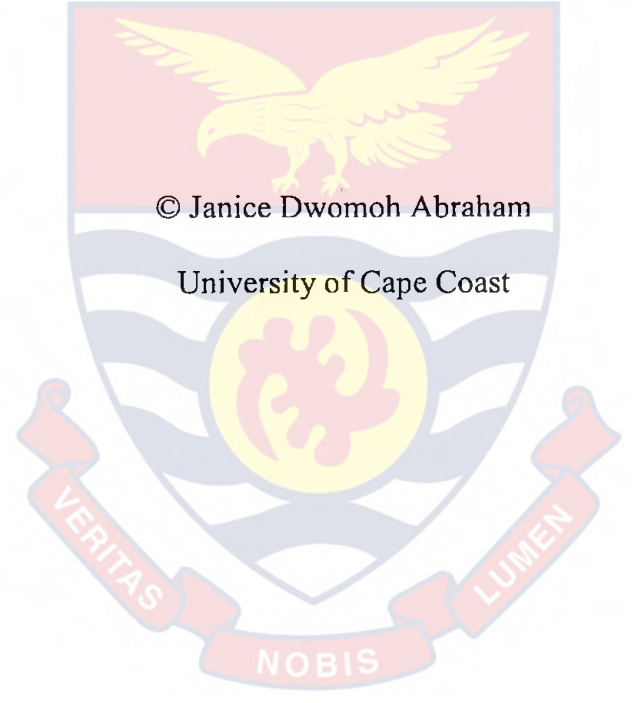
UNIVERSITY OF CAPE COAST

NUTRITIONAL QUALITY OF CROPS AND SURFACE WATER QUALITY OF SELECTED COMMUNITIES IN GHANA

JANICE DWOMOH ABRAHAM

2018



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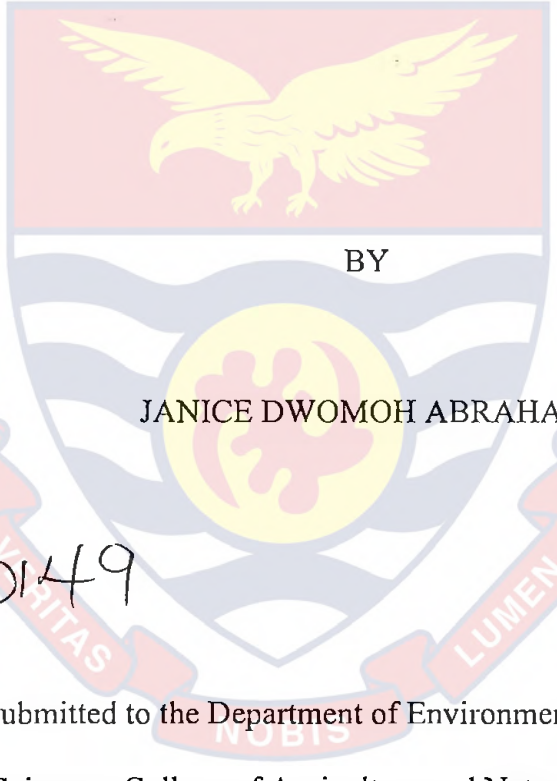

BY

JANICE DWOMOH ABRAHAM

Thesis Submitted to the Department of Environmental Science, School of Biological Sciences, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of Doctor of Philosophy Degree in Botany

NOVEMBER, 2018

DECLARATIONS

Candidate's Declaration

I hereby declare that this thesis is the results 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: 03-05-2019

Name: Janice Dwomoh Abraham

Supervisors' Declaration

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

Principal Supervisor's Signature:..... Date: 09-05-2019

Name: Prof. Hugh Komla Akotoye

Co- Supervisor's Signature:..... Date: 09-05-201

Name: Prof. Frederick Ato Armah

ABSTRACT

Like any other country, Ghana is working to achieve the Sustainable Development Goals, part of which is targeted at ending hunger and ensuring clean water by 2030. In line with these, this study investigated what people eat at the household level, assessed the micronutrient concentrations in three varieties of maize, four varieties of plantain, two varieties of cassava and some fruits and vegetables eaten by Ghanaians. The study also investigated the relationship between micronutrient concentration in the soil and the crop. Additionally, the micronutrient content in some surface water bodies and the microbial loads in those water bodies were assessed. A household survey covering 3521 households was conducted in all ten regions of Ghana. Laboratory analyses were conducted to identify the micronutrient concentrations in the food crops and water from different water bodies. Moreover, the microbial loads of the different water bodies were analyzed. Findings from this study showed that respondents eat vegetables, fruits, animal products and maize on daily bases, and cassava and plantain on weekly bases. The region in which respondents live influence their consumption of vegetables ($\chi^2_{(45, 3521)} = 2.7 \times 10^3$, $P < 0.001$; Cramér's V = 0.3887), fruits ($\chi^2_{(45, 3521)} = 2.5 \times 10^3$; $P < 0.001$; Cramér's V = 0.3779), animal products ($\chi^2_{(27, 3521)} = 966.38$, $P < 0.001$; Cramér's V = 0.3025), cassava products ($\chi^2_{(45, 3521)} = 1.7 \times 10^3$, $P < 0.001$; Cramér's V = 0.3125), plantain ($\chi^2_{(45, 3521)} = 2.8 \times 10^3$, $P < 0.001$; Cramér's V = 0.3996) and maize ($\chi^2_{(36, 3521)} = 1.4 \times 10^3$, $P < 0.001$; Cramér's V = 0.3099). It was observed that 66% of respondents depended on pipe borne water for drinking. This study also revealed that within the same species of crop, the micronutrient concentration varied among

varieties. The soil also influenced the micronutrients in the crop. The pH of the soil influenced the amount of micronutrients in the crops investigated. The anthropogenic activities along the water bodies studied affected the purity of their water. Findings of this study suggest that females are very influential in determining the food eaten at the household but the expenditure on food is mostly borne by men. Education, ecological location, and community setting have influence of the food and water consumed at the household. There is therefore the need for people to diversify their food in order to obtain all the required micronutrient needed for the proper functioning of the body. Measures should be put in place to protect all surface water bodies since they are the main source of water supply as well as replenishing underground water.

KEY WORDS

Beta carotene

Hidden hunger

Micronutrient

Nutrition

Soil

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DEDICATION

To my family, my husband John and children Janice, John, Jayne and Jenette Abraham.

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LIST OF ACRONYMS

FAO	Food and Agriculture Organization
GWCL	Ghana Water Company Limited
IAA	Indoleacetic acid
IDA	Iron Deficiency Anaemia
IFAD	International Fund for Agricultural Development
ILSI	International Life Sciences Institute
MDGs	Millennium development goals
SDGs	Sustainable Development Goals
UN	Unites Nations
UNICEF	United Nations International Children's Emergency Fund
VAD	Vitamin A deficiency
WFP	World Food Programme
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

The health of people influences national and supranational development. For instance, it has been shown that, the human capital of a nation is affected if there are growth defects in children during the first two years of life (Gertler *et al.*, 2014). The growth defects partly come about as a result of poor nutrition (food) (Branca & Ferrari, 2002) and this could persist over several generations (Addo *et al.*, 2015; Walker, Chang, Wright, Osmond & Grantham-McGregor, 2015). Poor nutrition could even lead to death (Thapar & Sanderson, 2004). Good nutrition supports good health of both plants and animals (Lichtenstein & Russell, 2005; Thorning *et al.*, 2016; Lucena, & Hernandez-Apaolaza, 2017; uz Zaman *et al.*, 2018).

Many a time, malnutrition is examined from the perspective of macronutrients. Usually, micronutrient deficiency is pushed to the background (Annibale *et al.*, 2003; Manzanares & Hardy 2010; Biesalski, 2016). Micronutrient deficiencies lead to permanent destruction of some organs such as the eye and cause impairment in the functioning of affected organisms (Biesalski, 2013; Biesalski, 2016). These destructions and impairments are irreversible and the micronutrient deficiency that causes them is usually referred to as 'hidden hunger'. Hidden hunger leads to destruction and in some cases death of both plants and animals, especially humans (Huber, 2000; Biesalski, 2013; Biesalski, 2016). In humans, Iron, Zinc and Vitamin A deficiency is known to cause stunting, eye defect and poor immune system functioning (Biesalski, 2016). These result in preventable blindness, low

cognition and diarrhoea in children and in some cases death (Biesalski, 2013; von Grebmer *et al.*, 2014; Biesalski, 2016).

Minerals in water bodies have the potential to improve micronutrient levels in plants and animals. Unfortunately, these water bodies in Ghana are polluted due to anthropogenic activities such as mining and farming that go on around them (Armah *et al.*, 2010; Obiri, Dodoo, Essumang, & Armah, 2010). The pollution of water bodies may result in microbial growth in the water body thereby making it unsafe for drinking (Ashbolt, 2015; Chen *et al.*, 2017; Luo, 2019; Rayasam, Ray, Smith & Riley, 2019).

Background to the Study

Food insecurity and quality water supply have become a worldwide problem that needs serious attention (Copenhagen Consensus, 2008; 2012; Hoddinott, Rosegrant, & Torero, 2012). A new agreement at the United Nations (UN) Conference on Sustainable Development in 2012 set new goals referred to as the Universal Sustainable Development Goals (SDGs) which came into force in 2016. To achieve the SDGs it is imperative for all governments to work even harder than they did for the MDGs at combating food and water scarcity (Osborn, Cutter & Ullah, 2015). The WHO defines hunger in terms of the minimum daily requirement of energy which currently stands on average at 1874kcal per person per day (Biesalski, 2013).

'Hidden hunger' is said to be "a lack of vitamin A, iron, zinc, and iodine simply due to the fact that a deficiency of any of these micronutrients can lead to visible clinical symptoms such as permanent brain damage, poor sight and goiter which affect most people worldwide" (Kennedy, Nantel, & Shetty, 2003; Biesalski, 2013; Dimkpa & Bindraban, 2016). It is also said to

be "a state of chronic malnutrition whereby ones very last energy reserves are not utilized to search for food but rather are 'saved'. The 'saving' of energy, however, is only possible as long as the body still has reserves – starting with the small amounts of fat that are left in the body and the protein in the muscles. After these reserves are gone, the body starts to metabolize the depots that are essential for performing bodily functions. In the end the body consumes itself by attempting to extract the remaining bit of protein and energy that are contained in the vital organs. This leads to stint in growth and development among children and to varying degrees of incapacitation and limited mobility among adults" (Biesalski, 2013). Hidden hunger, also known as micronutrient deficiencies, afflicts more than 2 billion individuals, or one in three people, globally (FAO, 2013). Its effects can be devastating, leading to mental impairment and poor health which leads to low productivity, and even death. Its adverse effects on child health and survival are particularly acute, especially within the first 1,000 days of a child's life, from conception to the age of two, resulting in serious physical and cognitive consequences (von Grebmer *et al.*, 2014).

Indeed "hidden hunger" arises from the over dependence on crops such as cereals and tubers because, cereals and starchy root tubers in general provide very small amount of the daily required micronutrients that will ensure nutritional security (Nuss & Tanumihardjo, 2010; Noack & Pouw, 2015; Dimkpa & Bindraban, 2016). There have been a number of food surveys and food quality analyses in Ghana notably, den Hartog (1972), and World Food Programme (2012). den Hartog (1972) used questionnaire to obtain some information on preferences for traditional and imported foods in Ghana

while WFP (2012) assessed the food eaten in some regions in the country. Souganidis (2011) reported that, the absence of micronutrients in the diet of people usually results in poor health conditions such as poor eye sight, night blindness, stunted growth, and poor body and mental development.

It is known that vitamin A, zinc, iron and manganese are very important for pre- and post-natal development (Caulfield, Zavaleta, Shankar & Merialdi., 1998; Brown, Wuehler, & Peerson, 2001; Khan, 2013; Lu, Lu, Li, & Zhang, 2014). These vitamin and minerals are needed for the proper functioning of the eye and metabolic functioning of the body (Kennedy *et al.*, 2003; Nuss & Tanumihardjo, 2010; Biesalski, 2013; Biesalski, 2016).These micronutrients are even more important for pregnant women and children living in developing countries since they are among the most vulnerable in society. To ensure proper growth of the vulnerable in society, there is the need to find means of sustaining the micronutrient supply of their diet. This could be achieved by producing staple foods of better quality and with adequate micronutrients content (i.e. vitamin A, zinc, iron, copper and manganese). It can also be achieved if the varieties with species of some staple crops are investigated to identify the mineral potentials of these crops to enhance selection and breeding.

Water is life, and access to clean and safe drinking water is essential for protecting public health (Mintz, Bartram, Lochery, & Wegelin, 2001; Montgomery & Elimelech, 2007). It is estimated that 75% of the human body is water (Helmenstine, 2018) indicating that water is one of the prime elements of life on earth and is a vital resource for human survival. Though humans use water regularly, people think very little about its place in human

lives. This is evident in the rise of pollution levels of water bodies worldwide (Schwarzenbach, Egli, Hofstetter, von Gunten, & Wehrli, 2010; Zhang *et al.*, 2010). Several anthropogenic activities including bathing, washing, mining and dumping of refuse contribute to water pollution (Figure 1).

Figure 1: Washing of household utensils, rice farming and mining in water bodies in Amisano, Cape Coast in the Central region (A), Juaben in the Ashanti region (B) and Kyebi in the Eastern region (C) respectively.

The microbial load of drinking water is of concern to consumers, suppliers, regulators and public health workers. The World Health Organization (WHO) suggests that hygiene related diseases have a significant impact on human health (WHO, 2004). As at 2009, diarrhoea alone caused about 2.0 million deaths in children under five years every year (Boschi-Pinto, Lanata, & Black, 2009). Recent report suggests that although about 1.7 billion cases of childhood diarrhoeal disease are reported globally every year, the number of deaths due to diarrhoea have reduced to 525,000 per year in children (WHO, 2017). It is important therefore, to provide households with good quality drinking water to prevent water related diseases thereby

enhancing good health among communities. Good quality water with adequate micronutrients can help reduce "hidden hunger" in communities since water forms a major part of the daily dietary consumption of many people. The amount of money that could be used on fortified food and supplements by poor countries could be saved if the country's water is clean and has the right amounts of micronutrients.

High quality water with adequate concentration of micronutrients can also help to achieve the SDGs goal 6 on water and sanitation which will lead to improved health and help eradicate poverty. Therefore, there is a need for strict regulations on activities around water bodies and in the environment in general to help improve the quality of surface water which is used by most households in developing countries for drinking and household activities. It is estimated that over 1.1 billion people in the world do not have good quality water (WHO, 2001). Majority of this population who are in developing countries that depends on rivers and other surface water bodies are part of this statistics. Interestingly, the pollution levels of these countries are rising because of recent increases in anthropogenic activities such as farming, mining and fishing.

Currently, Ghana faces serious challenges relating to safe drinking water and arable land for farming as a result of indiscriminate surface mining popularly known as "galamsey". Galamsey is usually illegal and it degrades forests, destroys farmlands and pollutes water bodies (Aryee, Ntibery, & Atorkui, 2003; Boateng, Nana, Codjoe, & Ofori, 2014). Pollution of water bodies through galamsey is so grave that, there have been suggestions that Ghana may have to import water in the near future (Ashon, 2015; Fiati, 2017).

Hunger, malnutrition and poverty

The nutrient content of food consumed is necessary to ensure a healthy society. Micronutrients and vitamins such as iron, copper, zinc, manganese and vitamin 'A' are needed in food for good health and growth, more especially in children under five years, pregnant women and nursing mothers (Nuss & Tanumihardjo, 2010; Biesalski, 2013). Absence of these micronutrients in food results in "hidden hunger". This medical condition is so serious that it causes stunting and poor eye sight especially in children. Although the global hunger index in Ghana has gone down from 29.9 in 2000 to 15.5 as at 2015 (von Grebmer *et al.*, 2015), hidden hunger and poor water quality continues to be a big challenge in the country. In May 2015, the UN agreed on 17 Sustainable Development Goals (SDGs) as a follow up work on the MDGs. The SDGs seek to eradicate extreme poverty and hunger, promote gender equality and empower women, reduce child mortality. It also seeks to improve maternal health, ensure environmental sustainability and end poverty in all of its form everywhere. Additionally, it seeks to end hunger, achieve food security and improved nutrition and promote sustainable agriculture (UN, 2015a; UN, 2015b). Just like the SDGs are seeking to do, the MDGs also sought to ensure healthy lives and promote well-being for all at all ages, ensure availability and sustainable management of water and sanitation for all (Copenhagen Consensus, 2008).

It is inadequate to consider the nutritional content of the final crop product without considering the nutritional content of the medium in which the crop grows. Moreover, hidden hunger cannot be discussed without considering the available nutrients in the soil in which the plants grow. For

instance, it has been reported that plants cannot easily draw micronutrients such as Iron, Zinc and Copper from the soil to protect themselves and grow as compared to other nutrients and some macronutrients which are easy to come by (Huber, 2000). Furthermore, it has been suggested that high soil pH reduces the availability of micronutrients such as Copper, Iron, Zinc, Manganese etc in the soil and availability of the micronutrient differ from plant to plant due to differences in soil properties (McKenzie, 2003; Begum, Sikder, Khanom, Hossain, & Parveen, 2015; Bravo *et al.*, 2017). However, in the case of the macronutrients, the nutrients become available when the soil pH is high (Bravo *et al.*, 2017). This implies that soil pH plays a critical role in soil micronutrient availability (McKenzie, 2003; Begum *et al.*, 2015) and for that matter influences 'hidden hunger'. Although plants need micronutrients in small quantities, they are of critical importance for the growth and metabolic activities of plants, most especially for the resistance of plants to some diseases (Huber, 2000; Adrees *et al*, 2015). The nature of a plant's nutrition influences its resistance or susceptibility to diseases. Micronutrients play a major role in the nutrition and metabolic functions of the plant (Adrees *et al.*, 2015) by regulating the physiological activities of the plants. Therefore, the devastating effect of micronutrient deficiency is more dangerous than pest attack (Huber, 2000). Unfortunately, farmers pay more attention to pests than the micronutrient content in the soil (Huber, 2000). In fact, it has been observed that micronutrient deficiencies have both direct and indirect impact on crops (Huber, 2000; Adrees *et al*, 2015; Dimkpa & Bindraban, 2016). This must be an area of critical concern to farmers and governments.

Water quality in relation to poverty and health

Life without water is lifeless and the quality of water is key to good health. However, it is expensive to treat water to make it potable. This makes it difficult for the poor in society to access quality drinking water. Current records suggest that about one billion people in the world do not have access to treated tap water or potable water and so depend on polluted surface water and ground water for their daily water needs (Pacific Institute, 2017). These polluted water sources cause a number of water-related diseases such as diarrhoea, typhoid fever, cholera and worm infestation (Pacific Institute, 2017) which has long term consequences on health and even death in some cases.

In 2013, United Nations International Children's Emergency Fund (UNICEF) reported that about 2000 children under five years die daily from diarrhoea and that 1500 of these deaths are linked to water, sanitation and hygiene (UNICEF, 2013). Further reports indicate that about 4500 children die every day from preventable, water- related diseases (UNICEF, 2013). Usually, poverty levels continue to increase if there is no access to potable water because, absence of potable water leads to ill health which requires money to treat. Absence of potable water may also lead to absenteeism from school which will affect education and have negative consequences on the working force of a country. This in turn results in lower income levels of households and consequently, increases the poverty level in the country. The country will also spend a lot of foreign exchange to import drugs to treat the disease conditions and may have a budget deficit.

Ghana stands to lose a lot of money if people do not have access to potable water. There have been recent reports of galamsey activities in the

country's surface water bodies which are making it more expensive for Ghana Water Company to treat water for consumption. For instance, in October 2013, it was reported that the heavy pollution of water bodies is making it too expensive for Ghana Water Company Limited (GWCL) to operate water treatment plants in many mining communities (Yeboah, 2013). This made GWCL shut down water treatment plants in areas where galamsey is rife. One of such communities which had its water treatment plant shut down was Odaso in the Ashanti region which was supplying water to parts of Obuasi and its surrounding communities. The Eastern region of Ghana had serious water crises because River Birim which supplies water to the Kyebi water treatment plant was also heavily affected by the galamsey activities (Afum & Owusu, 2016, Hadzi, Essumang & Adjei, 2015; Hadzi, Essuman & Ayoko, 2018; Baako, Sadick, Awuah, Mahama & Obeng, 2018). The central region was also not left out because heavy pollution in the Pra and Offin River made it difficult for water from these rivers to be treated and supplied to communities that depend on treated water from the Rivers (Duncan, de Vries & Nyarko, 2018). These shut downs causes communities to fall on untreated and polluted surface water or groundwater for their daily water needs. Consumption of contaminated water from the environment will affect the nutritional quality and health of the people and therefore affect the attainment of the SDG goals 1 and 3 which seeks to eradicate poverty and improve health (UN, 2015a).

Statement of the Problem

According to Jati, Vadivel, Nöhr & Biesalski (2012) and Biesalski (2013), people in developing countries eat foods which are deficient in micronutrient partly because of the over dependence on cereals (e.g. maize,

rice, millet) and tubers (e.g. cassava, yam, potato). These cereals and tubers have little micronutrient content (Nuss & Tanumihardjo, 2010; von Grebmer *et al.*, 2014). The micronutrients are essential for diverse metabolic activities in the body (uz Zaman *et al.,* 2018). The absence of these micronutrients leads to permanent health damage in the brain, eyes and also affects other metabolic and enzymatic activities in the organism especially human (Kennedy *et al.*, 2003, Biesalski, 2013; Biesalski, 2016; uz Zaman *et al.*, 2018). Unfortunately, the Ghanaian food basket is dominated by cereals and tubers which are noted for their carbohydrate for energy (von Grebmer *et al.*, 2014). Furthermore, many Ghanaians hardly eat enough vegetables and fruits which are rich in micronutrients. Often, people do not add enough vegetables to their staple food to get enough micronutrients needed by the body (Jati *et al.,* 2012). Children under five years, pregnant women and nursing mothers are especially vulnerable to micronutrient deficiency (Fanzo, 2012). However, some of the traditions and cultural practices in Ghana do not allow pregnant women, nursing mothers and young children to eat some micronutrient-rich foods such as eggs, snails and mango (Gadegbeku, Wayo, Ackah–Badu, Nukpe, & Okai, 2013; Arzoaquoi, *et al.*, 2015).

The focus on food security has always been on yield (Cordell, Drangert & White, 2009) and post-harvest storage. Little attention is paid to the nutritional quality of the food crop that is harvested and the micronutrient content of the soil that harbours the plant (Yang, Chen & Feng, 2007). In view of this, farmers keep cultivating the same piece of land for several years without treating the soil to replenish the lost nutrients, especially the micronutrient content. Therefore, there is a micronutrient deficiency from the

point of planting to the final consumer. This affects the growth and development of the plants and eventually causes hidden hunger in the animals (including humans) that feed on the plants.

Most communities in Ghana are rural whose inhabitants depend on surface water bodies for their domestic water requirements. However, there are a lot of anthropogenic activities that go on around these water bodies that pollute and make them unsafe for drinking and also for domestic use. Gold mining for instance have led to the destruction of many water bodies in Ghana (Aryee *et al.*, 2003; Boateng *et. al.*, 2014) thereby worsening access to portable water. Water bodies contain micronutrients which can serve as alternative micronutrient supplements. The pollution of water bodies due to anthropogenic activities makes it impossible for people to drink the water from these sources, thereby reducing their access to the micronutrients.

Micronutrient deficiency is rife in some of the poorest regions of the world including Ghana (Figure 2). Therefore, this study sought to investigate the composition of the Ghanaian food basket, the concentration of Fe, Zn, Cu, Mn and *beta* carotene in major Ghanaian staple food crops (cassava, maize and plantain) and some fruit and vegetable identify in the food basket. This study will also examine the relationship between the micronutrient content in the soil before planting and after harvesting using cassava and maize as a test case. The Fe, Zn and Cu concentrations in some surface water bodies were also assessed. In addition to that, the microbial loads of such water bodies were also assessed.

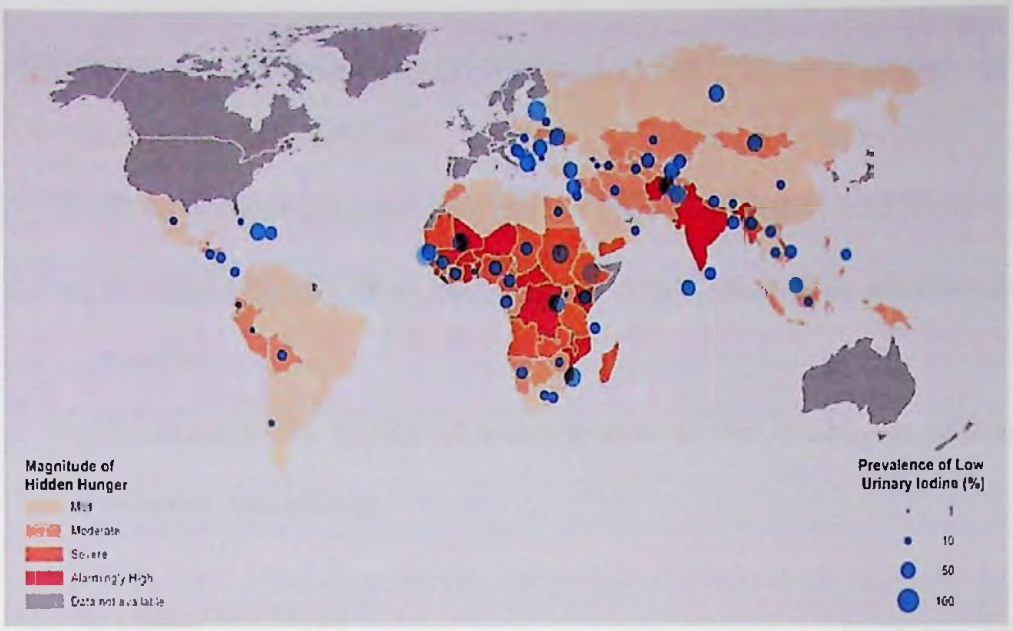

Figure 2: Magnitude of hidden hunger around the world
Source: Muthayya *et al* (2013). Accessed, 12/11/ 2015

Purpose of the Study

In view of the many problems associated with micronutrient deficiency (Branca & Ferrari, 2002; Biesalski, 2013; Addo *et al*., 2015; Walker, Chang, Wright, Osmond & Grantham-McGregor, 2015; Dimkpa & Bindraban, 2016), it is important to diversity the food basket of people in order to maximize the micronutrients obtained from food and water consumed by a household. Therefore, this study will provide information on the composition of the Ghanaian food basket, concentration of Fe, Zn, Cu and Mn in the various food crops and the soil in which crops grow. The concentration of Fe, Zn and Cu in water and the microbial load in such water bodies will also be investigated. The information provided will inform food choices and combination of food crops to maximize micronutrients content in diet. It will also help to educate the people on the need to conserve surface water bodies for the future.

Objectives

The objectives of this study are:

1. To investigate the nutritional status of Ghanaian staple food, especially at the household level with special focus on maize, plantain and cassava.
2. To examine the quality of water sources to the inhabitants of some selected communities.

Significance of the Study

Malnutrition may lead to defective growth which is easily seen in both plants and animals. Therefore, malnutrition can be easily seen and addressed before any permanent harm is caused to either the plant or animal suffering from it. In plants, malnutrition can easily be addressed with the application of fertilizers like NPK or organic manure to the deficient soil. In humans, deficiencies can be addressed by giving a good balanced diet to the person or administering nutrient supplements to the affected person to correct the defect. However, one cannot say same about micronutrient deficiency in both plants and animals, especially humans. Micronutrient deficiency may end up causing permanent damage in humans (Biesalski, 2013) and plants (Huber, 2000).

Recent attempts to improve micronutrients supply in Ghana by studying and providing supplement to pregnant women and children under 5 years did not yield the desired results. Moreover, work on nutrients in food consumed in Ghana has so far not focused on analysing micronutrients such as vitamin A, iron, copper, zinc and manganese. This work will analyse the nutritional status of Ghanaian staple food at the household level with special

focus on maize, plantain and cassava. It will also examine the quality of water sources to the inhabitants of communities.

The results from the study will provide information on the micronutrient concentration of the food items studied, especially the focus staple crops, namely, plantain, cassava and maize. It will also help identify some fruits and vegetables that are micronutrient rich and can be used to supplement micronutrient deficient diet in Ghana. Findings from this study will help farmers to decide on which soils are good for farming for quality and nutrient-rich crops. It will also help farmers to decide on the type of fertilizer to use for farming to prevent 'hidden hunger' in plants.

