UNIVERSITY OF GHANA

NUTRITION AND FOOD SCIENCE DEPARTMENT

COMPARISON OF ANAEMIA PREVALENCE BETWEEN WOMEN IN FISH SMOKING AND NON-FISH SMOKING LIVELIHOODS IN BIRIWA IN THE CENTRAL REGION OF GHANA

BY

DANIEL ARMO-ANNOR

(10409360)

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL IN NUTRITION DEGREE

JULY, 2019

DECLARATION

I, Daniel Armo-Annor hereby declare that this thesis titled: "*Comparison of anaemia prevalence between women in fish smoking and non-fish smoking livelihoods in Biriwa in the Central Region of Ghana*" is my own work carried out in the Department of Nutrition and Food Science, University of Ghana under the supervision of Dr. Esi Colecraft and Dr. Seth Adu-Afarwuah. This work has never been submitted for a degree in this University or elsewhere. The appropriate references have been used to acknowledge other people's work.

Daniel Armo-Annor	………………………	27th May, 2020 ………………….
(Student)	Signature	Date
Dr. Esi Colecraft	………………………	27 May 2020 ………………….
(Main Supervisor)	Signature	Date
Dr. Seth Adu-Afarwuah	………………………	27 May 2020 ………………….
(Co-Supervisor)	Signature	Date

ABSTRACT

Background and objective: Anaemia among Ghanaian women of reproductive age is an important public health concern that contributes to morbidity, poor reproductive outcomes, low productivity and mortality. Chronic smoke inhalation from the use of biomass fuel for cooking has been shown to be associated with anaemia in some populations. Fish smoking using biomass fuel is an important livelihood among women living in coastal communities in Ghana which may increase their risk of anaemia. The objective of the study was to determine whether women who smoke fish as their primary livelihood had a greater risk of anaemia compared to women not engaged in fish smoking livelihood.

Methodology: This was a cross-sectional study with 330 randomly selected non-pregnant, non-lactating adult women (18-49 years) living in Biriwa (a fishing community in the Central Region of Ghana) whose primary livelihood was either fish smoking (n=175) or a non-fish smoking activity (n=155). A structured questionnaire was used to interview the women on their socioeconomic and household characteristics, reproductive history, anaemia-related health information and exposure to biomass smoke. The 24-hour recall method was used to record dietary intake in the past 24 hours and a 7-day animal source food frequency questionnaire used to capture types of animal source foods (ASF) consumed in the past week. The Urit12 HemoCue system was used to measure the finger-prick blood haemoglobin concentration. Continuous outcome variables (dietary diversity and haemoglobin concentration) were compared using General linear model and ANCOVA for unadjusted and adjusted analysis, respectively while anaemia prevalence was compared using simple logistic regression (unadjusted analysis) and multiple logistic regression (adjusted analysis). Multiple logistic regression was used to determine whether fish smoking, as a primary livelihood, independently predicts anaemia among the women. The SAS PROC GLIMMIX procedure was used for these analyses. For anaemia, binary distribution and the log-link function were specified in the SAS procedures, so that relative risks between groups and their 95% CIs were calculated

Results: Women who smoked fish as their primary livelihood were on average older (38 vs 29; P<0.001) and had a higher parity (5 vs. 2; P<0.001) than women engaged in other livelihoods (primarily vocational occupations included hairdressing and dressmaking. After adjusting for potential confounders, there was no significant group difference in mean dietary diversity but women in non-fish smoking livelihoods consumed a wider variety of animal source foods (3.3 ± 0.1 vs. 2.8 ± 0.1; P=0.002). Fish and seafood was the most commonly consumed animal source food by both groups of women). Adjusted anaemia prevalence was higher among women in fish smoking livelihood compared with women in non-fish smoking livelihood (32.0% vs. 20.3%: P=0.023). The relative risk of anaemia was 1.8 (95% CI: 1.1, 3.1) times greater among women in fish smoking livelihood than women in non-fish smoking livelihoods. Other factors such as age, marital status and animal source food diversity were not significantly associated with anaemia in the population.

Conclusion: The risk of anaemia was greater among women who smoke fish as a primary livelihood compared to women engaged in other types of livelihoods.

DEDICATION

I dedicate this work to the Almighty God for his grace and mercies on my life and to my family for their love and support.

ACKNOWLEDGEMENTS

First and foremost, I want to acknowledge the Almighty God for being my strength and my shield. I want to extend my profound gratitude to my main supervisor, Dr. Esi Colecraft for her time, supervision, support and encouragement during the research period. My sincerest gratitude also goes to Dr. Seth Adu–Afarwuah, my co-supervisor, whose expertise and immense contributions made this thesis work even better.

I am grateful to all lecturers, support staffs and colleagues of the Nutrition and Food Science Department who in one way or the other helped towards the completion of this thesis work. To my family and friends, I say a big thank you for your support, prayers and encouragement. I want to express my appreciation to Griffith Armah for his unwavering support throughout the thesis work. I am also grateful to Princess Abakah and Eric Arthur for the role they played during the data collection period. I want to show my appreciation to the study participants for their cooperation and willingness to partake in the study. Many thanks to Mr. Boateng Bannerman for his contributions during the data analysis process. My heart is filled with much appreciation to Rose Otema Baah for her timely advice and encouragement during the time of the study. I wish to also thank Senam Klomegah and Loretta Baidoo for their support during the thesis write-up.

