2007) estimated in mg/kg

Heavy metal	Maximum Permissible Limit(MPL)
Lead (Pb)	10
Copper (Cu)	50
Cadmium (Cd)	0.3

Source: Oladoye and Jegede (2016); Olusakin and Olaoluwa (2016)

A total of 60 commonly consumed spice samples available in Abura and Kotokoraba Markets in the Cape Coast Metropolis were analyzed for lead, copper and cadmium. The values are expressed as mean and standard deviation (mean ±SD) of three replicates from independent samples for each spice of the metal concentrations in the Table 8. All the analyzed samples contained detectable levels of lead and copper however cadmium, if present

were below the detection limit. Results indicated total mean concentrations in all samples from both markets in an ascending order of lead>copper>cadmium, with lead recording the highest value of 77.33mg/kg followed by copper with a value of 31.18mg/kg. Thus, total mean concentration of the detected heavy metals (lead and copper) in the analyzed samples from both markets realized highest concentration in ginger and the lowest being recorded in negro pepper with values of 100.18mg/kg and 16.47mg/kg respectively.

Table 8: Heavy Metal Concentrations in spices from Abura and Kotokoraba Markets

Market	Sample	Sample Code	Pb(mg/kg)	Cu(mg/kg)	Cd(mg/kg)	Total
Abura (A)	Ginger	A-GI	72.60±11.80	31.50±5.11	<DL	52.05±8.45
	Garlic	A-G	8.39±4.48	22.59±1.67	**	15.49±3.07
	Rosemary	A-RM	148.76±55.10	33.28±12.69	**	91.01±33.89
	Aniseed	A-AS	156.56±45.01	30.32±24.24	**	93.44±34.62
	Grains of paradise	A-GP	34.63±23.06	27.09±4.44	**	30.85±13.74
	Negro pepper	A-NP	17.52±12.14	13.03±1.51	**	15.27±6.82
	Bay leaf	A-BL	4.50±0.33	21.91±8.94	**	13.20±4.63
	Clove	A-C	131.25±2.59	19.79±7.85	**	75.51±5.22
	African nutmeg	A-AN	9.21±5.78	33.51±8.16	**	21.36±6.97
	Chilli pepper	A-CP	208.04±15.49	17.91±4.21	**	112.97±9.85
Total			**79.15±75.82**	**25.09±10.84**	**	**52.11±43.33**
Kotokoraba(K)	Ginger	K-GI	156.74±14.61	139.92±87.12	**	148.32±50.86
	Garlic	K-G	133.45 ±37.41	29.48±1.90	**	81.46±19.65
	Rosemary	K-RM	11.16 ±4.48	12.44±1.18	**	11.79±2.82
	Aniseed	K-AS	24.19±11.35	32.96±13.36	**	28.57±12.35
	Grains of paradise	K-GP	91.30±8.7	39.33±7.84	**	65.31±8.26
	Negro pepper	K-NP	22.63±13.21	12.72±1.43	**	17.67±7.31
	Bay leaf	K-BL	146.24±9.68	33.03±2.92	**	89.63±6.29
	Clove	K-C	9.16±1.68	16.93±9.72	**	13.04±5.69

Table 8: continued

	African nutmeg	K-AN	129.08±19.97	42.19±8.37	**	85.63±14.16
	Chilli pepper	K-CP	31.05±14.69	13.80±7.61	**	22.42±11.14
Total			**75.51±60.89**	**37.27±43.42**	**	**56.38±52.15**
(A and K)	Ginger	GI	114.66±47.59	85.70±81.07	**	100.18±64.33
	Garlic	G	70.92±72.52	26.03±4.09	**	48.47±38.31
	Rosemary	RM	79.96±83.07	22.86±13.79	**	51.41±48.43
	Aniseed	AS	90.37±78.21	31.64±17.56	**	61.01±47.86
	Grains of paradise	GP	62.96±34.74	33.21±8.79	**	48.08±21.76
	Negro pepper	NP	20.07±11.69	12.87±1.32	**	16.47±6.51
	Bay leaf	BL	75.37±77.88	27.47±8.51	**	51.42±43.2
	Clove	C	70.20±66.89	18.34±8.05	**	44.27±37.47
	African nutmeg	AN	69.14±66.96	37.85±8.78	**	53.50±37.87
	Chilli pepper	CP	119.54±97.87	15.86±5.94	**	67.7±51.905
Total			**77.33±68.21**	**31.18±31.97**	**	**54.24±47.74**

Source: Field data, 2022; **= <DL (Below detection limit)

Lead Concentrations in Spices

Lead is the most recognized toxic environmental pollutant (Dghaim et al., 2015; Oladoye & Jegede, 2016). It is documented that, lead exposures have been reported to be associated with severe anaemia, neurological disorders, diminished intelligence, and reproductive problems, to mention a few. Thus, the ATSDR of the US Public Health Services (US-PHS), has claimed that fruits, vegetables and grains constitute the major food sources of lead exposures to the general public (Nkansah & Opoku Amoako, 2010). However, results from this study have shown relatively significant concentrations of lead in the spices that were sampled and analyzed from the two markets.

From Table 8, analytical results indicated that lead concentrations varied widely among the spices. Mean concentrations ranged from 4.50mg/kg - 208.04mg/kg with Abura bay leaf (A-BL) and Abura chilli pepper (A-CP) recording the lowest and highest mean concentrations respectively. However, it was realized that, total mean concentrations of Pb was recorded at a range between 20.07mg/kg in negro pepper and 119.54mg/kg in chilli pepper. Again, amongst the samples that were analyzed, Abura garlic (A-G), Abura bay leaf (A-BL), Abura African nutmeg (A-AN) and Kotokoraba clove (K-C) with mean concentrations of 8.39mg/kg, 4.50mg/kg, 9.21mg/kg and 9.16 mg/kg representing 20% of the total number of spices analyzed fell below the WHO (2007) MPL of 10mg/kg. The remaining 80% recorded mean concentrations that exceeded the permissible limit which expresses some level of concern to consumers' health.

From the 80% of spice samples which recorded mean concentrations above the MPL, Abura (chilli pepper, aniseed, clove, rosemary) and Kotokoraba (ginger, garlic, bay leaf, African nutmeg) with concentrations of 208.04mg/kg, 156.56mg/kg, 131.25mg/kg, 148.76mg/kg, and 156.74mg/kg, 133.45mg/kg, 146.24mg/kg and 129.08mg/kg were about ten-fold above the permissible limits. Results from the study further indicated that total mean concentration of lead in the samples from the two markets were 79.15mg/kg and 75.51mg/kg for Abura and Kotokoraba respectively. This means that, samples from Abura market contained higher total Pb concentration compared to samples from Kotokoraba market which may be attributed to several factors such as differences in the source or origin of the spice.

Several incidents of high lead concentration in spices have also been reported in literature from other studies. Nkansah and Opoku Amoako (2010) reported of 0.1153g/kg-0.973g/kg of lead concentration which was also above the permissible limits from Kumasi Metropolis in Ghana, with lead content reaching its highest peak in ginger and cinnamon, though the mean concentrations were lower than values reported in this present study. Nordin and Selamat (2013) also reported that, Malaysian spices investigated contained high levels of lead exceeding the permissible limits with a range of 1.54µg/g to 8.94µg/g with highest concentration being found in Vietnamese coriander and the lowest in garlic. Mubeen et al., (2009), also reported of high concentrations of lead in Pakistan spices recording a range of 54-70mg/kg above the permissible limits.

Contrary to the results in this present study, lower concentration below the international standards with a range of 0.007µg/g-0.087µg/g for lead with

maximum concentration being found in chilli powder, were reported by Senanayake et al (2013) in Sri Lankan spices. Though differences exist between the report of Senanayake et al., and this study in terms of lead concentrations, it is important to note that chilli pepper recording highest values for lead in both studies is worthy of mentioning. Oladoye and Jegede (2016) also reported the non-detection of lead in spices that were sampled and analyzed from Odo-Ori in Nigeria probably because levels of lead in the spice samples were below the detection limit. Gaya and Ikechukwu (2016) also reported of low levels of lead within permitted limits in Nigerian spices with a range of 2.7mg/kg to 4.71mg/kg, with the highest concentration being recorded in African nutmeg. Bua et al., (2016) also assessed the level lead in spices found in Italian markets and found a range of 0.16mg/kg to 2.92mg/kg with maximum concentration being found in Vietnamese cinnamon with values falling below the international standards.

Darko et al., (2014) reported that, spices may obtain lead during growth in soils that are contaminated with lead and from the use of lead-base pesticides which are used during the cultivation of the spices. Darko et al.,(2014) attributed the location of the markets from where the spices used for their study were collected and concluded that, the location of the markets in high traffic density sites could be the reason for the increased levels of lead concentrations in the analyzed spice samples as literature asserts and studies have confirmed that high traffic density may increase the lead load in the environment hence increasing the lead content of the spices. This reason, can also be applied to this study as both markets from which the spices were collected are located in the midst of very busy roads with high traffic density

apart from the probable contamination of the spices from the soils from which these spices grew.

Copper Concentrations in Spices

Although copper is an essential trace element that is required for the synthesis of many enzymes, excess levels can be toxic to the human body (Mubeen et al., 2009). Krejpcio et al., (2007) added that, copper is an important trace element as it functions in the oxidative defensive system. However, the presence of copper in the human body beyond certain limits can pose varying number of health problems such anaemia, nervous system disorder, behavioural disorder, liver damage, and increase in an individual's risk of cancer (Fadhil, et al., 2021). Chronic toxicity levels can also cause severe poisoning (Krepcio et al.,), oily skin, loss of skin tone and loss of hair especially in women (Oladoye & Jegede, 2016; Mubeen et al.,).