In addition, this study will help identify the possible micronutrient that can be obtained from water bodies to help in the management of micronutrient deficiency. It will also help educate people on the need to prevent water pollution to prevent some water related disease. This will inform policy formulation and help put measures in place to protect these water bodies.

Delimitation

The study focuses on nutritional quality and surface water quality. The study investigates the food consumed at the household level and also investigates the micronutrient content in the food whose deficiency constitutes hidden hunger. Moreover, the study also investigates how soil affect micronutrient concentration of varieties of maize, plantain and cassava planted in places.

In investigating water quality, the study looks at the sources of drinking water to households. In addition, it also assesses the quality of surface water bodies in nine surface water bodies in the Ashanti, Central and

Eastern regions of Ghana. The water bodies are sources of water supply to the local households in the communities. The study assesses some micronutrient concentrations in the water bodies. The study further assesses the microbial load in those water bodies.

Limitation

The household food survey did not have any means to validate the answers from the respondents to ascertain the facts in the response given. This can affect the results and skew that result in a direction that might not be the exact fact in the society. However, follow up questions were asked to minimize any potential misrepresentation of facts by respondents. Interviews were also used to get much information from respondents to minimize potential biases.

The field experiment was dependent on the natural climatic and soil conditions. Therefore any variation in the climatic condition in the environment may affect the final result and the error margin. There was a high risk of people and animals invading the study fields.

Organisation of the Study

The study covers two thematic areas namely nutrition and water and how they contribute to hidden hunger. Chapter one gives a general introduction of the work, touching on the thematic areas of the research and why it is necessary for the research to be conducted. Chapter two comprise of a review of literature in the subject area. The chapter reviews studies that have been conducted in the area. This is followed by chapter three which considers the materials and methods used for the research. It discusses the experimental

design, equipments used for the analytical studies and the statistical tools used for the analyses of data obtained from the various studies. Results and discussion of the studies in this work are presented in chapters four and five respectively. The conclusion, summary and recommendations are presented in chapter six.

CHAPTER TWO

LITERATURE REVIEW

This study focuses on the quality of surface water and some nutrients of some staple food crops, fruits and vegetables in Ghana. The study also looks at what people are consuming at the household level. (Figure 3)

This chapter reviews nutrition in general, 'hidden hunger' and impact of soil micronutrient levels on the micronutrient levels in food. Additionally, the chapter reviews the effect of anthropogenic activities on water quality.

Conceptual Framework

The conceptual framework of the study is based on what goes into the food basket of typical Ghanaian households, the concentration of micronutrients and beta carotene in some crops in the food basket, how soil deficiency affects food crops and the effect on life. The conceptual framework also takes into account some human activities that results in water pollution and thus prevents assess to micronutrients in these water bodies by the final consumer. Typically, people will avoid polluted water and thus are denied of micronutrient that could be obtained from such water source. The conceptual framework further predicts some of the long term effects of micronutrient deficiency based on literature (Figure 3).

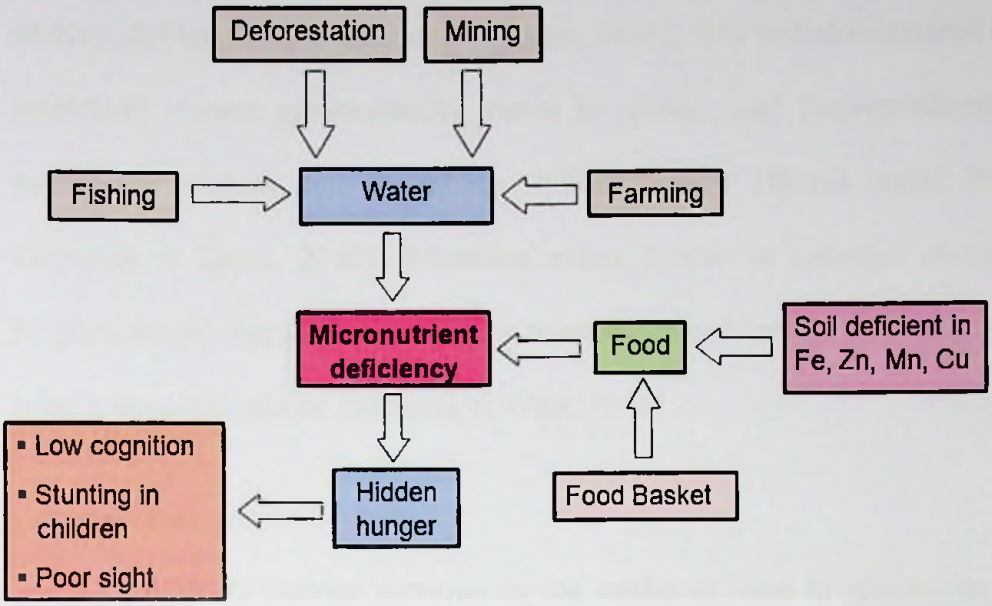

Figure 3: Conceptual framework of the research

From Figure 3, it is clear that hidden hunger leads to low cognition, poor eye sight and stunting in children (Biesalski, 2013, Biesalski, 2016). It emanates from a plethora of factors that manifest at different levels—individual, household, social and geospatial. Primarily, food and water that are deficient in micronutrients and other essential elements drive hidden hunger (Kennedy *et al.*, 2003; Jati *et al.*, 2012; von Grebmer *et al.*, 2014; Sharma *et al.*, 2017). Water quality is intrinsically linked to the survival of plant, humans, fish, and by extension adequate nutrition. Agriculture and mining of minerals may compromise water quality due to pollution and eutrophication (nutrient enrichment). In most cases removal of ground cover and canopy cover depletes top soil of the most essential nutrients needed for plant growth (Waring *et al.*, 2015). Besides this, roles assigned by society and culture, determine household income and household food choices (Quisumbing *et al.*, 1995; FAO, 2001; World Bank, 2009; Chiputwa & Qaim, 2016). In order words, food choices at the household level are structured by society (Bazerghi,

McKay, & Dunn, 2016; Chiputwa & Qaim, 2016). It is well-documented that household income systematically varies by gender and disproportionately predisposes women and children to hidden hunger (World Bank, 2009; Chiputwa & Qaim, 2016). Education either formal or informal mediates people's knowledge on nutrition, how to access it and how to derive optimal benefit from it (Mabuza, Ortmann, & Wale, 2016).

General Overview of Nutrition

The WHO defines nutrition as the intake of food in relation to the body's dietary needs and that adequate, well balanced diet combined with regular physical activity is important for good health (WHO, 2019). The Cambridge dictionary also defines nutrition as the substance that you take into your body as food and the way that the substance influences your health. It also defines nourishment as food that one needs to grow and stay healthy. These include food and water which are ingested to help improve health and promote growth. Humans can therefore boast of good health only when there is clean water supply and well-balanced diet.

There is growing concern about food security due to the fast-growing population in the world. Earlier, issues of nutrition were handled by those in the public health sector. As at now, food security concerns the agriculture sector and other stakeholder groups such as farmers, health workers, policy makers, chiefs, plant scientists and governments. Nutrition has become a concern because there have been several reports on malnutrition, micronutrient deficiency and polluted water and how it affects the life of people (Aryee *et al.*, 2003; Kennedy *et al.*, 2003; World Bank, 2009; Jati *et al.*, 2012; Boateng

et. al., 2014; von Grebmer *et al.*, 2014; Chiputwa & Qaim, 2016; Sharma *et al.*, 2017).

According to the United Nations (UN), over 800 million people across the world go hungry every day (Johns & Sthapit, 2004; Ahmed, *et al.*, 2007) and approximately two billion people in the world suffer from malnutrition or 'hidden hunger' (Bain *et al.*, 2013; von Grebmer *et al.*, 2014; Sharma, Dwivedi, & Singh, 2016). These situations are alarming and so require all stakeholders to play their part to contribute to finding a lasting solution. In view of this, the UN tried to address the problem by including nutrition and food security in its MDGs. Unfortunately, most of the discussions and submissions on food security focus on macronutrient and calories intake and not nutritional security (Noack & Pouw, 2015).

It is important to note that obtaining enough calories to feed the masses does not translate into good nutrition for the people. The nutritional aspect should be considered at any time that food security is discussed to prevent growth defects which might result from poor nutrient supply to the body. The FAO (2012) report showed that sub-Saharan Africa has the highest percentage of malnutrition in the world (FAO, 2012). The International Fund for Agricultural Development (2012) also reported that the Republic of Kenya is estimated to have 43 million people, eighty percent of its population which live in rural areas (IFAD, 2012). If Kenya, which is regarded as one of the most developed countries in East Africa has this huge number of rural settlers, then what can be said of the under developed countries in Africa. The situation in Kenya might not be much different from the situation in Ghana. According

to the 2010 population and housing census, 49.12% of the Ghanaian population is in the rural communities (Ghana Statistical Service, 2012).

Although the number of nourished people in the world as at 2016 is reported to be less than it was about a decade and half ago (900 million in 2000 to 815 million in 2016), the number increased from 777 million in 2015 to 815 million in 2016 (FAO, IFAD, UNICEF, WFP & WHO, 2017). There is therefore the need for stakeholders such as government and researchers to check the cause of food shortage and/or shortage in nutrients and put in appropriates measure to resolve the situation. This is because the situation poses a threat to the stability and achievement of SDG 2 by the year 2030. According to the FAO (2012), the food security situation has worsened in parts of sub-Saharan Africa and South–Eastern and Western Asia (FAO, 2012). Some countries affected by undernourishment include South Sudan, Somalia, Yemen and Nigeria. These countries were affected by undernourishment as a result of conflict, drought and flood (FAO, IFAD, UNICEF, WFP & WHO, 2017). It could therefore be inferred that, the situation would have been different if conflicts were prevented in the affected countries. Conflicts do not allow an enabling environment for agricultural production and as a result compromise nutritional quality of available food. Ultimately, this causes undernourishment in the world. It is always the poor and the rural folks that suffer most when these crises occur in any country in the world. It is worth noting that while the number of undernourished people reduced in Asia from 554.2 in 2010 to 508.3 in 2016, it rather increased in Africa from 191.1in 2010 to 243.2 in 2016 (FAO, IFAD, UNICEF, WFP &

WHO, 2017). Africa has the highest prevalence of undernourished population in the world as at 2016 (FAO, IFAD, UNICEF, WFP & WHO, 2017).

Although there is an increase in the number of under nourished people in the world (FAO, IFAD, UNICEF, WFP & WHO, 2017), the available food contains some of the required nutrients for proper growth. The FAO, IFAD, UNICEF, WFP & WHO (2017) report stated that there is a decrease in the prevalence of child stunting in the world. This is good news and it calls for the sustainable management of child nutrition to help reduce 'hidden hunger'. Though there has been improvement in the nutrition of children, nursing mothers and pregnant women in the world, there is a need for a multi-sectoral approach to finding a solution to malnutrition. In that regard, the global objective of good nutrition for all by 2030 and the UN decade of action on nutrition, 2016-2025 can all be achieved by the set times.

Hidden Hunger

Report from the FAO indicated that up to 840 million people do not receive the required energy needed for growth and daily activities from the diet taken (Kennedy *et al.*, 2003; Dar, Bantilan, Anupama, Deepthi & Padmaja, 2007). By 2011, the number of people in this situation had increased to about 920 million (Sage, 2011). It is estimated that 799 million of the people in such situation live in developing countries in Asia and Africa. It is quite easy to notice when one is not getting enough energy from what is eaten but when the diet is deficient of micronutrients, it is not easily seen. Studies have revealed that micronutrient deficiency is much higher than energy-deficient diets across the world (Kennedy *et al.*, 2003; Nuss & Tanumihardjo, 2010). This is so because energy-rich foods are much cheaper than nutrient-

rich foods especially micronutrient-rich foods (Darmon & Drewnowski, 2015).

Micronutrient deficiency in diet became noticeable to the world upon high prevalence of blindness and goiter (Kennedy *et al.*, 2003; Zimmermann, Jooste & Pandav, 2008). Moreover, there are more serious symptoms of micronutrient deficiency such as low cognitive development, poor growth and low immune system functioning (Biesalski, 2013). These other systems of micronutrient deficiency remain hidden in affected individuals for a long time and because of this, the name "hidden hunger" was coined. "Hidden hunger" is hunger which can be experienced in the mist of plenty. Micronutrient deficiencies are said to be most common in areas with monotonous diet (Kennedy *et al.*, 2003; Biesalski, 2013; Sharma, Aggarwal & Kaur, 2017). Micronutrient deficiency is therefore typical of developing countries where most of the staple foods are cereals and tubers which do not have adequate amounts of micronutrients (Jati *et al.*, 2012; Biesalski, 2013; Sharma *et al.*, 2017). Micronutrient deficiency is aggravated in developing countries by the fact that people are simply not able to diversify their diet with adequate amounts of fruits, vegetables or animal products because of poverty (Kennnedy *et al.*, 2003; Biesalski, 2013; Darmon & Drewnowski, 2015). Countries with high micronutrient deficiency end up with continued and sustained loss of productivity, permanent mental disability, blindness, low immune system function and increased infant and maternal mortality (Kennedy *et al.*, 2003). Often, women and children are the most vulnerable of these conditions (Muthayya *et al.*, 2013).

There are nineteen vitamins and minerals which are essential for physical and mental development, immune system functioning and various metabolic processes (Kennedy *et al.*, 2003; Biesalski & Nohr, 2004). Vitamin A, iron, copper, zinc and manganese are good for sight, immune system functioning and metabolic processes of the body (FAO/WHO, 2002; Kennedy *et al.*, 2003; Jati *et al.*, 2012; Biesalski, 2013; Black *et al.*, 2013; Gul *et al.*, 2015; Biesalski, 2016; uz Zaman *et al.*, 2018) . Not having enough food could results in not having enough of these vitamins and minerals and hence, micronutrient deficiency.

The micro-element iron helps in the transport of oxygen and the efficient functioning of haemoglobin in the body. Aside other factors that causes anaemia in the body, a deficiency of iron causes anaemia which eventually leads to the decline of red blood cells in the body (Kennedy *et al.*, 2003). Diversifying what one eats could enhance the level of iron in the body if the diet includes meat, poultry and fish which have great bioactive iron needed for the metabolic activities of the body (Kennedy *et al.*, 2003; Biesalski, 2013, Biesalski, 2016). It is good to minimize foods such as grains, seeds, nuts and legumes that contain phytate since they could inhibit iron absorption (Kennedy *et al.*, 2003). This is so because they contain tannin, a phenolic compound which influences their binding with phytic acid and makes iron less absorbable in the intestines (Kennedy *et al.*, 2003). Some cereals, pulses, fruits and vegetables also contain non-haem iron which is not bioavailable to the body (Kennedy *et al.*, 2003). It is good to eat food that contains ascorbic acid which enhances iron absorption in the body (Kennedy *et al.*, 2003). It is therefore good to diversify one's food intake to include fruits

and vegetables that will enhance the absorption of iron for the metabolic activities of the body especially during menstruation, pregnancy, breastfeeding and the initial growth period of an individual. Due to the high prevalence of malaria in Ghana, it will be good for the country to encourage the consumption of food with high iron content and minimize phytate foods so as to enhance the release of iron to people who will have malaria and lose a lot of red blood cells.

One indicator used for the detection of iron deficiency worldwide is Iron Deficiency Anaemia (IDA) which is very useful clinically for public health workers (WHO, 2001). Unfortunately, most people suffer from nutritional iron deficiency or habitual insufficient iron intake for a long time before the IDA test is administered (FAO/WHO, 2002). It is therefore necessary to ensure a diet rich in absorbable iron that help reduce the risk of iron anaemia. It is also good to consider haem and non-haem iron foods when considering a nutritional requirement for humans especially children less than 5 years old, pregnant and nursing mothers. This way, the risk of malnutrition could be reduced and the high cost of treating anaemia among humans especially those in developing countries could be avoided. Iron found in animal-source foods such as meat, poultry and fish has greater bioactivity than non-haem iron found in cereals, pulses, fruits and vegetables (Kennedy *et al.*, 2003). This fact should be noted when choosing food so that micronutrient malnutrition with public health consequences could be minimized by a simple act of choosing the right source of food.

It is known that iron-deficient women have a high mortality rate during childbirth and have a high incidence of giving birth to babies with low-birth-

weight (WHO, 2002). It has also been suggested that women in southeast Asia present the highest prevalence of anaemia in the world with over 50% of pregnant women affected (Mason, Lotfi, Dalmiya, Sethuraman & Deitchler, 2001). Children who suffer from iron deficiency also have problems with their cognitive performance, behaviour and physical growth (WHO, 2001). It is therefore unfortunate that as much as 18.1 % of pre-school children in the world and 20.2% of pre-school age children in Africa suffer from iron deficiency (Black *et al.*, 2013). Consequently, national productivity is affected by up to 1.5% (FAO, 2002) which affects gross national income. This deepen poverty situations in affected countries since the expected household income is reduced as a result of reduced working potentials of the adults (and most likely the breadwinners) of the households. This situation has a likely negative consequence on the attainment of the SDGs. There is, therefore, the need to put some interventions in place to reduce the incidence of IDA and enhance the achievement of the SDGs by the year 2030.

As mentioned earlier, micronutrients are needed by the body for normal growth and tissue repair. Vitamins cannot be left out in this. It is established that the visual and immune systems are particularly dependent on vitamin A to function (Kennedy *et al.*, 2003; Biesalski & Nohr, 2004) and a deficiency may lead to blindness in humans. Although this vitamin is freely available in animal products like milk, egg and fish, over 40% of children under age five years suffer from vitamin A deficiency (Black *et al.*, 2013). This could be due to the fact that foods are expensive and therefore not affordable to the poor in developing countries. However, there is a precursor of vitamin A in plant products which may help improve the situation of

vitamin A deficiency in poor countries and also create jobs for local farmers if they cultivate the plants that have precursors of vitamin A. According to Biesalski (2013), 80% of Vitamin A in developing countries is from provitamin A which is found in plants. Eating 12 g of provitamin A in a diet will provide 1 g of vitamin A (Biesalski, 2013) and is much cheaper than vitamin A supplements. Farmers engaged in producing such crops may earn money and be able to take care of their families and themselves. That way, some of the goals of the SDGs could be achieved by 2030 as scheduled.

Carotene is a precursor of vitamin A that is found in yellow fruits and vegetables, green leafy vegetables and red palm oil (Kennedy *et al.*, 2003; Gupta & Prakash, 2009; Gul *et al.*, 2015). According to Kennedy *et al.* (2003) the retinol form of vitamin A can easily be absorbed by the human body than carotene which is also a provitamin A. Ghana produces a number of yellow fruits plants e.g. mango, *Borassus aethiopum* and red oil plam which when consumed will help improve sight and reduce preventable blindness in children, especially those less than five years of age. The cost of purchasing and distributing laboratory-prepared vitamin A will reduce if people are encouraged to eat diet rich in vitamin A and provitamin A. The hard-earned foreign exchange used for the importation of such vitamin A supplements for children less than five years in the country could be used for other developmental activities. An adequate supply of vitamin A to children will not only improve the function of their immune system but will also decrease the overall child mortality rate by 25%, measles death rate by 50% and death caused by diarrhoea by 40% (UNICEF, 2002).

Zinc is a requirement for the metabolic activity of over 300 enzymes (FAO/WHO, 2002; uz Zaman *et al.,* 2018). However, its deficiency has increased rapidly over several years (Kennedy *et al.*, 2003). This is an alarming situation that needs urgent intervention. In spite of the alarming situation, information on prevalence of its deficiency is still not available although it is assumed that zinc deficiency is widespread in areas that do not have dietary diversity (uz Zaman *et al.,* 2018). Zinc can be obtained from offal, shellfish, eggs and dairy products (Kennedy *et al.*, 2003). Its absorption and bioavailability are inhibited by phytate as in the case of other micronutrients (Kennedy *et al.*, 2003). Symptoms of Zinc deficiency include stunting and diarrhoea in children (Brown & Wuehler, 2000). In an attempt to ameliorate zinc deficiency, the Ministry of Health in Ghana is educating mothers to give zinc tablets to children with diarrhoea for ten days to help prevent the children from dehydrating. The approach of administering supplements is good but involves money which could be channeled into other developmental activities if people are encouraged to eat zinc rich food to reduce and/or prevent the conditions that come with zinc deficiency.

Copper is another micronutrient that maintains nerve cells, immune system and make red blood cells in the body (Scheiber, Mercer & Dringen, 2014; Greenough, Munoz, Bush & Opazo, 2016; Morrell, Tallino, Yu, & Burkhead, 2017). It also helps in the formation of collagen and iron absorption in the body and also plays a role in energy production (Ware, 2017). Although high level of copper can affect brain function, its deficiency can also lead to Menker's, Wilson's and Alzheimer's disease (Morrell *et al.*, 2017). It is important to note that copper deficiency impedes the repair of collagen and

elastin and thus reduces the chances of repairs on the health of bones (Ware, 2017). Additionally, copper deficiency may also lead to osteoporosis, skin and hair depigmentation, anaemia and an increased risk of infection (Greenough *et al.*, 2016; Morrell *et al.*, 2017).

Manganese is another micronutrient needed for digestion, bone growth, immune system functioning, cellular energy regulation, reproduction and blood clotting (Aschner & Aschner, 2005). It is a cofactor for the activation of a number of enzymatic reactions in the body such as amino acid, lipid and carbohydrate metabolism (Yoon *et al.*, 2011). Studies have shown that the element is good for pregnant women but excessive accumulation of manganese in the nervous system may cause Parkinson's type syndrome called Manganism (Aschner & Aschner, 2005). A diet with nuts, garlic, pineapple, grapes, green beans, banana, legumes, avocados, and whole-grains are good sources of manganese (Okochi & Okpuzor, 2005).

Soil Nutrient and Nutritional Quality of Food Crops

The FAO, IFAD and WFP reported that over 2 billion people the world over suffer from "hidden hunger" because of inadequate intake of micronutrients (The FAO, IFAD & WFP, 2014). The plant is one of the main sources of micronutrient to animals in the food chain for onward transport to humans and other organisms that consume the plant.

Soil is said to be home to plants. Soil is made up of minerals, organic matter, air and water. An ideal soil has 50% solids including minerals and organic matter, and the remaining 50% of its pore spaces is filled with water (Nathan, 2017). It is reported that 17 essential nutrients are good for plant growth and 14 out of these 17 can be found in the soil (Nathan, 2017; Wang *et*

al., 2017) while carbon and oxygen are obtained from air. Soil, therefore, serves as the parent that nurture and enhance the growth of every seed or spore to become a matured plant. In human life, if a child has parents who will supply him/her with the required nutrients in their correct proportion, that child will grow to attain his/her maximum potential on earth. So is the case of the seed and the soil. A seed that get a very nutritious soil to grow has the potential to attain its maximum growth and give a good yield with high nutrient content than one that grows in a very poor soil that has high nutrient deficiency. Plants are unable to complete their vegetative and reproductive cycle when there is a deficiency in their essential nutrient content (Bottinelli, *et al.*, 2015; Dimkpa & Bindraban, 2016; Nathan, 2017). This is because some of the nutrients are needed for various enzymatic activities in the plant. Some of these nutrients are primary, some are secondary and others are micronutrients. Plants that grow on fertile soils containing micronutrients including iron, copper, zinc and manganese perform well. These micronutrients are obtained from the soil. Deficiency of these micronutrients in the soil will lead to stunting and poor metabolic activities of plants which affect productivity and nutrient concentration of the products from such micronutrient-deficient fields (Dimkpa & Bindraban, 2016).

Zinc deficiency results in reduced bud formation, decreasing stem length and resetting of terminal leaves, dieback of twigs after the first year, mottled leaves and interveinal chlorosis (Alloway, 2009; Nathan, 2017). As in the case of animals, zinc is essential for several enzyme activities in plants and controls indoleacetic acid (IAA) synthesis in plants (Alloway, 2009). This goes a long way to affect the growth of plants and finally the yield obtained

from such plants. Research shows that sandy soil with organic matter is more likely to be deficient in zinc compared with other soil types.

Iron deficiency can be observed when there is interveinal chlorosis of young leaves, twigs dieback and death of limbs (Srivastava, 2013; Nathan, 2017). These symptoms of iron deficiency are shown in plants because iron is one of the micronutrient needed for chlorophyll formation in plants. In addition, iron also serves as activator of the biochemical processes involved in respiration, photosynthesis and symbiotic nitrogen fixation (Nathan, 2017).

As in the case of iron deficiency, manganese deficiency also leads to interveinal chlorosis of young leaves. This is because manganese assists iron as an activator for enzymes in chlorophyll formation. Its deficiency is likely in sandy soils with pH of 8 (Nathan, 2017). Manganese deficiency is easily seen when crops such as onion, beans, potato, spinach, tomato, peas, raspberries, strawberries, apples and grapes are grown on such soils (Nathan, 2017).

Stunted growth, dieback of terminal shoots in trees, poor pigmentation, wilting and eventual death of leaf tips are deficiency symptoms observed in a copper deficient soil (Freitas *et al.*, 2015). Just like the other micronutrients, copper is also an activator of several enzymes in plants (Huber, 2000). Copper plays a role in the production of vitamin A in plant (Nathan, 2017) and its deficiency also interferes with protein synthesis in plants.

Anthropogenic Activities and Water Quality

About 71% of the space in and around the planet earth is filled with water but out of this, only 0.3% of the water is usable by humans (Mullen, 2012). Several studies show that most of the water used by humans is surface water coming from rivers (Kistemann *et al.*, 2002; Mullen, 2012). Among the

several uses of surface water in Ghana, households use it for their domestic activities such as cooking, washing, bathing, and drinking (Mullen, 2012; Maupin *et al.*, 2014; Pacific Institute, 2017; Perlman, 2017). Plants and other organisms in the ecosystem use water for their nourishment, growth and transport (Le & McQueen-Mason 2006; Bareja, 2013). Some of the water is also stored in the soil while others evaporate into the atmosphere (Bareja, 2013), condense and fall as rain. Humans use several gallons of water a day. In the United States of America (USA) alone, it was estimated that approximately 1, 238 trillion litres of surface water was used a day as at 1990 (Mullen, 2012). This implies that a world without water a day may lead to the destruction of life in the world. Using the extent of water usage in the USA as a baseline, the world might be using about ten times more surface water a day that the amount being used in the USA. With the increasing population over the years, the story is not different in Ghana.

It is important for every human to have access to and use potable water to ensure good health. This is one of the reasons why the SDG's considered water and sanitation. Many a time, the water in the environment gets polluted due to anthropogenic activities such as agriculture, mining and urbanization (Aryee *et al.*, 2003; Henegama, Dayawansa, & De Silva, 2013; Kessey & Arko, 2013; Owusu, Asumadu-Sarkodie, & Ameyo, 2016). Some of these activities results in the introduction of pollutants in water bodies which serves as substrate for the breeding of microbes.

The high growth in human population is likely to have a direct effect on the demand for water in the world. The UN world report on water development in 2015 indicates that 2.4 billion of the expected 9.1 billion

people in the world by 2050 will be found in sub-Saharan Africa. It also projects 40% global water deficit by 2030. Ghana has already started experiencing some water problems recently to the extent that it has been reported that the country might import water in the near future (Ashon, 2015; Fiati, 2017). Therefore, there is the need to protect Ghana's water bodies from pollution.

The increase in human population coupled with urbanization, industrialization, farming and now 'galamesay' has resulted in the destruction of many surface water bodies and the pollution of a few surviving water bodies, especially the rivers and streams in local communities. The polluted water is taken up by plants grown in the soil. In the process of water uptake, pollutants that are dissolved in the water body are also taken up by plants and this may compromise the quality of the final product from the crop consumed by man. This situation makes it necessary to treat contaminated water.

CHAPTER THREE

MATERIALS AND METHODS

The study investigates food eaten by Ghanaian households and the micronutrient concentration in such food. It also examines how soil contributes to micronutrient concentration in two major staple food crops namely cassava (*Manihot esculenta* Cranz) and maize (*Zea mays* L). Furthermore, this study investigates the micronutrient concentration in Plantain (*Musa paradisiaca* L.), some fruits and vegetables (including some leafy vegetables). In addition to the above, the study investigates the micronutrient concentration and microbial load in surface water bodies.

This chapter presents the experimental design of the research. It deals with the research process, execution of experiments and how data obtained from the experiments were analysed using different analytical tools and softwares. There is a brief description of the study area and the population used for the research. This is followed by the household food survey, the design of the field experiment, laboratory experiment and data analysis.