I wish to also acknowledge the Bill and Melinda Gates Foundation through for funding this project through the Invisible Fishers. I want to say a very big thank you and I am very honoured to be given this opportunity.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

ACD: Anaemia of Chronic Disease

ASF: Animal Source Food

CDC: Centre for Disease Control

CO: Carbon Monoxide

COHb: Carboxyhaemoglobin

FAO: Food and Agriculture Organization

FSL: Fish Smoking Livelihood

Hb: Haemoglobin

NFSL: Non-fish Smoking Livelihood

NPNL: Non-pregnant, Non-lactating women

PAH: Polycyclic Aromatic Hydrocarbon

$PM_{2.5}$: Particulate Matter

RBC: Red Blood Cell

VO_2 max: Maximum Oxygen Uptake

WHO: World Health Organization

WRA: Women of Reproductive Age

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Anaemia, defined as an insufficient number of red blood cells in the body, is a major global public health concern which has been linked to morbidity and mortality, low productivity and poor birth outcomes in women (Figueiredo et al., 2018; Mann et al., 2002; Scott et al., 2014). Worldwide, over 1.62 billion people suffer from anaemia of which an estimated 468.4 million are non-pregnant women. In Central and West Africa countries, anaemia disproportionally affects children under five years of age and women of reproductive age (15 to 49 years) (WHO, 2015). In Ghana, 42% of women of reproductive age (WRA) are anaemic (GDHS, 2014).

Well recognized contributors to the high anaemia burden in the African region are iron deficiency due primarily to suboptimal intake of dietary iron, infections and infestations and inherited blood disorders (CDC, 2015). More recently, chronic inhalation of biomass smoke has also been implicated as a non-dietary risk factor for anaemia among both children and women (Accinelli & Leon-Abarca, 2017; Kyu et al., 2010; Machisa et al., 2013; Mishra & Retherford, 2006; Page et al., 2015). The incomplete burning of biomass fuel produces huge amounts of carbon monoxide (CO), hydrocarbons, oxygenated organics and particulate matter (PM) (Salvi & Brashier, 2014). The mechanism by which these toxins cause anaemia has not been fully understood. A more probable way biomass smoke has been linked with anaemia is due to its role in triggering systemic inflammation in the body. This systemic inflammation is known to cause anaemia mediated by certain inflammatory cytokines. The cytokines causes anaemia by the dysregulation of iron homeostasis, impaired marrow response to the production of red blood cells and erythropoietin response to reduced haemoglobin (Weiss & Goodnough, 2005)

Over 50% of people living in developing countries use some form of biomass fuel (e.g. wood, dung, straw and crop residues) for cooking, which is typically done by women (Kyu et al., 2010). About 40% of all households in Ghana use biomass fuel for cooking (Ghana Statistical Service, 2012). Women whose livelihoods expose them to chronic smoke inhalation may be at increased risk of anaemia. Fish smoking in Ghana, using biomass fuel, is an important livelihood for women living in proximity to fishing communities. More than half of women living in coastal areas in Ghana are involved in fish smoking livelihood (FAO, 2018). The fish smoking industry in Ghana relies heavily on firewood as a fuel source. A study conducted in Ghana by the Netherlands Development Organization (SNV) revealed that there were over 100,000 smoking ovens in the coastal areas in Ghana which were in constant use (SNV, 2019). Women involved in fish smoking livelihood have additional levels of smoke exposure and associated health consequences including anaemia. A long period of exposure to biomass fuel has been linked to a greater risk of developing anaemia among women of reproductive age (WRA) (Sukhsohale et al., 2013). The aim of this study was to determine whether women who smoke fish as their primary livelihood have a higher prevalence of anaemia compared with women involved in non-fish smoking livelihood.

1.2 Study Rationale

Anaemia among Ghanaian women of reproductive age is an important public health concern that contributes to morbidity, poor reproductive outcomes, low productivity and mortality. Use of biomass fuel for cooking has been shown to contribute to higher anaemia prevalence among pregnant and non-pregnant women due to chronic smoke inhalation. However, little research has been done on the association between biomass smoke exposure and anaemia. Fish smoking using biomass fuel is an important livelihood among women living in coastal communities in Ghana which may increase their risk of anaemia. In Ghana, anaemia prevalence in women has remained consistently high for decades, and women in fish smoking livelihood are chronically exposed to smoke. This study assessed whether anaemia is more prevalent among women who smoke fish as their primary livelihood compared with women in non-fish smoking livelihood. The findings from our study may inform interventions to enhance nutrition and health of women who smoke fish for a living and the study has also contributed to the body of knowledge on the association between biomass smoke exposure and anaemia among women of reproductive age.

1.3 Study Objectives

1.3.1 Main Objective

The overall objective of the study was to compare women whose primary livelihood is fish smoking and those engaged in non-fish smoking livelihoods with respect to their anaemia prevalence in Biriwa in the Central Region of Ghana.

1.3.2 Specific Objective

The specific objective of the study were to:

i. Determine if the mean haemoglobin concentration and prevalence of anaemia among women who smoke fish as their primary livelihood and women in non-fish smoking livelihoods differ.

ii. To determine if animal source food diversity between women who smoke fish as their primary livelihood and women in non-fish smoking livelihood differ.

iii. Determine whether smoking fish as a primary livelihood independently predicts anaemia among women in this study

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of Anaemia

Anaemia is defined as a condition in which the number of erythrocytes or its oxygen-carrying capacity is not sufficient to meet the body's physiologic needs (WHO, 2011). Anaemia is usually diagnosed when the concentration of haemoglobin in the blood is lower than the set thresholds which are based on the age, sex and physiological status of an individual. According to the World Health Organization, generally, in non-pregnant women of reproductive age (15-49 years), anaemia is defined as haemoglobin concentration <12g/dL. Specifically, haemoglobin concentrations of 11.0-11.9 g/dL, 8.0-10.9 g/dL and < 8.0g/dL are classified as mild, moderate and severe anaemia respectively among non-pregnant women of reproductive age (WHO, 2011).

The burden of anaemia of a particular country according to the WHO is based on the prevalence rates of the country. Countries with anaemia prevalence of <4.9% are classified as not having a public health problem. Countries with prevalence between 5.0-19.9% are classified as having a mild public health problem. Also, countries with a prevalence rate of between 20.0-39.9% and >40% are classified as having a moderate public health problem and a severe public health problem respectively (WHO, 2009).