As revealed by the analytical results in this present study, mean concentrations in the analyzed samples from the two markets varied widely. Findings revealed that a range between 139.92mg/kg to 12.44mg/kg being the highest and lowest concentrations were found in Kotokoraba ginger (K-GI) and rosemary (K-RM) from the same market. However, total mean concentration of copper from both markets was recorded in a range between 87.70mg/kg in ginger and 12.85mg/kg in negro pepper. In comparison with international standards, only Kotokoraba ginger (K-GI) with a mean concentration of 139.92mg/kg representing 5% of total number samples analyzed exceeded the WHO MPL of 50mg/kg for copper.

However, samples such as Kotokoraba African nutmeg (K-AN), Kotokoraba grains of paradise (K-GP), Abura African nutmeg (A-AN), Abura

Rosemary (A-RM), Kotokoraba bay leaf (K-BL), Kotokoraba Aniseed (K-AS), Abura Ginger (A-GI), Abura Aniseed (A-AS), Kotokoraba Garlic (K-G), and Abura grains of paradise (A-GP) with mean concentrations of 42.19mg/kg, 39.33mg/kg, 33.51mg/kg, 33.28mg/kg, 33.03mg/kg, 32.96mg/kg, 31.50mg/kg, 30.32mg, 29.48mg/kg and 27.09mg/kg respectively representing 50% of the total samples size analyzed that exceeded half of the WHO permissible limit of 50mg/kg.

Generally, 95% of the total number of samples analyzed recorded mean copper concentrations within the WHO permissible limits with the remaining 5% exceeding the permissible limit. Results further revealed that, spice samples such as A-C (19.79) and K-C (16.93), A-CP (17.91) and K-CP (13.80), K-NP (12.72) and A-NP (13.03) recorded mean concentration values similar and close to each other. This suggests that even though they are the same kind of spice, samples differ in locality in terms of market hence the copper levels may be influenced by the same factors.

In comparison to what has been reported in literature, Fadhil et al. (2021) found copper concentration range of 0.58ppm to 3.81ppm with the highest concentration in turmeric and the lowest in mixed type of spices. Fadhil et al., (2021) reported that copper concentrations were below the permitted levels used in their study. Soliman (2015) also reported of the highest copper level of 21.4mg/kg in hot red pepper and the lowest in paprika with 3.72mg/kg, with all samples recording values below half of the value of the MPLs. Mubeen et al., (2009) reported of copper concentration range of 9mg/kg-44mg/kg which also fell below the MPL of copper. Krejpcio et al., (2016) also reported of low levels of copper concentration range between

4.20mg/kg in cloves and 9.12mg/kg in basil, with paprika recording excess copper in their study. The highest concentration of copper in the ginger sample was found in K-GI. Krejpcio et al., (2016) also found the highest concentration of coper in their study in ginger from Polish markets.

Cadmium Concentrations in Spices

Bua et al., (2016) reported that cadmium, according to WHO is among the top 10 chemical contaminants that have gained major public health concern as they persistently accumulate in the environment and adversely affect environmental and human health, when properly unmanaged. Cadmium, a non-essential food element accumulates principally in the liver and kidneys (Nordin and Selamat, 2013). Thus human chronic exposures to this metal in even the minutest quantities causes osteoposrosis, high blood pressure, lung diseases and kidney problems, and is a known potential human carcinogen (Fadhil et al., 2021). According to Oladoye and Jegede (2016), excess concentrations of this non-essential element in the human body targets major organs such as the liver, kidneys, brain, placenta and bones.

In this present study, cadmium was not detected in any of the local spices from the two markets. It could be that they were present in some of the spices but below the detection limit of 0.004ppm. The study of Darko et al. (2010) reported of a similar trend in spices from Kumasi, Ghana, in a way that is in line with the results of this present study. They did not detect cadmium in any of the samples they analyzed except in nutmeg that recorded a range between <0.01 (detection limit of cadmium used in that study) to 0.90mg/kg.

In Malaysia, Nordin and Selamat (2013) reported of cadmium concentration range between 0.23µg/g to 8.07µg/g above the permissible limit used in their

study. Gaya and Ikechukwu (2016) also reported higher levels cadmium above the FAO/WHO permissible limits in spice samples obtained from Nigeria. Again in Nigeria, Oladoye and Jegede (2016) also reported of cadmium concentration range between 0.30mg/kg to 0.45mg/kg that exceeded that MPL of 0.3mg/kg used in the study, with maximum concentrations being found in garlic, ginger and locust bean. Bua et al., (2016) also reported a range of cadmium concentration between 0.029mg/kg to 0.24mg/kg which were below the permissible limits used in the study with lowest concentrations being found in Indonesian ginger and the highest in Sri Lankan curcuma.

From the findings of this present study, it could be deduced that, the non-detection of cadmium in the sampled spices could be attributed to several factors such as distant location of farmlands from the sources of cadmium pollution and the use of quality, unpolluted irrigation water in the cultivation of the spices.

Hypothesis Testing

The One-way ANOVA was used in testing for the hypothesis stated for the study. However, the test of homogeneity is a necessity to enable the ANOVA test. This was to check if the variability of means levels of heavy metals (Cu and Pb) in the spices is similar. The significant value of 0.240 was obtained from the Levene's test. Since 0.240 is greater than $\alpha = 0.05$, it indicates that the test is not significant, which also implies the variances of the levels of heavy metals in the spices are the same. In view of this, the assumption of equality of variances was satisfied hence warranted the ANOVA test.

Research Hypothesis 1

$H_0$1**:** There is no statistically significant difference in the mean copper and lead levels in all the ten spices from Abura Market.

Table 9: Analysis of variance for lead and copper levels in spices from Abura market

Metal	Degrees of freedom	Sum of squares	Mean Squares	F-value	P-value
Pb	9	154375.721	1715.858	27.749	0.000
	20	12362.923	618.146		
Cu	9	1356.838	150.760	1.470	0.226
	20	2057.248	102.560		

Source: Field data, 2023**.**

Report on $H_0$1

From Table 9, the calculated F-values for Pb was 27.749 and that of Cu was 1.470. The p-values were 0.000 and 0.226 for Pb and Cu respectively. Since the p-value for Pb is less than 0.05, there is a statistically significant difference in the mean levels. Therefore, the researcher rejects the null hypothesis. This implies that at least one of the mean Pb levels in the ten spices is significantly different. On the other hand, the p-value for Cu which was 0.226, is greater than 0.05, therefore there is no statistically significant difference, hence the researcher fails to reject the null hypothesis. This means that the means of the Cu levels for the ten spices from Abura Market were the same.

A multiple comparison (Tukey's test) was conducted to determine the means of the Pb levels which were significantly different at a level of significance = 0.05. The mean Pb levels in the ten spices that were significantly different are summarized in the Tukey's Post Hoc test in a table

at appendix E. From the Post Hoc test, it was observed that ginger (72.60±11.80) is significantly lower than rosemary (148.76±55.10) in terms of Pb mean levels. However, there were significant differences between ginger (72.60±11.80) and aniseed (156.56±45.01), as well as, ginger (72.60±11.80) and chilli pepper (208.04±15.49). Significant differences were further observed in garlic (8.39±4.48) and rosemary (148.76±55.10), garlic (8.39±4.48) and aniseed (156.56±45.01), garlic (8.39±4.48) and cloves (131.25±2.59) as well as garlic (8.39±4.48) and chilli pepper (208.04±15.49).

Again, significant differences were also observed in rosemary (148.76±55.10) and ginger (72.60±11.80), rosemary (148.76±55.10) and garlic (8.39±4.48), rosemary (148.76±55.10) and grains of paradise (34.63±23.06), rosemary (148.76±55.10) and negro pepper (17.52±12.14), rosemary (148.76±55.10) and bay leaf (4.50±0.33) and rosemary (148.76±55.10) and African nutmeg (9.21±5.78). Aniseed (156.56 45.01) and ginger (72.60±11.80), aniseed (156.56 45.01) and garlic (8.39±4.48), aniseed (156.56 45.01) and grains of paradise (34.63±23.06), aniseed (156.56 45.01) and negro pepper (17.52±12.14), aniseed (156.56 45.01) and bay leaf (4.50±0.33), and aniseed (156.56 45.01) and African nutmeg (9.21±5.78) also showed significant differences in terms of Pb levels.

Additionally, significant differences were observed between grains of paradise (34.63±23.06) and rosemary (148.76±55.10), grains of paradise (34.63±23.06) and aniseed (156.56 45.01), grains of paradise (34.63±23.06) and cloves (131.25±2.59), grains of paradise (34.63±23.06) and chilli pepper (208.04±15.49). Negro pepper (17.52±12.14) and rosemary (148.76±55.10), negro pepper (17.52±12.14) and aniseed (156.56 45.01), negro pepper

(17.52±12.14) and cloves, negro pepper (17.52±12.14) and negro pepper (17.52±12.14) and chilli pepper (208.04±15.49) also recorded significant differences. Further significant differences were also noticed in bay leaf (4.50±0.33) and rosemary (148.76±55.10), bay leaf (4.50±0.33) and aniseed (156.56 45.01), bay leaf (4.50±0.33) and cloves (131.25±2.59), bay leaf (4.50±0.33) and chilli pepper (208.04±15.49).

