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The diet and high blood selenium concentrations: A study of battery repair workers in the Ashanti Region of Ghana

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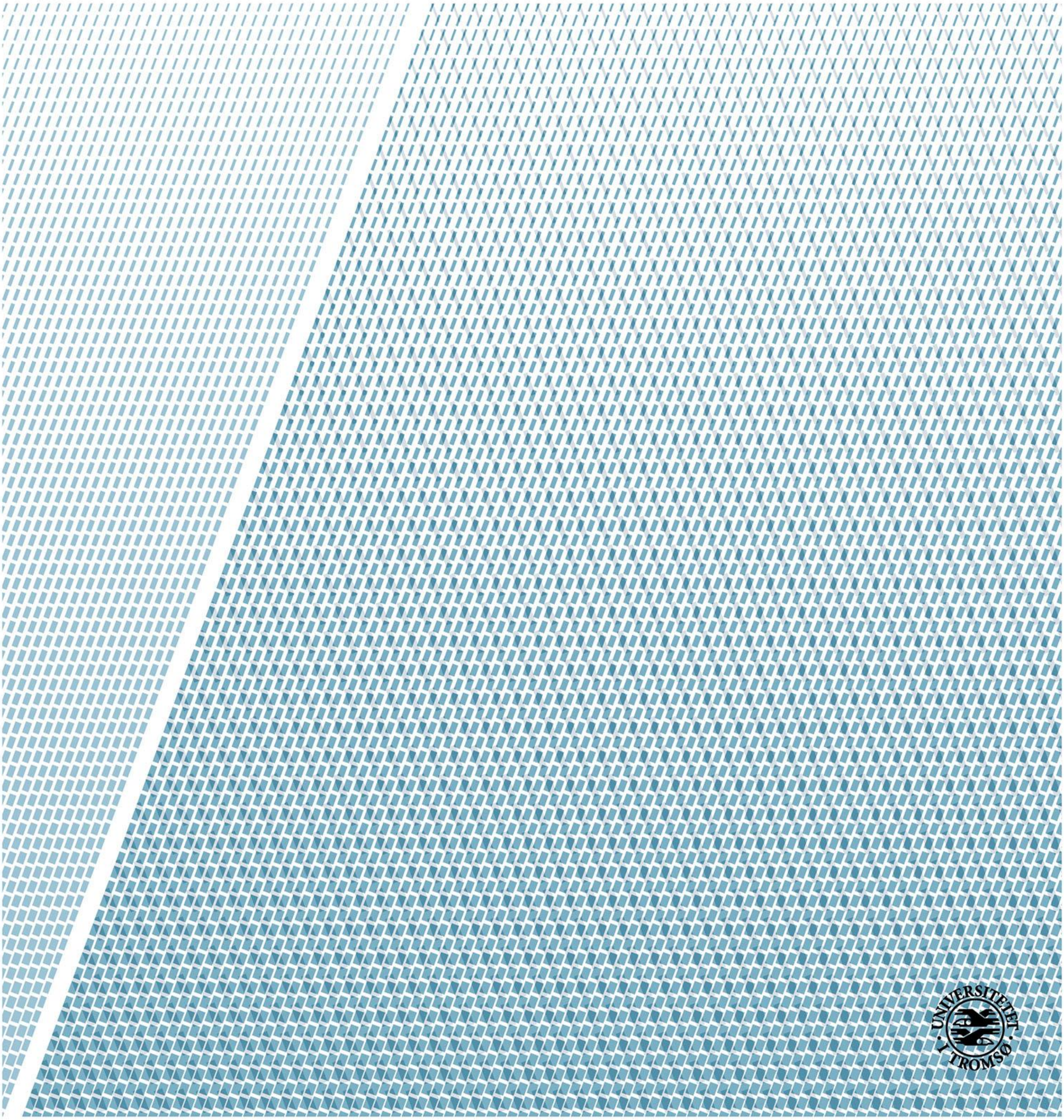

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Table of contents

List of figures

List of Tables

Abbreviations

FFQ: Food Frequency Questionnaire

WHO: World Health Organization

BMI: Body Mass Index

RDA: Recommended Dietary Allowance

FAO: Food and Agriculture Organization

HIV/AIDS: Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome.

Abstract

Background: An earlier study on the assessment of the bioavailability of inorganic elements among battery repair workers in the Ashanti Region of Ghana revealed high blood concentrations of selenium, lead and antimony. Selenium is obtained mainly through the diet in the form of food and dietary supplementation. The purpose of this study was to investigate the food patterns of the battery repair workers and how this correlates with blood selenium concentrations.

Method: Sixty-three of the sixty-four battery repair workers from a background study were the subjects for the current investigation (one had passed away). A food frequency questionnaire was used to gather information on the frequency of consumption of foods within the six food groups of Ghana. An additional food group, namely beverages, was also incorporated. Multiple linear regression was used to test associations between demographic characteristics and selenium concentrations, and also to test associations between food items and selenium concentrations. The level of significance was set at 0.05.

Results: The mean blood selenium concentration was 256 ± 46 µg/L. The battery repair workers had frequent intakes of meat, fish, tomatoes, onions, pepper, vegetable and palm oil. These food items constitute the basic ingredients in Ghanaian soups and sauces. Among the demographic factors, BMI significantly predicted selenium concentrations. The battery workers' selenium concentrations were also found to decline with age. The food items that significantly predicted selenium were plantain, snails, palm fruits, palm oil, tigernut milk, and oats. Of these, tigernut milk, palm oil and snails exhibited positive correlations. In addition, quite a few other foods exhibited non-significant positive regression coefficients in the multivariable linear regression models.

Conclusion: The diet and food patterns correlated with blood selenium concentrations. After a review of potential environmental and occupational sources, the relatively high blood selenium concentrations observed are interpreted to reflect that the soil, vegetation and foods in the study area are reasonably rich in selenium.

Key words: Selenium, food patterns, diet, battery repair workers.

CHAPTER ONE

INTRODUCTION

1.1 Background

Selenium is an essential nutrient in human nutrition which has generally been understudied in sub-Saharan Africa. It was first discovered in 1818 by a Swedish chemist during sulfuric acid production, and was regarded as a toxic element for humans until its vital role was proven in the last decade [1,2]. Glutathione peroxidase and iodothyronine deiodinase are selenium- dependent essential enzymes, which together with Vitamin E, protects the cells against oxidative damage [3,4,5,6,7]. It is also believed to protect against pollutants such as toxic metals [3,8]. Selenium is reported to be protective against mercury toxicity and plays a role in the detoxification of arsenic compounds [1,9]. Selenium can also combine with lead forming inactive complexes, which minimizes the availability of free lead ions in the body and thereby exert a protective effect from lead toxicity [6]. A reduction in selenium concentrations has also been found to positively influence the effect of lead in increasing diastolic and systolic blood pressure [7].

Selenium appears effective in the prevention of cancer, heart diseases, diabetes, inflammatory diseases, strokes, rheumatoid arthritis, degenerative diseases, cataracts, and can also delay the ageing process and enhance immunity [1,2,8,10,11,12,13]. It has been found to have a protective effect against goiter in the Ugandan context [2]. Selenium also plays a vital role in spermatogenesis and hence, seems to enhance fertility in men [10,14,15].

A commonly used biomarker of selenium status is plasma/serum or whole blood selenium and they also are useful indicators of short-term responses to changes in selenium intake. However, the indicated biomeasures are influenced by confounding factors such as smoking, alcoholism and some disease states such as HIV/AIDS, which lower plasma selenium concentrations [15]. Aging has also been found to affect the plasma concentration of selenium— it declines with age independent of intake [16]. Urinary selenium can also be a useful indicator of possible selenium overload and can reflect recent intakes, while hair and toenails can be used to assess dietary selenium status and depict long-term intakes [15,17]. Selenium can be quantified in biological materials by atomic absorption spectrometric techniques [8].

Selenium absorption has been found to be modulated by Vitamins A, E and C and there exists a complex relationship between Vitamin E and selenium, which has not yet been fully understood [15]. Interestingly, serum and whole blood concentrations appear to be of comparable magnitude (10). The minimum concentration of selenium required in the bloodstream for optimal production of selenoproteins is 80 µg/L, according to the National Prevention of Cancer Trial [2]. Selenium concentrations have been found to have local and regional variations, with no formal international range. In China, concentrations below 30 µg/L have been observed, while values between 80-180 µg/L have been reported in Canada [2]. In areas like Burundi and Malawi, plasma selenium status has been found to be low (< 60 µg/L) [18]. In Norway, prior to 1990 selenium concentrations were higher compared to other European countries. During the 1990s however, the concentrations were comparable. Smoking has been shown to depress serum selenium concentrations [10].

1.2 Sources of selenium

Selenium in its organic forms is present in the human diet as part of selenoproteins; specifically, as the amino acids selenomethionine and selenocysteine. It also occurs in inorganic salts as selenite (SeO_3^{2-}) or selenate (SeO_4^{2-}) anions [19]. Consequently, the type of diet has been shown to be a factor that determines serum concentrations of selenium [20]. The soil in which plant foods are grown influences their selenium contents [2,19,21]. In addition, food items like fish, red meat, cereals and grains, eggs, chicken and Brazil nuts (also known as paranuts) are also good sources of selenium [2,5,11,15,17,21]. Meat products produced from animals that feed on plants grown in selenium-rich soils have higher concentrations of selenium [2]. Seafoods are also considered important sources of selenium because of their high protein content [22]. Fruits, vegetables and drinking water do not provide substantial amounts of selenium, but vegetables like broccoli, cauliflower, garlic, chives and onion can accumulate selenium; the latter, when grown on selenium-rich soil, can have up to 140- 100mg/kg selenium [2,5,16,17,22]. Grains on the other hand, vary in their content of selenium depending on the soil in which they are cultivated [5].

Foods can be enriched with selenium and in Europe, sodium selenate, sodium hydrogen selenite and sodium selenite are permitted forms of selenium in foods for specific nutritional uses, such as in total parenteral nutrition and baby formula. To increase the selenium concentration in animal products, feeding supplements can be given to animals and selenium-enriched fertilizers can be applied to soils [16]. Selenium can also be obtained through dietary supplements in the form of multi-vitamin/multi-mineral supplements and also as a stand-alone supplement [11,17].

As implied earlier, selenium concentration in food is usually quantified by atomic absorption spectrometry [5,19]. Dietary recommended intakes of selenium are 26 and 35 µg per day for adult females and males, respectively [11]. In the United States, the estimated average requirement of selenium is set at 45 µg for people aged 10 and above, 23 µg for those below 10 and 49-59 µg for pregnant and lactating women [18]. Global average intake of selenium is between 20-300 µg/day. An intake of 55 µg/day is generally recommended, and signs of toxicity have been found in intakes of about 350 µg/day [5].

Importation of selenium-rich foods, dietary supplementation, food fortification, bio-fortification and diversification of the diet are means of addressing suboptimal intakes of selenium [23]. Studies from Malawi provide evidence of low selenium status and intakes among the population. The main reason for this is believed to be lack of dietary diversity and low concentrations of selenium in soils that result in low selenium availability for plants [23]. In Finland, a public health strategy was implemented to alleviate dietary selenium inadequacy by introducing agronomic bio-fortification with selenium-rich fertilizers. This has raised the selenium content of Finish foods and improved dietary intake and status [18,23]. Grains can also be readily enriched with selenium enriched fertilizers [18]. It is posited, that due to the global importing of foods, the selenium status in a particular country is not entirely dependent on the soil mineral content. Consumption of imported foods can therefore potentially influence selenium status [24].

1.3 Selenium deficiency and toxicity

Selenium deficiency may occur in areas where the soil selenium concentrations are low and may occur in patients on long-term parenteral nutrition without adequate supplements [4]. People living in selenium-deficient areas, those undergoing kidney and hemodialysis or living with HIV/AIDS are particularly susceptible to selenium deficiency [11]. The lack of adequate selenium in the body is associated with muscle pain, heart failure and predispositions to cardiovascular diseases [11,14,19]. Selenium deficiency also contributes to iodine deficiency disorders and can pose a risk for cancer, viral diseases, a congestion cardiomyopathy known as Keshan disease, other cardiovascular diseases and Kashin-Beck disease, a type of osteoarthritis [1,2,5,11]. Keshan and Kashin-Beck diseases have been observed in areas of China and Russia where selenium deficiency is endemic [15].