2.2 Prevalence of Anaemia

2.2.1 Worldwide magnitude

Anaemia, is a public health problem affecting mainly children and women worldwide. Globally, anaemia affects over 1.62 billion people with the highest prevalence being among children (42.6%) (WHO, 2015). Using nationally representative data from 1995 to 2011, it was reported by WHO (2015) that, 29.0% and 38.2% of non-pregnant WRA and pregnant WRA were anaemic respectively. Further, anaemia prevalence among non-pregnant WRA ranged from 37.7% to 41.5% in the South-East Asia, Eastern Mediterranean and African regions (WHO, 2015).

Although little improvement has been reported for anaemia between 1995 and 2011, its prevalence remains intolerable globally (Stevens et al., 2013). In 2012, a systematic analysis was conducted from the years 1995 to 2011 to study the trends of anaemia prevalence among pregnant, non-pregnant women of reproductive age and children. Data were gathered about anaemia and haemoglobin concentration for women (15 to 49 years) and children (6-59 months) from 257 population-representative sources from 107 countries around the world. According to the review, globally, anaemia prevalence among non-pregnant women decreased from 33% in 1995 to 29% in 2011 (Stevens et al., 2013). However, the prevalence among high-income countries increased slightly from 14% in 1995 to 16% in 2011 even though the prevalence was still very low as compared to other regions (Stevens et al., 2013).

2.2.2 Magnitude in Africa

Most African countries have an anaemia prevalence of severe public health concern. In Africa, anaemia is highly prevalent among children under 5 years, followed by pregnant WRA (WHO, 2011). Anaemia prevalence is highest among pregnant women (56%) and non-pregnant WRA (48%) from Central and West Africa regions. Non-pregnant women in East Africa had the second highest (40%) prevalence of anaemia. During this period, the region with the lowest anaemia prevalence was Southern Africa (33%) (WHO, 2015). Over the years, the anaemia prevalence has improved among non-pregnant women from these regions. In 2011, the prevalence dropped from 52% to 48% in the Central and West Africa region, from 40% to 28%

in the East Africa region and also dropped to 28% in the Southern Africa region from 33% (Stevens et al., 2013)

2.2.3 Magnitude in Ghana

The recent study in Ghana by the Ghana Micronutrient Survey in 2017 reported that anaemia prevalence among non-pregnant women of reproductive age is 21.7% with less than 1% of the population suffering from severe anaemia. Among pregnant women, anaemia prevalence was 42% (GMS, 2017). Between 2003 and 2008, anaemia prevalence increased from 45% to 59% among women of reproductive age and decreased again to 42% in 2014. From 2014 to 2017 there has been a reduction in the prevalence of anaemia in Ghana. Among non-pregnant women, anaemia has decreased from 41.3% to 21.7% and from 44.6% to 42% among pregnant women (GDHS, 2014; GMS, 2017). Anaemia among non-pregnant women is no longer a severe public health problem but a moderate public health problem in Ghana. However, among pregnant women, despite the decline, the anaemia rate remains a severe public health problem (WHO, 2015). In Ghana, there is no significant difference in the prevalence of anaemia in terms of age, educational level, residence or household wealth among non-pregnant women. However, women from the middle belt have the lowest anaemia prevalence (17.5%) as compared to the Southern (23.9%) and Northern (27.6%) belts (GMS, 2017).

2.3 Consequences of anaemia

Anaemia is known to have negative impacts on the health and wellbeing of, especially women and children. Anaemia increases the risk of premature delivery and low birth weight among women of reproductive age. According to WHO (2012), increased prevalence of anaemia among women of reproductive age affects performance and work rate. It is also believed to have an effect on pregnancy outcomes in women and the newly born baby, which goes a long way to impact negatively on the health of individuals, economic potential and development of the community. Anaemia due to iron deficiency alone is estimated to cause over 90,000 deaths among both males and females of all age groups. Based on calculations for 10 developing countries, the total economic losses due to reduced work productivity and cognitive losses was almost 17 dollars per capita (Horton & Ross, 2003).

2.3.1 Maternal and Child mortality

Anaemia is linked with increased risk of maternal and child mortality. A meta-analysis of about 12,000 children in six African countries showed that, increasing haemoglobin concentration by 1g/dL decreases the risk of mortality by 24% (Scott et al., 2014). In a systematic analysis to determine the link between maternal anaemia and low birth weight, it was concluded that maternal anaemia was a risk factor for low birth weight (Figueiredo et al., 2018). According to Petrou (2003) preterm birth and low birth weight increase the risk of infants to mortality and morbidity. A research conducted by Muoneke et al. (2012) in Nigeria revealed that out of the 140 severely anaemic children under 5 years recruited for the study, 19 died (a case fatality rate of 13.6%) while 117 (83.6%) recovered (Muoneke et al., 2012). The factors associated with higher mortality among the children in this study were malnutrition ($P=0.02$), coma ($P<0.001$), tachycardia ($P=0.033$) and not receiving blood transfusion ($P=0.001$) (Muoneke et al., 2012). In another study by Khaskheli et al. (2016), the mortality rate of 305 pregnant women with iron deficiency was 5.24%. These women also had an increased risk of having complications such as renal failure (15.73%), and antepartum haemorrhage (16.06%) (Khaskheli et al., 2016).

2.3.2 Decreased Cognitive development

Evidence suggests that women of reproductive age may be at increased risk of cognitive alterations due to iron deficiency (Murray-kolb & Beard, 2007). A blinded, placebo-controlled experiment was performed among women between 18 and 35 years classified as iron sufficient (control group), non-anaemic but with iron deficiency (ID group), or with iron deficiency anaemia (IDA group). Eight (8) cognitive performance tasks (Detterman's Cognitive Abilities Test) were used to assess the participant's cognition at baseline (n=149) and after 4 months of the experiment (n=113). The control group performed better on cognitive tasks ($p<0.011$) and performed them at a faster rate ($P<0.038$) than the iron-deficient anaemia women at baseline. After treatments, there was a 5 to 7 fold improvement in cognitive performance associated with significant improvement of serum ferritin. Also, there was a positive relationship between the speed at which cognitive tasks were performed and a significant improvement in haemoglobin concentration (Murray-kolb & Beard, 2007). This study was similar to another research by Sen & Kanani (2006) among adolescent girls in primary school where the non-anaemic girls scored significantly higher in various cognitive function tests even after controlling for undernutrition measured by their BMI.