Cloves (131.25±2.59) and garlic (8.39±4.48), cloves (131.25±2.59) and grains of paradise (34.63±23.06), cloves (131.25±2.59) and negro pepper (17.52±12.14), cloves (131.25±2.59) and bay leaf (4.50±0.33), cloves (131.25±2.59) and African nutmeg (9.21±5.78) and, cloves (131.25±2.59) and chilli pepper (208.04±15.49) also recorded significant differences. African nutmeg (9.21±5.78) and rosemary (148.76±55.10), African nutmeg (9.21±5.78) and aniseed (156.56 45.01), African nutmeg (9.21±5.78) and bay leaf (4.50±0.33) and then, African nutmeg (9.21±5.78) and chilli pepper (208.04±15.49) further recorded significant differences. Finally, chilli pepper (208.04±15.49) and ginger (72.60±11.80), chilli pepper (208.04±15.49) and garlic (8.39±4.48), chilli pepper (208.04±15.49) and rosemary (148.76±55.10), chilli pepper (208.04±15.49) and grains of paradise (34.63±23.06), chilli pepper (208.04±15.49) and negro pepper (17.52±12.14), chilli pepper (208.04±15.49) and bay leaf (4.50±0.33), chilli pepper (208.04±15.49) and cloves (131.25±2.59) and, chilli pepper (208.04±15.49) and African nutmeg (9.21±5.78) recorded significant differences in the mean Pb levels.

Research Hypothesis 2

$H_0$2: There is no statistically significant difference in the mean copper and lead levels in all the ten spices from Kotokoraba Market.

Table 10: Analysis of variance for lead and copper levels in spices from Kotokoraba market

Metal	Degrees of freedom	Sum of squares	Mean square	F-value	Sig-value
Pb	9	102078.206	11342.023	41.611	0.000
	20	5451.512	272.576		
Cu	9	38538.169	4282.019	5.307	0.001
	20	16137.212	806.861		

Source: Field data, 2023

Report on $H_0$2

From Table 10, the F-value for Pb and Cu were 41.611 and 5.307 respectively. The p-values however, were 0.000 for Pb and 0.001 for Cu. Since the p-values for both Cu and Pb were less than 0.05, there are significance differences in the mean levels of all ten spices. Therefore, the researcher rejects the null hypothesis. This implies that at least one among the ten spices differed in both Cu and Pb mean levels.

A multiple comparison (Tukey's test) was conducted to determine which of the spices differed in terms of mean Pb and Cu levels. At a level of significance = 0.05, the mean lead and copper levels in the ten spices that were significantly different are summarized in the Tukey's Post Hoc test at appendices C and D respectively.

From the Post Hoc test presented in appendix C, it was observed that, ginger (156.74±14.61) is significantly higher than rosemary (11.16±4.48) in terms of Pb. However, there were significant differences between ginger (156.74±14.61) and aniseed (24.19±11.35), ginger (156.74±14.61) and grains of paradise (91.30±8.70), ginger (156.74±14.61) and negro pepper (22.63±13.21), ginger (156.74±14.61) and cloves (9.16±1.68), then ginger

(156.74±14.61) and, chilli pepper (31.05±14.69). Significant differences were further observed between garlic (133.45±37.41) and rosemary (11.16±4.48), garlic (133.45±37.41) and aniseed (24.19±11.35), garlic (133.45±37.41) and negro pepper (22.63±13.21), garlic (133.45±37.41) and cloves (9.16±1.68), then garlic (133.45±37.41) and chilli pepper (31.05±14.69).

Again, between rosemary (11.16±4.48) and ginger (156.74±14.61), rosemary (11.16±4.48) and garlic (133.45±37.41), rosemary (11.16±4.48) and grains of paradise (91.30±8.70), rosemary (11.16±4.48) and bay leaf (146.24±9.68), then rosemary (11.16±4.48) and African nutmeg (129.08±19.97), significant differences were also recorded. Furthermore, significant differences also existed in grains of paradise (91.30±8.70) and ginger (156.74±14.61), grains of paradise (91.30±8.70) and rosemary (11.16±4.48), grains of paradise (91.30±8.70) and aniseed (24.19±11.35), grains of paradise (91.30±8.70) and negro pepper (22.63±13.21), grains of paradise (91.30±8.70) and cloves (9.16±1.68), then in grains of paradise (91.30±8.70) and chilli pepper.

The analysis further revealed significant differences between negro pepper (22.63±13.21) and ginger (156.74±14.61), negro pepper (22.63±13.21) and garlic (133.45±37.41), negro pepper (22.63±13.21) and grains of paradise (91.30±8.70), negro pepper (22.63±13.21) and bay leaf (146.24±9.68), and then negro pepper (22.63±13.21) and African nutmeg (129.08±19.97). Bay leaf (146.24±9.68) and rosemary (11.16±4.48), bay leaf (146.24±9.68) and aniseed (24.19±11.35), bay leaf (146.24±9.68) and grains of paradise (91.30±8.70), bay leaf (146.24±9.68) and negro pepper (22.63±13.21), bay leaf (146.24±9.68) and cloves (9.16±1.68), then bay leaf (146.24±9.68) and

chilli pepper (31.05±14.69) also recorded significant differences from the Post Hoc analysis.

Further significant differences were observed between cloves (9.16±1.68) and ginger (156.74±14.61), cloves (9.16±1.68) and garlic (133.45±37.41), cloves (9.16±1.68) and grains of paradise (91.30±8.70), cloves (9.16±1.68) and bay leaf (146.24±9.68) and then in cloves (9.16±1.68) and African nutmeg (129.08±19.97). Significant differences were also observed between African nutmeg (129.08±19.97) and rosemary, African nutmeg (129.08±19.97) and aniseed (24.19±11.35), African nutmeg (129.08±19.97) and negro pepper (22.63±13.21), African nutmeg (129.08±19.97) and cloves (9.16±1.68) and then African nutmeg (129.08±19.97) and chili pepper (31.05±14.69). Chilli pepper (31.05±14.69) and ginger (156.74±14.61), chilli pepper (31.05±14.69) and garlic (133.45±37.41), chilli pepper (31.05±14.69) and grains of paradise (91.30±8.70), chilli pepper (31.05±14.69) and bay leaf (146.24±9.68) and then in chilli pepper (31.05±14.69) and African nutmeg (129.08±19.97) also showed significant differences.

From appendix D, the Post Hoc test showed that ginger (139.92±87.12) is significantly higher than garlic (29.48±1.90) in terms of Cu levels. However, there were significant differences between garlic (29.48±1.90) and ginger (139.92±87.12), garlic (29.48±1.90) and rosemary (12.44±1.18), garlic (29.48±1.90) and aniseed (32.96±13.36), garlic (29.48±1.90) and grains of paradise (39.33±7.84), garlic (29.48±1.90) and negro pepper (12.72±1.43), garlic(29.48±1.90) and bay leaf (33.03±2.92),

garlic (29.48±1.90) and cloves (16.93±9.72), garlic (29.48±1.90) and African nutmeg (42.19±8.37), then garlic (29.48±1.90) and chilli pepper (13.80±7.61).

Significant differences were also recorded in rosemary (12.44±1.18) and ginger (139.92±87.12), grains of paradise and ginger (139.92±87.12), negro pepper and ginger (139.92±87.12), bay leaf and ginger (139.92±87.12), cloves and ginger (139.92±87.12), African nutmeg and ginger (139.92±87.12) as well as chilli pepper and ginger (139.92±87.12).

Research Hypothesis 3

$H_0$3: There is no interaction between the mean levels of lead and copper in all the ten spices from both markets.

Table 11: Analysis of variance for lead and copper levels in each of the ten spices from both markets

Metal	Degrees of freedom	Sum of squares	Mean square	F-square	Sig-value
Pb	9	42001.158	4666.795	1.004	0.450
	50	232465.955	4649.319		
Cu	9	23197.416	2577.491	3.472	0.002
	50	37113.187	742.264		

Source: Field data, 2023

Report on $H_0$3

From Table 11, the calculated F-value the mean Pb levels from both markets was 1.004, whereas the p-value was 0.450. Since the p-value was greater than 0.05, the researcher fails to reject the null hypothesis. This means that, there is no interaction in the mean Pb levels of the ten spices from both markets.

On the other hand, the F-value and the p-value for the mean Cu levels for both markets were 3.472 and 0.002 respectively. Since the p-value was less than 0.05, the researcher rejects the null hypothesis. This implies that, there is an interaction in the mean Cu levels of the ten spices from both markets.

A multiple comparison (Tukey's test) was conducted to determine which of the spices had interactions with each other in terms of their mean Cu levels. At a level of significance = 0.05, the mean Cu levels in the ten spices that had interactions with each other are summarized in the Tukey's Post Hoc test at appendix F. From the Post Hoc test, all the means of the ten spices did not show significant interactions between the two markets excepts in ginger and garlic, ginger and rosemary, ginger and aniseed, ginger and grains of paradise, ginger and negro pepper, ginger and bay leaf, ginger and cloves, and then ginger and chilli pepper. Other significant interactions were found in garlic and ginger, rosemary and ginger, aniseed and ginger, grains of paradise and ginger, bay leaf and ginger, cloves and ginger, chilli pepper and ginger.