Research Design

This study comprise of household food surveys, field sample collection, field experiment and laboratory analysis. An overview of the steps followed in the entire research process is presented in Figure 4.

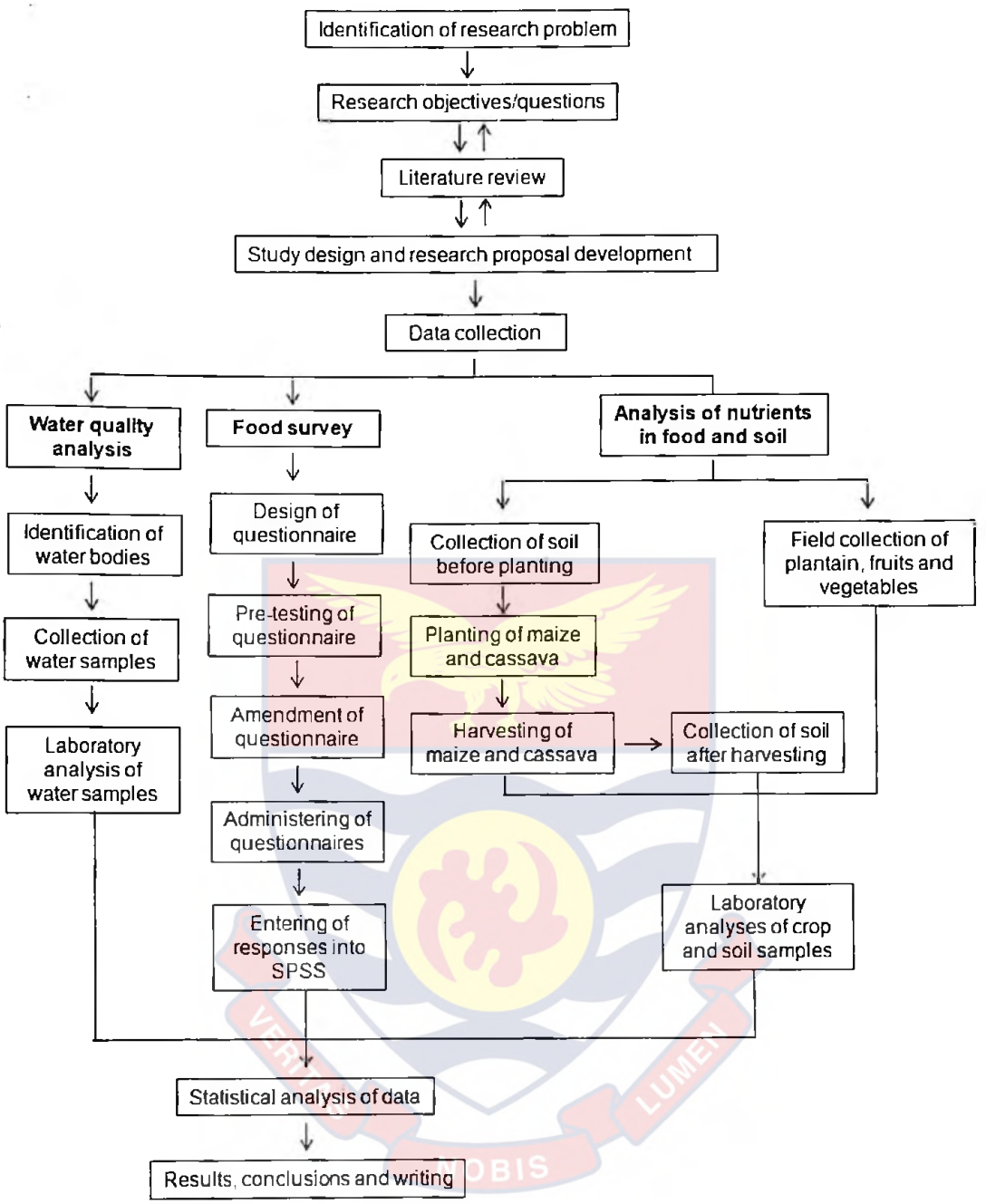

Figure 4: Flow chart showing the steps followed in the entire research process

A household food survey was carried out using household food survey questionnaire (Appendix A). The household food survey questionnaire covered all relevant factors that could influence the choice of food such as demographic data, educational background, financial situation of the household and specific questions on what the households eat and how often (Gibson, 2005).

To determine the nutrients in the various food crops eaten by households, such food crops (cassava, maize, plantain, some fruits and some vegetables) were collected from farms and open markets in communities such as Mampong – Ashanti and Nintin in the Ashanti Region. In addition to this, different varieties of two staple food crops, cassava and maize were purposely planted and harvested for nutritional analysis.

Three surface water bodies each from three Regions of Ghana namely Ashanti, Eastern and Central regions of Ghana were sampled for Fe, Zn, Cu and microbial loads in them.

Study Area

The study was carried out in Ghana, a sub-Saharan country. The country covers a total area of 238,540 km^2 out of which 230,020 km^2 is land area. Ghana is located along the Gulf of Guinea and is divided into 10 administrative regions (Figure 5). It shares land borders with Republic of Côte d'Ivoire in the West, Burkina Faso in the North and Togo in the East. The population of the country is approximately 28,308,301 as at 2016 (Ghana Statistical Service, 2016). The citizens of Ghana are from multicultural backgrounds with several ethnic languages (Asante & Gyimah-Boadi, 2004). There are different ecological zones with two rainfall patterns in the country. The vegetation ranges from rain forest in the south-western part to savanna in the northern part of the country. There are also different soil series which supports crop production in the country. There are a number of rivers and stream that support a wide range of economic activities in the country. Some of the water bodies found in the country are the Black Volta, White Volta, Pra, Ankora, Densu, Birim, Offin and Kakum.

There are varying traditional staple foods, culture, custom and beliefs among the ethnic groups. Ghanaians also share different religious beliefs namely Christianity, Muslim and traditional religions which cut across the different tribes in the country. The food basket of the household varies from ethnic group to ethnic group and from region to region (J.D Abraham, Personal Observation).

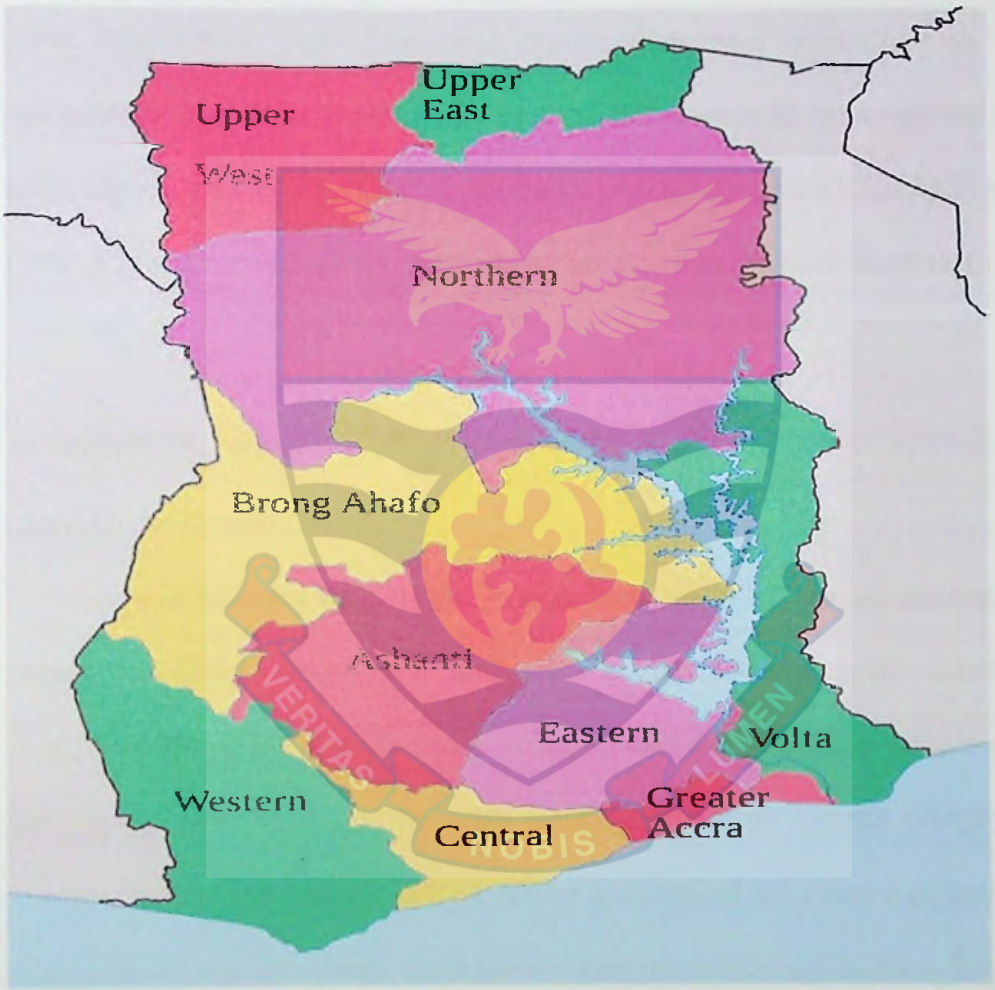

Figure 5: Map of Ghana showing all the 10 administrative regions.
Source: http://davidampofo.com. Downloaded on 11.02.2018

Population

The population used for the household survey comprised of Ghanaian families. A total of 3521 of 4500 structured questionnaires administered to

respondents by stratified sampling were retrieved and used as sample size for the household food survey. The country was stratified into ten (10) strata based on the ten administrative regions (Figure 5). For each administrative region, households were selected for interview based on community structure, tribe, culture and socio-economic activities that people in the region engage in. The heads of households were contacted for permission before the households were interviewed. Each household choose their own respondent to the questionnaire. However, other members of the household were allowed to contribute to the responses where necessary. All adults in the household who were 18 years or older and resident in the community were eligible to be interviewed.

Sampling Procedure

Household food survey

A household food survey was carried out in all ten administrative regions of Ghana (Figure 5). Respondents were selected using stratified random sampling where each region of Ghana was a stratum. The sample size per region was based on the 2010 population census (Ghana Statistical Service, 2012). The household food survey was carried out using a structured questionnaire and interviews. Each stratum (administrative region) was further stratified into urban, peri-urban and rural communities. Respondents were selected randomly and interviewed from these strata (urban, peri-urban and rural communities). Between ten and fifty households were selected for interview per community depending on the population of the community (Ghana Statistical Service, 2012). The selection of respondents also took into account bio-social (example sex, age) and socio-cultural (example marital

status, education) factors of the residents. These factors were considered in order to minimize error in the data collection process.

Sampling of plantain from the field

Four varieties of plantain, *Musa paradisiava* var. apem, *M. paradisiava* var. apantu, *M. paradisiava* var. asiamienu and *M. paradisiava* var. oniaba were collected from different fields in Ashanti region using purposive sampling for micronutrient assessment. Purposive sampling was employed because the varieties of the plantain were available only in certain places.

The plantains were prepared for laboratory analysis by removing the peel and cutting the pulp into small chunks as done for the cassava samples. They were also stored in a chest freezer at -20°C until they were assessed for their Fe, Zn, Mn, Cu and carotene content.

Sampling of fruits from the field

Fruits of *Mangifera indica* var. Palmer, *M. indica* var. Jaffna, *M. indica* var. Alphonso were collected from 10 different trees in the Ashanti region. From each tree, ten fruits were harvested for each of the three taxa. They were prepared for laboratory assessment of their micronutrients the same way the plantains were prepared.

Sampling of vegetables from the field

A total of five sample of *Solanum torvum* (Kwahu nsusua), *Tetrapleura tetraptera* (Prekese), cabbage, spring onion, cocoyam leaves, cassava leaves, tomatoes, palm, pepper, okro,white beans, carrots, green beans, garden eggs, green pepper, ayoyo, alefu, bota and hibiscus leaves

coming from four different sources were obtained from open markets in the Ashanti region of Ghana for micronutrient assessment.

For each crop, the samples from different sources were washed under running water and mixed together to obtain a composite sample. The composite sample was packaged in 200 g quantities and stored in a chest freezer at -21°C (Sumsung) until a freeze drier was available for further processing. The samples were then freeze dried using a Drawell Freeze drier (Shanghai Drawell Scientific Instrument Co., Ltd. Shanghai, China) and milled into fine powder using a blender (Kenwood Limited, Tokyo, Japan) before they were assessed for their micronutrient (Fe, Zn, Mn, Cu) and carotene content.

Field experiment

To be able to compare the micronutrients in the soil before planting and the micronutrient in the soil after harvesting as well as study the micronutrients in different cassava and maize varieties, two varieties of cassava namely *Manihot esculenta* var. Capevars bankye and *Manihot esculenta* var. Ampong were obtained from Asuansi Agricultural Research Institute in the Central Region for the study. Furthermore, two varieties of maize, *Zea mays* var. Obatanpa and *Zea mays* var. Golden Jubilee were obtained from the Ghana Association of Seed Growers, Ejura. A third maize variety, *Zea mays* var. Asante aburo was obtained from local farmers. These were planted in a randomized complete block design (RCBD) in May 2016 to assess the concentrations of Fe, Zn, Mn and Cu and *beta* carotene in them. The crops were planted in Mampong-Ashanti, Nintin and Juaben which were treated as blocks. There were different blocks for the different crops. For

cassava, the block in Mampong-Ashanti was divided into four plots measuring 5 × 5 m such that each variety had two replicate plots. In Nintin and Juaben, there were six plots each such that each variety had three replicate plots. The planting distance for the cassava was 1 × 1 m in each plot. In the case of maize, there were two replicate plots for each variety in Mampong and three replicate plots for each variety in Nintin and Juaben. The maize was planted at a distance of 0.5 × 0.5 m.

The cassava was harvested after 12 months and maize was also harvested on maturity (ca. 40 days) and prepared for laboratory analysis. In preparation of the cassava samples for laboratory assessment, the peels were removed and the pulp was cut into small chunks (ca 1 cm × 1 cm) and stored in a chest freezer at -20°C (Sumsung, Gurugram, India) until they were assessed for their Fe, Zn, Mn, Cu and *beta*-carotene content.

The concentrations of the micronutrient (Fe, Zn, Mn and Cu) in the soils in which the crops grow were also assessed. Three samples of the soil in each block were taken before planting at a depth of 20 cm to assess the concentration of micronutrients (Fe, Zn, Mn and Cu). After harvesting, soil samples were taken from the spot where the crops were planted for micronutrient assessment. The samples were transported on ice kept in a fridge at 4°C (Nasco, Jos, Nigeria) until they were assessed for their micronutrients. After AAS analysis, the difference between the concentration of micronutrients in the soil before planting and after harvesting of the crop was compared to the concentration of micronutrients in the soil before planting.

Water sampling

Water samples from nine water bodies across three administrative regions of Ghana. There were, Bonene, Aponapon and Adwee in the Ashanti region; Dwayire, Atonsu and Suruwi in the Central region; and Jejeti, Abumesu and Asupong in the Eastern region of Ghana. Each water body was stratified into three sampling points namely the source, midpoint and out flow. Water samples were collected from the sampling points along the river using sterile plastic bottles monthly for six consecutive months (January, 2016 to June, 2016) following Abraham, Fosu, Agyapong, Hope, and Abraham, (2016) and Abraham, Fosu, Agyapong, Agyemang, Hope, and Abraham (2017). Wearing nitrile gloves (Beaucare Medical Ltd, North Yorkshire, UK) and a nose mask, 500 ml of water from all the sampling points of the nine water bodies were collected into sterilized bottles, labeled and put on ice immediately to prevent bacterial growth and transport to the laboratory for analysis. Each bottle was rinsed two to three times with some of the water to be collected before sampling was done. Sample collection was done in the mornings between 6:00 and 9:00 (Figure 6). The samples were transported to the laboratory under refrigeration for physico-chemical and microbial analysis. Particular care was taken to ensure that samples for microbial analyses reached the laboratory within 24 hours of collection from the field.

Figure 6: Collection of water samples for physico-chemical and microbial load analysis. Photo credit: J. D. Abraham, 2016.

All samples collected were assessed for their Fe, Zn, and Cu concentrations using AAS.

Data Collection Instruments

A structured questionnaire was used to interview households on their nutritional status following a modified method of conducting food consumption surveys described by Gibson (2005). The objectives of the research were carefully explained to respondents and key stakeholders ahead of the administration of the questionnaire and interviews. Respondents were also assured and guaranteed their anonymity. This was done by removing their names from the survey. Moreover, household surveys were conducted with the consent of the head of the household and/or the respondents. All participants were duly informed of their liberty to withdraw from the study if they chose to do so.

Training and field work

The study employed twenty five (25) research assistants who speak different Ghanaian languages across the country to assist in the field data

collection. The research assistants were given five-day training on field data collection from October 5-9, 2015. The subjects of training included interviewing techniques, distribution and retrieval of questionnaires, and establishing rapport with respondents. The procedure used during the training involved mock interviews among participants and testing of questionnaires on College of Agriculture Education campus of University of Education, Winneba in Mampong Ashanti. After the training, the research assistants were put in groups of five based on their proficiency of the languages in the country. Each group of five research assistants interviewed respondents from two regions.

Data Collection Procedures

Household food survey

The structured questionnaire mentioned above, was administered to respondents through interviews. This allowed for probing questions that sought to clarify answers that were not clear. The questionnaire focused on key themes such as the kind of food eaten by the household, who influences the food consumed by the household, the source of water for the household, the percentage of the household income that goes into food, etc (Appendix I). The responses obtained were coded and entered into IBM SPSS version 16, Armonk, NY.

Laboratory analysis

Beta-carotene analysis

The carotenoids in the crop samples were extracted following Rodriguez-Amaya and Kimura (2004). The weight of each sample used for the

extraction depended on the nature of the sample; thus for fresh crop samples, 5 g each were used for the extraction whiles for freeze dried samples, 3 g each were used. Samples were weighed into a mortar (Fisher Scientific, Leicestershire, England) and 0.5 g of pyrogallol (Merck, Darmstadt, Germany) was added and mixed. Furthermore, 20 ml of ice cold acetone (VWR, Leicestershire, England) was added to the mixture and left for five min. The extract was filtered using Whatmans filter paper (GE Healthcare Bio-Sciences, Pittsburgh, PA) after which the residue was washed twice with acetone till it became colourless. In all, 50 ml of acetone was used for the extraction. The residue was discarded and the filtrate was washed in 15 ml of petroleum ether (Merck) in a 500 ml-separating funnel (Fisher Scientific). Deionized water was added slowly (by the side of the funnel to avoid emulsification of the carotenoid) to wash the acetone used for the extraction. The washing was repeated 6 - 9 time until all the acetone was washed out. The carotenoid extract dissolved in the petroleum ether was filtered through 2 g of anhydrous sodium sulphate (Merck). The volume of the filtrate was then recorded and the extract dried on nitrogen gas.

The dried sample was reconstituted with 1 ml hexane, vortexed and transferred into an HPLC vial (Agilent, Santa Clara, CA). The samples were analysed in an Agilent 1100 series HPLC (Agilent). The analyses were performed on a tracer excel 120 ODS-A column (25 cm × 0.46 cm , 5µm particle size, Teknokroma, Barcelona, Spain) at a temperature of 25 °C. The mobile phase was a mixture of methanol, hexane and methyl ether amine (Merck) in a ratio of (90: 10: 0.01 v/v/v). The flow rate of the mobile phase was 1 ml/min. The total analysis time per sample was 35 min. All analyses

were performed in triplicate. Hexane was analysed as a blank in order to identify chromatograms coming from the samples. The chromatogram of beta-carotene was identified by comparing the retention times of chromatograms from the samples with that of a beta-carotene standard (Merck). For purposes of quantification, calibration curve was obtained using solutions containing a carrot standard at a concentration of 0.17µg/ml in hexane, 3 injections per concentration. The concentration of beta-carotene in each sample was calculated based on the linear relationship between the peak area of the standard and that of the sample.

Analysis of micronutrients in crops samples

The plantain and cassava samples were peeled, cut into small pieces (ca. 1 cm × 1cm), packaged in brown envelopes and oven dried at 60°C to remove moisture until a constant weight was obtained (in about three days). The dried samples were milled using a Kenwood blender, packaged, labeled and stored in a freezer at -20°C until Fe, Zn, Mn and Cu analysis. The maize samples were air dried, milled and kept in the same condition as the plantain and cassava until Fe, Zn, Mn and Cu analysis. The samples were then digested using the sulphuric acid–hydrogen peroxide method (Allen, Grimshaw, Parkinson & Quarmby, 1974; Lowther, 1980). Thus, for crop samples, 0.10 g of oven dried crop samples were placed into a 100 ml Kjeldahl flask. A volume of 4.4 ml of digestion reagent comprising of a mixture of 350 ml hydrogen peroxide, 0.42 g selenium powder, 14 g lithium sulphate and 420 ml sulphuric acid was added and heated gently at 80-90°C with a gradual increase in temperature to 150-200°C and held for 2 hours until digest was clear. The samples were then left on the plate for another 30 min. to cool. The

digest was topped up to 50 ml with distilled water for further analysis. The filtrate from the digestion was used for Fe, Zn, Mn and Cu analysis using a 200 series Atom Absorption Spectrophotometer (Agilent Technologies). The digestion and analysis were repeated three times per sample and the mean value used for statistical analysis.

Determination of micronutrients in soil

The micronutrients in soil were extracted using diethylene triamine pentaacetic acid (DTPA) following Lindsay and Norvell (1978). An amount of soil sample (10 g) was placed in a 50 ml graduated conical centrifuge tube and 20 ml of DTPA extracting solution was added to it. The centrifuge tube and its content were shaken for 2 hours on a shaker. The contents were then filtered (Figure 7). The extract obtained was used for estimation of different micronutrients using the Atomic Absorption Spectrophotometer following Motsara and Roy (2008). To estimate the concentration of a specific micro-element, the element-specific hollow cathode lamp was selected and mounted on the AAS. When the flame was started, the instrument was set at zero using a blank solution. The standard solutions of different concentrations were aspirated and a standard concentration curve was plotted for the element. The samples were then aspirated and the concentration of the samples were read and recorded.

Figure 7: Extraction of micronutrients from soil for Atomic Absorption Spectroscopy (AAS) analysis

Water Analysis

For a period of six months, beginning January 2016, 9 water bodies from the Ashanti, Eastern and Central Regions of Ghana were selected and monitored for their micronutrient content. In each of the three regions, three water bodies of economic importance were selected. Rivers Bomene at Amenase, Aponapon at Juaben (Figure 8A) and Adwee at Mampong Ashanti were selected in the Ashanti Region. Rivers Jejeti at Jejeti, Abumasu at Osiem (Figure 8B) and Asupong at Nsutem were selected in the Eastern Region. In

the Central region, rivers Dwayire at Anyinabrim, Atonsu at Atonsu (Figure 8C) and Suruwi at Amissano were selected in the Central Region. Water samples were taken once a month and sent to the laboratories of the Technology village of the School of Agriculture at the University of Cape Coast for physico-chemical analysis. Microbial load analyses were conducted at the laboratory of the Department of Medical Laboratory Technology.

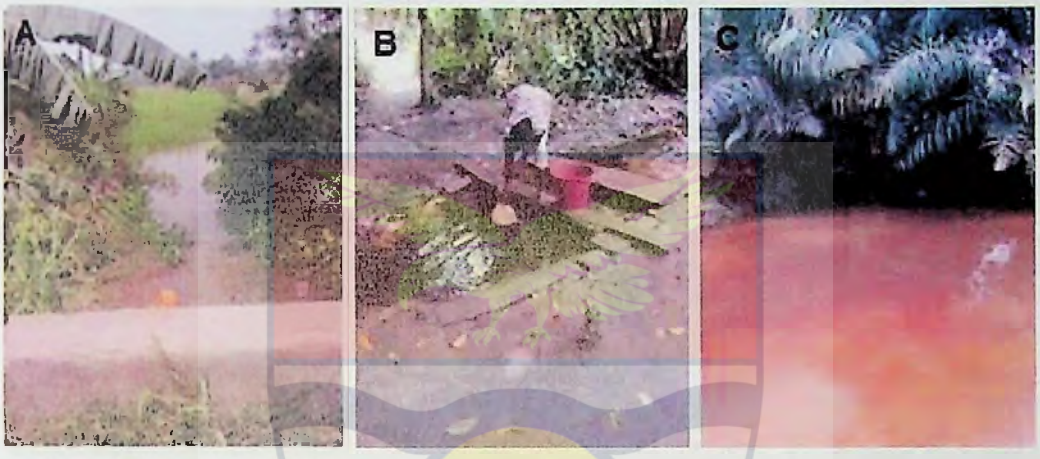

Figure 8: A water body (Aponapon) at Juaben in the Ashanti region (A); a water body (Abumasu) at Osiem in the Eastern region (B); a water body (Atonsu) in the Central region (C). Photo credit: J. D Abraham, 2016.

The temperature, conductivity and pH of the water bodies were taken using hand held Wagtech pH meter (Eutech Instruments, Ayer Rajah Crescent, Singapore)

Analyses conducted on water samples

Physico-chemical and microbial analyses were conducted on the water samples. Physico-chemical analyses conducted included pH, conductivity, temperature, total hardness, total dissolved solids, total suspended solutes, concentrations of iron, zinc, copper, nitrate, phosphate, calcium, magnesium, potassium and sodium. Microbial analyses conducted included total coliforms, faecal coliforms and *Escherichia coli* determination.

The physico-chemical analyses

Quality indicators such as Ph and temperature were measured using a hand-held pH meter (Eutech Instruments) on the field.

Microbial analysis

Test media and indicators

Total and faecal coliforms, and *E. coli* were determined by colony-forming unit method (Chouhan, 2015). Using Ghana Standards Authority's standards (GS. 175-1: 2013), the samples were analyzed for total coliforms (TC), fecal coliforms (FC), and *Escherichia coli* (EC), all in colony-forming units (CFU) per ml using the pour plate method.

Culture media consisting of Plate Count agar (Oxoid, Hampshire, England), Peptone Water (Oxoid) and Eosin Methylene Blue agar (Oxoid) were prepared according to the manufacturer's instructions where 37.5g of dehydrated media was dissolved in 1000 mililiters of distilled water to dissolve the powdered media. The dissolved media was heated on Bunsen burner to bring the media to boiling and the media was sterilized at 121°C, 15psi for 15 minutes. The sample was shaken vigorously and the area around the lip or the top of the bottle was wiped with clean tissue soaked with 70% ethanol.

Duplicate dilutions of 0.1 ml and 1 ml of each sample were plated on plate count agar and incubated at 37°C for 48 hours. Plate count agar was prepared according to manufacturer's instructions where 17.5g of dehydrated media was dissolved in 1000mililiters of distilled water to dissolve the powdered media. The dissolved media was heated on Bunsen burner to bring the media to boiling and the media was sterilized at 121°C, 15psi for 15

minutes. All colonies were counted and an average of duplicate samples was recorded as THB counts/ml (CFU/ml) for the sample.

Likewise, 2 duplicate dilutions of 0.1 ml and 1 ml of each sample were plated on Eosin Methylene Blue agar. One each of the duplicate dilutions was incubated at 37°C for 48 hours to observe for TC and the other duplicate was incubated at 44°C for 48 hours to observe for FC. All pink, purple, black and metallic green sheen colonies were counted and an average of duplicate samples was recorded as TC and FC counts/ml (CFU/ml) respectively for the sample.

Identification and enumeration of *Escherichia coli*

Each of the presumptive colonies (metallic green sheen colonies on the FC) was sub-cultured in 10 ml of Peptone Water for biochemical testing. Each colony was grown in peptone water and incubated at 44°C for 24 hours. A drop of Kovac's reagent was then added to the tube of peptone water. All tubes that showed red ring colour development after gentle agitation indicated the presence of indole and were recorded as a confirmation of *E. coli.* All colonies of that morphological type were then enumerated.

Data Processing and Analysis

Data from the food survey was subjected to descriptive statistics (IBM SPSS version 16, Armonk, NY). Cross tabulations to determine the relationships between the data set were conducted. The nutritional data from the food crops and soils were compared using analysis of variance followed by Turkey's test where statistical differences were obtained (Minitab version 17; Minitab Inc., State College, PA). Similarly, data from physico-chemical and microbial load

analyses were subjected to analysis of variance (Minitab). Where significant differences were observed, they were followed by Turkey's test (Minitab).

Chapter Summary

The research work was carried out using household food survey, field experiments and field collection of crops, fruits, vegetables and water. The samples from the field experiments and field collection including water samples were taken to the laboratory for micronutrient analysis. Additionally, the microbial loads in the water samples were assessed. Data obtained were subjected to descriptive statistics, cross tabulation (IBM SPSS version 16) and analysis of variance followed by Turkey's test where statistical differences were obtained (Minitab version 17).