Cognitive development of children may be affected as a result of anaemia. A secondary data analysis conducted on cognition and iron deficiency based mainly on the past 15 years showed that, iron deficiency anaemia has a negative effect on the behaviour, motor skills and cognition of children, with especially those with low socio-economic background more affected (Jáuregui-lobera, 2014). Contrary to Jáuregui-lobera (2014), a study by Akca & Bostanci (2017), to assess the impact of anaemia and body mass index (BMI) on neuromotor development among 916 preschool children revealed that mild anaemia had a positive association on a child's neuromotor development whiles being overweight or obese was negatively associated with neuromotor development. However, a major limitation to this study which might have presented a positive effect of anaemia on neuromotor development was due to the fact that children who participated in the study did not show moderate or severe anaemia (Akca & Bostanci, 2017). According to Santos et al. (2009), anaemic children between the ages of two to six years demonstrated poorer language development when compared with children who were not anaemic. This was a cross-sectional study involving 44 children as controls (no anaemia) and 22 as cases (anaemia present). It was observed that there was a significant difference in all the language evaluations between the two groups. The cognition performance score was higher in the controls (77) than the cases (45) at ($p<0.001$). There was also a significant difference ($p<0.02$) between the anaemic group (75) and non-anaemic group (100) in terms of the reception performance score (Santos et al., 2009). According to Saloojee & Pettifor (2002) more of the development of the central nervous system (CNS) processes greatly relies on iron-rich enzymes and proteins. This implies that the deficiency of iron may have various effects on brain growth.

2.3.3 Low work productivity

Physical working capacity of humans is known to be affected greatly by iron deficiency anaemia. A study conducted by Kalasuramath et al. (2015) showed the effect of anaemia and iron deficiency (ID) on physical and cardiorespiratory fitness of women working in small scale industries in India. The study participants were 600 non-pregnant, non-lactating women (NPNL) who were between the ages of 18 and 55 years. The women were divided into groups of three (200 per group); ID, anaemic and control women. Their physical fitness index (PFI) was determined by using the Queens College step test (QCT) and by calculating the maximum oxygen uptake (VO_2 max). The participants with ID had an average VO_2 max of 40.24

ml/kg/min, women in the anaemic group had an average of 38.65 and the control group had the highest with an average mean of 45.53 ml/kg/min. It was suggested that anaemia and ID both impair the delivery of oxygen to the tissues and thus leads to a reduced VO_2 max, therefore, affecting their physical activity levels (Kalasuramath et al., 2015).

Another research was conducted among 30 female students between 16 and 20 years to assess whether iron and energy supplementation improves physical work capacity among them (Mann et al., 2002). The study participants were grouped into two, being anaemic but having adequate energy or being anaemic but having inadequate energy. Both groups were given iron capsules for 9 months to bring their haemoglobin levels to 12 or above. Energy supplements were also given to the energy-deficient group based on the energy gap between the two groups. Exercise time and maximum workload increased significantly ($p< 0.01$) after iron supplements were given and after both iron-energy supplementation in the two groups (Mann et al., 2002). These results were similar to a study by Sen & Kanani, (2006), which revealed that non-anaemic adolescent girls between 9 and 14 years were able to take more steps and at the same time get back to the recovery time faster than anaemic girls. This was assessed by asking the girls to climb up and down within 3 minutes, a set of five steps. Moderately anaemic girls climbed an average of 165 steps within the three minutes whiles the non-anaemic climbed an average of 175 steps. With regards to the recovery time, anaemic girls took a much longer time 3.69 minutes than non-anaemic girls who took an average of only 2.55 minutes ($p<0.001$) (Sen & Kanani, 2006).

2.4 Causes of anaemia

Causes of anaemia are multifactorial including both nutritional and non-nutritional factors. Nutritional causes of anaemia mainly comprise nutrient deficiencies arising from poor dietary intake and eating disorders. It is estimated that at least more than half of all anaemia cases around the world may be caused by non-nutritional factors (WHO, 2015). Non-nutritional factors which cause anaemia include conditions such as blood loss from injury or certain physiological states (such as menstruation in women), chronic inflammation, infection and disease as well as drug toxicity (Haidar, 2010).

2.4.1 Nutritional causes of anaemia

2.4.1.1 Iron deficiency anaemia

Iron-deficiency anaemia is a type of anaemia which is characterised by insufficient iron to produce haemoglobin to carry oxygen to the rest of the body. According to WHO (2015), about 50% of all anaemia cases in the world is believed to be caused by iron deficiency anaemia (IDA). According to a review by Petry et al. (2016), this value is exaggerated, iron deficiency is less than what is assumed. When the results of 25 nationally representative studies which measured ID, IDA and anaemia among children (6-59 months) and women of reproductive age (15-49 years) from all parts of the world between 2003 and 2014 were combined, the proportion of anaemia due to iron deficiency was about 25% among children and 37% among women of reproductive age. For both groups, the proportion of anaemia associated with ID was substantially lower for countries with a severe burden of anaemia (Petry et al., 2016). In the recently ended Ghana Micronutrient Survey in 2017, about 14% of non-pregnant women of reproductive age were iron deficient (GMS, 2017). Some of the effects of iron deficiency anaemia are characterized by reduced work capacity and cognitive development. Iron supplements have been proven to increase physical activity levels and also improve the cognitive performance of women (Mann et al., 2002; Murray-kolb & Beard, 2007). Signs and symptoms such as easily getting fatigued, weakness, headaches, rapid or irregular heartbeat, brittle nails and dizziness accompany iron deficiency anaemia (Lopez et al., 2016).

Women of reproductive age are at increased risk of iron deficiency anaemia due to menstruation, pregnancy and lactation (Jangjoo & Hosseini, 2016). Iron deficiency anaemia during pregnancy is caused by the increased plasma volume (30-40%) compared to the haemoglobin mass and red blood cell volume (20-25%). As a result, there is a reduction in Hb levels, which leads to an increase in the transportation of oxygen to the foetus and the placenta causing an increased demand for iron (Gupta & Gadipudi, 2018).