Chapter Summary

Chapter four dwelt on the findings and discussions of the research. It discussed the common spices available on Cape Coast markets, specifically Abura and Kotokoraba markets. It also touched on the purposes of spices from both consumers' and sellers' perspectives, and finally on the metal (lead, copper and cadmium) concentrations in ten of the commonly consumed spices found on Cape Coast markets.

Key findings of the research included the following:

1. Top ten frequently purchased spices in Cape Coast markets included; ginger, garlic, rosemary, aniseed, grains of paradise, cloves, negro

pepper, bay leaf, African nutmeg and chilli pepper though about twenty-five to twenty-seven different spices were identified at the two selected markets.

2. Notable purposes of spices revealed by the study constituted; culinary (as seasoning and flavourings in dishes and beverages), health (for their anti-fungal, anti-bacterial, anti-inflammatory, anti-oxidant properties etc.), spiritual, and preservative purposes.
3. In terms of total heavy metal concentrations in the analyzed samples, lead ranked the highest with 77.33mg/kg, followed by copper with 31.18mg/kg and then cadmium. However, cadmium was not detected in any of the samples that were analyzed.
4. Results indicated that lead recorded a mean concentration range between 4.50mg/kg in Abura bay leaf and 208.04mg/kg in Abura chilli pepper. Copper on the other hand, recorded a mean concentration between 12.44mg/kg in Kotokoraba rosemary and 139.92mg/kg in Kotokoraba ginger. Hence it could be deduced that, lead recorded its highest and lowest concentrations in spices from Abura market, whereas the lowest and highest concentrations for copper were recorded in spice samples from Kotokoraba.
5. In terms of total mean concentrations in both lead and copper were recorded in negro pepper (20.07mg/kg) and chilli pepper (119.54mg/kg) and then in negro pepper (12.85mg/kg) and ginger (87.70mg/kg) respectively. Hence negro pepper recorded the least value for total lead and copper concentrations of all spices from both markets.

6. It was further revealed that about 80% of the spices from both markets recorded mean concentrations that exceeded the WHO permissible limits for lead, with 20% of the spices having values within the permissible limits. With regards to copper, 95% of the samples recorded mean concentrations within the permissible limits with only 5% of the samples exceeding the limits.
7. The study revealed a statistically significant difference in the mean Pb levels in all spices from Abura market, meaning that at least one of the spices had it its mean Pb levels significant from the other spices. Mean Cu levels for the spices from the same market however, did not show a statistically significant difference.
8. Again, spices from Kotokoraba market, on the other hand, showed statistically significant differences in the mean levels for both Pb and Cu, implying that, at least one of the spices from Kotokoraba market was differed in terms of the Cu and Pb mean levels.
9. Finally, when the mean levels for both Cu and Pb for each of the ten spices from both markets were compared, the study revealed there was an interaction between the mean Cu levels for the spices from both markets.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Overview

This chapter gives a snapshot of all the results of the study on the determination of heavy metals in local spices in two selected markets in Cape Coast. The summary dealt with the objectives of the study, methodology and summary of the results. The conclusion dwelt on the findings deduced from the results of the analysis whiles the recommendations make suggestions to inform policies and improve practice.

Summary

The overriding purpose of the study was to determine heavy metals concentrations in common spices from selected markets in Cape Coast. The research objectives the study sought to address included: "To identify commonly bought spices on markets in Cape Coast", "To identify the purposes for the common spices bought" and "To determine the levels of lead, copper and cadmium in ten common spices in Cape Coast". The study adopted the exploratory sequential mixed method design in undertaking the research. The sample frame for the study first phase of the study comprised a total of 48 sellers and buyers of natural spices from the two selected markets. Twelve (12) buyers and sellers each were selected with the purposive sampling procedure from each market based on the saturation of themes by Guest et al. (2006).

However, in the second of the study, three samples of ten (10) different kinds of natural spices were randomly bought from both markets. Data from the first phase of the study was gathered through the use of the interview guide

whereas the atomic absorption spectrophotometer (AAS) was used in the second phase after acid digestion. Data collected from the interviews were analyzed thematically whereas data from the AAS were expressed as mean and standard deviations using SPSS. The ANOVA was used to test if there existed differences in the lead and copper concentrations in spices form the two markets.

Key findings that were made based on each of the specific objectives of the study are briefly explained below.

Commonly bought spices available on Cape Coast markets

Majority of the respondents opined that among the spices sold in the two selected markets chilli pepper, ginger, garlic, rosemary and aniseed are basic in their everyday cooking of meals. Some respondents added that, grains of paradise (due to its popularity in herbal/ traditional medicine) is also among the frequently purchased and consumed spices, together with clove, negro pepper, African nutmeg, and bay leaf, hence forming the basis of choice for this research when the spices available for sale were ranked in terms of those which are frequently bought by consumers.

Purposes of commonly bought spices

Many purposes of spices were expressed by respondents from the interview sessions. However, they were all grouped under themes such as culinary, health, spiritual/religious, and for their preservative properties. It was revealed that spices are mainly bought for their culinary uses, such as being used as seasonings and flavourings in both dishes and beverages. Thus, spices are used to season fish, meat, game, poultry etc., while they also function as

flavourings in juices and in popular Ghanaian local drinks such as 'sobolo', 'lamugin' and 'zomkom'.

Furthermore, a variety of health purposes of spices were recorded from the study. It was indicated that spices tend to have positive health effects on the human circulatory, respiratory and reproductive systems. It was also established that, spices also have immune boosting qualities as well as effects on the GI (gastrointestinal) system. Other health functions of spices revealed in the study included their febrifugal, anti-diabetic, anti-hypertensive properties. All these health functions are due to the anti-fungal, anti-bacterial, anti-oxidant, and anti-inflammatory properties contained in spices.

Additionally, the study revealed that, spices have preservative properties due the ability to inhibit the growth of some gram positive and negative bacteria, as well as their anti-oxidant characteristics, which prevent spoilage of food, and hence extend the shelf life of food.

Finally, on the spiritual and religious purposes of spices, it was revealed that, spices such as garlic, rosemary, grains of paradise and aniseed are used to ward off evil, bad omen, break spells and for good luck. They are also used in funeral, marriage and naming ceremonies for as a sign of immortality, virginity, and protection.

Heavy metal concentrations in spices

Findings indicated that, lead recorded the highest total mean concentration of 77.33mg/kg followed by copper with a value of 31.18mg/kg though cadmium was not detected in any of the spices. It was also observed that, lead recorded a mean concentration range of 4.50mg/kg in Abura bay leaf and 208.04mg/kg in Abura chilli pepper. Copper on the other hand recorded a

mean concentration range of 12.44mg/kg in Kotokoraba rosemary and 139.92kg/mg in Kotokoraba ginger. Additionally, total mean concentration for lead in all samples were recorded in a range between 20.07kg/mg in negro pepper and 119.54mg/kg in chilli pepper, whereas that of copper ranged between 12.85mg/kg in negro pepper and 87.70mg/kg in ginger, pointing to negro pepper as the spice among the ten samples that recorded the least total mean concentration.

Again, about 80% of the spices recorded mean concentrations that exceeded the WHO permissible limits for lead, whereas 95% of the samples recorded mean concentrations for copper within the permissible limits stipulated by WHO as (cited in Oladoye and Jegede, 2016; Olusakin & Olaoluwa, 2016).

Differences in lead and copper levels among spices from Abura market

A One-way ANOVA analysis was conducted to find out whether spices differed in terms of the Pb and Cu levels in Abura market. From the analysis, the calculated p-values were 0.000 and 0.226 for Pb and Cu respectively. The study found a statistically significant difference in the mean levels for Pb since the p-value was less than 0.05, but no significance difference in the Cu mean levels for the spices since the p-value was greater than 0.05. A Post Hoc test was then conducted to find out where the differences in the Pb levels emanated from and Appendix E gives a summary of all those spices that showed statistically significant differences in their Pb levels.

Differences in lead and copper levels among spices from Kotokoraba market

The study further sought to determine if there is a statitistically significant difference in the mean Pb and Cu levels in the spices from Kotokoraba market. The One-way ANOVA revealed p-values of 0.000 for Pb and 0.001 for Cu. The study found statistically significant differences in both the mean Pb and Cu levels in the spices since the p-values for both Cu and Pb were less than 0.05. This implied that at least one among the ten spices differed in both Cu and Pb mean levels from Kotokoraba market. A multiple comparison (Tukey's test) was conducted to determine which of the spices differed in terms of mean Pb and Cu levels in appendices C and D respectively.

Interactions between lead and copper levels among spices from both markets

Finally, the study sought to find out if there was interaction between the mean Pb and Cu levels of the spices from both markets. The study found no interaction in the mean Pb levels of the spices from both market since the p-value, 0.450, was greater than 0.05. However, there was an interaction in the mean Cu levels of the ten spices from both markets since the p-value, 0.002 was less than 0.05. A multiple comparison (Tukey's test) was conducted to determine which of the spices had significant interactions, and this has been presented in Appendix F.

Conclusions

This study was designed to determine the levels of lead, copper and cadmium in common spices available on Cape Coast markets. From the results

and discussions above it could be concluded that, a good number of the total number of spices were contaminated with lead as 80% of the total number of spices recorded mean concentrations above the permissible limit. This indicates that spices on cape coast market are contaminated with high lead concentrations which could be attributed to the sources from which the spices were cultivated and the location of the two markets (that is in areas where there is high traffic density).