Higher serum concentrations of selenium have been found in diabetics and it is reported that selenium supplementation over a long period of time can increase the chances of diabetes type 2 [25,26]. High concentrations of selenium could also result in chronic selenosis (i.e., selenium intoxication) [26]. Outbreaks of selenosis related to the consumption of crops grown in contaminated soils are known (16). As far back as 1975, it was found that high concentrations of selenium were present in the liver of patients with acute and chronic selenosis that could lead to hepatic abnormalities [27]. The inhalation of the poisonous gas hydrogen selenide in occupational settings causes vomiting, bronchitis, chemical pneumonia, nausea, bronchial spasms, coughing, headaches and eye irritation [1]. The ingestion of selenium compounds can result in acute selenium poisoning, however only a few such cases have been reported [1]. Signs of selenium toxicity are garlic odour in the breath and a metallic taste in the mouth, mottled teeth, irritability and fatigue [1,11]. Selenosis is further characterized by hair loss, skin and nerve lesions, nail abnormalities, nausea, diarrhea and high urinary selenium excretion [15,22,27].

1.4 Selenium in Ghana

Ghana has been identified as an area in Africa with dietary selenium availability [18]. The map in Figure 1 portrays this, as well indicating a low risk of dietary selenium inadequacy.

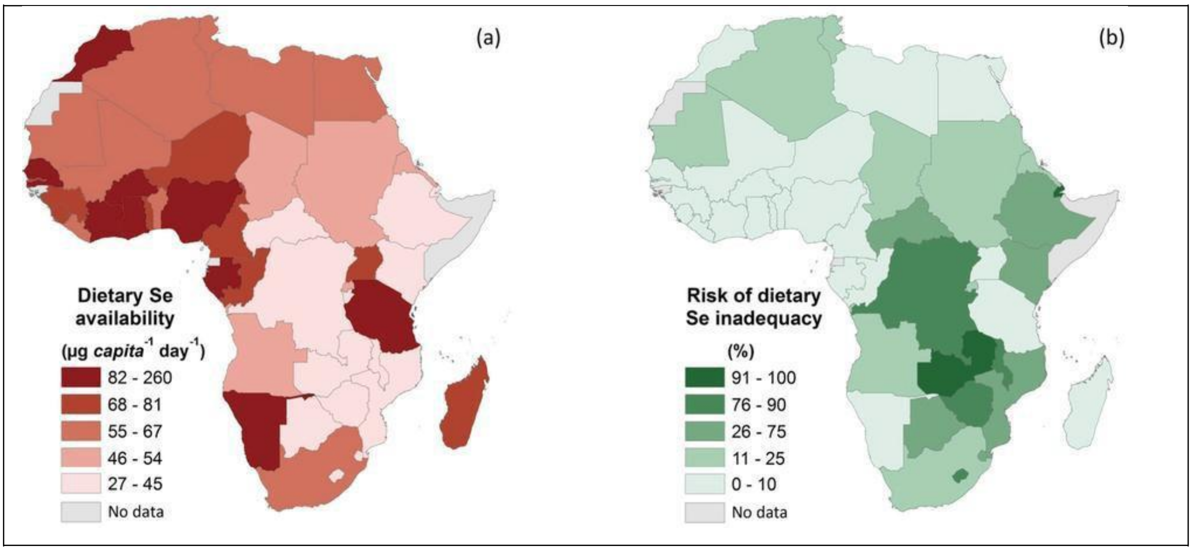

Figure 1: Dietary selenium availability and risk of dietary selenium inadequacy in Africa.
(a) Mean dietary selenium (Se) availability, and (b) estimated risk of inadequate Se intake based on US Estimated Average Requirement (EAR) of 45 and 23 µg Se person^{-1} d^{-1} for those aged >10 and <10 years, respectively, and 49 and 59 µg Se person^{-1} d^{-1} for pregnant and lactating women, respectively[18]. [For the location of Ghana see Figure 2.in Section 2.4]

A few studies have been carried out to determine the trace element concentration of some foods in Ghana [28,29,30]. In one study on the dietary supply of selenium in three orphanages, the mean dietary intakes of selenium were: 57.6 ± 17.3 µg/day, 82.0 ± 30.7 µg/day and 91.7 ± 44.2 µg/day. However, the daily dietary supply of selenium observed in most of the days during the study did not meet the recommended dietary allowance (RDA) of 55 µg/day [5]. Another study revealed that selenium concentrations in a Ghanaian rural population were higher than that of their urban counterparts [4]. In an assessment of the intake of selenium among university students in Ghana, it was discovered that the majority of the students (83%) did not meet the RDA of selenium, 15.7% exceeded it and only 1.3% complied [21]. In an air sampling and biological monitoring study of workers in lead acid battery repair shops in the Ashanti Region of Ghana, it was observed that the workers had high blood concentrations of lead, as well as of antimony, arsenic and selenium [31]. It was therefore recommended that an assessment of diet be undertaken to explore it as a potential source. This suggestion was the basis for the current study. Though the mentioned study focused on the toxic elements mentioned, the current project does so on selenium because it is a nutritional element of importance. Time availability for conducting the fieldwork was a limiting factor in the study design.

1.5 Problem Statement

The selenium studies in Ghana mentioned in the previous section report a generally low supply of dietary selenium. Nevertheless, the high blood selenium concentrations found among the battery repair workers in the Ashanti Region raises questions whether their high blood selenium had contributions from the consumption of selenium-rich foods.

1.6 Objectives of the Study

The objective of this study is to investigate dietary reasons for high selenium concentrations among battery repair workers in Suame and Asafo Fitam in the Ashanti region of Ghana.

1.6.1 Specific Objectives

The specific objectives are:

1. To investigate the food consumption patterns of the battery repair workers;
2. To investigate if there is any relationship between diet and high selenium concentrations among battery repair workers.

1.7 Research Questions

To meet the above objectives, the following two research questions were formulated.

1. What are the food patterns of the battery repair workers?
2. Can the high blood selenium concentrations of the battery repair workers be attributed to diet and food patterns alone?

1.8 Significance of the study/policy implications

Few studies have been carried out on selenium in Ghana. The objective of the current project is to enhance the knowledge about this important dietary element in Ghana, and thereby inform nutritional education and related public policies. In the case of the battery repair workers, it should help in the understanding of the balance between dietary intake and occupational exposure, as well contributing to the formulation of nutritional and health advice for them. Perhaps the approach and findings may also serve as background information for studies of selenium toxicity.

CHAPTER TWO

METHODOLOGY

In this chapter, the materials and methods used for the study are presented. An overview of the background study on which this study was based is also provided. The study design, questionnaire used, variables and ethical considerations are also presented.

2.1 The Background Study

This thesis makes use of biochemical data from an earlier study on the bioaccessibility of lead in airborne particulates among battery repair workers in the Kumasi Suame and Asafo Fitam suburbs by Dartey et al. (2014) [31]. These authors investigated the uptake of lead in Hatch solution (simulated lung lining fluid) and synthetic gastric juice. It was discovered that the mean respiratory uptake of lead was lower than that by way of the gut, implying that lead in this situation was more readily absorbed in the gastrointestinal tract compared to the respiratory route [31]. The low bioaccessibilty of lead in simulated lung fluid relative to that in gastric juice was the basis for this conclusion. In addition, blood and urine samples were taken and analyzed at the National Institute of Occupational Health in Norway. Analyses were done of both whole blood and serum concentrations of the elements mentioned in Section 1.4. Note that only the serum and whole blood results for lead were reported in Dartey et al. (2014) [31].

2.2 Study Design

A cross-sectional study was conducted and the purpose was to collect quantitative information on the diet and food patterns of the battery repair workers to explore the possibility of an association between food consumption and blood selenium concentrations. The fieldwork was conducted in a period of four weeks and the pertinent data was collected from a total of 63 male battery-repair workers who were part of the background study. Information on blood selenium concentrations, height and weight of the workers were taken from the background study.

2.3 The Hypothesis

The study was carried out based on the hypothesis that: *The diet does not correlate with high blood selenium concentrations.*

2.4 The study location and respondents

The research was conducted in Ghana, a country located in West Africa. Ghana is bordered by Togo on the East, Burkina Faso on the North, Ivory Coast on the West and the Gulf of Guinea on the South. A map of Africa showing the location of Ghana and that of Ghana showing the city of Kumasi, where this study was carried out, are shown below.

Fig 2: Map of Africa showing the location of Ghana[1]

Fig. 3: Map of Ghana showing the location of Kumasi[2]

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[1] Avaiable at World Atlas. Ghana. http://www.worldatlas.com/webimage/countrys/africa/gh.htm . Retrieved September 2015.

[2] Available at World Atlas. Ghana. http://www.worldatlas.com/webimage/countrys/africa/gh.htm. Retrieved September 2015.

Ghana has ten administrative regions including the Ashanti Region where this study was conducted. Kumasi, the capital of the Ashanti Region, is one of the largest cities in Ghana with a very bustling commercial centre. It is the country's midpoint between the Northern and Southern regions of Ghana. A map of the study area is provided below.

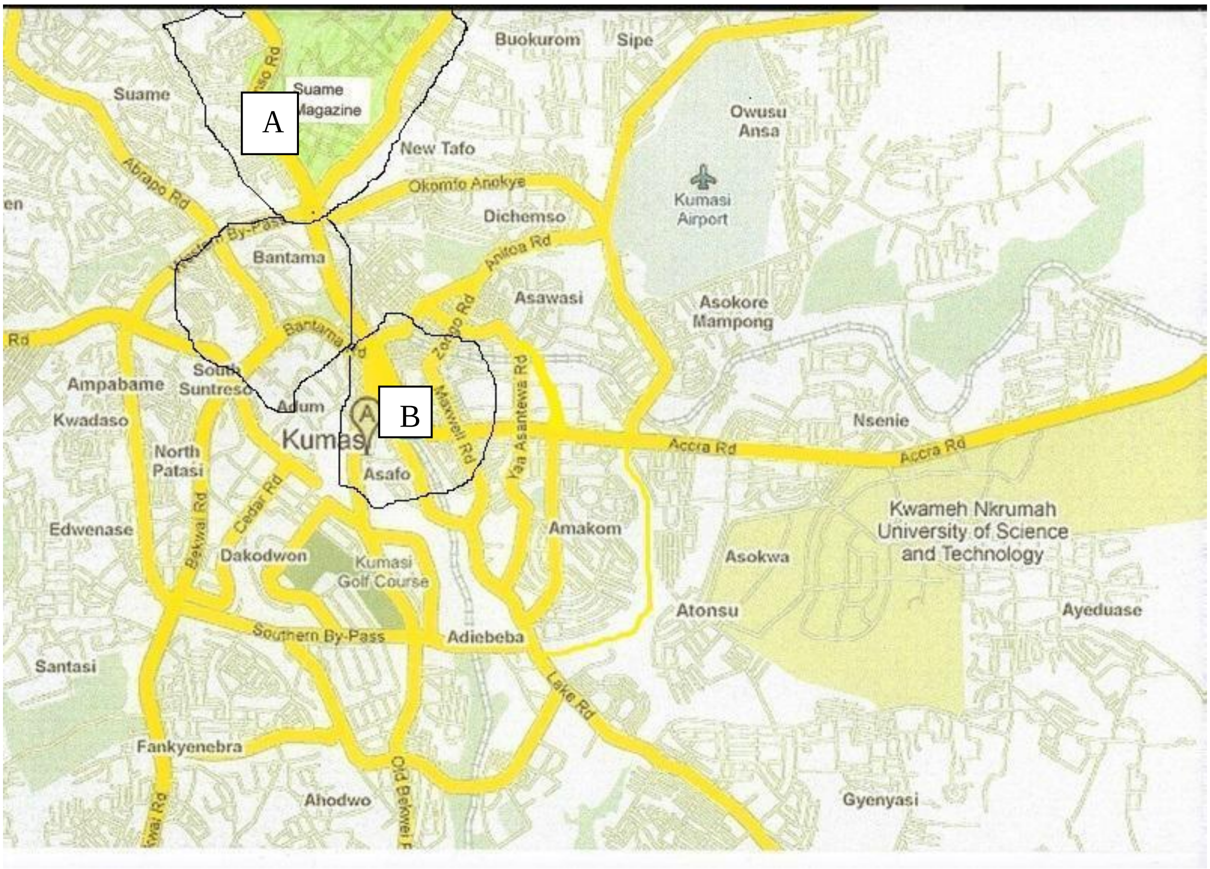

Figure 4: Map of Kumasi showing the study areas
Legend: A =Site A (Suame–Magazine), B = Site B (Asafo "Fitam") [31].