Not eating enough foods that contain iron also causes iron deficiency anaemia. The bioavailability of iron in foods differs, with haem iron from animal sources proven to be readily absorbed than iron from non-haem sources, typically from plant sources (Killip et al., 2010). A study was conducted by Pasricha et al., (2017) to know how much of an impact meat consumption has on anaemia status among 354 women of reproductive age in Northwest Vietnam. Logistic regression analysis proved that consumption of meat 3 or more times per week was protective against iron deficiency anaemia OR 0.46, p=0.002 (028, 0.76). (Pasricha et al., 2017). The bioavailability of iron in foods can be enhanced or inhibited by different substances as well as cooking methods. Boiling improves iron bioavailability in vegetables. Addition of vitamin C or cooking with vegetables rich in vitamin C such as tomatoes improves the amount of iron available for absorption (Yang & Tsou, 2006). On the other hand, chemical substances such as polyphenols and phytic acid hamper iron bioavailability. Data from the Korean National Health and Nutrition Examination Survey (2007-2012) was used to determine the relationship between green tea, coffee and serum ferritin concentration of Korean adults. Food frequency and 24-hour recall data were used to assess their intake. When multivariate linear regression was used to adjust for age, BMI, educational level, smoking status, physical activity, alcohol consumption, hypertension, diabetes mellitus and daily iron intake, intake of coffee was negatively associated with serum ferritin concentration for both males and females.

Serum ferritin levels decreased by 8.4% in males and by 18.8% in females among those who drink three or more cups of coffee in a day (Sung et al., 2018).

2.4.1.2 Folic acid and B12 deficiency anaemia

Aside from iron deficiency, inadequate folate and vitamin B12 lead to anaemia (Gupta & Gadipudi, 2018). These two vitamins play very crucial roles in many cellular processes in the body. When one or both is not adequate, it leads to a type of anaemia called megaloblastic anaemia (Castellanos-Sinco et al., 2015). Megaloblastic anaemia is due to the impairment of DNA synthesis which is caused by deficiency of folate and vitamin B12. Plasma homocysteine level is used to detect both vitamin B12 and folate deficiency in humans. An advanced effect of megaloblastic anaemia is loss of memory and vision which is characterised by increased serum homocysteine levels (Castellanos-Sinco et al., 2015; Hariz & Bhattacharya, 2019). Megaloblastic anaemia due to vitamin B12 deficiency is referred to as pernicious anaemia. It is mainly caused by either insufficient vitamin B12 from the diet or lack of intrinsic factor which is responsible for its absorption (Lahner & Annibale, 2009). The serum folate, vitamin B12 and homocysteine levels of 50 patients suffering from megaloblastic anaemia were compared with 50 non-megaloblastic anaemia patients (control). A total of 40 (80%) out of the 50 megaloblastic anaemia patients had very low vitamin B12 levels and 44 (88%) had very low folate levels. Out of the 50 control patients, only 2(4%) and 12 (24%) had low vitamin B12 and folate levels respectively. High serum homocysteine level was in 80% of patients expressing low vitamin B12 and folate serum levels (Yadav et al., 2016). Although megaloblastic anaemia is common, research regarding its prevalence around the world is not enough. Its burden is high in countries where malnutrition is a significant problem. The prevalence also increases among the elderly and pregnant women (Hariz & Bhattacharya, 2019). In 2017, the prevalence of megaloblastic anaemia among women of reproductive age (n=22,278) in Pakistan was analysed using the 2011 national-level secondary survey data (Rizvi et al., 2017). An electrochemiluminescence immunoassay method was used to measure serum folate and vitamin B12 levels. The prevalence of vitamin B12 deficiency and folate deficiency among the women was 8,400 (52.4%) and 8,371 (50.8%) respectively. Women who consumed eggs daily and weekly (RR 0.89; 95% CI 0.81, 0.98; P=0.02, and RR 0.88; 95% CI 0.78, 0.99; P=0.03, respectively) were less likely to be suffering from folate deficiency as compared to women who consumed eggs monthly. Increased intake of green leafy vegetables, which are known to be good sources of folate, was also found to lower the risk of folate deficiency anaemia (Rizvi et al., 2017).

2.4.2 Non-Nutritional Causes

2.4.2.1 Infections and infestations

Diseases or infections can cause anaemia through many mechanisms. Absorption and metabolism could be impaired by infections. Infections may also lead to the onset of anaemia through blood loss, nutritional deficiencies and side effects of medication. Acute and chronic infections like malaria, TB, HIV, cancer and chronic heart failure can all lead to anaemia. (Viana, 2011; WHO, 2017). For most cases the mechanism by which chronic infections cause anaemia is by the decrease in serum iron, coupled with a decrease in total iron-binding capacity as well as a decrease in the percentage of transferrin saturation due to reticuloendothelial siderosis. Though there may be other mechanisms in play at the same time depending on the type of disease, the main mechanism is the impairment of the reticuloendothelial system. According to Viana (2011), all the processes involved happens due to the brief increase in hepcidin.

2.4.2.2 Soil-transmitted helminth infections

Soil-transmitted helminth infections contaminate soil in poor sanitation areas and are usually transmitted by eggs from human faeces. According to WHO (2019c), globally, over 1.5 billion people are affected with soil-transmitted helminth. Roundworm, whipworm and hookworms are the main species that infects approximately over 800 to 1 million, 600 to 800 million and 500 to 700 million people in the world respectively (CDC, 2019; WHO, 2019c). Iron deficiency anaemia, blood and iron loss are caused mainly by hookworm infections. The worms eventually feed on host tissues such as blood which lead to loss of iron and protein. Hookworms may cause anaemia through intestinal chronic blood loss (WHO, 2019c). Hookworm (*Ancylostoma duodenale*) has been reported to cause a loss of 0.25 mL blood per worm in a day. A hookworm load of about 40 to 160 worms is associated with iron deficiency anaemia based on the iron status of the host. Women of reproductive age and young children are at most risk of developing hookworm related iron deficiency anaemia due to their low levels of iron stores (Shaw & Friedman, 2011).