Again, findings indicated there is limited knowledge among the participants who were interviewed from the two markets on the purposes of spices, especially the health aspect. Thus, findings from this work can be used by the general public to understand the many purposes of spices and also the chemical quality of spices used in everyday cooking.

Furthermore, findings could also help fill part of the gap that exists in literature in the Ghanaian setting pertaining to the heavy metal contamination of spices available or sold in the Ghanaian market as literature has confirmed this fact.

The study will also serve as a wake-up call to all agencies of public health concern such as the FDA, EHPA and GSA to devise strategies that will help safeguard both the health of our environment and that of humans as they formulate policies.

Recommendations

Regarding the conclusions drawn above, the following recommendations were made;

1. Local standards for spices should be issued by the FDA and SGA to be used as a guide for evaluating quality.

2. There should also be the regular monitoring of imported spices and a ban should be placed on import of spices from countries whose commodities exceed the permissible limits of the heavy metal content.
3. Again, attention should be paid to the study of spices and the harmful substances they may probably contain due to the frequent use of these food additives in both food and medicine.
4. There should be routine checks and frequent analysis of food stuffs by the FDA and the GSA to avoid the possible risk of exceeding the intake beyond the tolerable standard limits.
5. Existing regulations and bye-laws on environmental pollution should be reviewed and also enforced by the EHPA to help check all manner of pollution in the environment.
6. There should be the encouragement of the use of plastic pipes for boreholes and pipe borne water from dams and rivers for human consumption and agricultural purposes such as irrigation by the government as metal tubes have proven to be a source of heavy metal contamination at the household level.
7. Government through the EHPA should enact laws to compel industries to establish treatment plants for effluents, and such plants should also be changed from time to time in order to conform to changing global technology to ensure the sustenance of effective treatment.
8. By way of law, industries should be compelled to publish levels of heavy metals contained in their consumable finished products.
9. The tertiary and research institutions in Ghana should be encouraged by way of funding by the government to embark on regular monitoring

of industrial effluents in other to ascertain the compliance to the use of treatment plants.

Suggestions for Future Research

This study focused on the concentrations of only lead, copper and cadmium in ten common spices found in two selected markets in Cape Coast. It is therefore suggested that, future research studies focus on other heavy metal of health concern as well as other common spices found in many other markets of Cape Coast and even Central Region. Again, attention can also be given to the assessment of the risk on consumers' health involved in consuming spices which are contaminated by heavy metals.

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APPENDICES

APPENDIX A

UNIVERSITY OF CAPE COAST

DEPARTMENT OF VOCATIONAL AND TECHNICAL EDUCATION

TITLE OF THESIS

Cadmium, lead and copper levels in ten common spices sold in Cape Coast

INTERVIEW GUIDE FOR SELLERS

This interview guide seeks to gather information on the commonly bought spices and the purposes for which they are bought on markets in two selected markets in Cape Coast. The information gathered will be used as the basis for selecting spices for heavy metal analysis in the next phase of the study.

Themes for Interview

Theme A: Commonly bought spices on markets

Q1. What natural spices do you sell?

Q2. Which of the spices do consumers purchase the most?

Theme B: Purposes for which spices are bought

Q3. For what reasons do consumers mostly buy the specific spices mentioned in Theme A question 2?

APPENDIX B

UNIVERSITY OF CAPE COAST

DEPARTMENT OF VOCATIONAL AND TECHNICAL EDUCATION

TITLE OF THESIS

Cadmium, lead and copper levels in ten common spices sold in Cape Coast

INTERVIEW GUIDE FOR BUYERS

This interview guide seeks to gather information on the commonly bought spices and the purposes for which they are bought on markets in two selected markets in Cape Coast. The information gathered will be used as the basis for selecting spices for heavy metal analysis in the next phase of the study.

Themes for Interview

Theme A: Common spices available on markets

Q1. What natural spices do you find available at the market for sale?

Q2. Which of the above spices do you buy often?

Theme B: Purposes for which spices are bought

Q3. For what purposes do you buy the spices you often buy?

APPENDIX C

Multiple Comparisons for Pb concentrations at Kotokoraba Market

Dependent Variable: Pb

Tukey HSD

(I) SPICE	(J) SPICE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	GARLIC	23.28268	13.48025	.769	-24.4523	71.0177
	ROSEMARY	145.57147*	13.48025	**.000**	97.8365	193.3065
	ANISEED	132.54254*	13.48025	**.000**	84.8075	180.2776
	GRAINS OF PARADISE	65.43084*	13.48025	**.003**	17.6958	113.1659
GINGER	NEGRO PEPPER	134.10054*	13.48025	**.000**	86.3655	181.8356
	BAY LEAF	10.49207	13.48025	.998	-37.2429	58.2271
	CLOVES	147.57877*	13.48025	**.000**	99.8438	195.3138
	AFRICAN NUTMEG	27.65712	13.48025	.577	-20.0779	75.3921
	CHILLI PEPPER	125.68320*	13.48025	**.000**	77.9482	173.4182
	GINGER	-23.28268	13.48025	.769	-71.0177	24.4523
	ROSEMARY	122.28879*	13.48025	**.000**	74.5538	170.0238
	ANISEED	109.25987*	13.48025	**.000**	61.5249	156.9949
	GRAINS OF PARADISE	42.14817	13.48025	.112	-5.5868	89.8832
GARLIC	NEGRO PEPPER	110.81787*	13.48025	**.000**	63.0829	158.5529
	BAY LEAF	-12.79061	13.48025	.992	-60.5256	34.9444
	CLOVES	124.29609*	13.48025	**.000**	76.5611	172.0311
	AFRICAN NUTMEG	4.37444	13.48025	1.000	-43.3606	52.1095
	CHILLI PEPPER	102.40052*	13.48025	**.000**	54.6655	150.1355
	GINGER	-145.57147*	13.48025	**.000**	-193.3065	-97.8365
	GARLIC	-122.28879*	13.48025	**.000**	-170.0238	-74.5538
	ANISEED	-13.02892	13.48025	.991	-60.7639	34.7061
	GRAINS OF PARADISE	-80.14062*	13.48025	**.000**	-127.8756	-32.4056
ROSEMARY	NEGRO PEPPER	-11.47092	13.48025	.996	-59.2059	36.2641
	BAY LEAF	-135.07940*	13.48025	**.000**	-182.8144	-87.3444
	CLOVES	2.00730	13.48025	1.000	-45.7277	49.7423
	AFRICAN NUTMEG	-117.91434*	13.48025	**.000**	-165.6494	-70.1793
	CHILLI PEPPER	-19.88827	13.48025	.887	-67.6233	27.8467

	GINGER	-132.54254*	13.48025	**.000**	-180.2776	-84.8075
	GARLIC	-109.25987*	13.48025	**.000**	-156.9949	-61.5249
	ROSEMARY	13.02892	13.48025	.991	-34.7061	60.7639
	GRAINS OF PARADISE	-67.11170*	13.48025	**.002**	-114.8467	-19.3767
ANISEED	NEGRO PEPPER	1.55800	13.48025	1.000	-46.1770	49.2930
	BAY LEAF	-122.05048*	13.48025	**.000**	-169.7855	-74.3155
	CLOVES	15.03622	13.48025	.977	-32.6988	62.7712
	AFRICAN NUTMEG	-104.88542*	13.48025	**.000**	-152.6204	-57.1504
	CHILLI PEPPER	-6.85934	13.48025	1.000	-54.5944	40.8757
	GINGER	-65.43084*	13.48025	**.003**	-113.1659	-17.6958
	GARLIC	-42.14817	13.48025	.112	-89.8832	5.5868
	ROSEMARY	80.14062*	13.48025	**.000**	32.4056	127.8756
	ANISEED	67.11170*	13.48025	**.002**	19.3767	114.8467
GRAINS OF	NEGRO PEPPER	68.66970*	13.48025	**.002**	20.9347	116.4047
PARADISE	BAY LEAF	-54.93878*	13.48025	.016	-102.6738	-7.2038
	CLOVES	82.14792*	13.48025	**.000**	34.4129	129.8829
	AFRICAN NUTMEG	-37.77372	13.48025	.201	-85.5087	9.9613
	CHILLI PEPPER	60.25236*	13.48025	**.007**	12.5173	107.9874
	GINGER	-134.10054*	13.48025	**.000**	-181.8356	-86.3655
	GARLIC	-110.81787*	13.48025	**.000**	-158.5529	-63.0829
	ROSEMARY	11.47092	13.48025	.996	-36.2641	59.2059
	ANISEED	-1.55800	13.48025	1.000	-49.2930	46.1770
	GRAINS OF PARADISE	-68.66970*	13.48025	**.002**	-116.4047	-20.9347
NEGRO PEPPER	BAY LEAF	-123.60848*	13.48025	**.000**	-171.3435	-75.8735
	CLOVES	13.47822	13.48025	.989	-34.2568	61.2132
	AFRICAN NUTMEG	-106.44342*	13.48025	**.000**	-154.1784	-58.7084
	CHILLI PEPPER	-8.41734	13.48025	1.000	-56.1524	39.3177
	GINGER	-10.49207	13.48025	.998	-58.2271	37.2429
	GARLIC	12.79061	13.48025	.992	-34.9444	60.5256
	ROSEMARY	135.07940*	13.48025	**.000**	87.3444	182.8144
	ANISEED	122.05048*	13.48025	**.000**	74.3155	169.7855
	GRAINS OF PARADISE	54.93878*	13.48025	**.016**	7.2038	102.6738
BAY LEAF	NEGRO PEPPER	123.60848*	13.48025	**.000**	75.8735	171.3435
	CLOVES	137.08670*	13.48025	**.000**	89.3517	184.8217
	AFRICAN NUTMEG	17.16506	13.48025	.949	-30.5700	64.9001
	CHILLI PEPPER	115.19113*	13.48025	**.000**	67.4561	162.9261