Kumasi has a population of about 2,022,919 and covers an area of 254km^2. The Suame Magazine (Site A, Figure 4) suburb has a working population of over 200,000 [31]. The main commercial activities found in the area are manufacturing, vehicle repairs, metal welding, lead-acid batteries repair, sale of engineering materials, automobile spare-parts and food (mainly by women) [31]. The foods sold range from raw food products to cooked meals. The second site, Asafo Fitam (Site B, Figure 4), is located about 4 km from Kumasi Central. It has a total income earning population of about 12,000, and the commercial activities carried out are mainly vehicle repair and maintenance. There are several small-scale lead-acid battery repair workshops in this suburb [31]. Data were collected among 63 small scale male battery repair workers scattered all over the Suame and Asafo Fitam suburbs of Kumasi. The sample size of 63 was used in this study instead of 64 in the background study, as one of the respondents had passed away. Subjects with known chronic diseases like diabetes, heart diseases, and those abusing drugs and alcohol, were excluded from the background study. In addition, only those with active malaria at the time of the background study were excluded since malaria is endemic in Ghana [31].

2.5 The Questionnaire

A food frequency questionnaire (FFQ) was designed to collect dietary information from the respondents. Food frequency questionnaires have the advantage of being quick and inexpensive, can readily be used to survey a large number of respondents, minimize observer bias and may be more representative of the usual food intake of the population when compared to detailed studies that take a few days [32]. The FFQ was designed to investigate the types of food consumed and the frequency of their intake in the last month.

In Ghana, food is classified into six food groups, namely: starchy roots and plantain, animal products, legumes, nuts and oil seeds, fruits and vegetables, cereals and grains, and fats and oils. For the purpose of this study, an additional group was incorporated, namely beverages. It helped gather information on beverages consumed and their frequency. Limiting the past consumption to the previous month was done to make it easier for the respondents to recall details. Under normal circumstances people do not pay attention to the frequency of their food intake. Factors such as personal preferences, availability and costs also influence food intake. The frequency timeframe of one month instead of one week was chosen to prevent respondents from reporting only the foods taken within that very week they were interviewed. The FFQ helped to investigate if foods rich in selenium were more frequently eaten compared to others.

The questionnaire was first pretested on five Ghanaian students at the University of Tromsø prior to the fieldwork. Though the students did not match the respondents, it was necessary to get some feedback on the quality of the questionnaire before the trip to Ghana. The questionnaire was redesigned based on the first feedback gained from the students. The new questionnaire was given to the students for a second pre-testing. Further comments were taken into consideration, and the necessary changes made. Upon arrival in Kumasi, the questionnaire was again pre-tested on five battery repair workers. Additional changes were made and the final questionnaire was then used to complete the data collection.

2.6 Variables

Grouped (by site and ranges) and actual whole blood concentrations of selenium served as dependent variables in the study. Grouping made the descriptive analysis easier, while actual values were used in the linear regression analyses. The independent variables comprised of the demographic characteristics of the battery repair workers – age, marital status, household size, level of education, BMI and number of years in the occupation. Information on height and weight (from which BMI was calculated) and number of years in the occupation was taken from the background study. The various food items in the food groups also served as independent variables to investigate predictors of the selenium in blood. The frequency of intake of these products initially were grouped as: once, 2-4 times, 6-8 times, 8-10 times, more than 10 times and never; subsequently they were regrouped into “10 times or less” and "more than 10 times" for the linear regression analyses.

2.7 Data analysis

The statistical analyses were performed using the Statistical Package for Social Sciences software programme (SPSS) version 23. Two methods were employed for the analyses: descriptive statistics, such as means and standard deviations; and multiple linear regression. The latter was used to test associations between demographic characteristics and blood selenium, and also to test associations between food items and the selenium concentrations. The significance level for the regression analysis was set at $p < 0.05$.

2.8 Ethical considerations

This study is a part of a background study, which received ethical approval from the School of Medical Sciences, Kwame Nkrumah University of Science and Technology, the Komfo Anokye Teaching Hospital Committee on Human Research Publication, and the Ethics and Regional Committee for Medical Research Ethics of Northern Norway (REK).

CHAPTER THREE

FINDINGS

3.1 Demographic Characteristics

Table 1: Principal characteristics of the subjects

	Battery workers (n=63)
Age (years)	31.5±8.0
Height	1.69±0.1
Weight	65.8±9.9
BMI (kg/m2)	23.1±2.6
% Underweight (>18.5)	3.2
% Normal (<25)	74.6
% Overweight (25-<30)	20.6
% Obese (≥30)	1.6
Years in the occupation	11±7.3
Educational level (%)	
Junior high	79.4
Senior high	9.5
Polytechnic	1.6
Other	9.5
Marital status (%)	
Single	47.6
Married	47.6
Divorced	4.8
Household size	1.46±0.8

Age, height, weight, years in the occupation, household size and overall BMI are reported as means and standard deviation. Marital status, educational level and the BMI categories are reported in percentages.

The population of 63 battery repair workers was entirely male. They were aged between 20 and 49 years: with 27 (42.9%) between 23 and 32, 21 (33.3%) 42 and older, with the oldest being 49 and the youngest 20. With regards to marital status, 30 of the workers (47.6%) were single and an equal number were married, while 3 (4.8%) were divorced. The majority of respondents (66.7%) had a household size of 1-3, while one respondent (1.6%) had more than 12. With regards to education, the majority (79.4%) had finished junior high school, one of them had a university education, and 9.5% of them had either dropped out of school or did not have the opportunity to continue their education beyond primary school. The majority of the workers (63.5%) had working experiences between 1 and 10 years in their occupation, while 11.1% of them had 21 to 31 years. With regards to BMI, 74.6% of the workers had normal weights (BMI 18.5-24.9), 20.6% were overweight (BMI 25-29.9), while one of them (1.6%) was obese (BMI 30 or higher).

3.2 Concentrations of selenium in whole blood

As earlier indicated, blood selenium values were taken from the background study. The minimum concentration of blood selenium was 117 µg/L, while the highest was 369 µg/L; the majority of the battery repair workers (73%) had concentrations ranging from 201-300 µg/L, as depicted in the pie-chart below in Figure 5.

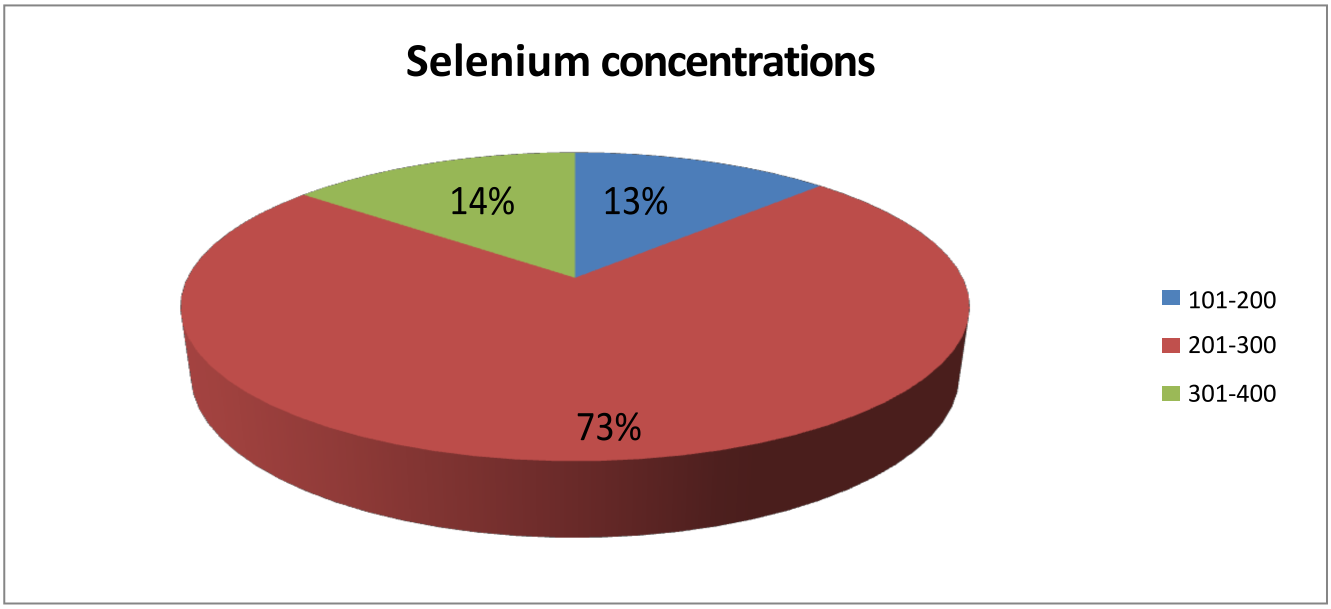

Fig. 5: Blood selenium concentrations of the battery repair workers in µg/L.

3.2.1. Mean concentrations of selenium in blood (µg/L)

Table 2: Mean blood concentrations of selenium in the battery repair workers.

Group	**Blood Selenium** (µg/L)
BRWSuame (n = 31)	262 ± 36
BRWAsafo Fitam (n = 32)	249 ± 54
BRWTotal (n = 63)	256 ± 46

BRW: Battery Repair Workers.

The battery repair workers at Suame recorded the highest mean selenium values of 262 ± 36 µg/L, while those at Asafo Fitam had a somewhat lower mean of 249 ± 54 µg/L. The overall mean for the study population was 256 ± 46 µg/L.

3.2.2 Battery workers' height and weight as predictors of blood selenium

Multiple linear regression was employed to predict battery repair workers' blood selenium concentrations based on their height and weight. A significant regression model was observed (*p*<0.05) with an R^2 of 0.152 (see Table 3). The overall equation is: Se (µg/L) = 532.2+1.59 (weight) – 224.5 (height), with weight in kilograms (kg) and height in metres (m). Selenium concentrations decreased by 224.5 µg/L for each metre of height, and weight had a positive correlation with blood selenium. Both height and weight were significant predictors of blood selenium concentrations (*p*<0.05).

Table 3: Dependence of battery repair workers' blood selenium concentrations on height and weight

Battery workers' height and weight	**B**	**95% CI**	***P-value***	**R^2**
Height	-224.53	-402.81;-46.24	0.014	0.152
Weight	1.59	0.43;2.75	0.008	

3.2.3 Demographic characteristics and associations with selenium concentrations.

Multiple linear regression was also used to investigate the influence of the following demographic characteristics on blood selenium: age, work experience, household size, level of education, marital status and BMI. For the purpose of the regression analysis, marital status was re-coded to single and married. The results of the regression indicated that the demographic characteristics explained about 15% of the variance, but the overall model was not significant (R^2=0.148, *p*>0.05). BMI was the only demographic characteristic that significantly predicted the battery repair workers' blood selenium concentrations (*p*<0.05) as shown in Table 4.

Table 4: Demographic characteristics as predictors of blood selenium concentrations

Demographic Characteristic	**B**	**95% CI**	***P-value***	**R^2**
				0.148
Marital status	9.24	-15.34;45.63	0.324	
Age	-0.09	-14.21;8.06	0.583	
Work experience	-0.59	-2.58;1.24	0.486	
Household size	-11.03	-25.72;7.39	0.272	
Level of education	5.39	-4.05;16.37	0.232	
BMI	5.72	0.59;10.87	0.030	

3.2.3.1. Selenium concentrations and BMI

As mentioned above, only BMI significantly predicted blood selenium concentrations ($p<0.05$) in the multivariate regression model. The data in Table 5 below provide the breakdown by ranges of blood selenium and BMI of the battery repair workers.

Table 5: Grouping of blood selenium concentrations and BMI of the battery repair workers

	BMI				**Total**
Selenium levels (range in µg/L)	**Underweight (Less than 18.5)**	**Normal weight (18.5-24.9)**	**Overweight (25.-29.9)**	**Obese (30 or more)**	
101-200	1	5	2	0	8
201-300	**1**	**35**	**9**	**1**	**46**
301-400	0	7	2	0	9
Total	2	47	13	1	63

Out of the forty-six workers with blood selenium between 201-300 µg/L, thirty-five had normal weight, nine were overweight, while one was underweight and one obese. Among those with the highest blood concentrations (301-400 µg/L), two were overweight, seven had normal weight and none were obese or underweight.