A study was conducted by Mengist et al., (2017) among pregnant women attending antenatal care to determine the prevalence of anaemia and intestinal helminthic infection in Oromia, Ethiopia. Intestinal helminthic infection was assessed by the collection of single stool specimen and observing it under a microscope. The prevalence of anaemia among the patients was 17.5%. Out of the 372 pregnant women, almost 25% were suffering from intestinal helminths infection. Hookworm infection (15.1%) was recorded as the highest intestinal helminths infection followed by roundworm infection (6.5%). After adjusting for confounders such as residence, age, educational status, food diversity, birth interval and other independent variables, only previous malaria infection within the past year (p=0.003), gestational age (p=0.009), not regularly taking iron (p=0.022) were all significantly associated with anaemia.

Also, anaemia was highly prevalent among pregnant women having hookworm infection [AOR, 95% CI: 3.53 (1.6, 6.7), P=0.001] and roundworm infection [AOR, 95% CI: 1.82 (1.1, 3.8), P=0.022] (Mengist et al., 2017). The results from another research by Gopalakrishnan et al, (2018) involving adolescent female school children in an urban area of Tamil Nadu in India confirmed this outcome. Having intestinal parasitic infection among the female students increased the odds of having anaemia by 2.84 times [OR, 95% CI: 2.84 (1.19, 6.76), P=0.014]

2.4.2.3 Malaria

According to the WHO, malaria cases found around the world in the year 2017 was over 219 million leading to approximately 400,000 deaths (WHO, 2019b). A significant number was caused either directly or indirectly by anaemia. About 90% of all malaria cases are from the WHO African Regions and the majority are caused by the Plasmodium falciparum (WHO, 2019b). The prevalence of malaria among pregnant women is 10% and 8.4% in non-pregnant women in Ghana. Over 98% of all the malaria cases was due to the Plasmodium falciparum specie (GMS, 2017). Malaria is known to be one of the important cause of anaemia globally. Pregnant women and children are the most vulnerable, especially in high malaria transmission areas. Malaria-related anaemia involves both decreased red blood cells production and destruction of red blood cells. Its contributions to anaemia depend on other factors such as the age of the person, pregnancy state, genetic make-up of the person affected, antimalarial immune status, and the local endemicity of malaria (White, 2018).

Observational studies involving hospitalized children under five years to estimate the prevalence of malaria parasites and anaemia in Uganda was performed within a year (May 2011 to May 2012) by (Kiggundu et al., 2013). As part of the study blood smears, haemoglobin concentration and HIV testing were done from finger-prick blood samples every 3 months interval. The prevalence of malaria parasitemia and anaemia was 54.6% and 56.3%

respectively. The average haemoglobin was significantly (p=0.001) lower in patients with parasitemia (8.3 g/dl) as compared to children with no parasitemia (10.0 g/dl). Again malaria parasitemia was linked with causing 76.8% of all severe anaemia cases among the children. (Kiggundu et al., 2013).

2.4.2.4 Genetic disorders

Anaemia is also caused by several genetic conditions. Genetic blood disorders impacting haemoglobin concentrations, commonly known as haemoglobinopathies, include alpha and beta thalassemia, sickle cell and haemoglobin E. Haemoglobinopathies are a group of inherited disorders characterized by abnormal structure or production of haemoglobin molecule (Kohne, 2011). Sickle cell disease is characterized by a change in the shape of red blood cell (RBC), unlike a healthy normal RBC which is usually smooth and takes the shape of a donut. Sickled RBCs are not able to pass through the blood vessels. Rather, they cause blockages that deprive other tissues and organs, oxygen-carrying blood (WHO, 2019a). Sickle cell disease is prevalent among people who trace their ancestry to sub-Saharan Africa, regions in the Western Hemisphere, India, Saudi Arabia and some other Mediterranean countries (CDC, 2015; WHO, 2019a). Thalassemia occurs most commonly among people in the Mediterranean, Middle East, Africa and Southern Asia. Thalassemia results when genes controlling for the development of the alpha and beta globin chains are missing or impaired resulting in abnormal haemoglobin with reduced oxygen-carrying capacities. In areas where malaria is endemic, both the alpha and the beta thalassemia are the most prevalent inherited single gene globally (WHO, 2019a). According to Karimi et al. (2015), in females, thalassemia may affect the proper functioning of certain hormones such as the luteinizing hormone, oestrogen, and progesterone leading to delayed puberty and development of secondary sexual characteristics. In a particular study in 2012, anaemia due to genetic haemoglobin disorders was a major predictor of anaemia than iron deficiency (Karakochuk et al., 2015). The aim of the study was to investigate the factors that were associated with anaemia in 450 rural Cambodian women of reproductive age. More than half of the study participants (54%) had a genetic haemoglobin disorder including 25 different gene variants. The two most common genetic haemoglobin disorder affecting them were haemoglobin E trait (14.9%) and thalassemia trait (11.6%) (Karakochuk et al., 2015). The strongest predictors of anaemia were haemoglobin E homozygous disorder 95% CI -18.24 (-21.74, -14.73), P=<0.0001 and pregnancy status 95% CI -11.99 (-15.60, -8.39), P=<0.0001]. The anaemia prevalence among women with genetic haemoglobin disorder was higher (~45%) compared with women without any disorder (~11%) (Karakochuk et al., 2015). Based on a worldwide review by Modell & Darlison (2008), 71% out of 229 countries had haemoglobin disorders present as a significant health problem. Over 300,000 infants are born with haemoglobin disorders from birth with sickle cell anaemia accounting for 83% and thalassaemia accounting for 17%. Over 7% of pregnant women are estimated to be carriers of significant genetic haemoglobin disorders (Modell & Darlison, 2008).