There was no means to validate the answers given by the respondents in the food survey. This could affect the results and skew it in a direction that might not be the exact fact in the society. To minimize the effect of this short fall on the outcomes of the research, follow up questions were asked to reduce any potential misrepresentation of facts by respondents.

The field experiment was dependent on the natural climatic and soil conditions. Therefore, any variation in the climatic condition in the environment could have affected the final result and the error margin. There was a high risk of people and animals invading the study fields, especially those on which food crops were grown, to harvest and/or consume/destroy the experimental crops.

CHAPTER FOUR

RESULTS

The research assessed nutrition and water quality in Ghanaian society. Household food survey and field experiments were carried out. In addition, field collection of crops, fruits, vegetables and water were carried out. Micronutrient concentrations in the samples collected from the field were carried out in the laboratory. Additionally, the microbial loads in the water samples were assessed. Data obtained were subjected to descriptive statistics, cross tabulation (IBM SPSS version 16, Armonk, NY) and analysis of variance followed by Turkey's test where statistical differences were obtained (Minitab version 17; Minitab Inc., State College, PA). Also, regression analysis was carried out to assess the relationship between the concentration of micronutrients in the soil and the concentration of micronutrients that were possible to be taken up by the crops (Minitab version 17; Minitab Inc., State College, PA). This was done by comparing the difference in concentration of micronutrients in soil before planting and after harvesting, and the concentration of micronutrients in the soil before planting.

Characteristics of Study Respondents

The results of the household food survey showed that out of the 3521 respondents interviewed in the household food survey, 214 which constitute 6% of the total number of respondents were in the Greater Accra Region, 668 (19%) were from the Ashanti Region, 295 (8%) were from the Eastern Region and the Central Region had 541 (15%). In addition to these, 152 and 150 which represent 4% of the respondent each were from the Upper West and Upper East respectively making a total of 8% from those parts of the country.

The Volta region had a representation of 392 (11%), Brong Ahafo 323 (9%), Northern 342 (10%) and Western 444 (13). Out of this number interviewed across the country, 985 (28%) were male and 2536 (72%) were female. Majority of the respondents were married 2,045 (58%), followed by 1,172 (33%) single respondents, 177 (5%) divorced respondents and 127 (4%) widows. The educational backgrounds of the respondents ranges from no literacy 692 (20%), Non-formal 148 (4%), Basic Education / Middle school 1,565 (44 %), Secondary/ Technical 617 (18%) and Tertiary 499 (14%) of the total respondents. The urban, peri-urban and rural communities had respondents of 624 (18%), 1,173 (33%), 1,724 (49%) respectively. Considering the age groups of the respondents, the results showed that 856 (25%) of the respondents were up to 25 years, 1,084 (31%) were within the 26-35 years age category, 690 (20%) were in the 36-45 years, while 415 (12%) fell within the 46-55 years, 231 (7%) in the 56-65 years and the least category of respondents 182 (5%) being the Greater than 65 years age group (Table 1a).

Table 1a: Socio-demographic characteristics of respondents (n=3521)

Respondents characteristics	Frequency	Percent
Region		
Greater Accra	214	6.1
Ashanti	668	19.0
Eastern	295	8.3
Central	541	15.4
Upper West	152	4.3
Upper East	150	4.3
Volta	392	11.1
Brong Ahafo	323	9.2
Northern	342	9.7
Western	444	12.6
Gender		
Male	985	28.0
Female	2,536	72.0
Marital status		
Single	1,172	33.0
Married	2,045	58.0
Divorced	177	5.0
Widower	127	4.0
Level of education		
No literacy	692	20.0
Non-formal	148	4.0
Basic Education / Middle school	1,565	44.0
Secondary/ Technical	617	18.0
Tertiary	499	14.0
Community type		
Urban	624	18.0
Peri urban	1,173	33.0
Rural	1,724	49.0
Age		
Up to 25 years	856	25.0
26-35 years	1,084	31.0
36-45 years	690	20.0
46-55 years	415	12.0
56-65 years	231	7.0
Greater than 65	182	5.0

It was observed from the results that respondents depend of different sources of water for their drinking water. From the results, 2,331 (66%) of the

respondents get their drinking water from pipe born water, 188 (5%) depend on well, 48 (1%) depend on spring, 111 (3%) depend on river, 492 (14%) depend on bole hole, 351 and (10%) depend on sachet water for their drinking water. It was also observed from the results that the incidence of diarrhoea within the last four weeks before the interview was very low. Out of the 3521 respondent, 3186 (90%) has no incidence of diarrhoea case and just a few totaling 335 (10%) had diarrhoea cases recorded in their household.

The results also showed that majority 2,092 (60%) of the respondents had household sizes in the 1-5 people group, 1,156 (33%) fell within the 6-10 people, 181 (5%) were in the 11-15 people, 50 (2%) were in the 16-20 people and the least respondents, 22 (1%) having household size More than 20 people. Analysis of the household income data showed that 492 (16%) of the respondents had income less or equal 100 GH a month, 1,415 (47%) of the respondents received 101-500 GH, 661 (22%) received 501-1000 GH, 168 (6%) were within the 1001-1500 GH, 109 (4%) were earning 1501-2000 GH and a few 165 (5%) earning greater than 2000 a month (Table 1b).

Table 1b: Socio-economic characteristics of respondents (n=3521)

Respondents characteristics	Frequency	Percent
Drinking water source		
Pipe borne	2,331	66.2
Well	188	5.3
Spring	48	1.4
River	111	3.1
Bore hole	492	14
Sachet water	351	10
Household size		
1-5 people	2,092	60.0
6-10 people	1,156	33.0
11-15 people	181	5.0
16-20 people	54	2.0
More than 20 people	22	1.0
Experienced Diarrhoea in the past four weeks		
No	3,186	90
Yes	335	10
Household income		
less or equal 100 GH	492	16.0
101-500 GH	1,415	47.0
501-1000 GH	661	22.0
1001-1500 GH	168	6.0
1501-2000 GH	109	4.0
Greater than 2000	165	5.0

Most respondents had fruits, plantain, cassava, vegetables, maize and animal products as part of their meals. Twenty-three percent (23%) of the respondents eat fruit either daily while 29% eat fruits when they are in season. Forty-two percent (42%) of the respondents eat plantains monthly and almost half (49%) eat cassava every week. However, 10% and 4% respectively do not eat plantain or cassava (Table 2).

Majority of the respondents (59%) eat vegetables daily with 8% and 2% eating vegetables when they are in season or monthly. Close to half of the respondents (46%) eat maize daily, 2% eat it monthly and 5% rarely eat it.

Half of the respondents eat animal products as part of their meal daily but 26% rarely eat animal products (Table 2).

Table 2: Distribution of dietary practices of survey respondents (n=3521)

Respondents characteristics	Frequency	Percent
Fruit consumption pattern		
Daily	816	23
Weekly	736	21
Monthly	63	2
Rarely	272	8
When in Season	1,019	29
Do not eat	615	17
Plantain consumption pattern		
Daily	648	18
Weekly	1,482	42
Monthly	114	3
Rarely	935	27
Do not eat	342	10
Cassava consumption pattern		
Daily	1,020	29
Weekly	1,719	49
Monthly	56	2
Rarely	588	16
Do not eat	138	4
Vegetable consumption pattern		
Daily	2,092	59
Weekly	488	14
Monthly	71	2
Rarely	118	3
When in season	292	8
Do not eat	460	13
Maize consumption pattern		
Daily	1,633	46
Weekly	1,309	37
Monthly	30	1
Rarely	549	16
Animal products consumption pattern		
Daily	1,776	50
Weekly	691	20
Monthly	144	4
Rarely	910	26

More than half of the respondents in all age categories eat fruit daily. Very few eat fruits monthly or rarely (Table 3). There were high significant differences ($P < 0.001$) in the eating of vegetables among the respondents but those differences did not show very strong association among the respondents (Table 3). Considering age and marital status, the association between them was very weak (Cramér's V = 0.0598 and Cramér's V = 0.0805 respectively). However, there was increasing strong association between gender, type of community setting, level of education, household size and household income with the region showing the strongest association among them (Table 3).

Table 3: Frequency of eating vegetables (n=3521)

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	When in season (%)	Other (%)	Inferential Statistics
Age							$\chi^2_{(25, 3521)} = 61.77$; $P < 0.001$
Up to 25 years	58	16	2	5	7	13	Cramér's V = 0.0598
26-35 years	62	12	2	2	7	14	
36-45 years	60	15	1	3	8	12	
46-55 years	59	13	2	4	8	15	
56-65 years	58	12	2	2	17	9	
Greater than 65 years	54	14	4	2	12	14	
Gender							$\chi^2_{(5, 3521)} = 52.14$; $P < 0.001$
Male	57	13	2	5	13	10	Cramér's V = 0.1217
Female	60	14	2	3	6	14	
Level of education							$\chi^2_{(20, 3521)} = 289.49$; $P < 0.001$
No literacy	54	12	1	4	21	8	Cramér's V = 0.1434
Non-formal	53	10	3	4	18	11	
Basic Education / Middle school	59	14	2	3	4	17	
Secondary/ Technical	64	15	1	2	3	15	
Tertiary	64	15	2	5	8	6	

Table 3 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	When in season (%)	Other (%)	Inferential Statistics
Household size							$\chi^2_{(20,3521)} = 348.39$; $P < 0.001$
1-5 people	60	15	2	3	5	16	Cramér's V = 0.1576
5-10 people	64	13	1	4	10	9	
11-15 people	45	13	3	7	24	8	
16-20 people	30	13	2	9	44	2	
More than 20 people	9	14	5	0	64	9	
Marital status							$\chi^2_{(15,3521)} = 68.45$; $P < 0.001$
Single	57	15	3	3	7	15	Cramér's V = 0.0805
Married	59	14	2	3	10	12	
Divorced	66	8	3	4	3	16	
Widower/widow	80	11	0	2	0	7	
Household income							$\chi^2_{(25,3521)} = 358.31$; $P < 0.001$
less or equal 100 GH	40	18	2	5	19	16	Cramér's V = 0.1543
101-500 GH	54	16	3	3	5	20	
501-1000 GH	71	12	2	3	5	7	
1001-1500 GH	73	12	4	4	3	5	
1501-2000 GH	84	8	0	2	2	4	
Greater than 2000	88	5	1	3	1	2	

Table 3 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	When in season	Other (%)	Inferential Statistics
Region							$\chi^2_{(45, 3521)} = 2.7 \times 10^3$; $P < 0.001$
Greater Accra	61	19	2	10	2	6	Cramér's V = 0.3887
Ashanti	83	8	2	1	2	4	
Eastern	7	22	5	0	0	65	
Central	88	6	0	1	0	4	
Upper West	9	11	0	7	68	4	
Upper East	58	35	1	2	3	1	
Volta	17	21	5	6	17	34	
Brong Ahafo	69	20	2	2	2	5	
Northern	49	12	1	8	26	5	
Western	80	9	1	3	1	6	
Community type							$\chi^2_{(15, 3521)} = 168.56$; $P < 0.001$
Urban	68	15	1	5	4	7	Cramér's V = 0.1263
Peri urban	61	13	2	3	4	17	
Rural	55	13	3	3	13	13	

The results show that there is a weak association between age and gender with regard to eating fruits. However, association between the fruit eating pattern and level of education, household size, marital status, type of community and household income were stronger relative to age and gender. The region showed a much stronger relationship than all the other demographic factors considered during the survey. Moreover, there were significant differences in the frequency of eating fruit among all the demographic factors (Table 4).

Table 4: Frequency of eating fruits (n=3521)

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	When in season (%)	Other (%)	Inferential Statistics
Age							$\chi^2_{(25, 3521)} = 120.71$; $P < 0.001$
Up to 25 years	27.57	24.88	1.87	7.83	20.68	17.17	Cramér's V = 0.0836
26-35 years	25.46	21.49	1.38	7.01	25.92	18.73	
36-45 years	22.17	21.88	1.74	7.39	32.17	14.64	
46-55 years	18.07	15.66	1.93	9.16	33.73	21.45	
56-65 years	17.32	15.15	2.16	5.63	45.89	13.85	
Greater than 65 years	13.19	15.38	2.2	11.54	38.46	19.23	
Gender							$\chi^2_{(5, 3521)} = 12.67$; $P = 0.027$
Male	21.83	21.42	1.83	8.73	31.57	14.62	Cramér's V = 0.0600
Female	23.7	20.7	1.77	7.33	27.92	18.57	
Level of education							$\chi^2_{(20, 3521)} = 505.52$; $P < 0.001$
No literacy	11.85	16.91	0.72	6.65	54.19	9.68	Cramér's V = 0.1895
Non-formal	16.89	25.68	3.38	17.57	29.05	7.43	
Basic Education / Middle school	19.36	21.41	2.17	7.41	26.01	23.64	
Secondary/ Technical	29.82	22.2	1.46	8.1	17.34	21.07	
Tertiary	44.49	21.84	2	6.81	17.43	7.41	

Table 4 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	When in season (%)	Other (%)	Inferential Statistics
Household size							$\chi^2_{(20, 3521)} = 212.57$; $P < 0.001$
1-5 people	24.33	21.18	2.06	7.5	22.47	22.47	Cramér's V = 0.1231
5-10 people	23.96	21.19	1.12	8.13	35.29	10.29	
11-15 people	12.15	17.13	3.31	8.84	48.07	10.5	
16-20 people	11.11	9.26	0	7.41	61.11	11.11	
More than 20 people	0	18.18	0	0	77.27	4.55	
Marital status							$\chi^2_{(15, 3521)} = 112.43$; $P < 0.001$
Single	27.73	22.7	2.39	7.17	18.94	21.08	Cramér's V = 0.1032
Married	20.39	20	1.56	7.78	34.08	16.19	
Divorced	22.6	20.34	1.13	6.21	33.9	15.82	
Widower/widow	26.77	19.69	0.79	14.17	31.5	7.09	
Household income							$\chi^2_{(25, 3521)} = 421.77$; $P < 0.001$
less or equal 100 GH	10.16	12.6	1.02	7.52	47.97	20.73	Cramér's V = 0.1674
101-500 GH	17.17	21.06	2.19	6.57	26.22	26.78	
501-1000 GH	27.84	25.57	2.27	9.08	25.26	9.98	
1001-1500 GH	45.24	14.29	3.57	7.74	22.62	6.55	
1501-2000 GH	53.21	12.84	3.67	4.59	22.02	3.67	
Greater than 2000	46.06	21.82	0.61	4.85	22.42	4.24	

Table 4 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	When in season (%)	Other (%)	Inferential Statistics
Region							$\chi^2_{(45, 3521)} = 2.5 \times 10^3$; $P < 0.001$
Greater Accra	53.74	23.36	3.27	10.28	4.67	4.67	Cramér's V = 0.3779
Ashanti	26.95	16.47	1.2	5.54	44.31	5.54	
Eastern	2.37	10.51	3.39	0.34	1.02	82.37	
Central	49.35	25.32	2.59	10.91	9.61	2.22	
Upper West	4.61	6.58	0.66	4.61	80.26	3.29	
Upper East	4.67	3.33	0.67	3.33	86.67	1.33	
Volta	3.83	10.2	2.3	9.44	22.96	51.28	
Brong Ahafo	32.51	39.01	1.86	6.81	16.41	3.41	
Northern	15.2	20.18	0.29	10.82	43.57	9.94	
Western	13.74	35.59	1.35	10.14	25.68	13.51	
Community type							$\chi^2_{(15, 3521)} = 322.07$; $P < 0.001$
Urban	42.95	17.79	1.76	6.57	17.63	13.30	Cramér's V = 0.1746
Peri urban	23.79	24.47	1.28	6.14	21.31	23.02	
Rural	15.61	19.6	2.12	9.23	38.23	15.21	

The results on the consumption of animal products showed that there were generally weak relationships between the frequency of consumption of animal product and age, gender, level of education, household size, marital status, household income, region and type of community (Cramér's $V \leq 0.30$) although there were significant differences in the frequency of consumption among all the variable ($P < 0.001$; Table 5). Among the weak relationships, the strongest association in the eating of animal product and the respondents was found in the regions (Cramér's $V = 0.3025$; Table 5).

Table 5: Frequency of consumption of animal products (n=3521)

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Inferential Statistics
Age					$\chi^2_{(15, 3521)} = 103.51$; $P < 0.001$
Up to 25 years	60	18	4	19	Cramér's V = 0.0999
26-35 years	53	20	3	24	
36-45 years	44	23	5	29	
46-55 years	46	20	7	28	
56-65 years	37	20	3	39	
Greater than 65 years	49	11	3	36	
Gender					$\chi^2_{(3, 3521)} = 30.76$; $P < 0.001$
Male	44	24	5	28	Cramér's V = 0.0935
Female	53	18	4	25	
Level of education					$\chi^2_{(12, 3521)} = 199.25$; $P < 0.001$
No literacy	33	18	5	44	Cramér's V = 0.1373
Non-formal	58	17	2	23	
Basic Education / Middle school	54	18	4	24	
Secondary/ Technical	55	22	4	19	
Tertiary	57	24	5	14	

Table 5 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Inferential Statistics
Household size					$\chi^2_{(12, 3521)} = 69.23$; $P < 0.001$
1-5 people	56	18	4	22	Cramér's V = 0.0811
5-10 people	44	22	4	30	
11-15 people	39	22	4	35	
16-20 people	30	22	6	43	
More than 20 people	27	32	0	41	
Marital status					$\chi^2_{(9, 3521)} = 84.55$; $P < 0.001$
Single	59	19	4	18	Cramér's V = 0.0895
Married	46	20	4	29	
Divorced	50	18	5	27	
Widower/widow	43	17	1	40	
Household income					$\chi^2_{(15, 3521)} = 110.33$; $P < 0.001$
Less or equal 100 GH	42	14	6	37	Cramér's V = 0.1105
101-500 GH	53	18	4	25	
501-1000 GH	53	24	3	20	
1001-1500 GH	51	26	5	18	
1501-2000 GH	53	28	6	13	
Greater than 2000	33	33	4	29	

Table 5 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Inferential Statistics
Region					$\chi^2_{(27, 3521)} = 966.38$; Pr < 0.001
Greater Accra	70	19	2	9	Cramér's V = 0.3025
Ashanti	27	28	7	38	
Eastern	91	7	0	1	
Central	66	17	0	16	
Upper West	14	41	3	42	
Upper East	15	12	19	53	
Volta	62	7	6	26	
Brong Ahafo	76	13	4	7	
Northern	40	16	3	41	
Western	35	32	2	31	
Community type					$\chi^2{}_{(9, 3521)} = 106.07$; P < 0.001
Urban	58	21	4	18	Cramér's V = 0.1002
Peri urban	55	21	2	22	
Rural	45	19	5	31	

Respondents consumed cassava regardless of age and gender (Cramér's $V \leq 0.065$). There were also weak but stronger relationships between the consumption of cassava and level of education, household size, marital status, household income, region and community type (Table 6). Among the variables, region had the strongest relationship with the consumption of cassava among respondents (Table 6).

Table 6: Frequency of eating cassava (n=3521)

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Do not eat (%)	Inferential statistics
Age						$\chi^2_{(25, 3521)} = 69.47$; $P < 0.001$
Up to 25 years	25	50	2	18	4	Cramér's V = 0.0634
26-35 years	27	52	2	14	4	
36-45 years	30	51	1	15	3	
46-55 years	28	50	2	17	4	
56-65 years	40	33	1	22	4	
Greater than 65 years	41	36	1	19	4	
Gender						$\chi^2_{(5, 3521)} = 12.60$; $P = 0.027$
Male	31	44	2	19	4	Cramér's V = 0.0598
Female	28	51	2	16	4	
Level of education						
No literacy	46	27	1	20	7	$\chi^2_{(20, 3521)} = 324.61$; $P < 0.001$
Non-formal	39	33	1	23	4	Cramér's V = 0.1518
Basic Education / Middle school	27	57	1	12	3	
Secondary/ Technical	21	58	2	16	3	
Tertiary	19	48	3	26	4	

Table 6 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Do not eat (%)	Inferential statistics
Household size						$\chi^2_{(20, 3521)} = 245.52$; $P < 0.001$
1-5 people	21	56	2	3	5	Cramér's V = 0.1323
5-10 people	37	41	1	5	3	
11-15 people	53	28	1	1	3	
16-20 people	63	11	2	4	2	
More than 20 people	41	9	0	14	9	
Marital status						$\chi^2_{(15, 3521)} = 93.85$; $P < 0.001$
Single	21	56	3	4	3	Cramér's V = 0.0943
Married	33	45	1	3	4	
Divorced	24	54	1	3	5	
Widower/widow	45	40	2	1	4	
Household income						$\chi^2_{(25, 3521)} = 104.84$; $P < 0.001$
less or equal 100 GH	32	38	1	5	7	Cramér's V = 0.0835
101-500 GH	27	54	2	3	3	
501-1000 GH	27	50	2	3	4	
1001-1500 GH	27	57	4	1	2	
1501-2000 GH	24	55	4	3	1	
Greater than 2000 GH	10	67	2	3	1	

Table 6 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Do not eat (%)	Inferential statistics
Region						$\chi^2_{(45, 3521)} = 1.7 \times 10^3$; $P < 0.001$
Greater Accra	30	42	3	20	5	Cramér's V = 0.3125
Ashanti	25	56	2	15	2	
Eastern	9	89	1	1	0	
Central	33	47	2	15	3	
Upper West	72	4	0	23	1	
Upper East	2	5	3	48	43	
Volta	16	60	3	20	1	
Brong Ahafo	35	48	1	15	2	
Northern	63	13	1	22	3	
Western	18	65	0	14	3	
Community type						$\chi^2_{(15, 3521)} = 150.38$; $P < 0.001$
Urban	23	53	2	19	3	Cramér's V = 0.1193
Peri urban	27	59	1	11	2	
Rural	33	41	2	19	5	

There were weak relationships between the frequencies of eating plantain and all the demographic variables investigated. Comparatively, the relationships were stronger between frequency of eating plantain and gender, level of education, household size, marital status, household income, community type and region than age (Table 7).

Table 7: Frequency of eating plantain (n=3521)

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Do not eat (%)	Inferential statistics
Age						$\chi^2_{(25, 3521)} = 142.33$; $P < 0.001$
Up to 25 years	14	44	5	32	7	Cramér's V = 0.0907
26-35 years	17	47	3	25	8	
36-45 years	19	44	2	25	10	
46-55 years	24	40	3	24	9	
56-65 years	26	26	3	27	18	
Greater than 65 years	23	24	4	28	21	
Gender						$\chi^2_{(5, 3521)} = 104.43$; $P < 0.001$
Male	14	43	2	23	17	Cramér's V = 0.1722
Female	20	42	4	28	7	
Level of education						$\chi^2_{(20, 3521)} = 601.92$; $P < 0.001$
No literacy	12	20	2	35	30	Cramér's V = 0.2067
Non-formal	31	33	1	28	6	
Basic Education / Middle school	23	47	4	22	4	
Secondary/ Technical	13	54	4	25	5	
Tertiary	15	45	3	32	5	

Table 7 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Do not eat (%)	Inferential statistics
Household size						$\chi^2_{(20, 3521)} = 448.41$; P = 0.001
1-5 people	17	49	4	25	4	Cramér's V = 0.1788
5-10 people	22	35	2	27	14	
11-15 people	17	19	3	34	28	
16-20 people	6	11	2	29	52	
More than 20 people	0	5	5	19	73	
Marital status						$\chi^2_{(15, 3521)} = 120.79$; P < 0.001
Single	16	48	5	27	5	Cramér's V = 0.1069
Married	18	39	3	27	13	
Divorced	24	44	3	24	5	
Widower/widow	39	32	1	22	6	
Household income						$\chi^2_{(25, 3521)} = 323.65$; P < 0.001
less or equal 100 GH	14	25	4	37	20	Cramér's V = 0.1466
101-500 GH	21	47	5	24	4	
501-1000 GH	22	48	2	24	4	
1001-1500 GH	23	53	2	19	2	
1501-2000 GH	24	53	2	20	1	
Greater than 2000	12	56	0	33	0	

Table 7 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Do not eat (%)	Inferential statistics
						$\chi^2_{(45, 3521)} = 2.8 \times 10^3$; $P < 0.001$
Region						Cramér's V = 0.3996
Greater Accra	29	40	2	24	5	
Ashanti	32	49	1	18	0	
Eastern	7	89	4	1	0	
Central	31	45	2	20	2	
Upper West	1	2	0	22	75	
Upper East	1	3	1	65	29	
Volta	6	25	17	48	4	
Brong Ahafo	20	43	1	33	3	
Northern	2	12	2	45	39	
Western	19	62	0	18	1	
Community type						$\chi^2_{(15, 3521)} = 254.79$; $P < 0.001$
Urban	21	48	2	26	4	Cramér's V = 0.1553
Peri urban	19	52	2	22	5	
Rural	17	34	4	30	15	

Just like the association between demographic factors and consumption of cassava and plantain, similar week associations were found between the consumption of maize and demographic factors. Specifically, age, gender, marital status, household income and community type had weak association with the number of times that one eats maize. The strongest association was found between consumption of maize and region (Table 8).

Table 8: Frequency of eating maize (n=3521)

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Inferential statistics
Age					$\chi^2_{(20, 3521)} = 73.02$; $P < 0.001$
Up to 25 years	41.82	40.77	0.58	16.82	Cramér's V = 0.0727
26-35 years	47.69	38.75	1.01	12.55	
36-45 years	50.72	35.94	0.58	12.76	
46-55 years	42.17	38.55	0.96	18.31	
56-65 years	50.22	25.97	1.73	22.08	
Greater than 65 years	47.8	30.22	1.1	20.88	
Gender					$\chi^2_{(4, 3521)} = 18.20$; $P = 0.001$
Male	48.83	32.69	0.81	17.66	Cramér's V = 0.0719
Female	45.43	38.92	0.87	14.79	
Level of education					$\chi^2_{(16, 3521)} = 223.83$; $P < 0.001$
No literacy	64.16	15.46	0.87	19.88	Cramér's V = 0.1261
Non-formal	47.97	32.43	0.68	18.92	
Basic Education / Middle school	43	42.36	1.02	13.61	
Secondary/ Technical	40.68	44.89	0.49	13.94	
Tertiary	38.88	42.89	0.8	17.44	

Table 8 continue

Respondents characteristics	Daily (%)	Weekly (%)	Monthly (%)	Rarely (%)	Inferential statistics
Household size					$\chi^2_{(16, 3521)} = 178.02$; $P < 0.001$
1-5 people	39.48	44.84	0.86	14.82	Cramér's V = 0.1127
5-10 people	53.81	28.55	0.87	16.78	
11-15 people	68.51	17.68	1	12.71	
16-20 people	77.78	5.56	0	16.67	
More than 20 people	63.64	4.55	0	31.82	
Marital status					$\chi^2_{(12, 3521)} = 87.91$; $P < 0.001$
Single	38.48	45.82	0.6	15.10	Cramér's V = 0.0912
Married	50.81	32.81	1.03	14.63	
Divorced	41.24	39.55	1.13	18.08	
Widower/widow	55.12	24.41	0	20.47	
Household income					$\chi^2_{(20, 3521)} = 98.57$; $P < 0.001$
less or equal 100 GH	41.67	33.74	1.42	23.17	Cramér's V = 0.0905
101-500 GH	41.41	44.1	1.06	13.43	
501-1000 GH	47.66	38.88	0.91	12.56	
1001-1500 GH	55.36	29.17	0	15.48	
1501-2000 GH	41.28	38.53	0	20.19	
Greater than 2000 GH	61.21	29.7	0	9.09	

Table 8 continue

Respondents characteristics	Daily (%)	Week (%)	Monthly (%)	Rarely (%)	Inferential statistics
Region					$\chi^2_{(36, 3521)} = 1.4 \times 10^3$; $P < 0.001$
Greater Accra	48.13	23.83	0.93	27.10	Cramér's V = 0.3099
Ashanti	52.1	27.84	1.05	19.01	
Eastern	8.14	91.53	0.34	0	
Central	61.74	34.01	0.37	3.88	
Upper West	82.89	1.97	0	15.13	
Upper East	35.33	9.33	5.33	50.00	
Volta	25	58.16	0.26	16.59	
Brong Ahafo	26.01	43.65	1.86	28.48	
Northern	82.16	7.31	0.29	10.23	
Western	40.99	46.62	0.45	11.94	
Community type					$\chi^2_{(12, 3521)} = 88.63$; $P < 0.001$
Urban	47.92	36.22	0.32	15.54	Cramér's V = 0.0916
Peri urban	44.76	43.39	0.68	11.17	
Rural	46.9	33.30	1.20	18.60	

In all the 10 regions of Ghana, women were the people influencing cooking at the household level: Men come next in the influence of cooking in the home (Figure 9).