3.3. Food patterns

The food intake patterns of the battery repair workers are highlighted in this section. They are grouped within the six food groups of Ghana plus the additional group added in this study.

a. Starchy roots and plantain

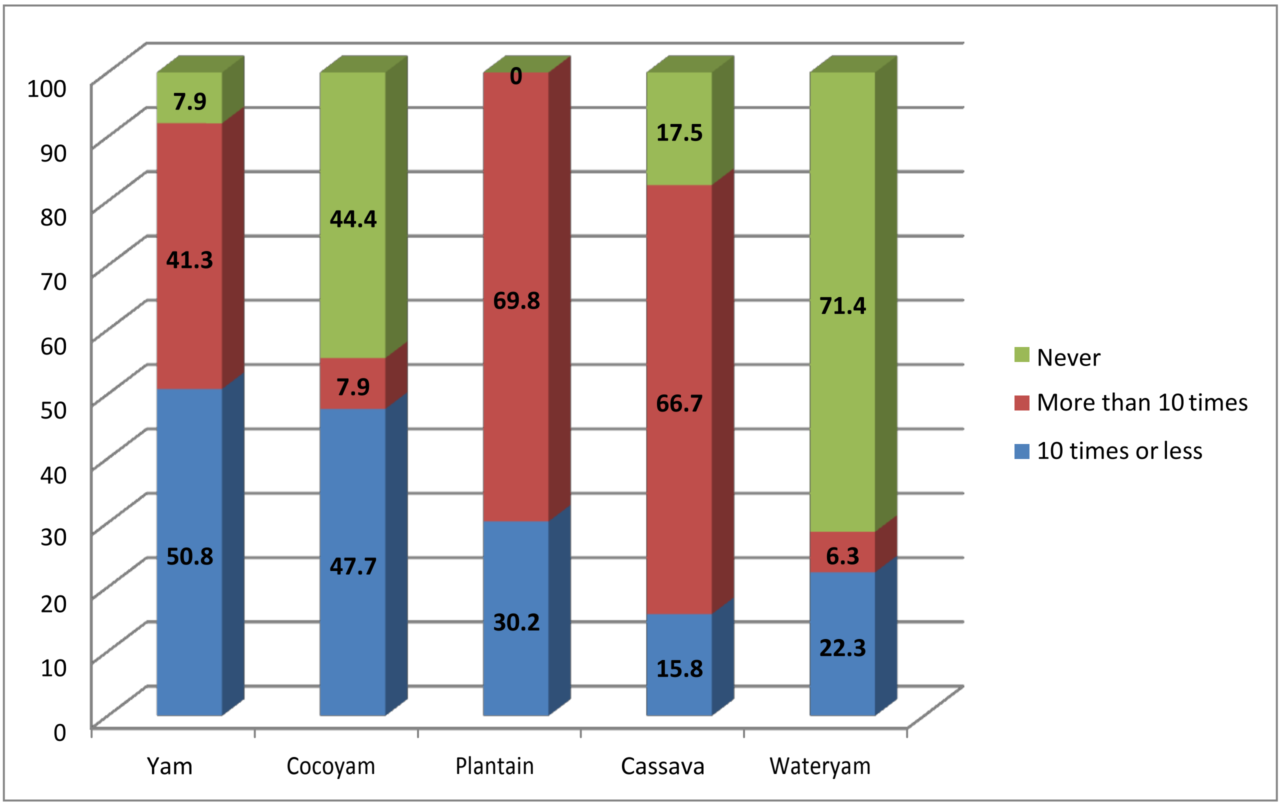

Fig. 6: Relative intake frequencies (%) of starchy roots and plantain within the previous month

Plantain (69.8%) and cassava (66.7%) were the most frequently consumed foods by the study participants in the starchy roots and plantain group, followed by frequent intake of yam at 41.3%. Respondents claimed that plantain was generally more affordable. Wateryam was rarely consumed because it was not readily available on the market.

b. Animal products

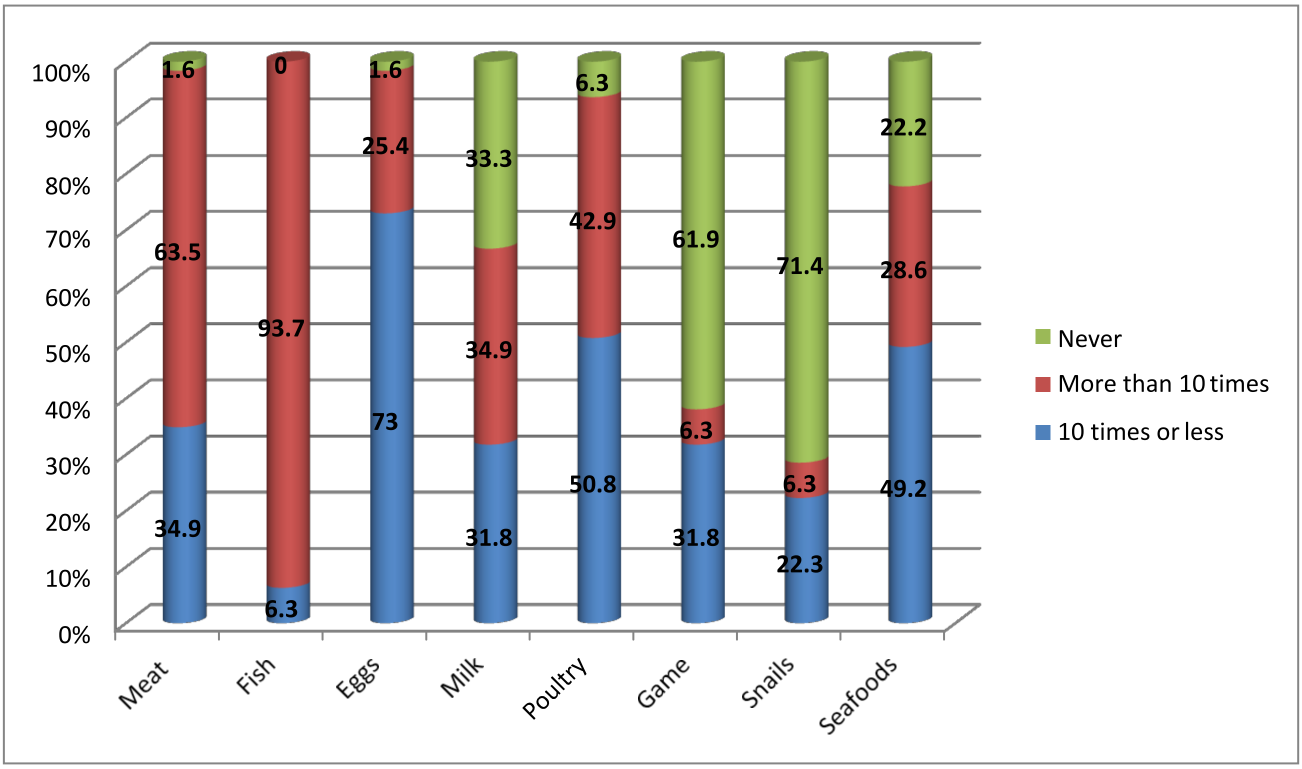

Fig. 7: Relative intake frequencies (%) of animal products within the previous month.

Fish had the highest intake in the animal products food group. The majority (93.7%) of the respondents consumed it frequently. This was followed by meat (pork, beef, goat, ram). The workers with a frequent intake of meat made up 63.5% of the study population. Poultry was frequently consumed by 42.9% and milk by 34.9%.

c. Legumes, nuts and oil seeds

Palm fruit, beans and groundnuts were the most frequently consumed foods within this food group – 79.4%, 69.8% and 52.4% had high intakes within the previous month, respectively. Soybeans and cowpeas were not frequently consumed, but they are mostly popular in the Northern Region of Ghana according to some respondents. The frequency of consumption of foods in this group is summarized in Figure 8.

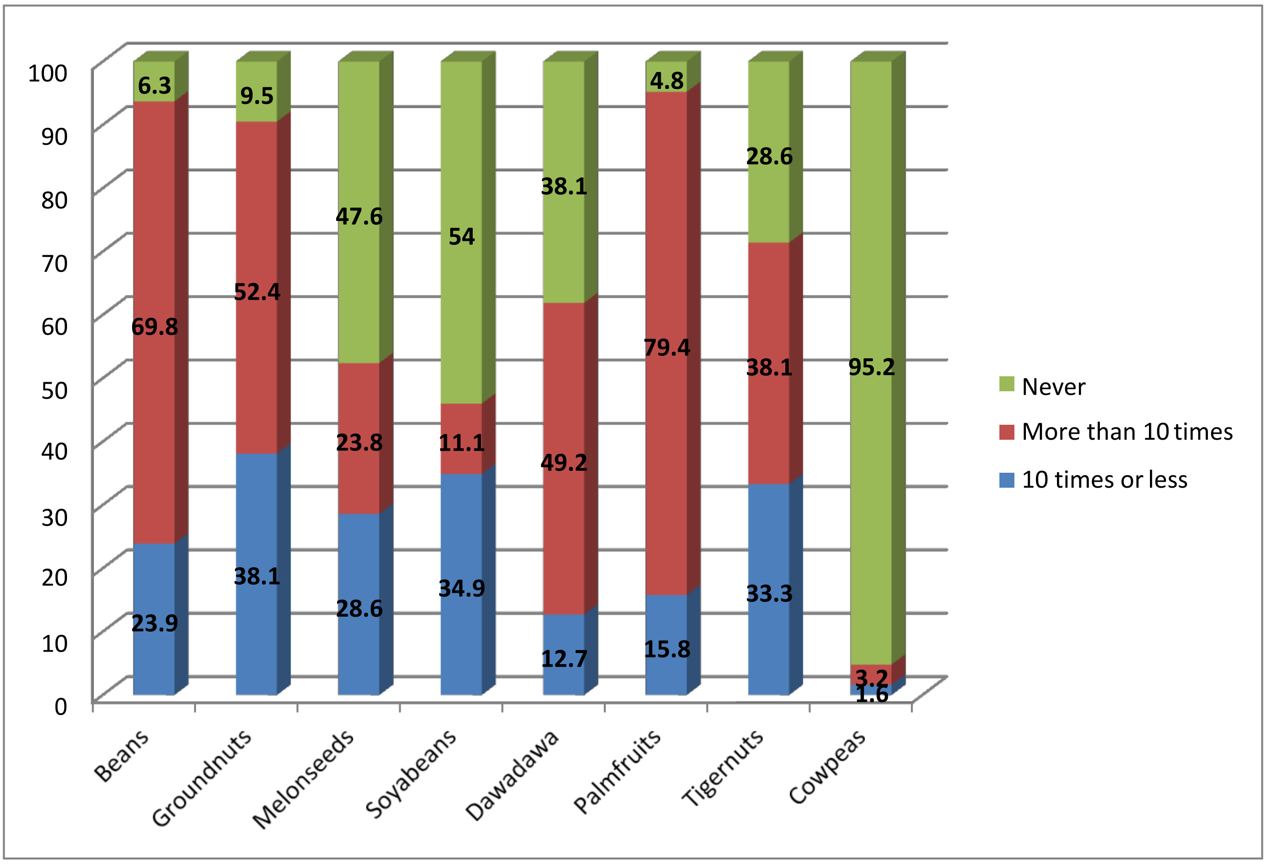

Fig.8: Relative intake frequencies (%) of legumes, nuts and oil seeds within the previous month

Table 6: Intake of fruits and vegetables within the previous month

	10 times or less		**More than 10 times**		**Never**	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**
Orange	20	31.7	41	65.1	2	3.2
Banana	14	22.2	47	74.6	2	3.2
Pineapple	28	44.5	29	46.0	6	9.5
Pawpaw	22	35.0	28	44.4	13	20.6
Watermelon	7	11.2	52	82.5	4	6.3
Apple	15	23.9	36	57.1	12	19.0
Mango	16	25.4	38	60.3	9	14.3
Leafy vegetables	14	22.2	48	76.2	1	1.6
Okro	25	39.7	31	49.2	7	11.1
Garden eggs	3	48.0	60	95.2	0	0
Tomatoes	0	0	63	100.0	0	0
Pepper	4	6.3	58	92.1	1	1.6
Onions	0	0	63	100.0	0	0
Carrots	25	39.6	26	41.3	11	17.5
Cabbage	29	46.0	27	42.9	7	11.1
Tangerine	28	44.4	9	14.3	26	41.3
Avocado	18	28.6	33	52.4	12	19.0
Coconut	25	39.7	36	57.1	2	3.2
Grapes	10	15.9	4	6.3	49	77.8

Tomatoes and onions had the highest intake in the fruits and vegetables food group. All the battery workers (100%) had high intakes of these vegetables. This was followed by garden eggs (95.2%), pepper (92.1%) and leafy vegetables (76.2%). These food items had high consumption rates because they are the basic ingredients in Ghanaian soups and sauces. The most frequently eaten fruit was watermelon (82.5%), followed by banana (74.6%), oranges (65.1%) and mango (60.3%).

d. Fats and oils

The most frequently consumed foods under this group were palm oil (90.5%) and refined vegetable oil (88.9%), which is consistent with them being basic ingredients of most Ghanaian dishes. Figure 9 below depicts the frequency of consumption of foods within this group.