	GINGER	-147.57877*	13.48025	**.000**	-195.3138	-99.8438
	GARLIC	-124.29609*	13.48025	**.000**	-172.0311	-76.5611
	ROSEMARY	-2.00730	13.48025	1.000	-49.7423	45.7277
	ANISEED	-15.03622	13.48025	.977	-62.7712	32.6988
CLOVES	GRAINS OF PARADISE	-82.14792*	13.48025	**.000**	-129.8829	-34.4129
	NEGRO PEPPER	-13.47822	13.48025	.989	-61.2132	34.2568
	BAY LEAF	-137.08670*	13.48025	**.000**	-184.8217	-89.3517
	AFRICAN NUTMEG	-119.92164*	13.48025	**.000**	-167.6567	-72.1866
	CHILLI PEPPER	-21.89557	13.48025	.822	-69.6306	25.8394
	GINGER	-27.65712	13.48025	.577	-75.3921	20.0779
	GARLIC	-4.37444	13.48025	1.000	-52.1095	43.3606
	ROSEMARY	117.91434*	13.48025	**.000**	70.1793	165.6494
	ANISEED	104.88542*	13.48025	**.000**	57.1504	152.6204
AFRICAN NUTMEG	GRAINS OF PARADISE	37.77372	13.48025	.201	-9.9613	85.5087
	NEGRO PEPPER	106.44342*	13.48025	**.000**	58.7084	154.1784
	BAY LEAF	-17.16506	13.48025	.949	-64.9001	30.5700
	CLOVES	119.92164*	13.48025	**.000**	72.1866	167.6567
	CHILLI PEPPER	98.02608*	13.48025	**.000**	50.2911	145.7611
	GINGER	-125.68320*	13.48025	**.000**	-173.4182	-77.9482
	GARLIC	-102.40052*	13.48025	**.000**	-150.1355	-54.6655
	ROSEMARY	19.88827	13.48025	.887	-27.8467	67.6233
	ANISEED	6.85934	13.48025	1.000	-40.8757	54.5944
CHILLI PEPPER	GRAINS OF PARADISE	-60.25236*	13.48025	**.007**	-107.9874	-12.5173
	NEGRO PEPPER	8.41734	13.48025	1.000	-39.3177	56.1524
	BAY LEAF	-115.19113*	13.48025	**.000**	-162.9261	-67.4561
	CLOVES	21.89557	13.48025	.822	-25.8394	69.6306
	AFRICAN NUTMEG	-98.02608*	13.48025	**.000**	-145.7611	-50.2911

Source: Field data, 2023

APPENDIX D
Multiple Comparisons for Cu concentrations at Kotokoraba Market

Dependent Variable: Cu

Tukey HSD

(I) SPICE	(J) SPICE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
GINGER	GARLIC	110.43839*	23.19282	**.004**	28.3101	192.5667
	ROSEMARY	127.47903*	23.19282	**.001**	45.3507	209.6073
	ANISEED	106.96049*	23.19282	**.005**	24.8322	189.0888
	GRAINS OF PARADISE	100.58630*	23.19282	**.009**	18.4580	182.7146
	NEGRO PEPPER	127.19954*	23.19282	**.001**	45.0713	209.3278
	BAY LEAF	106.88231*	23.19282	**.005**	24.7540	189.0106
	CLOVES	122.98998*	23.19282	**.001**	40.8617	205.1183
	AFRICAN NUTMEG	97.72506*	23.19282	**.012**	15.5968	179.8533
	CHILLI PEPPER	126.11261*	23.19282	**.001**	43.9843	208.2409
GARLIC	GINGER	-110.43839*	23.19282	**.004**	-192.5667	-28.3101
	ROSEMARY	17.04064	23.19282	.999	-65.0876	99.1689
	ANISEED	-3.47790	23.19282	1.000	-85.6062	78.6504
	GRAINS OF PARADISE	-9.85209	23.19282	1.000	-91.9804	72.2762
	NEGRO PEPPER	16.76116	23.19282	.999	-65.3671	98.8894
	BAY LEAF	-3.55608	23.19282	1.000	-85.6844	78.5722
	CLOVES	12.55159	23.19282	1.000	-69.5767	94.6799
	AFRICAN NUTMEG	-12.71333	23.19282	1.000	-94.8416	69.4150
	CHILLI PEPPER	15.67422	23.19282	.999	-66.4541	97.8025
ROSEMARY	GINGER	-127.47903*	23.19282	**.001**	-209.6073	-45.3507
	GARLIC	-17.04064	23.19282	.999	-99.1689	65.0876
	ANISEED	-20.51854	23.19282	.995	-102.6468	61.6097
	GRAINS OF PARADISE	-26.89273	23.19282	.971	-109.0210	55.2356
	NEGRO PEPPER	-.27949	23.19282	1.000	-82.4078	81.8488
	BAY LEAF	-20.59672	23.19282	.995	-102.7250	61.5316
	CLOVES	-4.48906	23.19282	1.000	-86.6173	77.6392
	AFRICAN NUTMEG	-29.75398	23.19282	.946	-111.8823	52.3743
	CHILLI PEPPER	-1.36642	23.19282	1.000	-83.4947	80.7619
ANISEED	GINGER	-106.96049*	23.19282	**.005**	-189.0888	-24.8322
	GARLIC	3.47790	23.19282	1.000	-78.6504	85.6062
	ROSEMARY	20.51854	23.19282	.995	-61.6097	102.6468
	GRAINS OF PARADISE	-6.37419	23.19282	1.000	-88.5025	75.7541
	NEGRO PEPPER	20.23906	23.19282	.996	-61.8892	102.3673
	BAY LEAF	-.07818	23.19282	1.000	-82.2065	82.0501
	CLOVES	16.02949	23.19282	.999	-66.0988	98.1578
	AFRICAN NUTMEG	-9.23543	23.19282	1.000	-91.3637	72.8929

	CHILLI PEPPER	19.15212	23.19282	.997	-62.9762	101.2804
	GINGER	-100.58630*	23.19282	**.009**	-182.7146	-18.4580
	GARLIC	9.85209	23.19282	1.000	-72.2762	91.9804
	ROSEMARY	26.89273	23.19282	.971	-55.2356	109.0210
	ANISEED	6.37419	23.19282	1.000	-75.7541	88.5025
GRAINS OF PARADISE	NEGRO PEPPER	26.61324	23.19282	.973	-55.5150	108.7415
	BAY LEAF	6.29601	23.19282	1.000	-75.8323	88.4243
	CLOVES	22.40368	23.19282	.991	-59.7246	104.5320
	AFRICAN NUTMEG	-2.86124	23.19282	1.000	-84.9895	79.2670
	CHILLI PEPPER	25.52631	23.19282	.979	-56.6020	107.6546
	GINGER	-127.19954*	23.19282	**.001**	-209.3278	-45.0713
	GARLIC	-16.76116	23.19282	.999	-98.8894	65.3671
	ROSEMARY	.27949	23.19282	1.000	-81.8488	82.4078
	ANISEED	-20.23906	23.19282	.996	-102.3673	61.8892
NEGRO PEPPER	GRAINS OF PARADISE	-26.61324	23.19282	.973	-108.7415	55.5150
	BAY LEAF	-20.31723	23.19282	.996	-102.4455	61.8111
	CLOVES	-4.20957	23.19282	1.000	-86.3379	77.9187
	AFRICAN NUTMEG	-29.47449	23.19282	.949	-111.6028	52.6538
	CHILLI PEPPER	-1.08693	23.19282	1.000	-83.2152	81.0414
	GINGER	-106.88231*	23.19282	**.005**	-189.0106	-24.7540
	GARLIC	3.55608	23.19282	1.000	-78.5722	85.6844
	ROSEMARY	20.59672	23.19282	.995	-61.5316	102.7250
	ANISEED	.07818	23.19282	1.000	-82.0501	82.2065
BAY LEAF	GRAINS OF PARADISE	-6.29601	23.19282	1.000	-88.4243	75.8323
	NEGRO PEPPER	20.31723	23.19282	.996	-61.8111	102.4455
	CLOVES	16.10767	23.19282	.999	-66.0206	98.2360
	AFRICAN NUTMEG	-9.15726	23.19282	1.000	-91.2855	72.9710
	CHILLI PEPPER	19.23030	23.19282	.997	-62.8980	101.3586
	GINGER	-122.98998*	23.19282	**.001**	-205.1183	-40.8617
	GARLIC	-12.55159	23.19282	1.000	-94.6799	69.5767
	ROSEMARY	4.48906	23.19282	1.000	-77.6392	86.6173
	ANISEED	-16.02949	23.19282	.999	-98.1578	66.0988
CLOVES	GRAINS OF PARADISE	-22.40368	23.19282	.991	-104.5320	59.7246
	NEGRO PEPPER	4.20957	23.19282	1.000	-77.9187	86.3379
	BAY LEAF	-16.10767	23.19282	.999	-98.2360	66.0206
	AFRICAN NUTMEG	-25.26492	23.19282	.980	-107.3932	56.8634
	CHILLI PEPPER	3.12263	23.19282	1.000	-79.0057	85.2509
	GINGER	-97.72506*	23.19282	**.012**	-179.8533	-15.5968
	GARLIC	12.71333	23.19282	1.000	-69.4150	94.8416
AFRICAN	ROSEMARY	29.75398	23.19282	.946	-52.3743	111.8823
NUTMEG	ANISEED	9.23543	23.19282	1.000	-72.8929	91.3637
	GRAINS OF PARADISE	2.86124	23.19282	1.000	-79.2670	84.9895
	NEGRO PEPPER	29.47449	23.19282	.949	-52.6538	111.6028