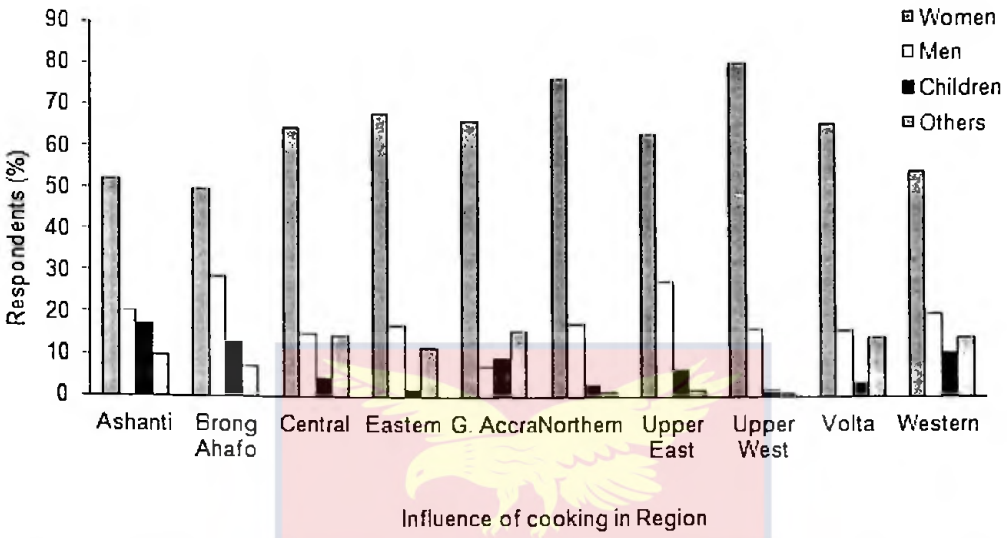

Figure 9: Persons that influence cooking in the regions of Ghana. G. Accra = Greater Accra Region.

Inspite of the overwhelming influence of women in the cooking process at the household level, men are also overwhelmingly the bread winner is of most homes in the country. The contribution of women and other family member cannot be discounted though (Figure 10).

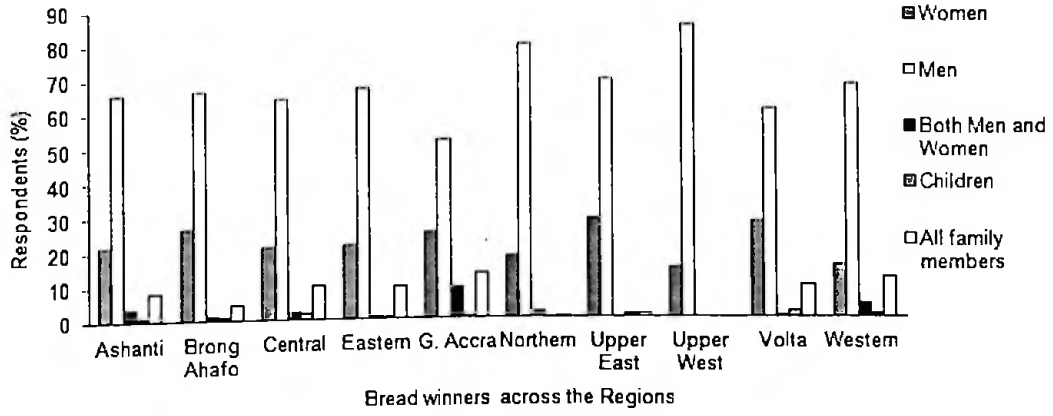

Figure 10: Bread winners of families across the regions of Ghana.

Concentration of micronutrients in cassava

The mean concentration of Fe in the samples of *M. esculenta* var. Capevars bankye and *M. esculenta* var. Ampong were 0.0251 ± 0.002 and 0.0256 ± 0.003 mg/Kg respectively. These were statistically not different (t = 0.22, P = 0.836). Furthermore, the mean concentration of Zn in Capevars bankye and Ampong were 0.034 ± 0.008 and 0.029 ± 0.003 respectively. These were also not significantly different from each other (t = 1.08, P = 0.330). Similarly, the concentrations of Mn (t = -0.60, P = 0.576) and Cu (t = 0.74, P = 0.493) were not significantly different among Capevars bankye and Ampong respectively (Figure 11).

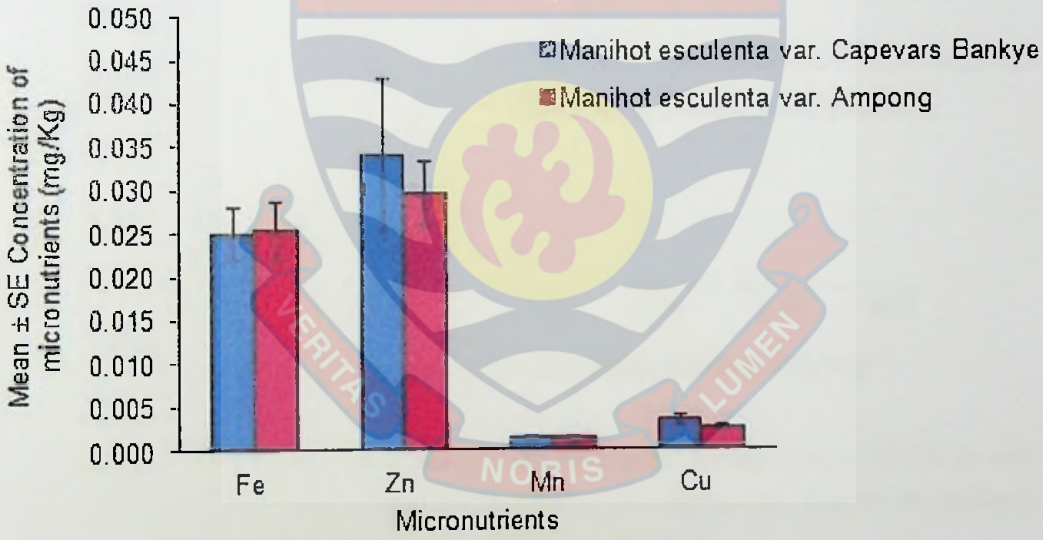

Figure 11: Mean ± concentration (mg/Kg) of Fe, Zn, Mn and Cu in Manihot esculenta var. Capevars and Manihot esculenta var. Ampong.

Difference in concentration of micronutrients in soil before planting and after harvesting of cassava

The concentration of micronutrients in the soil before planting was different from the concentration in soil after harvesting. For instance, the mean concentration of Fe in the soil before Capevars bankye was planted in the

three blocks was 0.44 ± 0.05 mg/Kg but after harvest, the mean concentration of Fe in the soil in the blocks was 0.14 ± 0.03 mg/Kg. Regression analysis showed a strong relationship between the difference in concentration of Fe in the soil before planting and after harvesting, and the concentration of Fe in the soil before planting (R^2 = 89.9%; Figure 12).

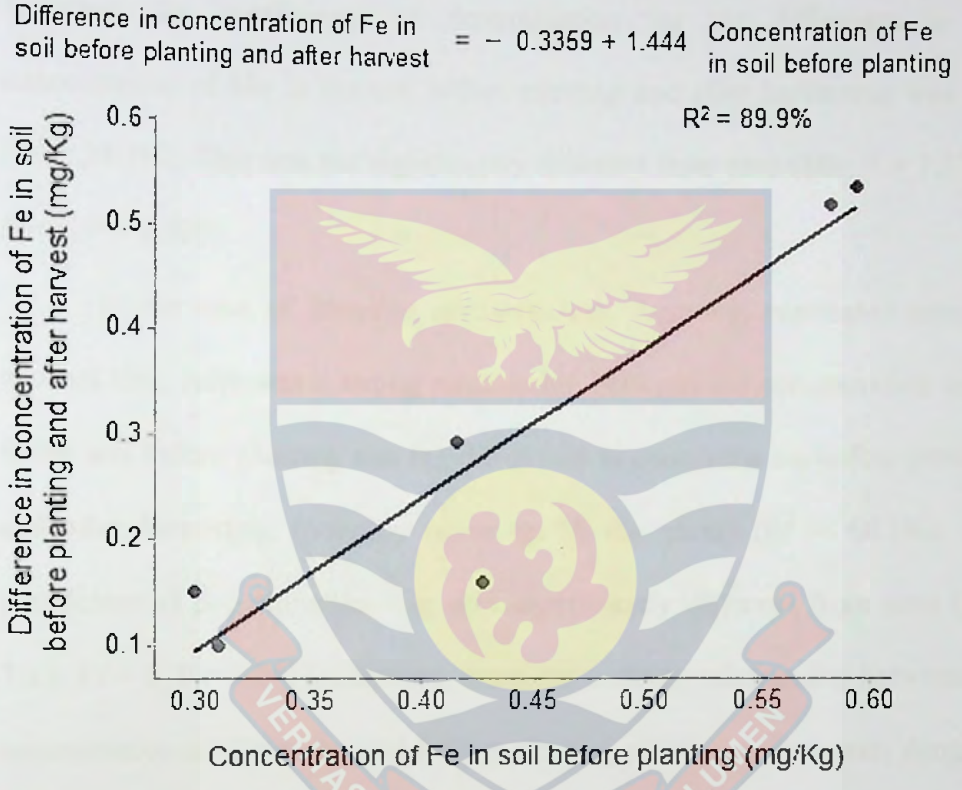

Figure 12: Relationship between the difference in concentration of Fe in soil before planting and after harvest of Manihot esculenta var. Capevars bankye, and the concentration of Fe in the soil before planting.

Analysis of variance also showed that there was a significant different between the coefficient of determination and zero (F = 35.7, d. f. = 5, P = 0.004). Similarly, there was a strong relationship between the concentration of Cu in the soil before planting of Capevars bankye and the concentration lost from the soil after harvest (R^2 = 89.1%; F = 32.79, d.f. = 5, P = 0.005). Therefore for both Fe and Cu, the concentration of micronutrients lost from

the soil (possibly taken up by the crop) increased significantly when the concentrations of those micronutrients were already high in the soil.

The coefficient of determination for the difference in concentration of Zn in soil before planting and after harvesting was relatively high (R^2 = 60.9) but was not significantly different from zero (F = 6.22, d. f. = 5, P = 0.067) However, the coefficients of determination for the difference in the concentration of Mn in the soil before planting and after harvesting was low (R^2 = 24.1%). This was not significantly different from zero (Mn: F = 1.27, d. f. = 5, P = 0.322).

In the case of *Manihot esculenta* var. Ampong, regression analysis showed that, there was a strong relationship between the concentration of Fe in the soil before planting and the difference in concentration before planting and after harvesting (possibly taken up by the plant) (R^2 = 60.1%). The coefficient of determination was also significantly different from zero (F = 7.53, d.f = 6, P = 0.041). Likewise, there was a strong relationship between the concentration of Cu in the soil before planting of *M. esculenta* var, Ampong and the concentration lost from the soil (possibly taken up by the plant) (R^2 = 99%; Figure 13). Analysis of variance also showed that there was a significant different between the coefficient of determination and zero (F = 14.22, d.f. = 6, P = 0.013). The relationships between the difference in concentration of Zn and Mn in the soil before planting and after harvest, and the concentration of these micronutrients originally in the soil were weak (Zn: R^2 = 4.7%; Mn: R^2 = 7.4%). There were also not significantlty different from zero (Zn: F = 0.24, d.f. = 6, P = 0.642; Mn: F = 0.40, d.f. = 6, P = 0.554).

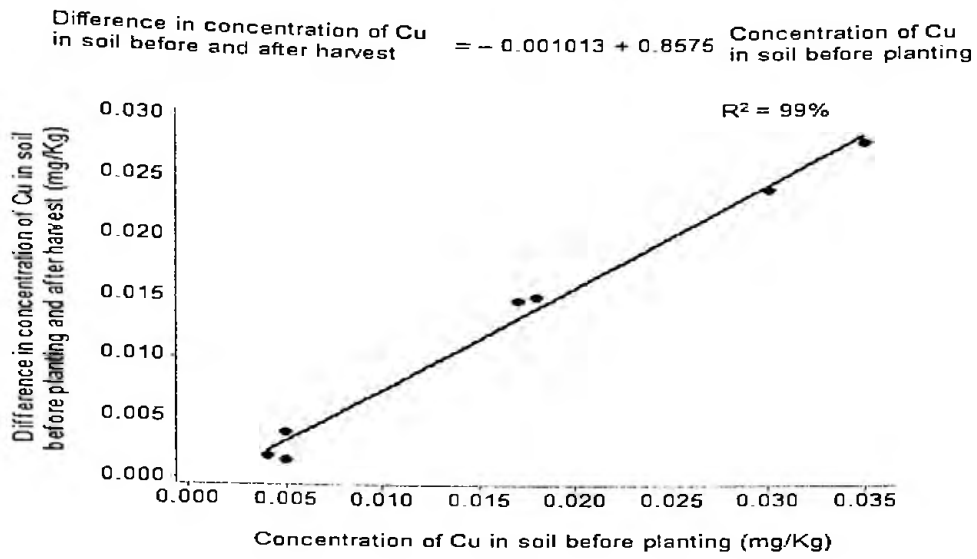

Figure 13: Relationship between the difference in concentration of Cu in soil before planting and after harvest of Manihot esculenta var. Ampong, and the concentration of Cu in soil before planting.

Concentration of beta-carotene in cassava

The *beta*-carotene concentration in the two varieties of cassava studied were not significantly different ($t = 0.07$, $P = 0.945$; Figure 14).

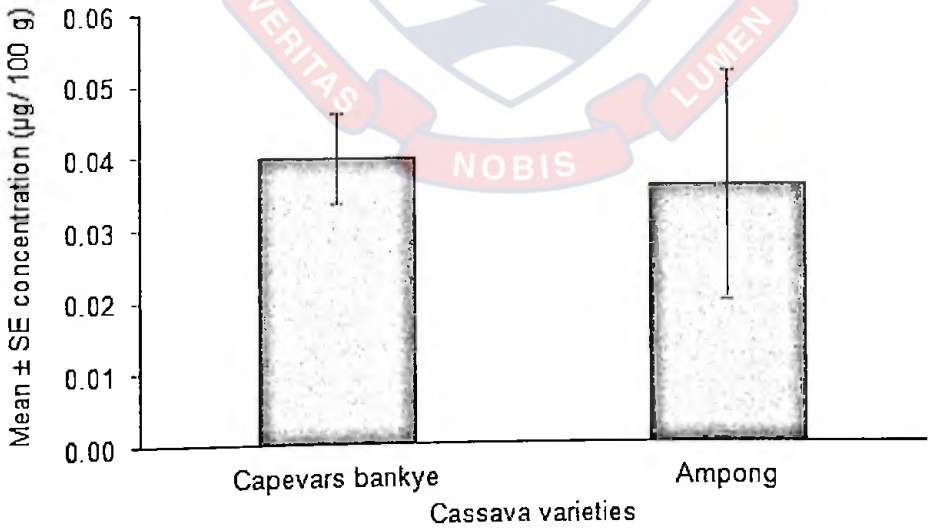

Figure 14: Mean ± concentration in µg/100g of beta-carotene in Manihot esculenta var. Capevars bankye and Manihot esculenta var. Ampong

Concentration of micronutrients in plantain

The concentration of each of the micronutrients, Fe, Zn, Mn, Cu studied was not significantly different in all four varieties of plantain (Fe: $F = 0.95$, d.f. = 3, $P = 0.428$; Zn: $F = 0.15$, d.f. = 3, $P = 0.927$; Mn: $F = 0.35$, d.f. = 3, $P = 0.789$; Cu: $F = 0.28$, d.f. = 3, $P = 0.841$; Figure 15).

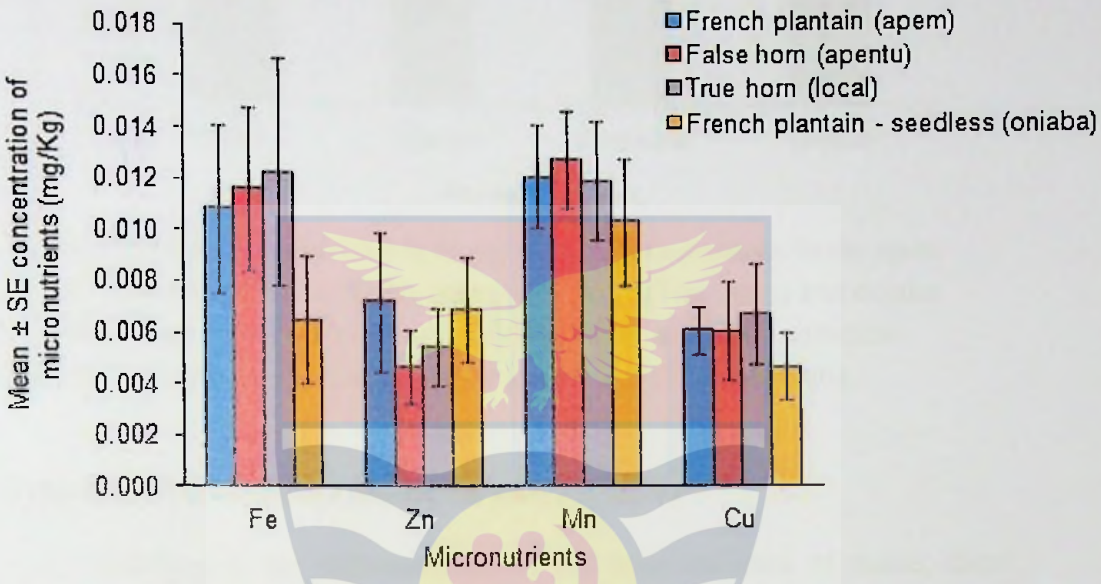

Figure 15: Mean ± concentration in mg/Kg of Fe, Zn, Mn and Cu in different varieties of Plantain. No significant differences were observed at a P-value ≤ 0.05 (ANOVA, Minitab).

Concentration of beta-carotene in plantain

The concentrations of beta-carotene in all four varieties of plantain were not significantly different although oniaba was slightly higher numerically ($F = 1.17$, d.f. = 3, $P = 0.33$; Figure 16).

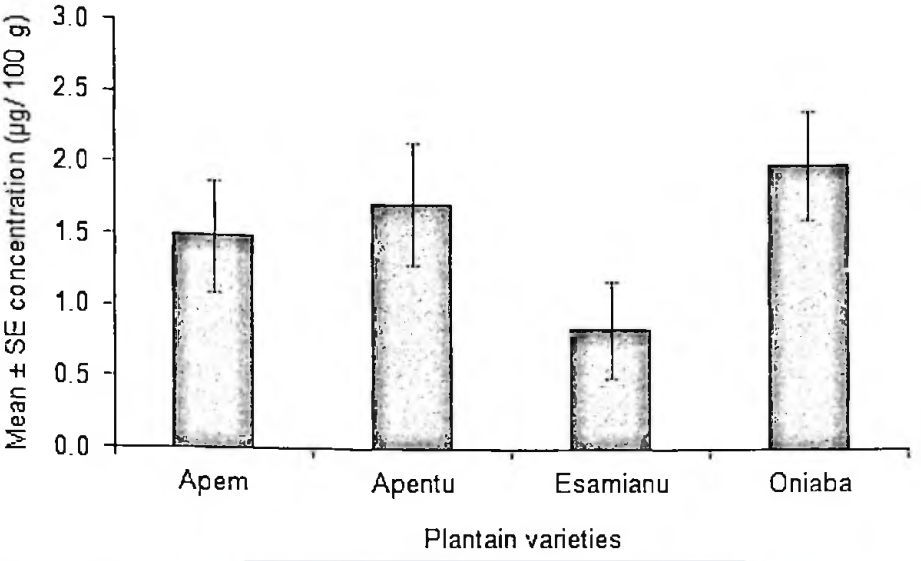

Figure 16: Mean ± concentration in µg/100g of beta-carotene in the apem (French plantain), Apentu (False horn), Esamianu (True horn) and oniaba (seedless French plantain) varieties of Musa paradisiaca. No statistical differences were observed at a P-value ≤ 0.05 (ANOVA, Minitab).

Concentration of micronutrients in maize

Comparing the micronutrients in the three varieties of maize, there were significant differences in the concentrations of Zn ($F = 21.57$, d.f. = 2, $P = 0.002$) and Cu ($F = 9.44$, d.f. = 2, $P = 0.014$; Figure 17). However, there were no significant differences in the concentrations of Fe ($F = 2.70$, d.f. = 2, $P = 0.146$) and Mn ($F = 1.10$, d.f. = 2, $P = 0.391$; Figure 17) among the different varieties of maize.

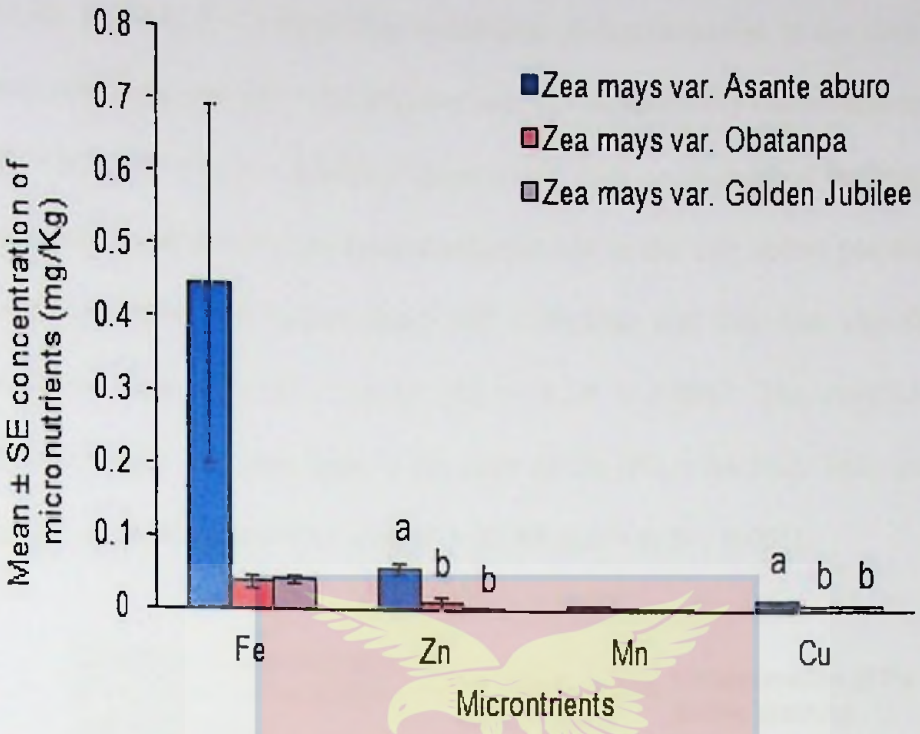

Figure 17: Mean ± concentration in mg/Kg of Fe, Zn, Mn and Cu in three Zea mays varieties (Asante aburo, obatanpa and golden jubilee). Bars capped with different letters indicate significant differences at a P-value ≤ 0.05 (ANOVA, Minitab).

Difference in concentration of micronutrients in soil before planting and after harvesting of maize

The micronutrients concentration in the soil before planting of maize was different from the concentration in soil after harvesting. The mean concentration of Fe in the soil before maize was planted in the three blocks was 0.43 ± 0.049 mg/Kg but after harvesting Asante aburo, the mean concentration of Fe at the spots where the maize were planted in the blocks was 0.173 ± 0.044 mg/Kg. Regression analysis of the difference in concentration of Fe in the soil before planting and after harvesting of Asante aburo showed a strong coefficient of determination (R^2 = 88.6%; Figure 18). The coefficient of determination was significantly different from zero (F =

54.42, d.f. = 8, P < 0.001). The coefficient of determination in the case of Zn was relatively low (R^2 = 48.9%) but was not significantly different from zero (F = 6.7, d.f. = 8, P = 0.036). There was a high coefficient of determination between the difference in concentration of Mn in the soil before planting and after harvesting of Asante aburo (R^2 = 84.9%) and this was significantly different from zero (F = 39.39, d.f. = 8, P < 0.001). The coefficient of determination was also high in the case of Cu (R2 = 84.7%). This was also significantly different from zero (F = 38.85, d.f. = 8, P < 0.001).

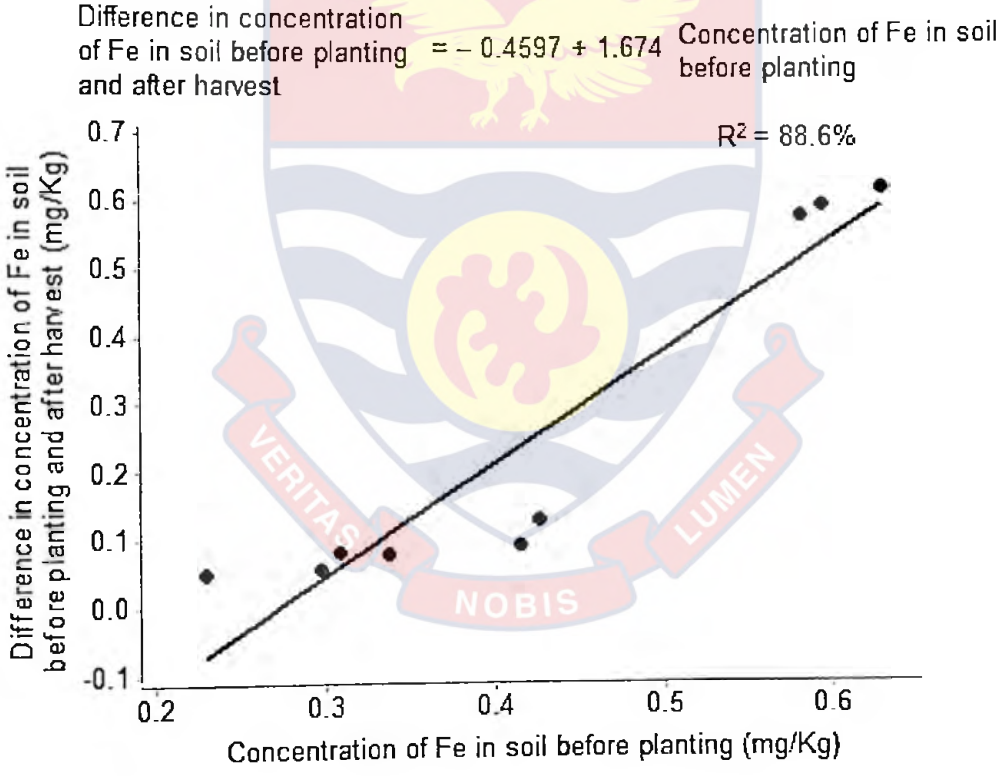

Figure 18: Relationship between the difference in concentration of Fe in soil before planting and after harvest of Zea mays var. Asante aburo, and the concentration of Fe in soil before planting.

In *Zea mays* var. obatanpa, there was a strong relationship between the difference in Fe concentration in the soil before planting and after harvesting, and the concentration of Fe in the soil before planting (R^2 = 84.4%). Analysis

of variance also showed a significant difference between the coefficient of determination and zero ($F = 37.73$, d.f. = 8, $P < 0.001$). There was a weak relationship in the case of Zn ($R^2 = 9.1\%$, $F = 0.70$, d.f. = 8, $P = 0.431$). There was a strong relationship in the case of Mn ($R^2 = 86.9\%$, $F = 46.2$, d.f. = 8, $P < 0.001$). Like Zn, there was a weak relationship between the difference in Cu concentration in the soil before planting and after harvest, and the concentration in the soil before planting ($R^2 = 5.5\%$, $F = 0.41$, d.f. = 8, $P = 0.545$).

In *Zea mays* var. Golden Jubilee, there was also a strong relationship between the difference in Fe concentration in the soil before planting and after harvesting, and the concentration of Fe in the soil before planting ($R^2 = 90.9\%$). Analysis of variance showed a significant difference between the coefficient of determination and zero ($F = 69.96$, d.f. = 8, $P < 0.001$). A similar trend was found in the case of Zn ($R^2 = 78.5\%$, $F = 25.56$, d.f. = 8, $P = 0.001$). There was also a very weak relationship in the case of Mn ($R^2 = 81.4\%$, $F = 30.67$, d.f. = 8, $P = 0.001$). Furthermore, there was a strong relationship between the difference in Cu concentration in the soil before planting and after harvest, and the concentration in the soil before planting ($R^2 = 88.4\%$, $F = 53.5$, d.f. = 8, $P < 0.001$).