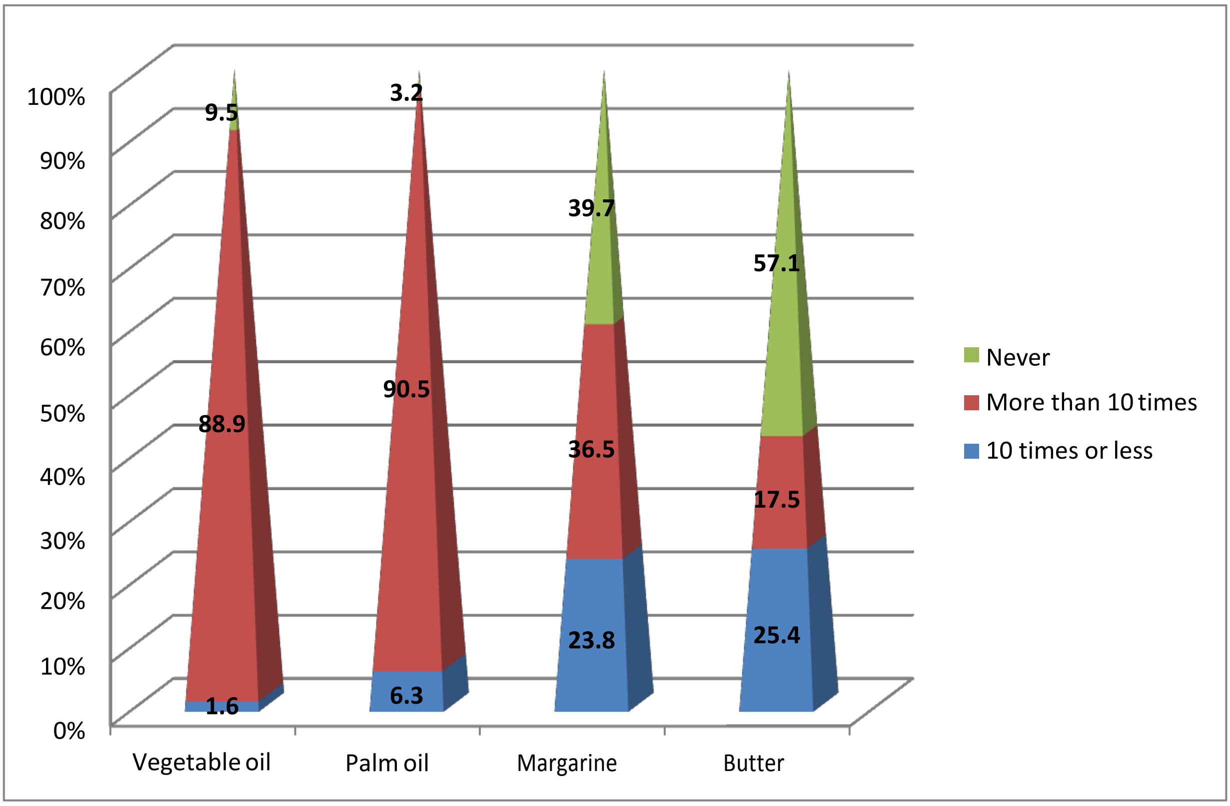

Fig. 9: Relative intake frequencies (%) of fats and oils within the previous month

e. Cereals and grains

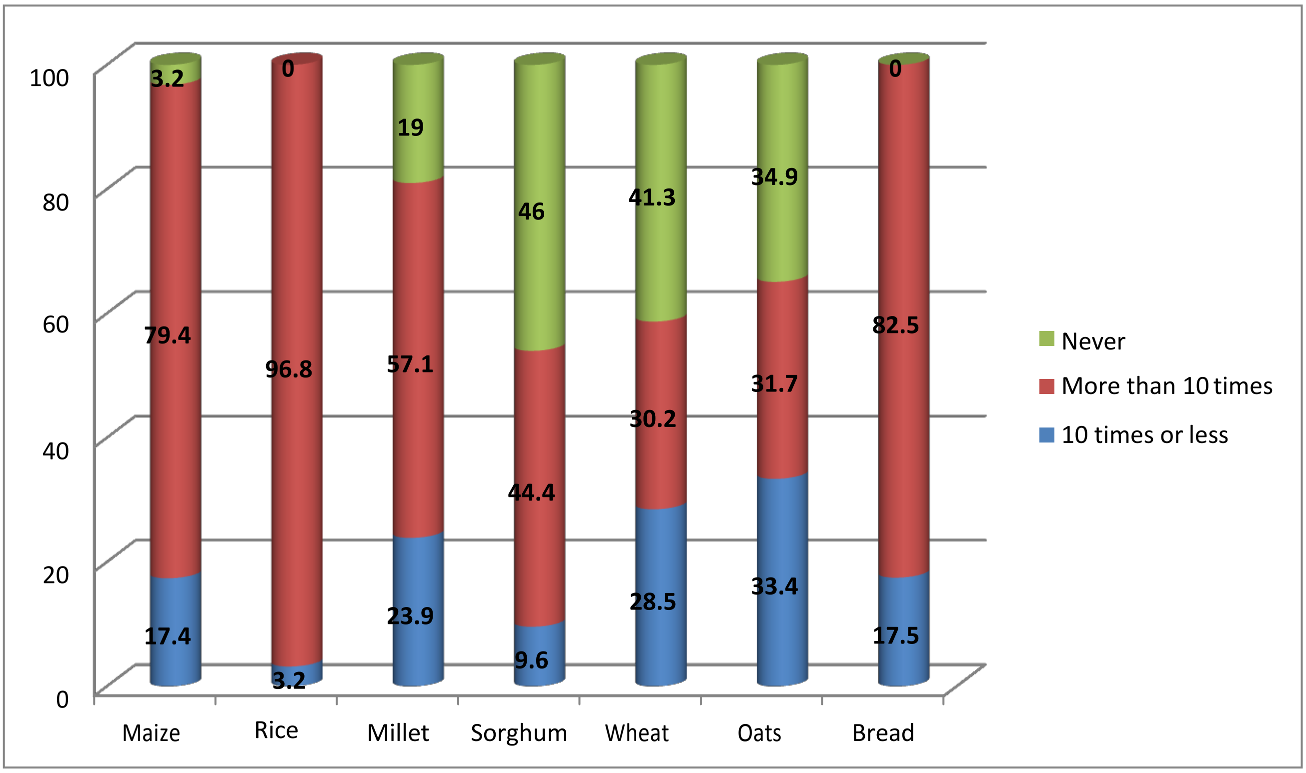

Fig. 10: Relative intake frequencies (%) of cereals and grains within the previous month.

Rice was the most frequently consumed food in the cereals/grains group. The majority (96.8%) of the battery repair workers had high intakes in the past month. Rice is very widely consumed in Ghana – both the locally produced and imported varieties. Previous studies have shown that the ease of preparation and availability account for this [29].

Bread and maize were also frequently consumed by 82.5% and 79.4% of the workers, respectively. Though one of the basic ingredients of bread is wheat flour, it has been distinguished from raw wheat in the current study. The reason being that wheat grains can be boiled and eaten just like rice. Respondents would, however, deny consuming wheat when asked, but did admit to eating wheat products like bread ─ hence, the distinction between the two in this study. Nti (2008) in a study of household dietary practices among women in the Manya Krobo district of the Eastern Region of Ghana reports that wheat plays a small role in the diet, although the majority of her respondents consumed it in the form of bread [33]. In the present study therefore, wheat refers to the raw, unprocessed wheat, while bread refers to wheat products.

Millet and sorghum were rarely consumed because they were not readily available in the Ashanti Region. Only 31.7% of the workers consumed oats frequently because it was mostly eaten for breakfast, although most battery repair workers either skipped breakfast or had a warm-meal at that time.

a. Beverages

As mentioned earlier, to identify other food items that may be of significance, a food group that focuses on beverages was created. This group includes tea, cocoa drinks, soft drinks, coffee, alcoholic drinks, *pito*, a local, home-made beverage and tigernut milk (a beverage made from tigernuts). Figure 11 depicts an overview of the intake of beverages.

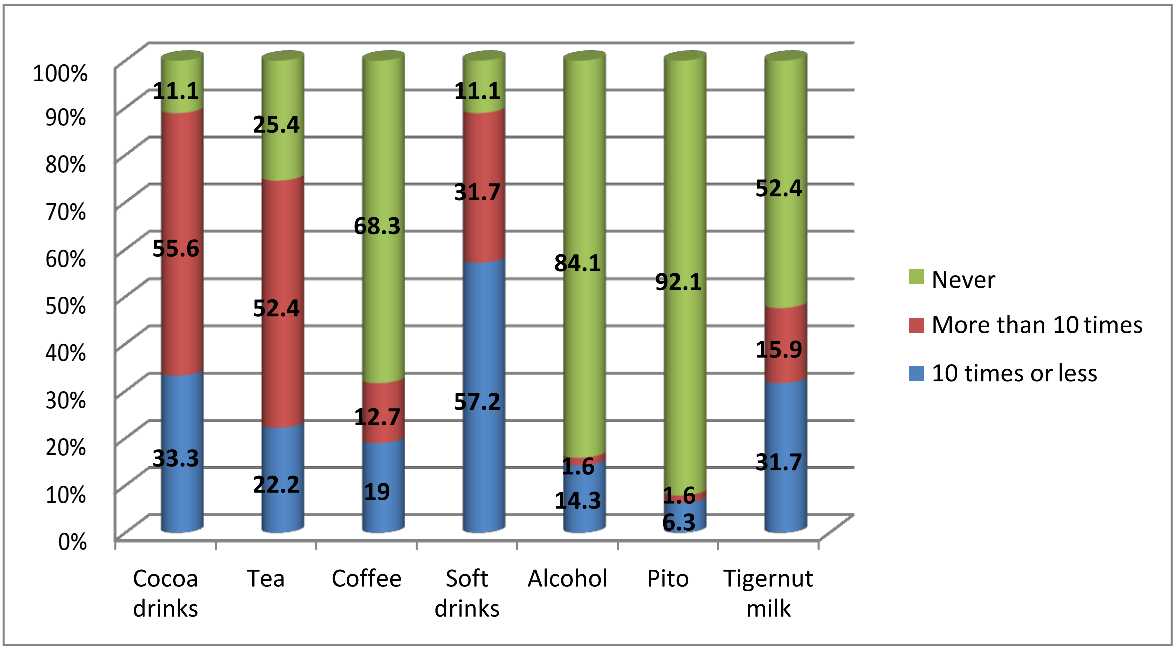

Fig. 11: Relative intake frequencies (%) of beverages within the previous month

Cocoa drinks (55.6%) and tea (52.4%) were the most frequently consumed beverages within the past month. Cocoa is a major produce in Ghana and thus, readily available and affordable. With regards to soft drinks, 31.7% of the respondents had a frequent intake. Soft drinks include juices and sodas. *Pito* was rarely consumed as it was not readily available. Alcoholic beverages had low consumption rates because the majority of respondents abstained from them due to religious and health reasons.

3.4 Food patterns and correlations with blood selenium concentrations

3.4.1 Association of starchy roots and plantain with blood selenium concentrations

In the multivariable regression model, a non-significant regression equation was observed ($p>0.05$) with an R^2 of 0.085, implying that only 9% of the variance was explained by it. Plantain was the only food item in this food group that predicted blood selenium concentrations ($p=0.030$).

Table 7: Consumption of starchy roots and plantain as predictors of blood selenium concentrations

Food Item	**B**	**95% CI**	***P-value***	**R^2**
				0.085
Yam	-0.19	-7.48; 7.10	0.958	
Cocoyam	-3.48	-8.85; 1.89	0.199	
Plantain	-5.69	-13.44; -2.06	0.030	
Cassava	2.04	-7.53; 11.60	0.672	
Wateryam	-2.78	-9.07; 3.51	0.380	

3.4.2 Association of animal products with blood selenium concentrations

In the multivariable regression model, a non-significant regression equation was observed (*p*>0.05), with an R^2 of 0.216. The model therefore explained 22% of the variance. The food items in this food group that were predictors of blood selenium were game (*p*=0.034) and snails (*p*=0.022) as indicated in Table 8 below.

Table 8: Consumption of animal products as predictors of blood selenium concentrations

Food Item	**B**	**95% CI**	***P-value***	**R^2**
				0.216
Meat	-5.79	-14.07; 2.50	0.167	
Fish	-6.86	-25.17; 11.46	0.456	
Eggs	2.43	-5.14; 10.01	0.522	
Milk	3.39	-2.78; 9.58	0.252	
Poultry	-2.42	-9.05; 4.21	0.467	
Game	-4.48	-9.07; - 0.75	0.034	
Snails	7.13	1.08; 13.19	0.022	
Seafoods	-1.85	-8.46; 4.76	0.577	

3.4.3 Association of legumes, nuts and oil seeds with blood selenium concentrations

In the multivariable regression model, a non-significant regression equation was found ($p>0.05$) with an R^2 of 0.090, which implies that only 9% of the variability of the data could be explained. In this food group, only palm fruits predicted blood selenium concentrations ($p=0.023$) as depicted in Table 9.