2.4.2.5 Anaemia of Inflammation

Anaemia of inflammation also known as anaemia of chronic disease (ACD) is a type of anaemia that usually occurs in people with chronic disease (e.g. cancer, autoimmune disease, infections) due to inflammation. It is regarded as the second leading cause of anaemia after iron deficiency anaemia globally (Nemeth & Ganz, 2014). Even though anaemia of inflammation may affect any age group, the elderly are more prone due to the likelihood to develop chronic diseases that cause inflammation. With this type of anaemia, it is possible to have a normal or even increased amount of stored iron in body tissues, but still have a low iron level on your blood (NIH, 2019). The inflammation may prevent the production of healthy RBC's due to the body losing its ability to use the stored irons which leads to anaemia. Anaemia of chronic disease may occur simultaneously with other conditions, there is no exact cause for it. It may be caused by either decreasing the survival chances of RBCs or the impairment of RBC production or the hormone erythropoietin (NORD, 2018). According to Page et al. (2015) Chronic inflammation is mediated by cytokines which are disruptive in iron homeostasis, reducing the sensitivity of erythropoietin to low haemoglobin levels and also affecting the sensitivity of bone marrow to erythropoietin.

Anaemia, especially in the older population, has been linked with various inflammatory conditions. Recently, a research was conducted among 191 (56 IDA and 135 ACD) consecutively hospitalized geriatric patients with iron deficiency anaemia and anaemia of chronic disease. Out of the patients with ACD, 96 (71%) had acute infections such as respiratory, urinary and gastrointestinal tract infections, 12 (12.3%) were diagnosed with cancer such as prostate, colon cancer, etc. and 22 (16%) were suffering from autoimmune inflammatory diseases such as gout, rheumatoid arthritis and others (Joosten & Lioen, 2015). Patients with cancer are prone to becoming anaemic due to inflammations. A prospective observational study of 888 cancer patients from 2011 to 2014 showed that the prevalence of anaemia was 63.4% (Macciò et al., 2015). The authors revealed that the mean haemoglobin concentration varied significantly depending on the type of cancer. For instance, the mean haemoglobin concentration of ovarian cancer patients was the least (10.9 ± 1.8) and it was highest among patients suffering from breast cancer (12.1 ± 0.2). Again, anaemia was more prevalent among patients in advanced stages of cancer (stage 3 to 4). This was further emphasized by the presence of more inflammatory indicators including C-reactive protein (CRP), fibrinogen, interleukin 1 beta (IL-1β), interleukin 6 (IL-6), tumor necrosis factor alpha (TNFα), reactive oxygen species (ROS), erythropoietin among patients in the advanced stage of cancer (Macciò et al., 2015).

2.5 Women in fish smoking livelihood

A fairly small number of women are involved in fishing compared to men. Generally, women are known to be actively involved in the post-harvest processing, marketing and distribution of fish (FAO, 2018). According to the FAO, in 2014, of all people directly involved in the primary sector of fisheries and aquaculture, women accounted for only close to 20%. However, when the secondary sector which involves processing and distribution is added women form about half of the total workforce (FAO, 2018). Among the 243 fish smokers in 9 local markets in Cameroon, it was revealed that all the fish smokers were women and among the married ones, many had husbands who were fishermen and they supplied them with the fish for smoking (Dongmo, 2019). Ghanaian women are the dominating force in the large or small scale traditional fish processing and trade in the country.

In Ghana and the continent as a whole, different methods such as smoking, drying, frying and salting are used to process, preserve and store fish. However, fish smoking is the most preferred option because of its advantages of prolonging shelf life, enhancing flavour and appearance (Pemberton et al., 2016). Fish smoking in Ghana is mostly done at the individual or household level. Most fish smokers from the Western, Volta and Central regions have been observed to work from their homes and usually prefer to work alone. They often use the help of either their children, other family members or local casual workers (Kwarteng et al., 2016). According to Kwarteng et al. (2016), payment is usually in cash or kind and those who employ helpers are usually paid an average amount of GH₵ 10.00 for each batch of fish smoked. Labour, packaging and transportation take about 16% of the total production cost. Some of the major types of fish smoked in the country are herring, anchovies, salmon and mackerel (Kwarteng et al., 2016; Tall & Failler, 2012). In Ghana, there are two seasons which define the availability of fish all year round for smoking (bumper and lean season). Due to replacement of warmer, and nutrient-depleted surface water with cooler and nutrient-rich water (upwelling) in the year, there is a massive increment in the fish catches known as the bumper season. The upwelling is usually greater from June to September and smaller from February to March. The rest of the months are considered as the lean season during which getting fish is quite difficult (Gordon et al., 2011). The fish for smoking are usually purchased from fish traders, however, some of the fish smokers purchase it directly from the fishermen. In the case where enough fish is not available, fish smokers travel to other communities themselves to get more (Gordon et al., 2011).

The process of fish smoking combines cooking, drying and smoking. This combined process employs the use of smoke from firewood, passing it over the fish at a specific temperature (Salvi & Brashier, 2014). The heat produced cooks the flesh of the fish and eliminates bacteria inside and outside the fish at a temperature of 80ºC. The fish is dried with the heat produced and finally, the fish is smoked by the smoke produced from burning the wood which enhances its shelf life (Kwarteng et al., 2016). The common smoke oven used in the country is the "Chorkor" oven. Through the supply of constant heat from firewood, Chorkor smoker provides uniformly smoked fish. The type and size of fish determine how they are stacked on the racks and prepared (Gordon et al., 2011). The Chorkor smoker was designed in 1969 in Ghana, before, there were other types of ovens namely the cylindrical mud oven, rectangular mud oven, the rectangular metal oven and the Adjetey and Altona ovens. The Chorkor smoker was designed because none of the four types of ovens were able to provide constant intense heat to cook the fish and later dry it over low fire for a long period (Kwarteng et al., 2016). They were not efficient enough to smoke all the catches from the landing site which led to very high post-harvest losses. Aside from producing fish with low market value, the health of the women was also compromised due to the long hours spent on smoking fish (UNDP, 2001). Before the official launch of the Chorker smoker, women who tested it testified that the use of trays made the smoking process easier. Also, it could carry more fish due to the framed wire mesh. Again the trays allowed smoke and heat to be trapped by forming a chimney. Another advantage was that the fish smoked with the Chorkor smoker gained a higher market value (UNDP, 2001).