Concentration of beta-carotene in maize

There were no significant differences in the beta-carotene concentration in the three varieties of maize ($F = 0.87$, d.f. = 2, $P = 0.466$) although the concentration in golden jubilee was numerically higher than that of obatanpa and Asante aburo varieties (Figure 19).

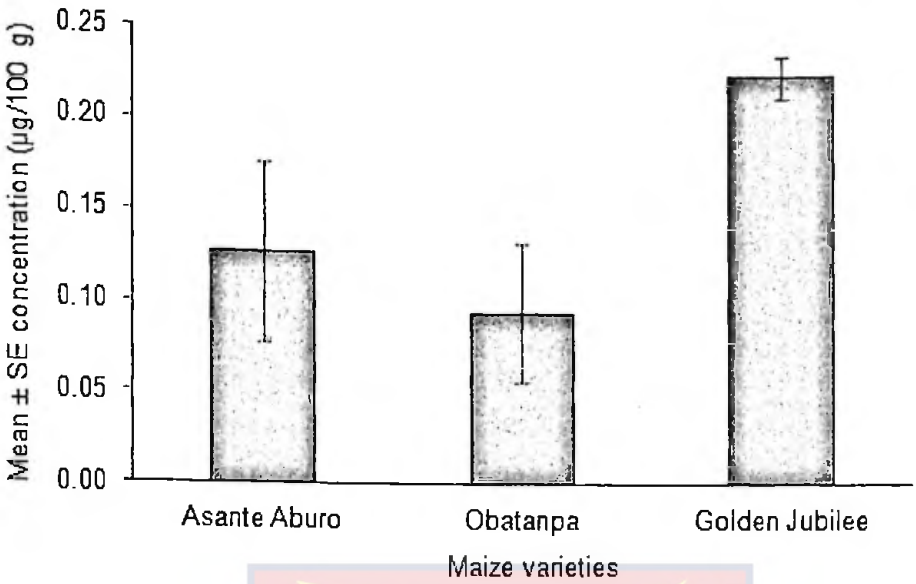

Figure 19: Mean ± concentration in µg/100g of beta-carotene in Asante aburo, obatanpa and golden Jubilee. No significant differences were observed at a P-value ≤ 0.05 (ANOVA, Minitab).

Concentration of micronutrients in selected fruits and vegetables

The concentration of Fe in three varieties of mango namely Palmer, Jaffna and Alphonso mango was different ($F = 25.66$, d.f. $= 2$, $P < 0.001$). The concentration of Fe was highest in the Alphonso mango followed by Jaffna. Palmer had the lowest concentration in Fe. A similar trend was observed in the concentration of Mn among the three mango varieties ($F = 62.32$, d.f. $= 2$, $P < 0.001$). However, there were no significant differences in the level of Zn ($F = 3.18$, d.f. $= 2$, $P = 0.060$) and Cu ($F = 1.31$, d.f. $= 2$, $P = 0.289$) in all three mango varieties although numerically, the followed the same trend as in Fe and Mn (Figure 20).

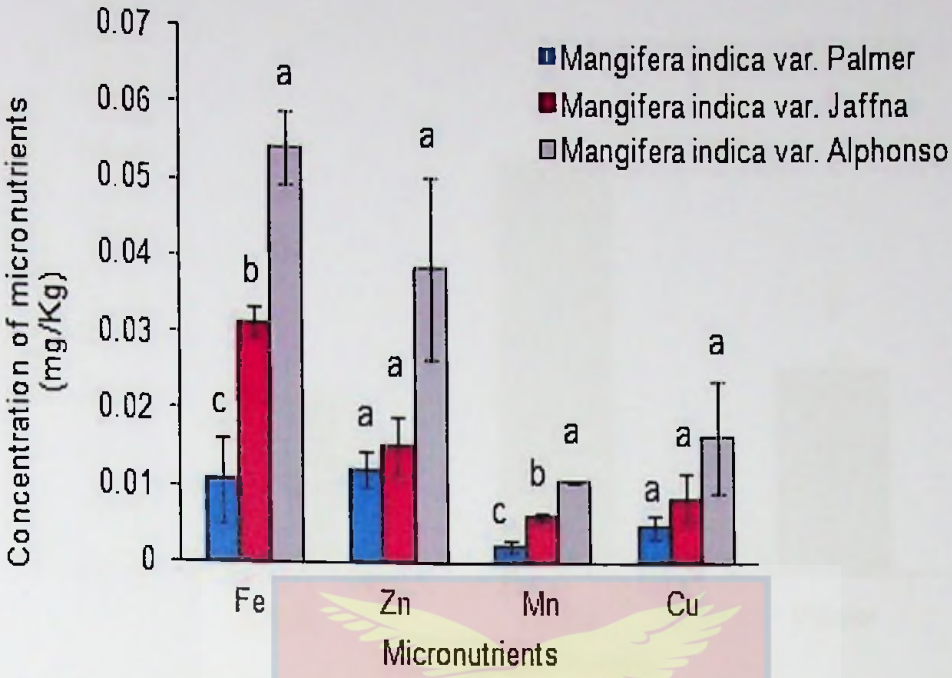

Figure 20: Mean ± concentration in mg/Kg of Fe, Zn, Mn, Cu in Palmer, Jaffna and Alphonso varieties of mango. Bars capped with different letters indicate statistical differences at a P-value ≤ 0.05 (ANOVA, Minitab)

The beta-carotene concentration in mango varied significantly among the three varieties ($F = 9.59$, d.f. = 2, $P = 0.001$; Figure 21). Jaffna had the highest concentration of beta-coreotene and this was significantly higher than the amount in Palmer and the Alphonso variety. The concentration of beta-carotene in the Alphonso variety and Palmer were statistically the same (Figure 21).

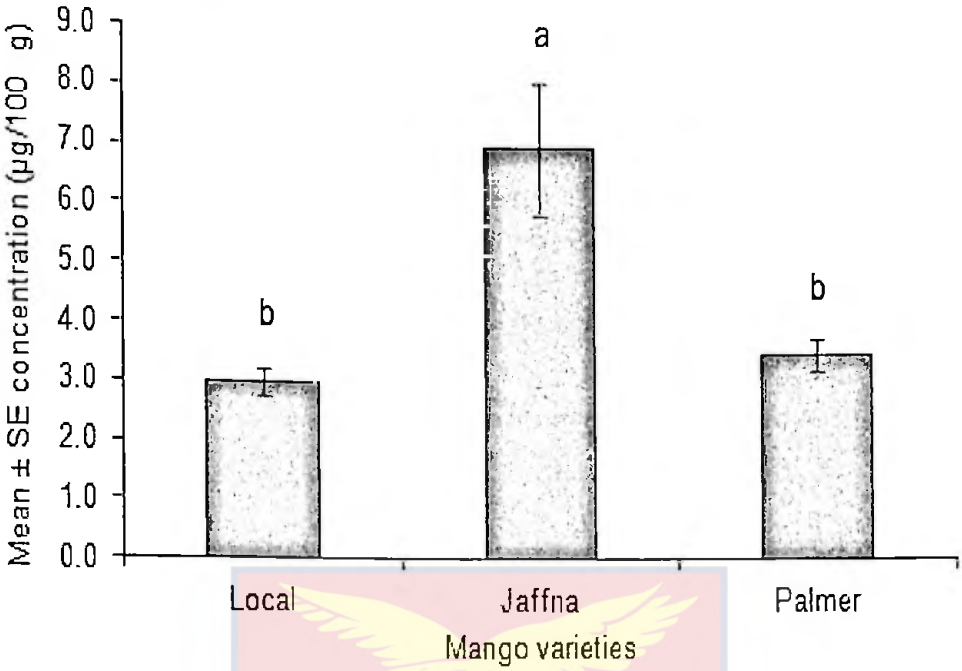

Figure 21: Mean ± concentration in µg/100g of beta-carotene in three varieties (Alphonso, Jaffna, Palmer) of Mangifera indica. Bars capped with different letters indicate statistical differences at a P-value ≤ 0.05 (ANOVA, Minitab).

There were variable amounts of micronutrients in various fruits and vegetables (Table 9). Concentration of micronutrients typically ranged from 0.0 – 0.08 mg/Kg and the concentration of macronutrients ranged from 0.32 – 68.73 mg/Kg.

Table 9: Concentration (mg/Kg) of micro and macronutrients present in selected vegetables

Scientific name	Local name	Crop type	Mean concentration of micronutrients			
			Fe	Zn	Mn	Cu
Corchorus olitorious	Ayoyo	Leafy vegetable	0.064±0.01	0.0072±0	0.0125±0	0.002±0
Amaranthus cruentus	Aleefu	Leafy vegetable	0.0805±0.06	0.0075±0.01	0.0115±0.01	0.00
Roselle calyx	Sobolo	Dried hibiscus flowers	0.051±0	0.0064±0	0.0455±0	0.003±0
Manihot esculenta	Capevars leaves	Leafy vegetable	0.036±0	0.0074±0	0.0395±0	0.00
Colocasia esculenta	Kontomire	Leafy vegetable	0.0255±0	0.00	0.0225±0	0.00
Capsicum annuum Group	Green pepper	Fruity vegetable	0.0055±0	0.0053±0	0.009±0	0.0055±0
Phaseolus vulgaris	Green beans	Fruity vegetable	0.00	0.0072±0	0.012±0	0.005±0
Brassica oleracea var. capitata	Cabbage	Leafy vegetable	0.00	0.00705±0	0.0285±0	0.005±0
Solanum melongena (L)	Garden Eggs	Fruity vegetable	0.011±0	0.0061±0	0.01±0	0.006±0
Daucus carota L.	Carrot	Root vegetable	0.0155±0	0.0077±0	0.018±0	0.007±0
Abelmoschus esculentus	Fresh okro	Fruity vegetable	0.00	0.00705±0.01	0.018±0.01	0.007±0
Abelmoschus esculentus	Dried okro	Fruity vegetable	0.0225±0	0.0103±0	0.0175±0	0.008±0
Phaseolus lunatus L.	Beans (Bush Lima)	Fruity vegetable	0.0275±0.02	0.00805±0	0.01±0	0.0085±0
Elaeis guineensis Jacq.	Palm fruit	Fruity vegetable	0.028±0	0.0057±0	0.0095±0	0.0095±0

Table 9 continue

Scientific name	Local name	Crop type	Concentration of micronutrients			
			Fe	Zn	Mn	Cu
Elaeis guineensis	Palm fruit	Fruity vegetable	0.024±0	0.00	0.008±0	0.0105±0
Capsicum chinense Habanero		Fruity vegetable				
Group	Pepper		0.023±0	0.00645±0	0.011±0	0.01±0
Solanum lycopersicum	Tomato	Fruity vegetable	0.02±0	0.00335±0	0.0085±0	0.01±0
Tetrapleura tetraptera	Prekese	Fruity vegetable	0.06±0	0.00645±0	0.013±0	0.0095±0
Solanum torvum	Kwawu nsusua	Fruity vegetable	0.048±0.007	0.01032±0.005	0.011167±0.0004	0.002±0.00026

The concentration of each vegetable was obtained from a mixture of 5 samples of the vegetable.

Concentration of micronutrient in water

Concentration of Fe

The concentration of Fe was variable in the different water bodies that were studied. In river Bomene at Amenase, there were significant differences in the concentration of Fe at the source, middle and outflow ($F = 11.03$, d.f. = 3, $P = 0.001$). The concentration was significantly higher at the middle and outflow than the source (Figure 22A). Similarly, there were significant differences in the concentration of Fe at the different segments of river Aponapon in Juaben ($Fe = 4.13$, d.f. = 2, $P = 0.037$). The concentration was significantly higher in the middle than the source but this was not significantly higher than the concentration at the outflow (Figure 22B). However, there were no significant differences in concentration of Fe at the source, middle and outflow of rivers Adwee at Mampong Ashanti ($F = 0.08$, d.f. = 2, $P = 0.924$; Figure 22C), Dwayire at Anyinabrim ($t = 0.02$, $P = 0.982$; Figure 22D), Atonsu at Atonsu ($t = 1.54$, $P = 0.183$; Figure 22E), Suruwi at Amissano ($F = 0.46$, d.f. = 2, $P = 0.638$; Figure 22F), Jejeti at Jejeti ($F = 0.615$, d.f. = 2, $P = 0.615$ Figure 22G), Abumasu at Osiem ($F = 0.0$, d.f. = 2, $P = 0.997$ Figure 44H) and Asupong at Nsutem ($t = 0.56$, $P = 0.60$; Figure 22I).

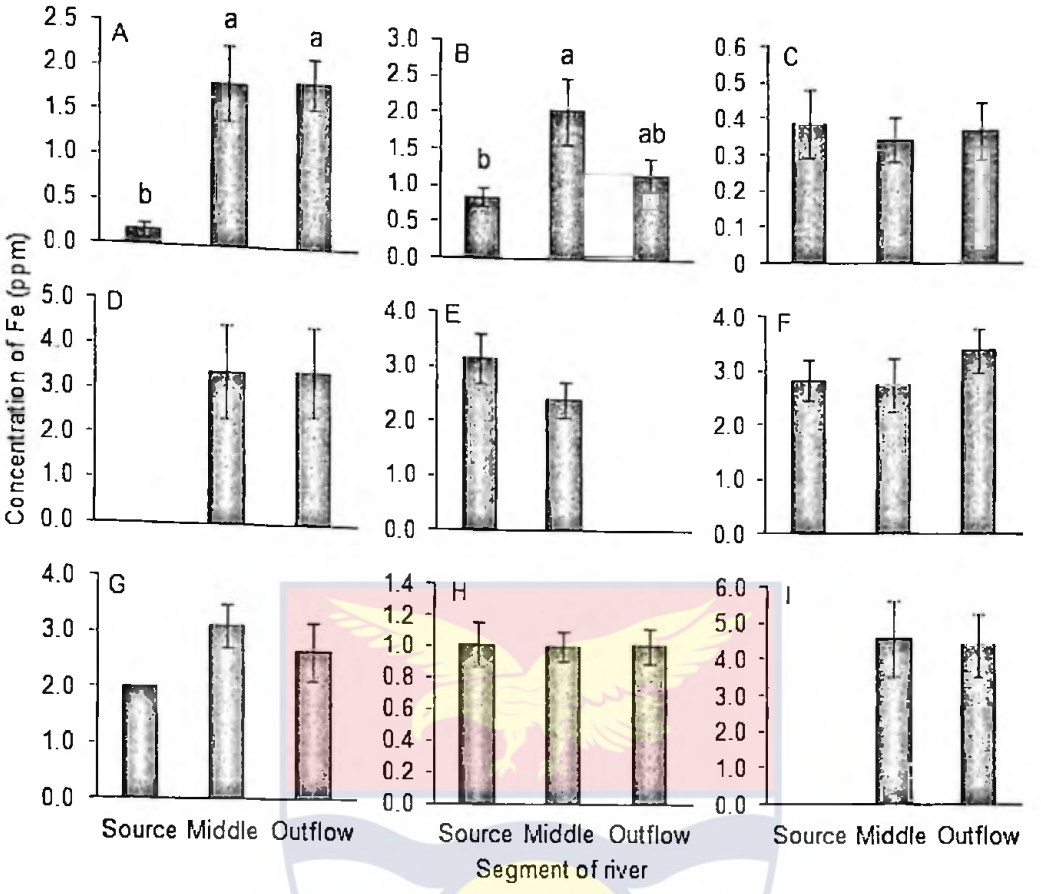

Figure 22: Mean ± concentration in ppm of Fe at the source, middle and outflow of rivers (A) Bomene at Amenase, (B) Aponapon at Juaben, (C) Adwee at Mampong Ashanti in the Ashanti Region; (D) Dwayire at Anyinabrim, (E) Atonsu at Atonsu, (F) Suruwi at Amissano in the Central Region and; (G) Jejeti at Jejeti, (H) Abumasu at Osiem and (I) Asupong at Nsutem in the Eastern Region of Ghana. Bars capped with different letters indicate significant difference at $P \leq 0.05$ (ANOVA and t-test, Mintab).

Concentration of Cu

The concentration of Cu at the source, middle and outflow of all the rivers studied was not significantly different (Bomene: $F = 0.18$, d.f. = 2, $P = 0.835$; Aponapon: $F = 0.05$, d.f. = 2, $P = 0.954$; Adwee: $F = 0.07$, d.f. = 2, $P = 0.936$; Dwayire: $t = 1.81$, $P = 0.131$; Atonsu: $t = 1.30$, $P = 0.250$; Suruwi: $F = 0.20$, d.f. = 2, $P = 0.824$; Jejeti: $F = 0.21$, d.f. = 2, $P = 0.817$; Abumasu: $F = 0.01$, d.f. = 2, $P = 0.987$; Asupong: $t = 1.06$, $P = 0.339$; Figure 23).

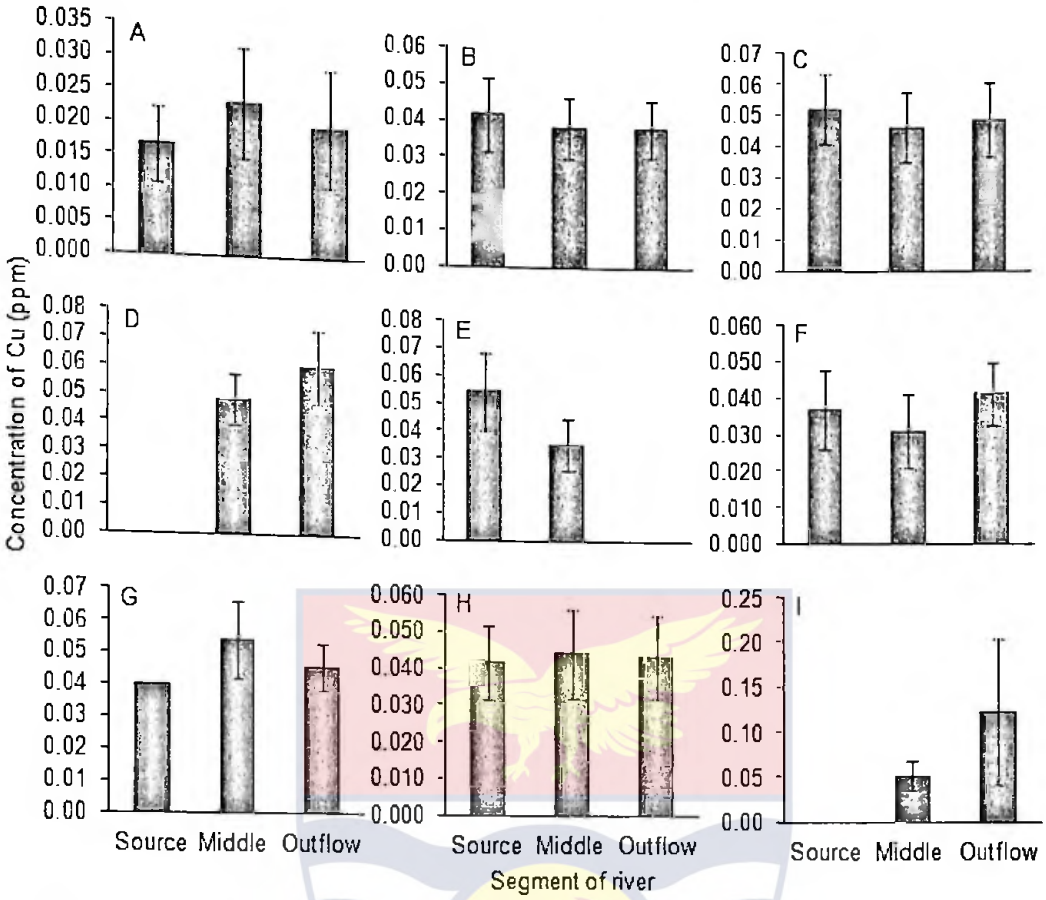

Figure 23: Mean ± concentration in ppm of Cu at the source, middle and outflow of rivers (A) Bomene at Amenase, (B) Aponapon at Juaben, (C) Adwee at Mampong Ashanti in the Ashanti Region; (D) Dwayire at Anyinabrim, (E) Atonsu at Atonsu, (F) Suruwi at Amissano in the Central Region and; (G) Jejeti at Jejeti, (H) Abumasu at Osiem and (I) Asupong at Nsutem in the Eastern Region of Ghana. No significant differences were observed at a P-value ≤ 0.05 (ANOVA, Minitab).

Concentration of Zn

The concentrations of Zn at the source, middle and outflow of all the rivers studied except Jejeti were not significantly different (Bomene: F = 0.99, d.f. =2, P = 0.394; Aponapon: F = 0.90, d.f. = 2, P = 0.426; Adwee: F = 0.48, d.f. = 2, P = 0.626; Dwayire: t = 0.0, P = 1.0; Atonsu: t = 0.46, P = 0.666; Suruwi: F = 0.35, d.f. = 2, P = 0.710; Jejeti: F = 7.21, d.f. = 2, P = 0.016; Abumasu: F = 0.16, d.f. = 2, P = 0.850; Asupong: t = 0.22, P = 0.833; Figure 24).

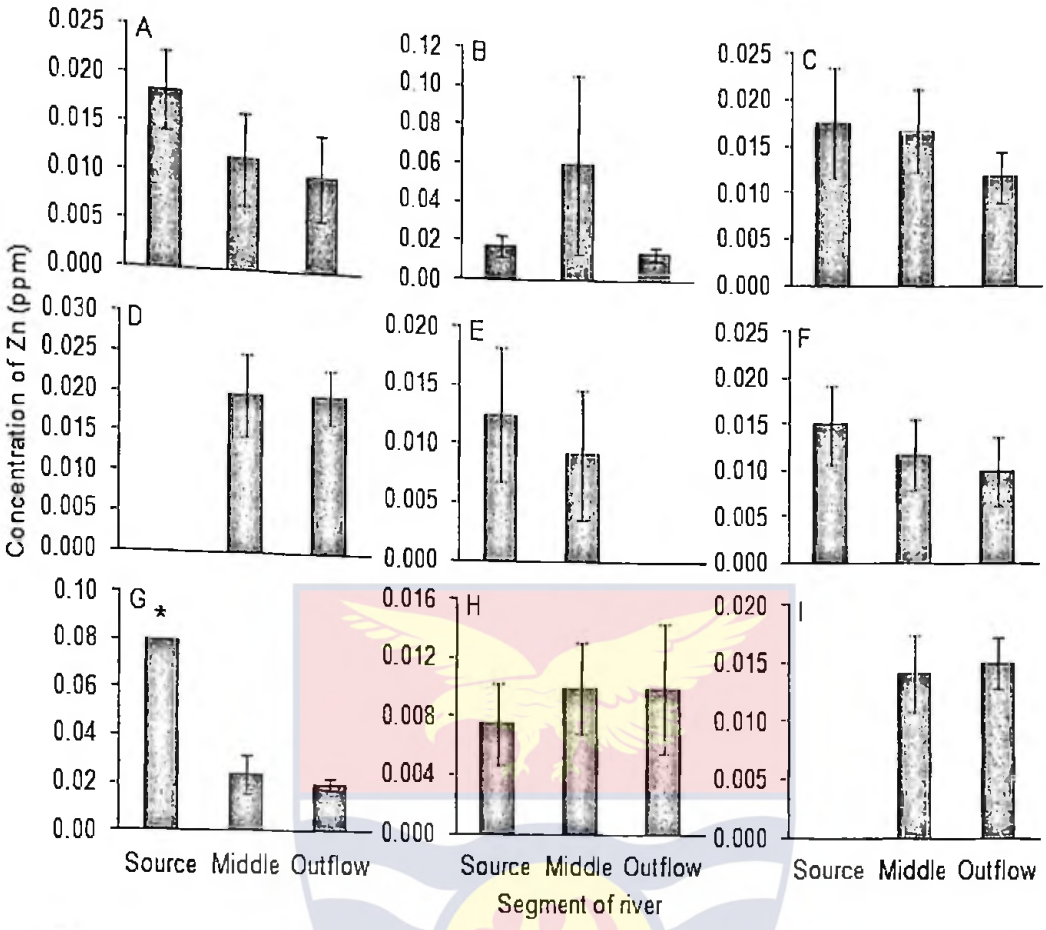

Figure 24: Mean ± concentration in ppm of Zn at the source, middle and outflow of rivers (A) Bomene at Amenase, (B) Aponapon at Juaben, (C) Adwee at Mampong Ashanti in the Ashanti Region; (D) Dwayire at Anyinabrim, (E) Atonsu at Atonsu, (F) Suruwi at Amissano in the Central Region and; (G) Jejeti at Jejeti, (H) Abumasu at Osiem and (I) Asupong at Nsutem in the Eastern Region of Ghana. Bar capped with asterisk is significantly difference at $P \leq 0.05$ (ANOVA, Minitab).

Comparing the composite concentration of all rivers, there were significant differences in the combined average concentration of Fe in all the rivers ($F = 9.34$, d.f. = 8, $P < 0.001$; Figure 25). Rivers Dwayire at Anyinabrim in the Central region and Asupong at Nsutem in the Eastern region had significantly higher Fe than rives Bomene, Aponapon, Adwee and Abumasu but their Fe concentration were not significantly higher than those in rivers Atonsu, Suruwi and Jejeti (Figure 25A).

The combined concentrations of Cu in all the water bodies studied were not significantly different ($F = 0.94$, d.f. = 8, $P = 0.494$; Figure 25B).

Similarly, the combined concentrations of Zn in all the water bodies studied were also not significantly different ($F = 0.94$, d.f. = 8, $P = 0.497$; Figure 25C).

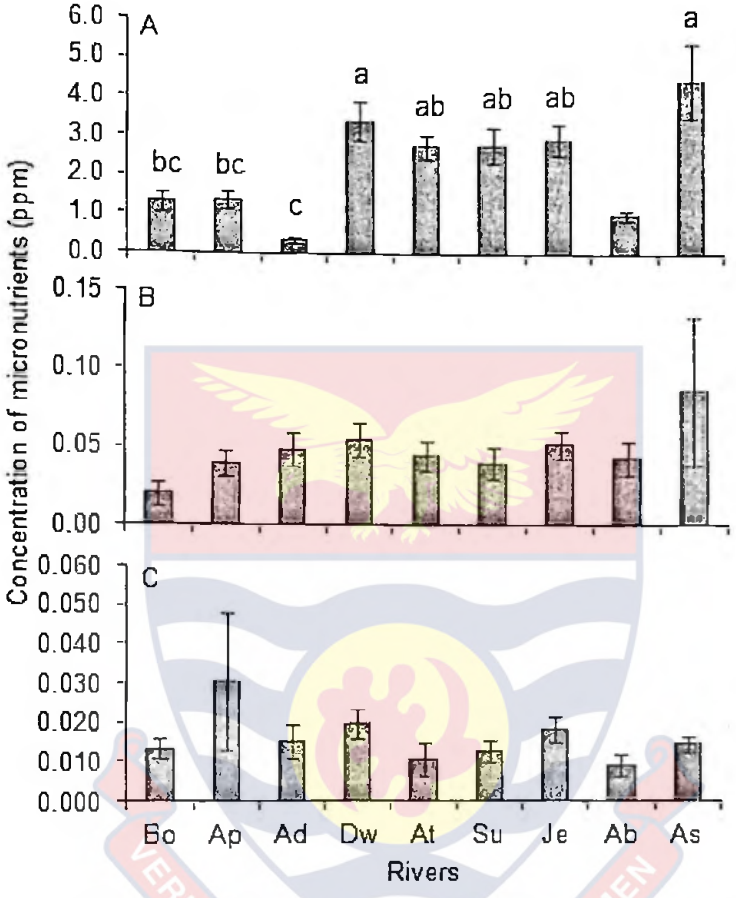

Figure 25: Mean ± concentration in ppm of Fe (A), Cu (B) and Zn (C) in the rivers Bo (Bomene), Ap (Aponapon), Ad (Adwee), Dw (Dwayire), At (Atonsu), Su (Suruwi), Je (Jejeti), Ab (Abumasu) and As (Asupong). Bars capped with different letters indicate significant difference at $P \leq 0.05$ (ANOVA, Minitab).

Microbial load in water

There were no significant differences in the total viable count ($F = 1.0$, d.f. = 2, $P = 0.390$), total coliforms bacteria ($F = 1.05$, d.f. = 2, $P = 0.374$), faecal coliforms ($F = 2.24$, d.f. = 2, $P = 0.141$) and the *Escherichia coli* loads ($F = 0.98$, d.f. = 2, $P = 0.40$) at the source, middle and outflow of river

Bomene although the counts at the outflow were always numerically higher. The source had the lowest numerical counts (Figure 26).