Table 9: Consumption of legumes, nuts and oil seeds as predictors of blood selenium concentrations

Food Item	**B**	**95% CI**	***P-value***	**R^2**
				0.090
Beans	-0.06	-9.45; 9.33	0.989	
Groundnuts	-1.96	-9.23; 5.31	0.591	
Melon Seeds	1.69	-4.56; 7.95	0.590	
Soybeans	1.06	-6.17; 8.29	0.769	
Dawadawa	7.11	-3.99; 18.20	0.205	
Palm fruits	-8.67	-20.64; -3.29	0.023	
Tigernuts	-3.32	-10.03; 3.39	0.325	
Cowpeas	-6.01	-26.13; 14.10	0.551	

3.4.4 Association of fruits and vegetables with blood selenium concentrations

A non-significant regression equation was observed ($p > 0.05$) with an R^2 of 0.254 implying that the model predicted 25% of the variance. However, none of the food items in this food group predicted blood selenium concentrations with significance (see Table 10).

Table 10: Consumption of fruits and vegetables as predictors of blood selenium concentrations

Food Item	**B**	**95% CI**	***P-value***	**R^2**
				0.254
Oranges	2.09	-6.77; 10.94	0.637	
Banana	0.64	-10.19; 11.49	0.905	
Pineapple	6.69	-1.67; 15.04	0.114	
Pawpaw	-1.96	-10.02; 6.10	0.627	
Watermelon	0.61	-16.84; 18.06	0.944	
Apples	-6.67	-16.05; 2.71	0.159	
Mango	-4.16	-12.58; 4.25	0.324	
Leafy vegetables	3.75	-7.30; 14.79	0.498	
Okro	-5.07	-12.35; 2.21	0.168	
Garden eggs	15.47	-7.32; 38.26	0.178	
Pepper	-5.82	-29.11; 17.48	0.617	
Carrots	0.53	-7.89; 8.95	0.900	
Cabbage	1.62	-5.92; 9.15	0.668	
Tangerine	3.31	-2.65; 9.26	0.270	
Avocado	3.38	-5.19; 11.95	0.431	
Coconut	-4.61	-13.01; 3.79	0.275	
Grapes	3.58	-4.15; 11.28	0.357	

3.4.5 Association of fats and oils with blood selenium concentrations

In the multivariable regression model, a non-significant regression equation was generated ($p>0.05$), with an R^2 of 0.004. The model therefore explained very little of the variability of the data. Nevertheless, among this food group, palm oil was the only predictor of blood selenium concentrations ($p=0.016$).

Table 11: Consumption of fats and oils as predictors of blood selenium concentrations

Food Item	**B**	**95% CI**	***P-value***	**R^2**
				0.004
Vegetable oil	-3.69	-27.05; 19.65	0.752	
Palm oil	2.67	11.96; 17.31	0.016	
Margarine	1.02	-8.86; 10.90	0.836	
Butter	-1.47	-10.63; 7.68	0.749	

3.4.6 Association of cereals and grains with blood selenium concentrations

In the multivariable regression model, a non-significant regression equation occurred (*p*>0.05), with an R^2 of 0.179. The model therefore explained approximately 18% of the variance, although only oats was a predictor of blood selenium concentrations in the model (*p*=0.015).

Table 12: Consumption of cereals and grains as predictors of blood selenium concentrations

Food Item	**B**	**95% CI**	***P-value***	**R^2**
				0.179
Maize	-5.22	-17.20; 6.76	0.386	
Rice	-18.36	-43.79; 7.06	0.153	
Millet	2.55	-5.89; 10.99	0.547	
Sorghum	6.12	-3.77; 8.99	0.318	
Wheat	2.61	-7.69; 4.28	0.415	
Oats	-1.71	-21.12; -5.51	0.015	
Bread	-7.81	-7.22; 6.22	0.245	

3.4.7 Association of beverages with blood selenium concentrations

In the multivariable regression model, a significant regression model was found (p<0.05) with an R^2 of 0.219, indicating that about 22% of the variability of the data could be explained. The only food item that predicted blood selenium was tigernut milk (p=0.010).

Table 13: Consumption of beverages as predictors of blood selenium concentrations

Food Item	**B**	**95% CI**	***P-value***	R^2
				0.219
Cocoa drinks	3.61	-2.93; 10.14	0.273	
Tea	1.42	-5.71; 8.56	0.691	
Coffee	-9.49	-15.78; -3.19	0.208	
Soft drinks	-4.45	-10.15; 1.24	0.123	
Alcohol	-7.74	-16.99; 1.51	0.099	
Pito	3.42	-8.64; 15.48	0.572	
Tigernut milk	1.66	4.34; 7.59	0.010	

3.5. Blood selenium concentrations and statistically significant foods

The linear regressions showed that tigernut milk ($p<0.05$), oats ($p<0.05$), palm fruits ($p<0.05$), plantain ($p<0.05$), palm oil ($p<0.05$), snails ($p<0.05$) and game ($p<0.05$) predicted blood selenium concentrations. Tables 11, 12 and 13 below show the blood selenium concentrations of the workers and the frequency of intake of these food items.

Table 14: Selenium concentrations and intake of game, tigernut milk and oats

Selenium Levels	**Game**		**Total**	**Tigernut milk**		**Total**	**Oats**		**Total**
	< 10 times	>10 times		< 10 times	>10 times		< 10 times	>10 times	
101-200	7	1	8	8	0	8	2	6	8
201-300	43	3	46	40	6	46	34	12	46
301-400	9	0	9	5	4	9	7	2	9
Total	**59**	**4**	**63**	**53**	**10**	**63**	**43**	**20**	**63**

The compilation in Table 14 illustrates that only three of the patients with blood selenium concentrations in the range 201- 300 µg/L frequently consumed game, while none did who were in the 301-400 µg/L interval. In the case of tigernut milk, six of the battery workers who frequently consumed this item had blood selenium between 201-300 µg/L, while four were within the highest range (301-400 µg/L) consumed it frequently. On the other hand, consumers of oats had twelve workers with blood selenium ranging 201-300 µg/L who ate them frequently, as did six workers in the range 101 µg/L-200 µg/L. Only two of those with the highest blood selenium concentrations (301-400 µg/L) frequently consumed this food item.

Table 15: Selenium concentrations and intake of palm fruits and palm oil

Selenium Levels	**Palm fruits**		**Total**	**Palm oil**		**Total**
	< 10 times	>10 times		< 10 times	>10 times	
101-200	1	7	8	1	7	8
201-300	8	38	46	5	41	46
301-400	4	5	9	0	9	9
Total	**13**	**50**	**63**	**6**	**57**	**63**

Palm fruits were frequently consumed by the majority (thirty-eight) of the battery repair workers who fell within the blood selenium range of 201-300 µg/L. Five out of the nine battery repair workers within the 301-400 µg/L interval frequently consumed palm fruits. Forty-one of the workers with blood selenium 201-300 µg/L consumed palm oil frequently, while all nine within the highest range (301-400 µg/L) did as well.

Table 16: Selenium concentrations and intake of snails and plantain

Selenium Levels	**Snails**		**Total**	**Plantain**		**Total**
	< 10 times	>10 times		< 10 times	>10 times	
101-200	8	0	8	0	8	8
201-300	42	4	46	17	29	46
301-400	9	0	9	2	7	9
Total	**59**	**4**	**63**	**19**	**44**	**63**

Snails constituted a minor food item. Only four of the forty-two participants with blood selenium concentrations 201-300 µg/L reported a frequent intake, while none did of those with the highest (301- 400 µg/L) and lowest blood selenium (101-200 µg/L).

Consumption of plantain on the other hand was generally high: twenty-nine of those with blood concentrations 201- 300 µg/L were frequent consumers; seven out of nine in the range 301- 400 µg/L did so frequently, as well as all eight workers with the lowest blood selenium (101- 200 µg/L).

CHAPTER FOUR

DISCUSSION

This chapter is a discussion of how the findings of the current study align with the published literature.

4.1 Selenium concentrations and demographic factors

The population for this study was entirely male. A Swiss study, however, found a statistically significant gender difference in selenium status and men are reported to have slightly higher concentrations than women [11, 24]. High concentrations of selenium basically reflect intake of selenium and the gender differences are usually balanced in seleniferous areas (i.e., having high concentrations of selenium in soils and foods) [24]. Studies on blood selenium concentrations in West Africa report no significant differences based on gender [4, 37].

The current study showed that age correlated negatively with selenium concentrations such that selenium concentrations decline as age increases (B = -0.09), but this was not statistically significant ($p > 0.05$). This finding is consistent with previous studies on selenium where it is reported to decline with age, and thus advanced age is a factor for decreased blood selenium concentrations [11,17,21]. In an Algerian study of whole blood selenium concentrations, the population ≥ 60 years had the lowest mean concentrations [38].

BMI was found to predict selenium concentrations ($p < 0.05$), and the latter increased with BMI (B = 5.72; Table 4). The number of years in the occupation did not significantly predict selenium concentrations, although it had a negative non-significant correlation (B =

-0.59) suggesting a decrease in its concentration with years employed as a battery worker (or age). A possible explanation for this is discussed in Section 4.4 below.

Other demographic factors such as household size, educational level and marital status did not significantly predict blood selenium concentrations of the workers ($p > 0.05$). Household size had a negative regression coefficient with selenium concentration (B = -11.03; Table 4), suggesting a decreasing tendency in selenium status with increasing household size. Marital status and educational level exhibited a similar non-significant positive trend (B = 5.39).

4.2 Food intake patterns

Plantain and cassava under the starchy roots and plantain food group had the highest intake. This is because they are the main ingredients of the local dish, *fufu*, which is very popular in the Ashanti Region. This is in agreement with previous Ghanaian studies [21, 33, 34]. Under the animal products group, a high intake of fish was observed. Ghana has a thriving fishing industry and fish is readily available. It is also more affordable when compared to meat and meat products. Some of the workers admitted to eating a lot more fish than meat. Other studies on dietary intake in Ghana have also recorded frequent intake of fish [33, 34, 35, 36]. Foods like game (also known as bush meat) and wateryam are rare and, as such, their intake was not frequent. Sea foods like prawns are usually dried and used in preparation of hot pepper sauce (*shito*). The intake was not as frequent compared to meat and fish.

The intake of palm fruit and groundnuts was high. This is consistent with them being major ingredients in palm nut and groundnut soup, respectively, and are widely eaten with *fufu*. Previous studies have also reported a high intake of groundnuts and palm fruits [33,34]. Onions, tomatoes, garden eggs and pepper also had high intakes and constitute basic ingredients of Ghanaian soups and sauces. This finding is consistent with other studies conducted on food patterns in Ghana [21,33-36]. Salads were not popular among the respondents, but leafy vegetables (76.2% had frequent intakes) are used in the preparation of soups and sauces. The high intake of rice reflects its availability, taste and ease of preparation. This is also in agreement with previous studies on dietary intake in Ghana [33,36]. Millet is basically eaten in the form of porridge while maize was frequently consumed as an ingredient of local dishes like *banku* and *kenkey,* in agreement with other Ghanaian studies [33,34].

Fruits and vegetables can be seasonal. The respondents admitted to having high intakes of certain fruits when in season, such as mangoes, tangerine, oranges and avocado. Seasonal availability of foods reduces prices which enhances intake. Previous studies have also identified increases in the consumption of fruits when in season [33,35]. Religious factors restrained some respondents from eating certain foods, as is the case for the Seventh Day Adventists and Muslims who do not eat pork and refrain from alcohol. As mentioned earlier, battery workers abusing alcohol were eliminated from the study. Alcohol intake was therefore between low and moderate. Several respondents ate most of their meals outside the home. They purchased food from vendors in the vicinity of the work area. Others prepared meals at the workplace. Selenium-rich foods such as those high in protein and wheat products were frequently eaten by the battery repair workers (generally speaking). Meat and fish had the highest intake during the study month, while consumption of game or bush meat were rare.

4.3 Selenium concentrations and intake of foods rich in selenium

Selenium concentrations in humans can be grouped into 3 categories: low (below 50-60 µg/L), intermediate (between 60-100 µg/L) and high (above 100-120 µg/L) [24]. Normal concentrations are between 88.23-102.76 µg/L [2]. The lowest concentration for the battery repair workers (117 µg/L) falls within the high category and the highest (369 µg/L) was well above the range for the high category. The selenium status of the Swiss population was classified as normal to high, with concentrations for males ranging 61.6-164.3 µg/L [24], which is lower than those of the battery repair workers. In the Swiss study, the individuals with selenium concentrations above 132.8 µg/L were reported to have likely taken selenium supplements [24]. Since the current study did not take into account the possibility of dietary supplements, this source cannot be taken into account. Because of its cost, such practice is likely not common in Ghana. In Macedonia, the highest value of selenium concentrations have been reported to be 93.02 ± 1.52 µg/L and the lowest 12.25 ± 0.57 µg/L [8].