	BAY LEAF	9.15726	23.19282	1.000	-72.9710	91.2855
	CLOVES	25.26492	23.19282	.980	-56.8634	107.3932
	CHILLI PEPPER	28.38756	23.19282	.959	-53.7407	110.5158
	GINGER	-126.11261*	23.19282	**.001**	-208.2409	-43.9843
	GARLIC	-15.67422	23.19282	.999	-97.8025	66.4541
	ROSEMARY	1.36642	23.19282	1.000	-80.7619	83.4947
	ANISEED	-19.15212	23.19282	.997	-101.2804	62.9762
CHILLI PEPPER	GRAINS OF PARADISE	-25.52631	23.19282	.979	-107.6546	56.6020
	NEGRO PEPPER	1.08693	23.19282	1.000	-81.0414	83.2152
	BAY LEAF	-19.23030	23.19282	.997	-101.3586	62.8980
	CLOVES	-3.12263	23.19282	1.000	-85.2509	79.0057
	AFRICAN NUTMEG	-28.38756	23.19282	.959	-110.5158	53.7407

Source: Field data, 2023

Appendix E

Multiple Comparisons for Pb concentrations in the ten spices from Abura Market

Dependent Variable: Pb

Tukey HSD

(I) SPICE	(J) SPICE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
GINGER	GARLIC	64.20749	20.30018	.105	-7.6776	136.0926
	ROSEMARY	-76.15856*	20.30018	**.032**	-148.0437	-4.2734
	ANISEED	-83.95977*	20.30018	**.014**	-155.8449	-12.0746
	GRAINS OF PARADISE	37.97131	20.30018	.687	-33.9138	109.8564
	NEGRO PEPPER	55.08047	20.30018	.233	-16.8047	126.9656
	BAY LEAF	68.10494	20.30018	.073	-3.7802	139.9901
	CLOVES	-58.64942	20.30018	.173	-130.5346	13.2357
	AFRICAN NUTMEG	63.38798	20.30018	.113	-8.4972	135.2731
	CHILLI PEPPER	-135.43729*	20.30018	**.000**	-207.3224	-63.5522
GARLIC	GINGER	-64.20749	20.30018	.105	-136.0926	7.6776
	ROSEMARY	-140.36604*	20.30018	**.000**	-212.2512	-68.4809
	ANISEED	-148.16726*	20.30018	**.000**	-220.0524	-76.2821
	GRAINS OF PARADISE	-26.23618	20.30018	.944	-98.1213	45.6490
	NEGRO PEPPER	-9.12702	20.30018	1.000	-81.0122	62.7581
	BAY LEAF	3.89746	20.30018	1.000	-67.9877	75.7826
	CLOVES	-122.85691*	20.30018	**.000**	-194.7420	-50.9718
	AFRICAN NUTMEG	-.81951	20.30018	1.000	-72.7046	71.0656
	CHILLI PEPPER	-199.64478*	20.30018	**.000**	-271.5299	-127.7596
ROSEMARY	GINGER	76.15856*	20.30018	**.032**	4.2734	148.0437
	GARLIC	140.36604*	20.30018	**.000**	68.4809	212.2512
	ANISEED	-7.80121	20.30018	1.000	-79.6863	64.0839
	GRAINS OF PARADISE	114.12987*	20.30018	**.001**	42.2447	186.0150
	NEGRO PEPPER	131.23902*	20.30018	**.000**	59.3539	203.1242
	BAY LEAF	144.26350*	20.30018	**.000**	72.3784	216.1486
	CLOVES	17.50913	20.30018	.996	-54.3760	89.3943

	AFRICAN NUTMEG	139.54653*	20.30018	**.000**	67.6614	211.4317
	CHILLI PEPPER	-59.27873	20.30018	.164	-131.1639	12.6064
	GINGER	83.95977*	20.30018	**.014**	12.0746	155.8449
	GARLIC	148.16726*	20.30018	**.000**	76.2821	220.0524
	ROSEMARY	7.80121	20.30018	1.000	-64.0839	79.6863
	GRAINS OF PARADISE	121.93108*	20.30018	**.000**	50.0459	193.8162
ANISEED	NEGRO PEPPER	139.04023*	20.30018	**.000**	67.1551	210.9254
	BAY LEAF	152.06471*	20.30018	**.000**	80.1796	223.9498
	CLOVES	25.31034	20.30018	.955	-46.5748	97.1955
	AFRICAN NUTMEG	147.34774*	20.30018	**.000**	75.4626	219.2329
	CHILLI PEPPER	-51.47752	20.30018	.308	-123.3627	20.4076
	GINGER	-37.97131	20.30018	.687	-109.8564	33.9138
	GARLIC	26.23618	20.30018	.944	-45.6490	98.1213
	ROSEMARY	-114.12987*	20.30018	**.001**	-186.0150	-42.2447
	ANISEED	-121.93108*	20.30018	**.000**	-193.8162	-50.0459
	NEGRO PEPPER	17.10916	20.30018	.997	-54.7760	88.9943
GRAINS OF PARADISE	BAY LEAF	30.13363	20.30018	.883	-41.7515	102.0188
	CLOVES	-96.62073*	20.30018	**.004**	-168.5059	-24.7356
	AFRICAN NUTMEG	25.41667	20.30018	.954	-46.4685	97.3018
	CHILLI PEPPER	-173.40860*	20.30018	**.000**	-245.2937	-101.5235
	GINGER	-55.08047	20.30018	.233	-126.9656	16.8047
	GARLIC	9.12702	20.30018	1.000	-62.7581	81.0122
	ROSEMARY	-131.23902*	20.30018	**.000**	-203.1242	-59.3539
	ANISEED	-139.04023*	20.30018	**.000**	-210.9254	-67.1551
	GRAINS OF PARADISE	-17.10916	20.30018	.997	-88.9943	54.7760
NEGRO PEPPER	BAY LEAF	13.02448	20.30018	1.000	-58.8607	84.9096
	CLOVES	-113.72989*	20.30018	**.001**	-185.6150	-41.8448
	AFRICAN NUTMEG	8.30751	20.30018	1.000	-63.5776	80.1926
	CHILLI PEPPER	-190.51776*	20.30018	**.000**	-262.4029	-118.6326
	GINGER	-68.10494	20.30018	.073	-139.9901	3.7802
	GARLIC	-3.89746	20.30018	1.000	-75.7826	67.9877
	ROSEMARY	-144.26350*	20.30018	**.000**	-216.1486	-72.3784
	ANISEED	-152.06471*	20.30018	**.000**	-223.9498	-80.1796
BAY LEAF	GRAINS OF PARADISE	-30.13363	20.30018	.883	-102.0188	41.7515
	NEGRO PEPPER	-13.02448	20.30018	1.000	-84.9096	58.8607
	CLOVES	-126.75437*	20.30018	**.000**	-198.6395	-54.8692

	AFRICAN NUTMEG	-4.71697	20.30018	1.000	-76.6021	67.1682
	CHILLI PEPPER	-203.54223*	20.30018	**.000**	-275.4274	-131.6571
	GINGER	58.64942	20.30018	.173	-13.2357	130.5346
	GARLIC	122.85691*	20.30018	**.000**	50.9718	194.7420
	ROSEMARY	-17.50913	20.30018	.996	-89.3943	54.3760
	ANISEED	-25.31034	20.30018	.955	-97.1955	46.5748
CLOVES	GRAINS OF PARADISE	96.62073*	20.30018	**.004**	24.7356	168.5059
	NEGRO PEPPER	113.72989*	20.30018	**.001**	41.8448	185.6150
	BAY LEAF	126.75437*	20.30018	**.000**	54.8692	198.6395
	AFRICAN NUTMEG	122.03740*	20.30018	**.000**	50.1523	193.9225
	CHILLI PEPPER	-76.78787*	20.30018	**.030**	-148.6730	-4.9027
	GINGER	-63.38798	20.30018	.113	-135.2731	8.4972
	GARLIC	.81951	20.30018	1.000	-71.0656	72.7046
	ROSEMARY	-139.54653*	20.30018	**.000**	-211.4317	-67.6614
	ANISEED	-147.34774*	20.30018	**.000**	-219.2329	-75.4626
AFRICAN NUTMEG	GRAINS OF PARADISE	-25.41667	20.30018	.954	-97.3018	46.4685
	NEGRO PEPPER	-8.30751	20.30018	1.000	-80.1926	63.5776
	BAY LEAF	4.71697	20.30018	1.000	-67.1682	76.6021
	CLOVES	-122.03740*	20.30018	**.000**	-193.9225	-50.1523
	CHILLI PEPPER	-198.82527*	20.30018	**.000**	-270.7104	-126.9401
	GINGER	135.43729*	20.30018	**.000**	63.5522	207.3224
	GARLIC	199.64478*	20.30018	**.000**	127.7596	271.5299
	ROSEMARY	59.27873	20.30018	**.164**	-12.6064	131.1639
	ANISEED	51.47752	20.30018	.308	-20.4076	123.3627
CHILLI PEPPER	GRAINS OF PARADISE	173.40860*	20.30018	**.000**	101.5235	245.2937
	NEGRO PEPPER	190.51776*	20.30018	**.000**	118.6326	262.4029
	BAY LEAF	203.54223*	20.30018	**.000**	131.6571	275.4274
	CLOVES	76.78787*	20.30018	**.030**	4.9027	148.6730
	AFRICAN NUTMEG	198.82527*	20.30018	**.000**	126.9401	270.7104