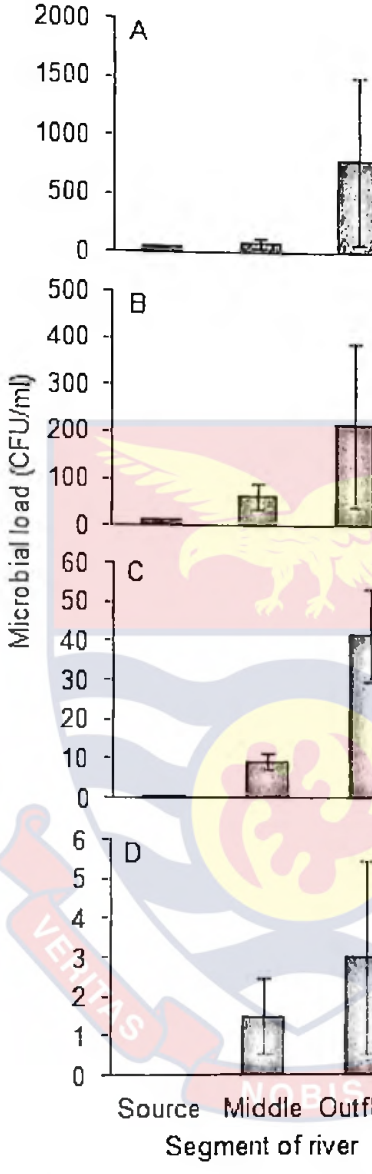

Figure 26: Total viable count of CFU/ml (A), total coliforms (B), faecal coliforms (C) and *Escherichia coli* in water samples from river Bomene at Amenase in the Ashanti Region. No significant differences were observed at $P \leq 0.05$ (ANOVA, Minitab).

In river Aponapon in Juaben located in the Ejisu-Juaben municipality, there were no significant differences in the total viable count ($F = 1.02$, d.f. = 2, $P = 0.384$), total coliforms bacteria ($F = 0.97$, d.f. = 2, $P = 0.402$), faecal coliforms ($F = 0.76$, d.f. = 2, $P = 0.484$) and the *E. coli* loads ($F = 2.78$, d.f. =

2, P = 0.094) at the source, middle and outflow. However, total viable count was numerically higher at the outflow and total coliforms bacteria, faecal coliforms and *E. coli* were numerically higher at the middle (Figure 27).

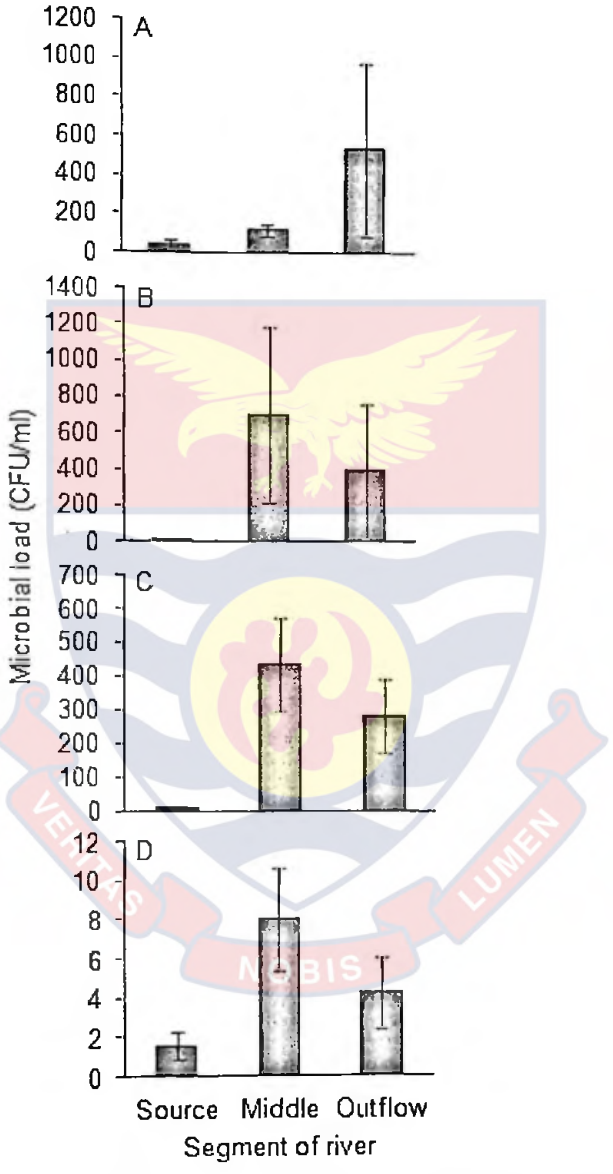

Figure 27: Total viable count of CFU/ml (A), total coliforms (B), faecal coliforms (C) and *Escherichia coli* in water samples from river Aponapon at Juaben in the Ashanti Region. No significant differences were observed at P ≤ 0.05 (ANOVA, Minitab).

In Mampong-Ashanti, there were no significant differences in the total viable count ($F = 1.04$, d.f. = 2, $P = 0.377$), total coliforms bacteria ($F = 0.20$, d.f. = 2, $P = 0.819$), faecal coliforms ($F = 0.32$, d.f. = 2, $P = 0.732$ and the *E. coli* loads ($F = 0.63$, d.f. = 2, $P = 0.548$) at the source, middle and outflow of River Adwee. Numerically, total viable count was highest at the outflow, and total coliform bacteria, faecal coliforms and *E. coli* were highest at the source (Figure 28).

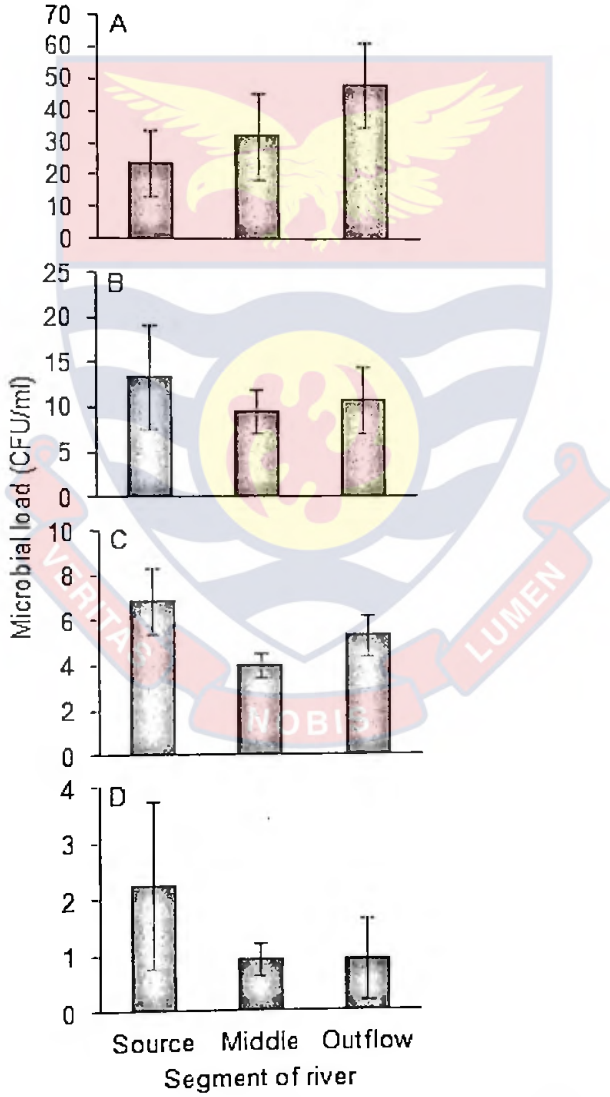

Figure 28: Total viable count of CFU/ml (A), total coliforms (B), faecal coliforms (C) and *Escherichia coli* in water samples from river Adwee at Mampong in the Ashanti Region. No significant differences were observed at $P \leq 0.05$ (ANOVA, Minitab).

River Dwayire in Anyinabrim had similar levels of microbial loads at the middle and outflow. There was no data for the source. Thus, there were no statistical differences in the total viable count ($t = 1.37$, $P = 0.229$), total coliforms bacteria ($t = 0.88$, $P = 0.417$), faecal coliforms ($t = 1.87$, $P = 0.135$) and the *E. coli* loads ($t = 1.48$, $P = 0.199$) at the middle and outflow (Figure 29).

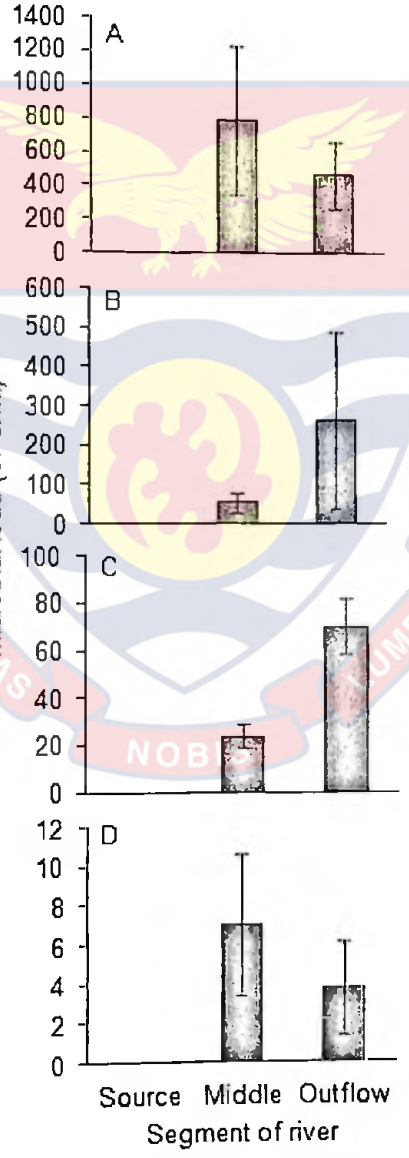

Figure 29: Total viable count of CFU/ml (A), total coliforms (B), faecal coliforms (C) and *Escherichia coli* in water samples from river Dwayire at Anyinabrim in the Central Region. No significant differences were observed at $P \leq 0.05$ (ANOVA, Minitab).

There were no significant differences in the total viable count ($t = 0.28$, $P = 0.792$), total coliforms bacteria ($t = 1.38$, $P = 0.228$), faecal coliforms ($t = 0.66$, $P = 0.540$) and the *E. coli* loads ($t = 0.57$, $P = 0.594$) at the source and middle of Atonsu although the counts at the middle were numerically higher than the source (Figure 30).

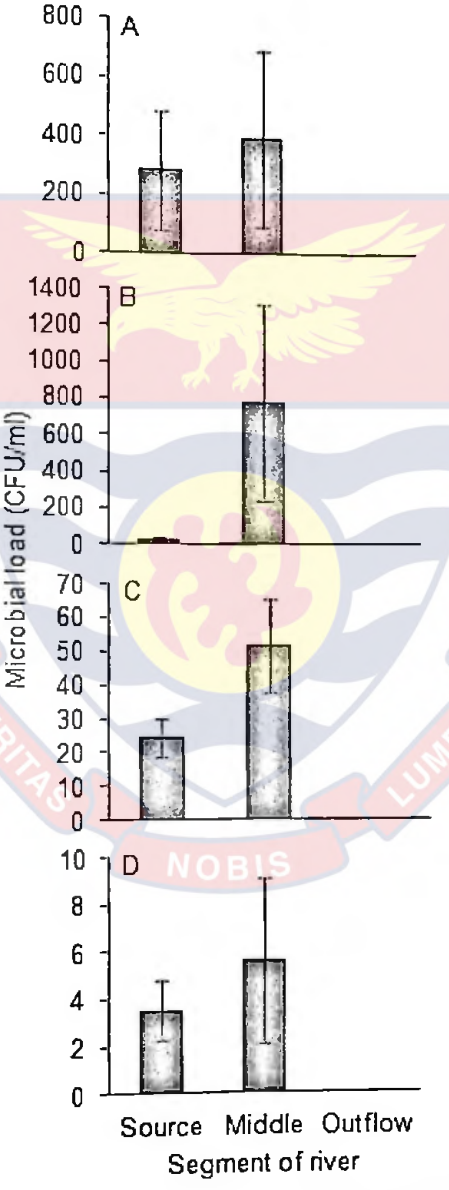

Figure 30: Total viable count of CFU/ml (A), total coliforms (B), faecal coliforms (C) and *Escherichia coli* in water samples from river Atonsu at Atonsu in the Central Region. No significant differences were observed at $P \leq 0.05$ (ANOVA, Minitab).

The river Suruwi had a numerically higher total viable count in the middle but this was not significantly different than the counts at the source and outflow ($F = 1.99$, d.f. = 2, $P = 0.172$). The total coliforms bacteria were also not significantly different ($F = 0.07$, d.f. = 2, $P = 0.930$). Similarly, the faecal coliforms ($F = 1.07$, d.f. = 2, $P = 0.368$) and the *E. coli* loads ($F = 0.04$, d.f. = 2, $P = 0.962$) at the source, middle and outflow of Suruwi were also not significantly different (Figure 31).

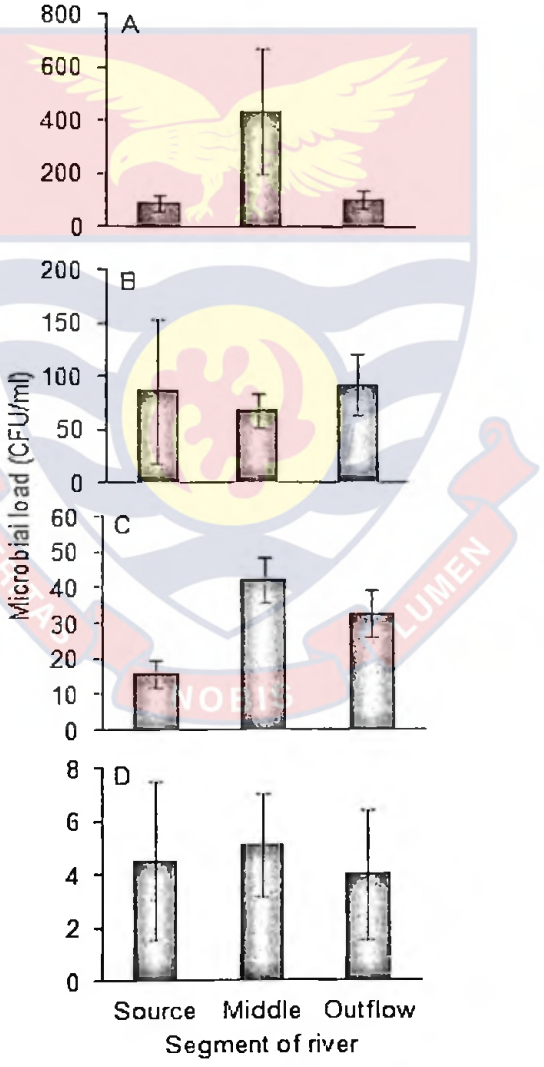

Figure 31: Total viable count of CFU/ml (A), total coliforms (B), faecal coliforms (C) and *Escherichia coli* in water samples from river Suruwi at Amisano in the Central Region. No significant differences were observed at $P \leq 0.05$ (ANOVA, Minitab).

There were no significant differences in the total viable count ($t = 2.40$, $P = 0.062$) at the middle and outflow of river Jejeti. There was no data for the source. The total coliforms bacteria ($F = 0.59$, d.f. $= 2$, $P = 0.574$), faecal coliforms ($F = 0.52$, d.f. $= 2$, $P = 0.618$) and the *E. coli* loads ($F = 0.26$, d.f. $= 2$, $P = 0.779$) were also not significantly different at the source, middle and outflow of Jejeti River (Figure 32).

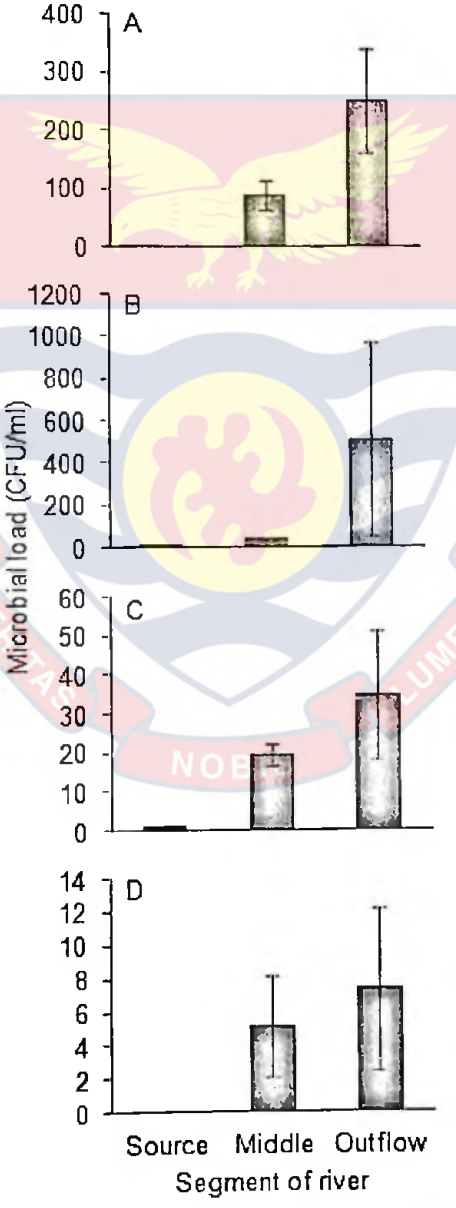

Figure 32: Total viable count of CFU/ml (A), total coliforms (B), faecal coliforms (C) and *Escherichia coli* in water samples from river Jejeti at Jejeti in the Eastern Region. No significant differences were observed at $P \leq 0.05$ (ANOVA, Minitab).

In Osiem in the Eastern region, there were no significant differences in the total viable count ($F = 0.92$, d.f. = 2, $P = 0.421$), total coliforms bacteria ($F = 1.41$, d.f. = 2, $P = 0.275$), faecal coliforms ($F = 0.16$, d.f. = 2, $P = 0.851$) and the *E. coli* loads ($F = 0.30$, d.f. = 2, $P = 0.743$) at the source, middle and outflow of river Abumasu (Figure 33).

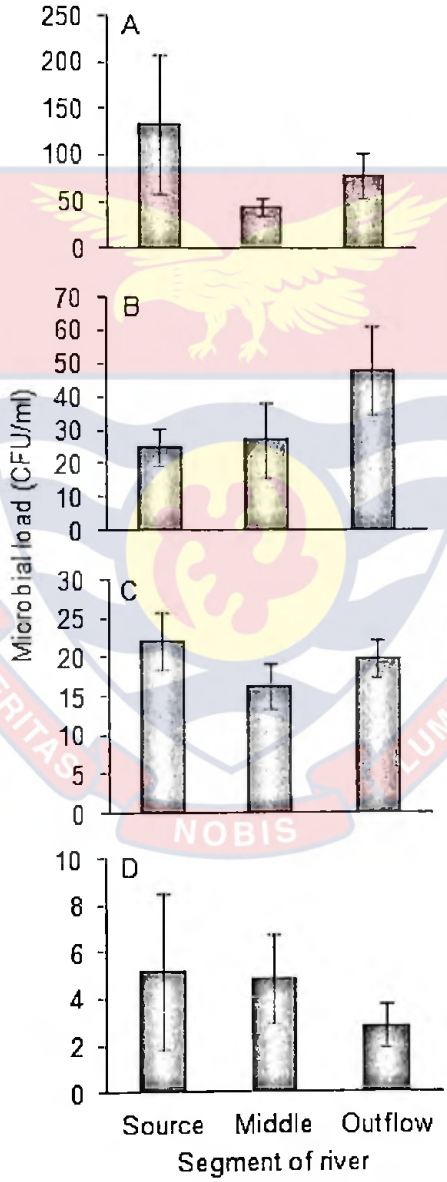

Figure 33: Total viable count of CFU/ml (A), total coliforms (B), faecal coliforms (C) and *Escherichia coli* in water samples from river Abumasu at Osiem in the Eastern Region. No significant differences were observed at $P \leq 0.05$ (ANOVA, Minitab).

There were also no significant differences in the total viable count ($t = 0.81$, $P = 0.452$), total coliforms bacteria ($t = 0.43$, $P = 0.686$), faecal coliforms ($t = 0.31$, $P = 0.774$) and the *E. coli* loads ($t = 0.61$, $P = 0.572$) at the middle and outflow of river Asupong (Figure 34).

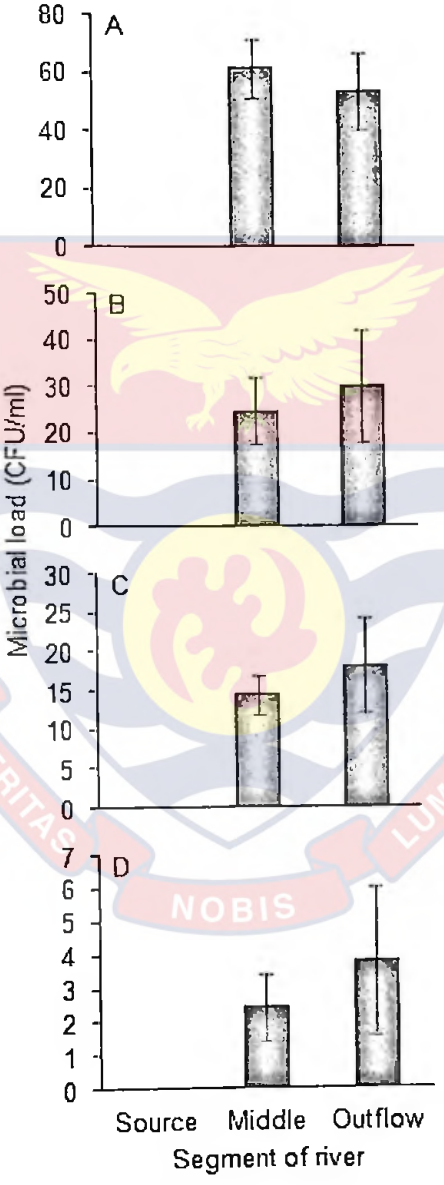

Figure 34: Total viable count of CFU/ml (A), total coliforms (B), faecal coliforms (C) and *Escherichia coli* in water samples from river Asupong at Nsutem in the Eastern Region. No significant differences were observed at $P \leq 0.05$ (ANOVA, Minitab).

Comparing the composite amount of microbial load for each river among all nine rivers, there were no significant differences in the mean total viable count ($F = 1.16$, d.f. $= 8$, $P = 0.342$; Figure 57A), total coliforms bacteria ($F = 1.17$, d.f. $= 8$, $P = 0.338$; Figure 57B) and *E. coli* loads ($F = 0.71$, d.f. $= 8$, $P = 0.681$; Figure 57D) in all the nine rivers. However, there were significant differences in the faecal coliforms load among the nine rivers ($F = 2.8$, d.f. $= 8$, $P = 0.013$; Figure 57C). Specifically, the faecal coliform load in river Aponapon was significantly more than those in rivers Bomene, Adwee, Atonsu, Suruwi, Jejeti, Abumasu and Asupong but this was not significantly more than that in river Dwayire (Figure 35C).

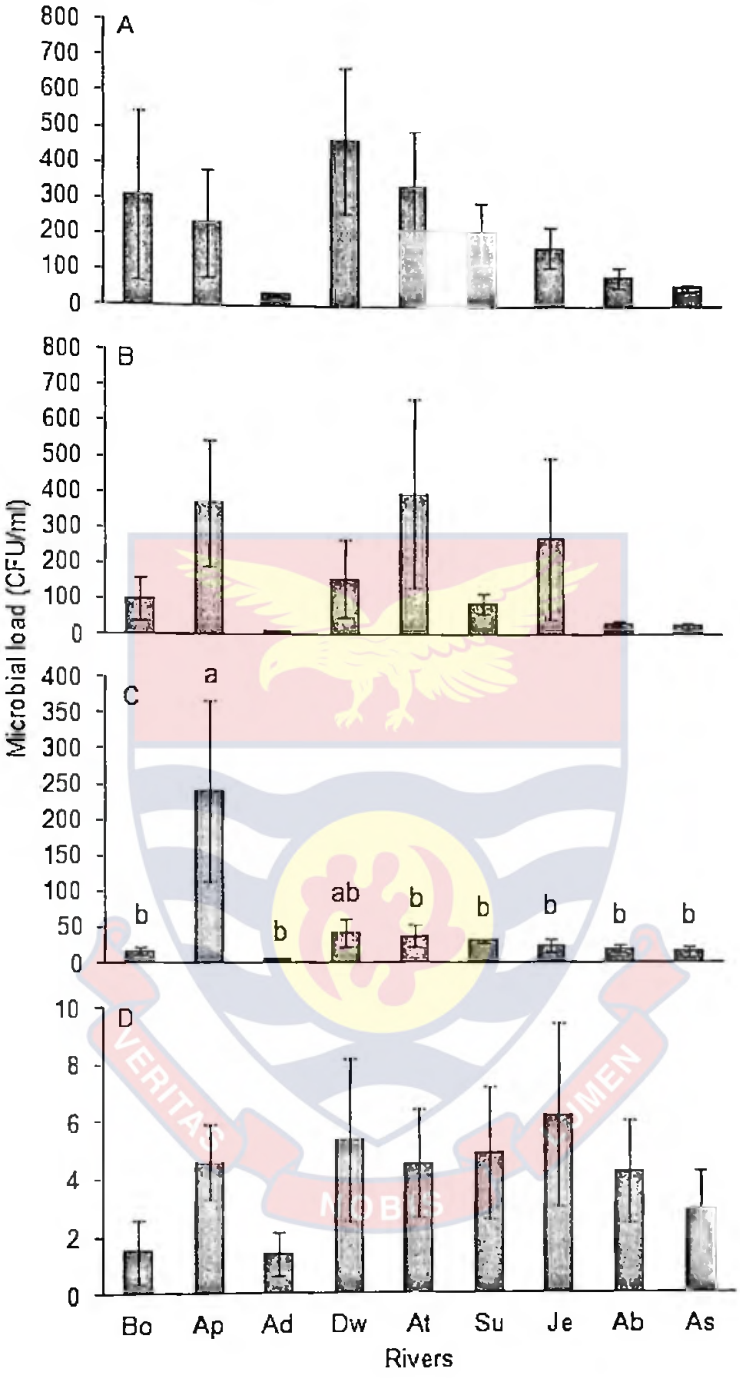

Figure 35: Total viable count of CFU/ml (A), total coliforms (B), faecal coliforms (C) and *Escherichia coli* in water samples from river Bomene (Bo), Aponapon (Ap), Adwee (Ad), Dwayire (Dw), Atonsu (At), Suruwi (Su), Jejeti (Je), Abumasu (As) and Asupong (As) in the Ashanti, Central and Eastern Regions of Ghana. Bars capped with different letters indicate statistical differences at a P-value ≤ 0.05 (ANOVA, Minitab).

Physicochemical properties

The water at the source of river Bonene was acidic but those at the middle and source were neutral. The temperature at the source was cooler and that at the outflow was the warmest (Table 10). The pH of the water in Aponapon and Adwee had similar patterns except that the water at the middle was slightly acidic. The temperatures were not so different (Table 10). Water in Dwayire and Atonsu were neutral in pH and had temperatures ranging between 25°C and 28°C (Table 2). River Suruwi was neutral at all three segments and the temperature ranged between 25°C and 29.5°C. Rivers Jejeti and Abumasu were slightly acidic and the temperatures at their sources were slightly cooler. The water in river Asupong was neutral and the temperature was between 24°C and 27°C (Table 10).