In a study of whole blood selenium concentrations in residents of Abeokuta, Nigeria, the mean selenium concentrations for males has been reported as 19.4 ± 2.7 µg/dL [37], whereas in an Algerian study it was 85.65 ± 21.60 µg/L (range 30.88 - 44.04 µg/L) [38]. In Uganda, mean selenium concentrations are reported as 95.50 µg/L for healthy adults [2]. In the Ghanaian study mentioned earlier, the mean selenium concentration in rural subjects was 97 ± 36 µg/L, which was higher than that for urban subjects 87 ± 31 µg/L [4]. These concentrations are also lower than those for the battery repair workers. In general, the battery repair workers appear to have high selenium concentrations in comparison to those within and outside Ghana.

In a study of trace elements in Ghanaian grain staples, all rice samples had a mean selenium concentration of 0.110 mg/kg, and for Indian rice on the Ghanaian market it was higher, namely 0.21±0.03mg/kg. The mean concentration of selenium in Ghanaian varieties of maize (0.13mg/kg) was also statistically comparable to global mean concentrations [29]. In the current study, none of the grain staples significantly accounted for the selenium concentrations of the battery workers even though they had high intakes of these food items.

Wheat flour is said to be rich in selenium, vitamins, folate and iron among other nutrients. In a Ghanaian study on trace elements in foods, wheat flour was found to contain 84.8mg/kg of selenium, which would account for about 121% of the daily intake value [39]. In our study, wheat and wheat products in the form of bread were frequently consumed by the workers, but they did not significantly account for their high selenium status ($p > 0.05$).

Measurement of selenium concentration in fresh water fish in the Volta Lake in Ghana found levels of 44.39-44.41 ng/g among some species, while those for tilapia were the lowest. One species had a level as high as 322.9 ng/g, while another as low as 1.59 ng/g. Fish is reported to have a significant impact on human selenium status. Since the acceptable limit of total selenium concentrations of fish is 3000 ng/g, these concentrations did not pose a threat to human health [30]. A study from neighbouring Cameroun reported a low selenium content of foods, with fish the only exception [40]. Fish did not significantly predict blood selenium concentrations of the battery repair workers in the current study, even though the workers had high intakes of fish.

Garlic and onions are said to be good dietary sources of selenium, as they are able to accumulate selenium. In fact, the extent of their intake can be detected by the selenium content of body fluids and human tissue [16,17]. Though our study omitted garlic as a food item, the battery repair workers had high intakes of onions but this did not significantly account for the observed blood selenium concentrations.

It is reported that raw coconut has significant concentrations of selenium and this accounts for the high selenium intakes in West Africa [18]. The intake of coconut in the current study was not found to have a positive association with selenium concentrations ($p > 0.05$). In a Nigerian study on the diet and selenium, yam was reported to have the highest content of this element. Grape, sorghum and chicken were also found to have high accumulation capabilities [37]. However yam, grape, sorghum and poultry did not significantly predict selenium concentrations of the battery repair workers as only poultry and yam were frequently consumed by them.

The foods that significantly correlated with selenium concentrations in the current study were game, tigernut milk, oats, palm fruits, palm oil, snails and plantain ($p < 0.05$; Table 14,15,16). Among these foods, palm fruits (B = -8.67), game (B = -4.48) and plantain (B = -5.69) exhibited negative correlations, suggesting that increases in their intake would result in lowering the selenium concentrations. Oats (B = -1.71) also had a negative association with selenium concentrations. By contrast, an Algerian study showed that a high consumption of cereals and cereal products resulted in high values of dietary selenium intake [41].

For tigernut milk (B = 1.66), palm oil (B = 2.67) and snails (B = 7.13) the correlations with selenium were positive, implying that an increase in their intake is associated with higher selenium concentrations. In a Nigerian study on the selenium content of beverages, it was reported that both canned and non-canned beverages had high amounts of selenium [42]. In our study, the only beverage that was a predictor of selenium was tigenut milk.

The current study embraced the hypothesis that the diet would not correlate with blood selenium concentrations. Since tigernut milk, palm oil and snails were significantly positive predictors of blood selenium concentrations, this hypothesis is rejected. However, only a few food items consumed by the workers constituted positive predictors that reached statistical significance. The study did show that the battery repair workers frequently consumed foods rich in selenium, including proteins (i.e., meat, fish, poultry, beans and groundnut), wheat products (bread), onions and grains such as rice and maize. Furthermore, the sum of the R^2 values for the multivariate analyses reported in Tables 7-13 was 1.052 and suggests that food items with statistically significant and non-significant positive B values seem to explain the relatively high blood selenium concentrations observed. Interestingly, the selenium concentrations observed in the present study compare well with those reported by Longnecker and colleagues [43] for subjects living in a seleniferous area of South Dakota and Wyoming in the USA, namely 2.95 ± 0.38 µmol/kg (233 ± 30 µg/kg; note that 1 kg of blood is 0.94 L) in whole blood and 1.95 ± 0.20 µmol/L (154 ± 16 µg/L) in serum. This comparison suggests that the soil, vegetation and foods in the Ashanti region of Ghana area are quite rich in selenium. Interestingly, no evidence of toxicity was observed.

4.4 Industrial and environmental sources

Although food seems to be confirmed as the main source of selenium, occupational and environmental exposures might have made some minor contributions. These dimensions are discussed in this subsection in the context of the literature.

It is known that workers in the metals industry, mechanics and painters may experience additional exposures [44]. As for the general population, combustion of oil and coal can be contributors in the workplace [44, 45]. The battery workers in our study are known not to have used gloves and personal protection, nor washed their hands thoroughly with soap before meals [31]. Nevertheless, our multivariate analyses found that an increase in work experience (years worked in the occupation) resulted in a decline of blood selenium concentrations as mentioned in Section 4.1. This suggests that exposure at work presumably was a minor source of selenium.

Selenium, apart from its availability in foods, is also found in the environment for instance in volcanic tuff, black slate and in high sulfur coals and can be generated in commercial quantities as a by-product in the refining of copper [1, 45]. Incineration of rubber tires, paper, and municipal waste is an additional source of atmospheric selenium. Industrially, it is applied in the production of fertilizers, antidandruff shampoo, electronics (such as photocopiers, rectifiers and capacitors) and fungicides and is currently being used in mammographic instruments [1,26,45]. Agricultural practices and high-tech industrial processes can lead to selenium pollution, which has generally been overshadowed by contamination due to pesticides, industrial chemicals and air pollutants [44, 45].

Selenium is released into water through power plant waste discharges, can leach out of mined coal through rainfall and contaminate surface waters in the vicinity of mine sites, thus posing a threat to aquatic life [44, 45]. The observance of aquatic pollution has resulted in the emergence of selenium as a significant environmental contaminant. It is posited that aquatic resources could actually be seriously threatened by selenium on a long term basis compared to other pollutants [45]. Another cause for concern is the disposal of electronics, which is usually on landfills. This is an environmental concern in Ghana. Since selenium is an essential component in their production, the disposal of electronics on landfills could result in selenium-laden leachate being released into soil and water bodies [45,46]. Inorganic forms of selenium are also reported to be present in some occupational settings [47].

A closer examination of contributions from occupational and environmental exposure factors to selenium could form the basis for further research among the workers, as they were not the focus of the current project.

4.5 Strengths and limitations of the study

The food frequency questionnaire used in the study was useful in gathering information on the food patterns and diet of the battery repair workers, which in turn was useful in determining if the diet accounted for the high selenium concentrations. Research into the actual daily intake of selenium by the battery repair workers would have enhanced this study, but this would have required selenium analysis of all major food items and detailed measures of the workplace exposures, which were beyond the scope of the project.

The study did not take into account the intake of dietary supplements by the battery repair workers. It also missed out on some food items like garlic which literature claims to be rich in selenium. There is also the probability that respondents may not have given accurate accounts of their food intake.

CHAPTER FIVE

Conclusion and Recommendation

5.1 Conclusion

The battery repair workers in this study have high blood selenium concentrations compared to Ghanaians living in both rural and urban areas, and international values. Height, weight and BMI significantly predict blood selenium concentrations. Aging results in a decline in the battery repair workers' blood selenium. The workers reported frequent intake of foods such as plantain, yam and cassava, which are under the starchy roots and plantain food group. Meat and fish had the highest intake under the animal products group, while onion, pepper, garden eggs and tomatoes were highly consumed under the fruits and vegetables group. Foods that significantly predict blood selenium concentrations are palm fruit, palm oil, oats, tigernut milk, snails, plantain and game. Increased intake in tigernut milk, palm oil and snails are likely to correlate positively with blood selenium concentrations while increased intake in plantain, palm fruits, game and oats would result in a decline in blood selenium concentrations. The battery repair workers had high intakes of foods rich in selenium. Their diet significantly correlates with their blood selenium concentrations, though very few food items positively correlated with the selenium concentrations.

5.2 Further research and recommendations

Geographical areas have been classified as low selenium areas (concentrations below 50-60 µg/L (as in China with concentrations below 30 µg/L) and high or rich selenium areas with values higher than 100-120 µg/L. Values between these two extremes are intermediate, while concentrations close to 330 µg/L are classified as toxic [2]. It might be of interest to carry out research to determine soil selenium concentrations in the Ashanti region of Ghana, and to assess their impact on selenium contents of local food products and vegetation. As earlier mentioned, selenium has been found to increase the risk of diabetes type 2 [25,27]. Further studies might therefore be carried out to investigate the current diabetic status of the workers as a result of their high selenium concentrations.

Further research could also be carried out to investigate the selenium concentration of local Ghanaian foods like plantain, snails, and palm fruits among others, as this would increase knowledge on their concentrations of selenium and contribution to the recommended daily intakes of selenium. Also, studies could be done to investigate the daily intake of selenium and of evidence of selenium toxicity among the battery repair workers.

Based on the findings of this study, it is recommended that the battery repair workers decrease their consumption of selenium-rich foods given their high blood selenium concentrations. This is to avoid the risk of selenium toxicity. It is also recommended that a public health initiative be undertaken to educate the workers on dietary habits especially in relation to trace minerals. The workers had a high consumption of the starchy roots and plantain food group in relation to the fruits and vegetables group. It is therefore recommended that they increase their intake of fruits and vegetables due to the health benefits that accompany their consumption.

REFERENCES

1. Lenz M., Lens P.N.L. The Essential Toxin: The changing perception of selenium in environmental sciences. *Science of the Total Environment* 2009;407:3620-3633.

2. Kishosha P.A., Galukande M., Gakwaya A.M. Selenium Deficiency a factor in endemic goiter persistence in Sub-Saharan Africa. *World Journal of Surgery*. 2011;35:1540-1545.

3. Sortland K. *Ernæring – mer enn mat og drikke*. 3 utgave. Bergen: Fagbokforlaget, 2007.

4. Asare G. A., Nani A., Serum Levels of Cu, Se, and Zn in Adult Rural/Urban Residents in Ghana: Paradigm Shift? *Biological Trace Element Research* 2010;137:139-149.

5. Adotey D. K., Stibilj V, Serfor-Armah Y, Nyarko B.J.B, Jacimovic R. Dietary supply of selenium for adolescents in three residential care orphanages in Southern Ghana. *Science of the Total Environment* 2011;410-411: 72-79.

6. Kasperczyk A., Prokopowicz A., Dobrakowski M., Pawlas N., Kasperczyk S. The Effect of Occupational Lead Exposure on Blood Levels of Zinc, Iron, Copper, Selenium and Related Proteins. *Biological Trace Element Research* 2012;150:49-55.

7. Telišman S., Jurasović J., Pizent A., Cvitkovic P. Blood Pressure in Relation to Biomarkers of Lead, Cadmium, Copper, Zinc and Selenium in Men without Occupational Exposure to Metals. *Environmental Research* 2001;87:57-68.

8. Čuparigova F., Stafilov T., Determination of Selenium in Human Blood Serum by Electrothermal Atomic Absorption Spectrometry. *Chemical Sciences Journal* 2011;46:1-8.

9. Chen C., Yu H., Zhao J., Li B., Qu L., Liu S., Zhang P., Chai Z., The role of serum selenium and selenoproteins on mercury toxicity in environmental and occupational exposure. *Environmental Health Perspectives* 2006;114(2):297-301.

10. Ellingsen D.G., Thomassen Y., Rustad P., Molander P., Aaseth J. The time-trend and the relation between smoking and circulating selenium concentrations in Norway. *Journal of Trace Elements in Medicine and Biology* 2009;23:107-115.