Source: Field data, 2023

APPENDIX F
Multiple comparisons for Cu concentrations from both markets

(I) SPICE	(J) SPICE	Mean Difference (I-J)	Std. Error	Sig.	conclusion
	GARLIC	59.67253*	15.72963	**.013**	**Reject**
	ROSEMARY	62.84673*	15.72963	**.007**	**Reject**
	ANISEED	54.06706*	15.72963	**.036**	**Reject**
	GRAINS OF PARADISE	52.49688*	15.72963	**.047**	**Reject**
GINGER	NEGRO PEPPER	72.83548*	15.72963	**.001**	**Reject**
	BAY LEAF	58.23581*	15.72963	**.017**	**Reject**
	CLOVES	67.36475*	15.72963	**.003**	**Reject**
	AFRICAN NUTMEG	47.85833	15.72963	.096	Fail to reject
	CHILLI PEPPER	69.84955*	15.72963	**.002**	**Reject**
	GINGER	-59.67253*	15.72963	**.013**	**Reject**
	ROSEMARY	3.17419	15.72963	1.000	Fail to reject
	ANISEED	-5.60547	15.72963	1.000	Fail to reject
	GRAINS OF PARADISE	-7.17566	15.72963	1.000	Fail to reject
GARLIC	NEGRO PEPPER	13.16294	15.72963	.998	Fail to reject
	BAY LEAF	-1.43673	15.72963	1.000	Fail to reject
	CLOVES	7.69222	15.72963	1.000	Fail to reject
	AFRICAN NUTMEG	-11.81420	15.72963	.999	Fail to reject
	CHILLI PEPPER	10.17702	15.72963	1.000	Fail to reject
	GINGER	-62.84673*	15.72963	**.007**	**Reject**
	GARLIC	-3.17419	15.72963	1.000	Fail to reject
	ANISEED	-8.77967	15.72963	1.000	Fail to reject
	GRAINS OF PARADISE	-10.34985	15.72963	1.000	Fail to reject
ROSEMARY	NEGRO PEPPER	9.98875	15.72963	1.000	Fail to reject
	BAY LEAF	-4.61092	15.72963	1.000	Fail to reject
	CLOVES	4.51802	15.72963	1.000	Fail to reject
	AFRICAN NUTMEG	-14.98839	15.72963	.994	Fail to reject
	CHILLI PEPPER	7.00282	15.72963	1.000	Fail to reject
	GINGER	-54.06706*	15.72963	**.036**	**Reject**
	GARLIC	5.60547	15.72963	1.000	Fail to reject
	ROSEMARY	8.77967	15.72963	1.000	Fail to reject
	GRAINS OF PARADISE	-1.57018	15.72963	1.000	Fail to reject
ANISEED	NEGRO PEPPER	18.76842	15.72963	.970	Fail to reject
	BAY LEAF	4.16874	15.72963	1.000	Fail to reject
	CLOVES	13.29769	15.72963	.997	Fail to reject
	AFRICAN NUTMEG	-6.20873	15.72963	1.000	Fail to reject
	CHILLI PEPPER	15.78249	15.72963	.991	Fail to reject
GRAINS	GINGER	-52.49688*	15.72963	**.047**	**Reject**
OF	GARLIC	7.17566	15.72963	1.000	Fail to reject

PARADISE	ROSEMARY	10.34985	15.72963	1.000	Fail to reject
	ANISEED	1.57018	15.72963	1.000	Fail to reject
	NEGRO PEPPER	20.33860	15.72963	.951	Fail to reject
	BAY LEAF	5.73893	15.72963	1.000	Fail to reject
	CLOVES	14.86787	15.72963	.994	Fail to reject
	AFRICAN NUTMEG	-4.63854	15.72963	1.000	Fail to reject
	CHILLI PEPPER	17.35267	15.72963	.982	Fail to reject
	GINGER	-72.83548*	15.72963	**.001**	**Reject**
	GARLIC	-13.16294	15.72963	.998	Fail to reject
	ROSEMARY	-9.98875	15.72963	1.000	Fail to reject
NEGRO PEPPER	ANISEED	-18.76842	15.72963	.970	Fail to reject
	GRAINS OF PARADISE	-20.33860	15.72963	.951	Fail to reject
	BAY LEAF	-14.59967	15.72963	.995	Fail to reject
	CLOVES	-5.47073	15.72963	1.000	Fail to reject
	AFRICAN NUTMEG	-24.97714	15.72963	.848	Fail to reject
	CHILLI PEPPER	-2.98593	15.72963	1.000	Fail to reject
	GINGER	-58.23581*	15.72963	**.017**	**Reject**
	GARLIC	1.43673	15.72963	1.000	Fail to reject
	ROSEMARY	4.61092	15.72963	1.000	Fail to reject
	ANISEED	-4.16874	15.72963	1.000	Fail to reject
BAY LEAF	GRAINS OF PARADISE	-5.73893	15.72963	1.000	Fail to reject
	NEGRO PEPPER	14.59967	15.72963	.995	Fail to reject
	CLOVES	9.12894	15.72963	1.000	Fail to reject
	AFRICAN NUTMEG	-10.37747	15.72963	1.000	Fail to reject
	CHILLI PEPPER	11.61374	15.72963	.999	Fail to reject
	GINGER	-67.36475*	15.72963	**.003**	**Reject**
	GARLIC	-7.69222	15.72963	1.000	Fail to reject
	ROSEMARY	-4.51802	15.72963	1.000	Fail to reject
	ANISEED	-13.29769	15.72963	.997	Fail to reject
CLOVES	GRAINS OF PARADISE	-14.86787	15.72963	.994	Fail to reject
	NEGRO PEPPER	5.47073	15.72963	1.000	Fail to reject
	BAY LEAF	-9.12894	15.72963	1.000	Fail to reject
	AFRICAN NUTMEG	-19.50642	15.72963	.962	Fail to reject
	CHILLI PEPPER	2.48480	15.72963	1.000	Fail to reject
	GINGER	-47.85833	15.72963	.096	Fail to reject
	GARLIC	11.81420	15.72963	.999	Fail to reject
	ROSEMARY	14.98839	15.72963	.994	Fail to reject
AFRICAN	ANISEED	6.20873	15.72963	1.000	Fail to reject
NUTMEG	GRAINS OF PARADISE	4.63854	15.72963	1.000	Fail to reject
	NEGRO PEPPER	24.97714	15.72963	.848	Fail to reject
	BAY LEAF	10.37747	15.72963	1.000	Fail to reject
	CLOVES	19.50642	15.72963	.962	Fail to reject

CHILLI PEPPER	CHILLI PEPPER	21.99122	15.72963	.922	Fail to reject
	GINGER	-69.84955*	15.72963	**.002**	**Reject**
	GARLIC	-10.17702	15.72963	1.000	Fail to reject
	ROSEMARY	-7.00282	15.72963	1.000	Fail to reject
	ANISEED	-15.78249	15.72963	.991	Fail to reject
	GRAINS OF PARADISE	-17.35267	15.72963	.982	Fail to reject
	NEGRO PEPPER	2.98593	15.72963	1.000	Fail to reject
	BAY LEAF	-11.61374	15.72963	.999	Fail to reject
	CLOVES	-2.48480	15.72963	1.000	Fail to reject
	AFRICAN NUTMEG	-21.99122	15.72963	.922	Fail to reject

Source: Field data, 2023; **Reject: reject null hypothesis; **Fail to reject: fail to reject null hypothesis

APPENDIX G

Ethical clearance

UNIVERSITY OF CAPE COAST

INSTITUTIONAL REVIEW BOARD SECRETARIAT

TEL: 0558093143 / 0508878309
E-MAIL: irb@ucc.edu.gh
OUR REF: UCC/IRB/A/2016/1540
YOUR REF:
OMB NO: 0990-0279
IORG #: IORG0009096

7TH SEPTEMBER, 2022

Ms. Winnifred Peace Mensah
Department of Vocational and Technical Education
University of Cape Coast

Dear Ms. Mensah,

ETHICAL CLEARANCE – ID (UCCIRB/CES/2022/62)

The University of Cape Coast Institutional Review Board (UCCIRB) has granted Provisional Approval for the implementation of your research **Determination of Heavy Metals in Spices.** This approval is valid from 7th September, 2022 to 6th September, 2023. You may apply for a renewal subject to 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 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,

Samuel Asiedu Owusu, PhD

UCCIRB Administrator

ADMINISTRATOR
INSTITUTIONAL REVIEW BOARD
UNIVERSITY OF CAPE COAST