Table 10: Physicochemical properties of water at the source, middle and outflow of studied rivers

River	River segment	pH	Temperature (°C)
Boneme	Source	4.6 ± 0.14	24.3 ± 0.98
	Middle	7.3 ± 0.20	27.9 ± 1.35
	Outflow	7.2 ± 0.22	28.2 ± 1.14
Aponapon	Source	5.8 ± 0.17	25.4 ± 0.67
	Middle	6.6 ± 0.12	27.7 ± 0.16
	Outflow	7.3 ± 0.10	27.6 ± 0.95
Adwee	Source	5.5 ± 0.15	26.4 ± 0.54
	Middle	6.7 ± 0.04	25.8 ± 0.63
	Outflow	6.9 ± 0.10	26.1 ± 0.74
Dwayire	Source	-	-
	Middle	7.2 ± 0.42	25.1 ± 1.28
	Outflow	7.1 ± 0.38	25.4 ± 1.53
Atonsu	Source	6.8 ± 0.16	27.5 ± 1.29
	Middle	7.1 ± 0.13	27.3 ± 0.89
	Outflow	-	-
Suruwi	Source	7.2 ± 0.14	26.4 ± 0.99
	Middle	7.2 ± 0.10	27.9 ± 0.63
	Outflow	7.2 ± 0.14	29.0 ± 0.41
Jejeti	Source	6.5	24.2
	Middle	6.8 ± 0.18	26.7 ± 0.99
	Outflow	6.7 ± 0.17	27.2 ± 0.61
Abumasu	Source	6.4 ± 0.17	24.8 ± 1.60
	Middle	6.3 ± 0.11	26.3 ± 0.37
	Outflow	6.2 ± 0.10	26.1 ± 0.33
Asupong	Source	-	-
	Middle	7.4 ± 0.22	25.2 ± 0.96
	Outflow	7.5 ± 0.23	26.7 ± 1.24

CHAPTER FIVE

DISCUSSION

The research assesses nutrition and water quality in Ghana. In this chapter, the results obtained from household food survey and field experiments are discussed. This chapter also discusses results on effect of soil nutrients on micronutrient concentrations in cassava and maize. Microbial load in surface water are also discussed considering the anthropogenic activities that characterize the environs of the surface water.

The results from the household food survey have revealed that geographical location is an important factor that determines what people eat. This is so because, some crops are simply not available in some locations. Culturally, people from some locations do not eat certain food items and this also contributes to the reasons why geographical location determines what people eat. This study has shown that other food crops e.g. mango could be good sources of beta-carotene and micronutrients to Ghanaians. Moreover, the field experiment showed that there is a linear relationship between the micronutrient concentration in the crop and the soils in which the crop grows. Results from the household food survey also showed that surface water is very important in terms of water supply to households. Through this study, it is clear that, majority of people rely on surface water indirectly through the use of tap water. The household food survey results also revealed that, women play critical roles in determining the diet of households.

Feeding Habits, Micronutrient Content and Self-reported Experiences of Micronutrient Content in Food

People (especially children) who consistently feed on diets deficient in micronutrients are stunted and have poor eye sights and poor mental development (Biesalski, 2013). In this study, it has been shown that, on weekly basis, majority of the respondents eat cassava, maize and plantain in one form or another. Moreover, a large majority of the respondents from the household food survey depend on maize and cassava on daily or weekly basis. This is in line with reports from the Ministry of Food and Agriculture that the starchy staples, cassava, plantain and maize are important food crops in the Ghanaian society (MOFA, 2011). Similar to findings in this study, Noack and Pouw (2015) found that most people depend on starchy cereals and tubers. Furthermore, it has been found that, the dependence on cereals and tubers is predominant in the diet of the rural poor (World Bank, 2009) due to poverty and none availability of food (FAO, 2006). It is further suggested that people from developing countries largely depend on cereals and tubers which contains small quantities of micronutrient and therefore results in micronutrient deficiency in the diet (Jati *et al.*, 2012; Biesalski, 2013; Sharma *et al.,* 2017). Contrary to the 2009 World Bank report, results from this study suggests that the dependence on starchy staple food is not only restricted to the rural communities but cuts across various communities, including selected urban communities in Ghana. Although cereals and tubers are eaten in various communities, preference for any particular food crop is influenced by the geographical location and culture of the people. Due to the heavy dependence on such food crops by many Ghanaians, the micronutrient concentration in the

diet is also heavily affected because of the minute concentration of the micronutrients in the crops (Noack & Pouw, 2015). The over dependence on maize and cassava, leads to nutrient deficiency among people (Kennedy *et al.*, 2003; Dar *et al.*, 2007; Jati *et al.*, 2012; Biesalski, 2013; Noack & Pouw, 2015). Nutrient deficiencies in people, especially in Asia and Africa, is aggravated by the over dependence on cereals and tubers (Jati *et al.*, 2012; Biesalski, 2013; Sharma *et al.*, 2017).

Results from this study shows that some of the respondents have access to fruits and vegetables during bumper seasons when most fruits and vegetables are available and cheap. This is a treat to nutritional quality and needs to be addressed in order to prevent hidden hunger. Hidden hunger caused by over dependence on cereals and tubers (Noack & Pouw, 2015) can be avoided if Ghanaians consume the diverse fruits and vegetables available to them in the correct proportions. It is therefore important for governments to find means of storing or processing excess fruits and vegetable when in season.

Though earlier report from the world bank suggest that rural folks eat nutrient-deficient food (World Bank, 2009), findings from this study indicate that people in rural communities in Ghana use more local green vegetables in the preparation of their meals e.g. cocoyam leaves, ayoyo, alefu whiles urban duelers eat a lot of fast food e.g. fried rice with chicken and banku with Tilapia and very little pepper source. Even financially endowed people living in urban communities eat some of such micronutrient-deficient food such as fried rice (Jati *et al.*, 2012; Darmon & Drewnowski, 2015) due to their

lifestyle, modernization and urbanization. They also regard such local nutrient-rich food as out of fashion and tasteless.

In this study it was clear that people with lower income (>101 GH cedi) were dependent on maize and cassava which are among the cheapest food stuffs in Ghana on daily. Even among these food crops, maize which is the cheapest among them was utilized more often. For instance, because maize is cheaper than plantain in Ghana, it is more often utilized than plantain. In addition, maize has a longer shelf life than plantain which makes it economically prudent for poor families to utilize them to reduce their cost on feeding. In an attempt to reduce cost of feeding, most families end up satisfying the energy demand of the household rather than the quality of the diet because many of the food items that satisfy the energy requirements are micronutrient deficient (Kennedy *et al.*, 2003). Even in developed countries, people who are poor turn to depend more on starchy cereals and tubers because they are cheaper than fruits and vegetables which are rich in micronutrient (Darmon & Drewnowski, 2015). This implies that lower income has a direct effect on malnutrition and hidden hunger (FAO, 2006). It is therefore important that Ghanaians limit their dependence on such micronutrient-deficient crops or supplement them with micronutrient-rich crops in order not to develop poor mental health, poor eye sight, stunting and other attendant consequence of eating food that is poor in micronutrients. This can be achieved if the per capital income of a household is improved to enable the family have the financial ability to add vegetables and fruits to their diet. It is also important that conscious efforts are made to improve post-harvest

technology to improve storage and processing to reduce cost of these fruits and vegetables and make them available throughout the year.

This gives a further confirmation to the FAO (2006) report that the quality of nutrition is dependent on the income of the household. Ghanaians compromise the consumption of micronutrient-rich staples, e.g. plantain for micronutrient-deficient staple, e.g. cassava not by choice or culture but due to the high cost of plantain. Therefore, households with higher income and that could afford to eat more plantain has a higher chance to obtain more beta-carotene than those households with lower income and so cannot afford plantain. Due to poverty, such families eat more cassava and maize than plantain.

Results from interviews conducted in this study also showed that, although all respondents eat fruits, vegetables, animal products and maize, not all of them eat cassava and plantain. The feeding habits of respondents suggest that substantial amounts of their micronutrient requirements are obtained from several food sources. The people needs to be encouraged to eat more of the fruits and vegetables which are known to be rich in micronutrient (Kennedy *et al.*, 2003; Gupta & Prakash, 2009; Gul *et al.,* 2015). This calls for the diversification of diet to help prevent or reduce micronutrient deficiency.

Micronutrient concentrations in four varieties of cassava

In this study, it was found that Ghanaians use cassava to prepare different types of dishes such as fufu, gari, plakale, akyeke, tuo zafi etc. This supports the report that cassava is an important food crop in South America, Asia (FAO, 2008; Mezette, Blumer, & Veasey, 2013) and parts of Africa (MOFA, 2011; FAO, 2014). Additionally, cassava is a known staple food crop

in Ghana (MOFA, 2011). In this study, findings showed that cassava is widely consumed in diverse forms across the various regions of Ghana. Cassava is found in all these areas because of their tropical climate that support the growth and production of the crop. The importance of cassava made it necessary to investigate the relative amounts of micronutrients in some of the common varieties of cassava eaten by Ghanaians.

The results showed that there were higher concentrations of Fe and Zn in both Capevar bankye and Ampong than the concentrations of Mn and Cu in both varieties of cassava. This implies the person consuming these two varieties of cassava has a higher chance of getting Fe and Zn in their diet but might get lower concentrations on Mn and Cu. This finding supports that of Garcia and Dale (1999) who found that the nutritional composition of a crop is dependent on the variety. Therefore, consumers of crops should consider the variety in order to obtain the right micronutrient. Moreover, Biesalski, (2013) reported that iron is an essential micronutrient whose deficiency in food could causes hidden hunger. One of the clinical symptoms of Fe deficiency is anaemia which impairs growth (WHO 2001; Kennedy *et al.*, 2003). Gegios *et al.*, (2010) earlier found that the consumers of cassava have a high chance of obtaining, Zn and Fe which are needed in the control of micronutrient deficiency and improve the functioning of the body. Research shows that, Zinc is good for the functioning of over 300 enzymes in the body (uz Zaman *et al.*, 2018). Some of the enzymes that require Zn to function including carbonic anhydrase, alcohol dehydrogenase, Cu/Zn-superoxide dismutase and RNA polymerase (FAO/WHO, 2002; Maret 2013; uz Zaman *et al.*, 2018). Deficiency in Zn has been reported to cause defective immune system,

impaired physical growth, defective learning capabilities, risk of infections and damage to DNA (Gibson, 2006).

The regression analysis showed a linear relationship between the micronutrient concentration in the initial soil and the difference in the micronutrient lost from the soil after harvesting of the crop. The concentration of Fe showed a higher relationship between the concentration difference in the initial and the final soils of the crop and this difference was significantly different. Additionally, Cu in Capevars bankye showed a strong relationship in the coefficient of determination and zero with a very low significant difference. There were significant differences in the variation of the coefficient of determination of both Mn and Zn in Capevars bankye. Meanwhile the coefficient of determintation recorded in the analysis of the results fron Capevars bankye showed a strong relationship between the difference in Zn in the soil before planting and after harvesting from the soil. The coefficient of determination recorded in the regression analysis of Mn in Capevars bankye was very weak. According to Nathan, 2017 avialability of micronutrient to plant is dependent on other factors such as soil pH and conductivity. There might be other inherent factors that might have affected the release of these micronutrients to the plant.

The results from the analysis of beta-carotene, a precursor of vitamin A, show no significant difference in the concentration of *beta*-carotene in Capevars bankye and Ampong. The results also showed that the copper concentration in the crops were lower than the other micronutrients analysed. It is therefore not surprising that the beta-carotene concentrations in the cassava varieties were low because the plant had lower concentration of the

mineral that enhances the synthesis of beta-carotene. It should be noted that these finding are in relation to the root which is the part consumed by Ghanaians. Recent studies showed that, the leaves of cassava were richer in beta-carotene than the root (Morgan & Choct, 2016). This indicates that, the micronutrient concentration in different parts of the crop could be different and could have different consequences on the nutrition of individuals and households who consume on different parts of the crop as food.

Micronutrient concentrations in four varieties of plantain

Plantains do well in a wide geographical area such as the tropics and serve as a staple food for some developing and tropical countries in the world (Englberger *et al.*, 2006; Oladejo, Barine, & Olubukola, 2012). The results from the analyses of the micronutrient concentrations of four varieties showed that French plantain, false horn, and true horn had higher concentrations of Fe than the French plantain seedless. The Mn concentrations in the four varieties were also high, The Zn and Cu in the varieties were low. Similar results were reported by Odenigbo *et al.* (2013) that plantains are a rich source of Fe and vitamin A. Iron and Mn are micronutrients that help improve blood hemoglobin level for proper metabolic functioning of the body and enhance growth.

Micronutrient concentrations in three varieties of maize

The over dependence of people on cereals and tubers has been one of the major contributory factors of micronutrient deficiencies in the world (Kennedy *et al.*, 2003; Biesalski, 2013). In addition to the monotonous diet, cereals are known to be deficient in micronutrients such as Fe, Zn and Mn if

the soil in which they grow is deficient of any of these micronutrients (Dimkpa & Bindraban, 2016; Nathan, 2017; uz Zaman, 2018). A deficiency of Zn in soil can result in reduction in nutrient quality as well as reduced Zn concentration in the yield up to about 80% (uz Zaman, 2018). Results from this study showed that the concentration of Fe in Asante abro and obatanpa maize varieties was about 4 times higher than that of Zn. This might have resulted from some inherent features of the varieties or the variation in the soil conditions. This goes futher to confirm the report from Nathan (2017), that avialability of micronutrient to plant is dependent on other factors such as soil pH and conductivity. The finding also supports the report from Garcia and Dale (1999) that the nutritional composition is dependent on the variety involved. Moreover, the concentrations of Mn and Cu were by far lower in all varities. The concentration of Fe was also higher in the local maize than the other two varieties. It was also observed that the concentration of Zn in the local varieties was also higher than the other two varieties. The three maize varieties had high Fe concentration which is good for the improvement of blood haemoglobin and proper metabolic functioning of the body. These findings suggest that Asante aburo is richer in Fe than Obatanpa and Golden jubilee, which are "improved" varieties. Bases on these finding, it is important for crop breeders to consider the nutrient contents of crops when working on new cultivars in future to help improve nutritional quality and prevent hidden hunger.

The low Zn, Mn and Cu might have been as a result of the low concentrations of these micronutrients in the soil and the less availability may be due to the pH (Nathan, 2017). It has been suggested that more than 30% of

the soil in the world are deficient in Zn (uz Zaman, 2018). This probably contributes to the higher deficiency of Zn in cereals than legumes (uz Zaman, 2018). It has also been reported that, fertilizer application can help improve the micronutrient concentration in the Soil (uz Zaman, 2018) and hence improve the micronutrient concentration in crops.

The beta-carotene concentration in Golden jubilee was numerically higher than Asante aburo and Obatanpa.

Micronutrient concentrations in some fruits and vegetables consumed by Ghanaians

Mango trees bear fruits only at a particular period in a year. Therefore, people can have mango fruits only when they are in season. It is therefore important to know the nutritional content of different varieties of mangoes to be utilized when they are in season. Among the three varieties of mango investigated in this research, Alphonso had high concentration of Fe. The Zn and Cu concentrations were also higher in Alphonso than the other two varieties. Moreover, the concentration of Mn in Alphoso was also significantly higher than the other two varieties. Althought Alphonso has higher concentration of all the micronutrients than the other two varieties; it has very low market value. This finding makes it important to encourage the cultivation and consumption of the Alphonso variety. In fact, the Alphonso variety of mango is cheaper and so there is a need to develop means of storage for future use when they are in abundance during the mango season. However, the beta-carotene concentration in Jaffna was about twice higher than the concentrations in the Alphonso and Palmer varieties.

Drinking Water Quality and Adverse Health Outcomes

Water is one of the most important commodities needed for the survival of humans on earth and is said to constitute about 75% of the human body (Helmenstine, 2018). It also turns out to be a cause of a number of diseases to humans when polluted (Boschi-Pinto, 2009; WHO, 2017). The results of this study show that, although there are different sources of water in Ghana, a large majority of respondents of the household survey indicated that they depend on pipe borne water. Pipe borne water is treated water from the surface water bodies. This supports the report that most of the water used by humans comes from surface water bodies such as rivers and streams (Kistemann *et al.*, 2002; Mullen, 2012). This implies that the destruction of the surface water bodies through activities such as mining and farming (Aryee *et al.*, 2003; Henegama *et al.*, 2013; Kessey & Arko, 2013; Owusu *et al.*, 2016) could lead to serious water crises. The second most dependent source of water by the respondents in this study was underground water from wells and boreholes. These sources of water are replenished by surface water, therefore underscoring the importance of surface water.

The concentration of the micronutrients in the water bodies studied was variable. This implies that the water bodies could be sources of micronutrients to supplement the micronutrient obtained from food. However, anthropogenic activities such as farming and fishing may affect the microbial loads of water bodies. For instance Feacal coliform, and *E. coli* in water may cause diseases. It is known that *E. coli* cause diseases such as travelers' diarrhoea, infant diarrhoea, dysentery, hemorrhagic colitis and hemolytic uremic syndrome (Levine, 1987; Zhang & Sack, 2015; Watson *et al.*, 2017).

Children under the age of five year are especially vulnerable (Zhang & Sack, 2015; Watson *et al.*, 2017). The results of this research show that there were microbial contaminants in all the nine water bodies studied. However, the degree of contamination varied from water body to water body and the type of microbes that caused the contamination also differed. There were numerically more viable counts of coliforms in all the water bodies except Abumasu, Asupong and Adwee. The amount of *E. coli* in these water bodies was quite low. This might have resulted from the minimal anthropogenic activities that go on along these water bodies and the dense vegetation cover along the river banks. This confirms an earlier report that a high vegetation cover along water bodies reduces the microbial load in the water and improves water quality (Abraham *et al.*, 2016).

In this study, River Adwee recorded the lowest faecal coliform load among the water bodies studied followed by Asupong and Abumasu. The highest faecal coliform load was recorded in River Aponapon in Juaben. The high faecal coliform load in River Aponapon was to be expected because at Juaben, there was a public toilet facility and a rubbish dump sited uphill about 50 m from the river. The runoff from this area and the premises of the toilet facility washes into the water body when it rains and in the process washes contaminants into the water body. Furthermore, several domestic animals including ducks were sighted swimming in the river. Faecal droppings from animals added to the contamination of the river water.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

In this chapter, the major findings of this study are highlighted in a summary. Some concluding remarks are made as well as some recommendations. The study examined the micronutrient profile of some Ghanaian food, fruits, and vegetables crops. Special emphasis was placed on staple food crops—cassava, maize and plantain. Specifically, this thesis assessed the nutritional status of these staple foods at the household level. The thesis also examined the quality of water sources in some communities.

Summary

The study investigated nutritional and water quality as the household level. The study revealed that the food crops eaten by the respondents have varying amounts of micronutrients. Therefore, there is a need to vary food and/or combine several food crops that may complement each other in terms of micronutrient supply. For instance, this study showed that many people depend heavily on maize for their daily nutrient requirement. However, this crop has low micronutrient and beta carotene. Among the maize varieties investigated, golden jubilee had the highest concentration of beta-carotene. Therefore, this maize variety could be promoted as a major source of maize for households to enhance nutritional quality. Cassava and plantain are also major food stuffs in the society but less people depend on these as food than maize. This study has also shown that, the concentration of micronutrients in the many other crops investigated is influenced by the soil in which the crops were planted as well as the variety of the crop.

Most of the respondents in the household survey depended on pipe borne water for their daily water needs. Many of the surface water bodies studied were polluted. The study showed that, anthropogenic activities that go on along water bodies are a main source of microbe in water.

Conclusion

The respondents eat vegetables, fruits, animal products, maize, plantain and cassava in their daily meals. Fruits, vegetables and animal products are known to be rich in micronutrient. This study has demonstrated that concentration of micronutrients in crops vary between species and within species. In order to obtain optimum micronutrient for the proper functioning of the body, food consumed should be diversified. This would enhance enzyme activities and proper metabolic function of the body. It is therefore important to vary the diet eaten at the household level in order to prevent micronutrient deficiency.

The soil in which a crop grows has a great influence on the nutrient composition and concentration of micronutrients in the crop. As such it is important for farmers to consider soil properties and micronutrient composition before planting to avoid micronutrient deficiency in the plant which could be passed on to the final consumer.

Surface water is a major source of water to most people and should be protected from destructive anthropogenic activities that negatively affect water quality. Water bodies contain micronutrients that can help improve the relative daily micronutrient requirements of people. If anthropogenic activities along the banks of water bodies are not controlled, they may lead to high

concentration of pollutants and microbes in the water bodies, making them unsafe for treatment and domestic use.

Recommendations

1. Further studies should be carried out to determine the concentration of micronutrient in other food crop in Ghanaian.
2. There should be laws by government and the district assemblies to protect all surface water bodies and wetlands across the country.

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APPENDIX A

Food Survey Research Questionnaire

University of Cape Coast

Department of Environmental Science

The research will help identify the kinds of food eaten by the people in Ghana.

NB: Information provided will be treated confidential.

Interviewer:

Date:

1. Demographic Data

1.1 Respondent Number:.....

1.2 Collection Number:.....

1.3 Locality: Region..... District.....Town/ Village.....

1.4 Community setting: Urban [ ], Peri Urban [ ], Rural [ ]

1.5 Place of residence: (community) .....

1.6 House number .....

1.7 Gender: Male [ ] Female [ ]

1.8 Name of respondent .....

1.9 Age of respondent:.....

1.10 Marital status: single [ ] married [ ] divorced [ ] other (specify) .....

1.11 Tribe: Akan [ ] (specify) ....., Guan [ ] (specify) ....., Ewe [ ], Dagomba [ ], Other (specify) .....

1.12 Occupation of the respondent: Farmer [ ] Trader [ ] Fisher man [ ] other (specify).....

1.13 Level of education of the respondent: No literacy [ ] Non-formal [ ] Basic Education/ Middle school [ ] Secondary / Technical [ ] Tertiary [ ]

1.14 Household size: .....

1.15 No. of Adults (18 years +)..... Adolescents (13-18 years)..... Children (5-12 years).....toddlers (>5 years).....

1.16 Age of each family member

Adult (18 years +) ..... Adolescents (13-18 years) ..... Children (5-12 years) ..... Toddlers (>5years) .....

1.17 Who is the bread winner of the family? Father [ ] Mother [ ] others (specify)

1.18 Occupation of the bread winner of the family: Farmer [ ] Trader [ ] Fisher man [ ] other (specify).....

1.19 Level of education of the bread winner:

No literacy [ ] Non-formal [ ] Basic Education/ Middle school [ ] Secondary/ Technical [ ] Tertiary [ ]

1.20 In what community setting were you raised?

Urban [ ] Peri Urban [ ] Rural [ ]

1.21 How would you classify the community in which you were raised:

Farming community [ ], Fishing community [ ], Industrial community [ ], Commercial community [ ], other (specify).....

2.0 Nutritional Data – General Questions

2.1 Who usually cooks in this house?

Mother [ ], father [ ], daughter [ ], son [ ], other (specify) .....

2.2 Age of the person responsible for cooking in this house .....years

2.3 Do you normally plan your meals? Yes [ ], No [ ] if **No** go to question 2.5

2.4 If Yes, how?

Spontaneous menu plan for a day [ ], Follow a fix menu for the week [ ], plan menu based on what is available in the market [ ], plan menu according to season [ ], others (specify) .....

2.5 How often do you eat vegetable?

daily [ ], weekly [ ], monthly [ ], rarely [ ] when in season[ ] others .....

2.7 What types of vegetables do you usually eat?

Leafy vegetables [ ] fruity vegetable [ ] others (specify)...

2.8 How often do you eat fruits?

daily [ ], weekly [ ], monthly [ ], rarely [ ] when in season [ ] others ...

2.9 What types of fruit do you usually eat? Orange [ ] mango [ ] pineapple [ ] water melon [ ] pear [ ] pawpaw [ ] others (specify)...

2.10. How often do you eat animal products? daily [ ], weekly [ ], monthly [ ], rarely [ ]

2.11 Do you prepare special meals for certain household members? Yes [ ], No []

2.12 If yes, which of the members of the household? Mother [ ], father [ ], child [ ], other (specify) .....

2.13 Why do you prepare a special meal for this (these) persons? Health reasons [ ], because of age [ ], person in question does not like to eat certain foods [ ], other (specify) .....

3.0 Nutritional Data – Eating habit

3.1 What is your household's favourite food? .....

3.2 In which form do you eat it? raw [ ], boiled [ ], fried [ ], roasted [ ], toasted [ ], baked [ ],other (specify) .....

3.3 Why do you like that food? .....

3.4 How do you prepare it? .....

3.5 What are the main ingredients used for preparing this .....

3.6 What quantity do you eat at a time? A little [ ] Moderate size [ ] Large quantity [ ]

(Questioner should estimate the quantity in grams). Quantity in grams .....

3.7 How many meals do you and your household members eat per day on average?

One [ ] Two [ ] Three [ ] Others .....

3.8 What do you usually eat for breakfast? .....

3.9 How do you prepare your breakfast? Boiled [ ], roasted [ ], toasted [ ], fried [ ], baked [ ], other (specify) .....

3.10 What do you usually eat for lunch? .....

3.11 How do you prepare your lunch? Boiled [ ], roasted [ ], toasted [ ], fried [ ], baked [ ], other (specify) .....

3.12 What do you eat for usually supper? .....

3.13 How do you prepare your supper? Boiled [ ], roasted [ ], toasted [ ], fried [ ], baked [ ], other (specify) .....

3.14 What is your staple food? Banku [ ], Fufu [ ], TZ [ ], Akple [ ], Ampesi [ ], Tubani [ ], others (specify)..... .....

3.15 What is the source of your staple food? Own farm [ ] local market [ ] super market [ ] other (specify) .....

3.16 Are you aware of any food item that can improve the health of a person? Yes [ ], No [ ]

3.17 If yes, list .....

3.18 Do you and your household take food supplements? Yes [ ], No [ ]

3.19 If yes, where do you get them from?

Local pharmacy [ ], hospital/clinic [ ], other (specify) .....

3.20 Do you buy food from food vendors? Yes [ ] No [ ]

3.21 If yes; how often? Every day [ ], Every week [ ], Monthly [ ], rarely [ ]

3.22 Which time of the day do you often buy from vendors?

Morning [ ], afternoon [ ], evening [ ]

3.23 What do you really buy from the vendors

Fufu [ ], Rice balls [ ], konkonte [ ], TZ [ ], gari and beans [ ], kenkey and fish [ ], fried rice [ ], plain rice [ ], hausa koko [ ], others (specify) .....

4.0 Consumption and source of focus crops

4.1 Do you eat plantain? Yes [ ], No [ ]

4.2 If yes, how often do you eat it?

Daily [ ], Weekly [ ], Monthly [ ] Rarely [ ], Do not eat [ ]

4.3 What cultivar of banana and plantain do you eat?

Plantains - apim [ ] apentu [ ] Oniaba[ ] Banana – Asante kodu [ ] alata kodu [ ]

4.4 In what form do you eat plantains? ampesi [ ], roasted [ ], eto [ ], fufu [ ], other (specify) .....

4.5 Where do you get the raw plantain and banana?

Own farm [ ] local market [ ] super market [ ] other (specify) .....

4.6 Do you eat cassava? Yes [ ], No [ ]

4.7 If yes, how often do you eat it?

Daily [ ], Weekly [ ], Monthly [ ], Rarely [ ]

4.8 What cultivar of cassava do you eat? Dabon [ ] bankye pa [ ], do not know [ ]

4.9 In what form do you eat cassava? ampesi [ ], roasted [ ], gari [ ], fufu [ ], cassava biscuit [ ], Yake yake [ ], Konkonte [ ] other (specify) .....

4.10 Where do you get the raw cassava from?

Farm [ ] local market [ ] super market [ ] other (specify) …

4.11 Do you eat maize? Yes [ ], No [ ]

4.12 If yes, how often do you eat it?

Daily [ ], Weekly [ ], Monthly [ ], Rarely [ ]

4.13 What cultivar of maize do you eat? Dobidi [ ], obaatanpa [ ], golden jubilee (yellow corn) [ ], mamaba [ ], do not know [ ] other (specify) .....

4.14 In what form do you eat maize? Banku [ ] etiw [ ], kenkey [ ], roasted [ ], porridge [ ], tuo safi [ ], boiled [ ], other (specify) .....

4.15 Where do you get the raw maize from? Farm [ ] local market [ ] super market [ ] other (specify).....

5.0 Economic Data

5.1 What is your households income..... (Questioner should try to get the specific figure and not the range)

5.2 Apart from your income, do you have other source of income?

Yes [ ] No [ ]. If No, go to 5.4

5.3 If yes, indicate

5.4 If you buy food, what percentage of your income do you spend on food?

10% [ ], 10.1-20%[ ], 20.1-30% [ ], 30.1-40% [ ], 40.1-50% [ ], 50.1-60% [ ], 60.1-70% [ ], More than 70% [ ],

5.5 What type of fuel do you usually use for cooking? Firewood [ ], charcoal [ ], gas [ ], agricultural residue [ ], others (specify) .....

5.6 What is the main source of your drinking water?

Pipe borne water [ ], well [ ], protected spring [ ], river [ ], bole hole [ ], others (specify)

5.7 Have you or any other family member had diarrhoea over the past 4 weeks?