11. National Institutes of Health. *Selenium: Dietary Supplement Fact Sheet* [Internet] Office of Dietary Supplements 2013. Retrieved June 2014. Available from http://ods.od.nih.gov/factsheets/Selenium-HealthProfessional.

12. Peters U., Takata Y. Selenium and the prevention of prostate and colorectal cancer. *Molecular Nutrition and Food Research.* 2008; 52(11):1261-1272.

13. Glattre E., Nygård J.F., Aaseth J. Selenium and cancer prevention: observations and complexity. *Journal of Trace Elements in Medicine and Biology* 2012;26:168-169.

14. Safaralizadeh R., Kardar G.A., Pourpak Z., Moin M., Zare A., Teimourian S. Serum concentration of selenium in healthy individuals living in Tehran. *Nutrition Journal*. 2005; 4(32):1-4.

15. Bates C. J., Selenium. In Caballero B., Allen L., Prentrice A., editors. *Encyclopedia of Human Nutrition*. 2nd Edition. Amsterdam: Elsevier Academic Press. 2005. pp. 118-124.

16. Fairweather-Tait S.J., Bao Y., Broadley M.R., Collings R., Ford D., Hesketh J.E., Hurst R. Selenium in Human Health and Disease. *Antioxidant and Redox Signalling.* 2011; 14(7):1337-83.

17. Navarro-Alarcon M., Cabrera-Vique C. Selenium in food and the human body: A review. *Science of the Total Environment* 2008;400:115-141.

18. Hurst R, Siyame E. W. P. Young S. D., Chilimba A.D. C, Joy E. J. M., Black C.R., Ander E. L., Watts M. J., Chilima B., Gondwe J., Kang'ombe D., Stein A. J., Fairweather-Tait S. J., Gibson R. S., Kalimbira A. A., Broadley M.R.. Soil-type influences human selenium status and underlies widespread selenium deficiency risks in Malawi. *Scientific Reports.* 2013; 3(1425):1-6.

19. Yadav S.K., Singh I., Sharma A., Singh D. Selenium status in food grains of Northern districts of India. *Journal of Environmental Management* 2008; 88:770-774.

20. Galan P., Viteri F.E., Bertrais S., Czernichow S., Faure H., Arnaud J., Ruffieux D., Chenal S., Arnualt N., Favier A., Roussel A-M., Hercberg S. Serum Concentrations of β-carotene, vitamins C and E, zinc and selenium are influenced by sex, age, diet smoking status, alcohol consumption and corpulence in a general French adult population. *European Journal of Clinical Nutrition.* 2005; 59:1181-1190.

21. Takyi E.E.K, Amankwa P. Dietary selenium and copper intake by resident undergraduate students of the University of Ghana. *East African Medical Journal*. 2004; 81(1): 34-39.

22. World Health Organization *Selenium in Drinking- Water. Background document for the development of WHO guidelines for drinking water quality*. 2011. Retrieved June 2014, Available from: http://www.who.int/water_sanitation_health/dwq/chemicals/selenium.pd

23. Chilimba A.D.C., Young S.D., Black C.R, Meacham M.C., Lammel J., Broadley M.R. Agronomic bio-fortification of maize with selenium (Se) in Malawi**.** *Field Crops Research,* 2012;125:118–128.

24. Burri J., Haldimann M., Dudler V. Selenium status of the Swiss population: Assessment and change over a decade. *Journal of Trace Elements in Medicine and Biology* 2008;22:112-119.

25. Asare G. A., Osae S., Nortey E.N.N., Yambire F.K., Amedonu E., Doku D., Annan Y. Evaluation of serum metallothionein-1, selenium, zinc, and copper in Ghanaian type 2 diabetes mellitus patients. *International Journal of Diabetes in Developing Countries* 2013;33(2):86-95.

26. Göen Th., Schaller B., Jäger Th., Bräu-Dümler Ch., Schaller K. H., Drexler H. Biological Monitoring of exposure and effects in workers employed in a selenium-processing plant. *International Archives of Occupational and Environmental Health* 2015;88(5):623-30.

27. McConnell K.P., Broghamer W.L. Jr., Blotcky A.J., Hurt J. Selenium levels in Human Blood and Tissues in Health and in Disease. *Journal of Nutrition*. 1975;105:1026- 1031.

28. Bempah C. K., Buah-Kwofie A., Osei Tutu A., Denutsui D., Enimil E., Adjei-Martey G., Blewu B., Asomaning J. Pesticide residues and heavy metals levels in some selected fruits and vegetables from Ghanaian markets. *Elixir Food Science* 2011;39:4964-4972.

29. Adomako E.E., Williams P.N., Deacon C., Meharg A.A. Inorganic arsenic and trace elements in Ghanaian grain staples. *Environmental Pollution* 2011;159:2435-2442.

30. Kwaansa-Ansah E.E., Asare-Donkor N.K., Adimado A.A., Nam Dong-ha Evaluation of mercury and selenium concentrations in the edible tissue of freshwater fish from the Volta Lake in Ghana. *Journal of Environmental and Occupational Science* 2013;2(3):109-118.

31. Dartey E., Berlinger B., Thomassen Y., Ellingsen D.G., Odland J. Ø., Nartey V. K., Yeboah F.A., Weinbruch S. Bioaccessibility of lead in airborne particulates from car battery repair work. *Environmental Sciences: Processes and Impacts* 2014;16(12):2782-8.

32. Fehily, A. Dietary Assessment. In: Thomas B and Bishop J Editors *Manual of Dietetic Practice*: 4th edition Oxford: Blackwell Scientific Publications; 2007. pp.32-40.

33. Nti C. Household dietary practices and family nutritional status in rural Ghana. *Nutrition Research and Practice*. 2008;2(1):35-40.

34. Nyangasa M.A. Nutritional status of Ghanaian women with young children – Dietary intake, anthropometric and life style data. [Dissertation]. Hamburg: Hamburg University of Applied Science; 2011.

35. Afoakwah A. N., Owusu W.B. The relationship between dietary intake, body composition and blood pressure in male adult miners in Ghana. *Asian Journal of Clinical Nutrition*. 2011;3(1):1-13.

36. Kobati G. Y., Lartey A., Marquis G.S., Colecraft E.K., Butler L.M. Dietary intakes and body mass indices of non-pregnant, non-lactating (NPNL) women from the coastal and guinea savannah zones of Ghana. *African Journal of Food, Agriculture, Nutrition and Development.* 2012;12(1):5843-5861.

37. Gbadebo A.M., Babalola O.O., Ajigbotesho F.L. Selenium concentration in food and blood of residents of Abeokuta Metropolis, Southwestern Nigeria. *Journal of Geochemical Exploration*. 2010;107:175-179.

38. Nouria D-M, Yahia H., Attar T., Larabi L., Whole blood selenium levels in healthy adults from the west of Algeria. *Biological Trace Element Research* 2011;147:44-48.

39. Doe, E. D., Awua, A. K., Gyamfi, O. K., Bentil, N.O. Levels of selected heavy metals in wheat flour on the Ghanaian market: a determination by atomic absorption spectrometry. *American Journal of Applied Chemistry*. 2013;1(2):17-21.

40. Gimou M.-M., Charrondière U.R., Leblanc J.-C, Noël L., Guérin T., Pouillot R Dietary exposure and health risk assessment for 11 minerals and trace elements in Yaoundé: the Cameroonian Total Diet Study. *Food Additives and Contaminants*: Part A, 2013; 30(9):1556-1572.

41. Beladel B., Nedjimi B., Mansouri A., Tahtat D., Belamri M., Tchanchane A., Khelfaoui F., Benamar M.E.A. Selenium content in wheat and estimation of the selenium daily intake in different regions of Algeria. *Applied Radiation and Isotopes* 2013; 71:7-10.

42. Orisakwe O.E., Oragwu C.I., Maduabuchi J.M.U, Nzegwu C.N., Nduka J.K.C. Copper, selenium and zinc content of canned and non-canned beverages in Nigeria. *African Journal of Environmental Science and Technology*. 2009; 3(1):042-049.

43. Longnecker MP, Taylor PR, Levander OA, Howe M, Veillon C, McAdam PA, Patterson KY, Holden JM, Stampfer MJ, Morris JS and Willett WC. Selenium in diet, blood, and toenails in relation to human health in a seleniferous area. *American Journal of Clinical Nutrition.* 1991 May;53(5):1288-94.

44. TSDR. Toxicological profile for selenium. Atlanta, GA: Agency for Toxic Substances and Disease Registry (ATSDR); 2003. p. 235-286.
Available from: ttp://www.atsdr.cdc.gov/toxprofiles/tp92.pdf

45. Lemly D. A., Aquatic Selenium pollution is a global environmental safety issue. *Ecotoxicology and Environmental Safety* 2004;59:44-56.

46. Frazzoli C., Mantovani A., Orisakwe O.E., *Electronic Waste and Human Health*. [Internet] PDF Elsevier B.V. 2011:269-281. Retrieved August 2015 from http://www.noodlesonlus.org/images/portal/doc/noodles/Electronic%20Waste%20and%20Human%20Health.pdf.

47. Vinceti M., Bonvicini F., Rothman, K.J., Vescovi L., Wang F. The relation between amyotrophic lateral sclerosis and inorganic selenium in drinking water: a population-based case-control study. *Environmental Health* 2010;9(77):1-8.

Map of Africa and Ghana.

Avaiable at World Atlas. Ghana. http://www.worldatlas.com/webimage/countrys/africa/gh.htm . Retrieved September 2015.

Available at World Atlas. Ghana. http://www.worldatlas.com/webimage/countrys/africa/gh.htm. Retrieved September 2015.

APPENDIX

Questionnaire for fieldwork

I am a student in the Masters in Public Health Programme conducting a study on a food nutrient called selenium. Selenium is an important trace element and a powerful antioxidant which protects cells against oxidative damage. It can be obtained from cereals, sea food, beef, pork, chicken and vegetables. In this study, I am investigating dietary reasons for high selenium levels in Ghanaians as a research finding has shown. I therefore need some information on dietary and food habits and would be very grateful if you could fill this questionnaire to help my study. You are assured of absolute confidentiality.

Section A: Demographic Characteristics

1. Age [ ] 18-22 [ ] 23-27 [ ] 28-32 [ ] 33-37

   [ ] 38-42 [ ] 42 and above

2. Gender [ ] Male [ ] Female

3. Marital Status [ ] Single [ ] Married [ ] Divorced

   [ ] Widowed[ ] Other (Specify)______________________________

4. What is the size of your household?____

5. Educational level? [ ] JSS [ ] SSS [ ] Polytechnic

   [ ] University [ ] Other (Specify)______________

Section B: Frequency of foods eaten

In this section, you are required to specify the frequency of your intake of the various foods and drinks listed in the questionnaire. Please specify how many times you have eaten the listed food items in within the past **one month**.

Food Frequency Questionnaire

Food group/Item	**Once**	**2-4times**	**5—7times**	**8-10times**	**More than 10 times**	**Never**
Starchy Roots and Plantains						
Cassava						
Yam						
Cocoyam						
Plantain						
Wateryam						
Others (Please specify) _____________________						
Animal Products						
Meat						
Fish						
Eggs						
Milk						
Poultry						
Game						
Snails						
Sea foods (crabs, shrimps, oysters)						
Others (Please specify)						

Food group/Item	Once	2-4times	5—7times	8-10times	More than 10 times	Never
Legumes, Nuts and Oil Seeds						
Beans						
Groundnuts						
Melon seeds						
Soybeans						
Dawadawa						
Palm fruits						
Tigernuts						
Cowpea (black-eyed peas)						
Others (Please specify) ______________________						
Fruits and Vegetables						
Oranges						
Banana						
Pineapple						
Pawpaw						
Watermelon						
Apple						
Mango						
Leafy vegetables						
Okro						
Garden eggs						
Tomatoes						
Pepper						
Onions						
Carrots						
Cabbage						

Food group/Item	**Once**	**2-4times**	**5—7times**	**8-10times**	**More than 10 times**	**Never**
Tangerine						
Avocado						
Coconut						
Grapes						
Others (Please specify) ____________________						
Fats and oils						
Refined vegetable oil						
Palm oil						
Margarine						
Butter						
Others (Please specify) ____________________						
Cereals and Grains						
Maize						
Rice						
Millet						
Sorghum						
Wheat						
Oats						
Bread						
Others (Please specify)						
Beverages						
Cocoa drinks (bournvita, Richoco etc)						
Tea						
Coffee						
Soft drinks						
Alcohol						

Food group/Item	**Once**	**2-4times**	**5—7times**	**8-10times**	**More than 10 times**	**Never**
Beverages contd.						
Pito						
Tigernutmilk						
Others(Please specify) ____________________						