Recently a more advanced smoking oven known as the "Ahotor" oven has been developed by the Netherlands Development Organization (SNV). According to the SNV, because the Chorkor and other traditional stoves require a lot of wood, it becomes scares which lead to increase in its prices (SNV, 2019). The Ahotor oven was designed to reduce the wood required to smoke fish. It was also developed to decrease polycyclic aromatic hydrocarbon (PAH) levels and reduce smoke leakages without necessarily decreasing the quantity of fish that can be smoked in a batch (SFMP, 2016). The wood used for smoking fish depends on the geographical location with mangrove, neem, acacia and cocoa trees as the most preferred in Ghana. About 6% of the total cost of processing smoked fish goes into fuelwood with women most at times purchasing them from local wood sellers or trucks from nearby communities (Kwarteng et al., 2016). According to Dongmo (2019), fish smokers based their choices of the use of a particular firewood on the capacity of the wood to heat as the main reason, followed by its ability to colour the fish to make it attractive and it's constant availability. Factors such as the cost and proximity to the collection site were not really important.

2.6 Use of biomass fuel by women

Globally, over 3 billion people use biomass fuel for their basic needs including cooking, heating and boiling water (WHO, 2006). According to the World Bank (2017), about 81% homes in Africa burn solid fuels, with the majority of them depending on wood-based biomass as their main cooking fuel. In terms of numbers, it is estimated that about 500 million people living in Africa rely on biomass for heating and cooking. This is expected to increase to over 800 million by the end of 2030 (Keles et al., 2017). Wood fuels form about 60% of the total energy used in Ghana. It provides the majority of the energy needed in the informal sectors such as fish smoking, bread baking, traditional textiles, etc. (Energy Commission, 2006)

Among the livelihood activities that predominantly use biofuel in Ghana is fish smoking, which is important, especially for women living within fishing communities. Women in fish smoking livelihood also play important roles such as cooking and heating in their homes. However, exposure to smoke from biomass fuel varies based on whether cooking or smoking is done indoors or outdoors and based on whether exposure repeats on a regular basis over a long period (Morandi et al., 2009). Women are normally involved in domestic activities as compared to men, which suggest that they are more exposed to smoke from biomass fuel (Piddock et al., 2014). Because females mostly do the cooking in many households around the world, they are largely in the collection of fuel as well (Cecelski & Matinga, 2014). Therefore, in addition to their constant inhalation of biomass fuel smoke, females are also faced with other associated health and social issues associated with collecting biomass (AFDB, 2016). Urban populations have access to cleaner fuels than rural populations where cost and infrastructure hinder them from the use of clean efficient fuels. In a study in some rural areas in India conducted by Attimogge & Devi, (2014) to assess the reasons why people use a particular type of biomass fuel, almost 90% of the people preferred using firewood due primarily to its low cost. The type of fuel used in a particular household may also depend on the educational level. Lower educational attainment corresponded to greater use of wood and less use of electricity in a cross-sectional study of household biomass fuel in Malawi (Piddock et al., 2014).

Biomass fuel combustion produces many pollutants which could be harmful to the body. Some women are not even aware of the risks involved with the constant exposure to biomass smoke. Over 200 chemicals have been discovered in wood smoke and more than 90% of these chemicals are in inhalable range. Normally, women and children inhale an excessive amount of smoke day in day out which is equivalent to two packs of cigarettes in a day (WHO, 2006). According to Kamal et al. (2015), two packs of cigarette forms a total of 40 mg/m^3 suspended particles, whiles the total suspended particles emitted from biomass smoke is approximately 10,000 mg/m^3, an amount which is higher in many folds. Some of the significant substances in biomass fuel smoke are particulate matter ($PM_{2.5}$), carbon monoxide (CO), sulphur dioxide, nitrogen dioxide, aldehydes, free radicals and polycyclic aromatic hydrocarbons (PAHs) (Machisa et al., 2013). Even though not enough research has been done, it has to an extent been proven that these compounds from biomass fuel combustion are linked to anaemia (Kyu et al., 2010; Machisa et al., 2013; Honda et al, 2017, Kamal et al, 2015). Chronic inhalation of smoke from the incomplete burning of biomass fuel through cooking and boiling has also been linked with lung cancer (Bruce et al., 2015).

Comparing the old traditional "Chorkor" oven to the more improved smoker "Ahotor" oven, it was observed that carbon monoxide and $PM_{2.5}$ were reduced by 12% and 13% respectively in the Ahotor oven, compared to the Chorkor oven (SFMP, 2016). Again the PAH analysis revealed that the Chorkor oven produced benzo[a]pyrene (BaP) and PAH4 of 22 µg/kg and 84 µg/kg respectively as compared with the 5.9 µg/kg (BaP) and 53.1 µg/kg (PAH4) produced by the Ahotor oven. The increased level of PAH in the Chorker oven is mainly due to the absence of a fat collecting system, which prevents fats, blood and other fluids from the fish from dripping into the fire to burn (SFMP, 2016).

Research has shown that women who smoke fish have increased risk of respiratory illness and reduced pulmonary function (Dienye et al., 2016; Torres-Duque et al., 2008). A case-control study among women 15 years and above involved in fish smoking in Nigeria was conducted. The study aimed at determining the prevalence of respiratory symptoms and also to assess the lung function of women fish smokers and non-fish smokers. The prevalence of all respiratory symptoms parameters measured during the study including sneezing (153; 72.86%), catarrh (159; 75.71%), cough (138; 65.71%) and chest pain (59; 28.1%) were all significantly higher among fish smokers compared with the non-fish smokers, odds ratio (OR) 2.49, 95% CI (1.62,3.82), P<0.001, OR 3.77,95% CI (2.44,585), P<0.001, OR 3.38, 95% CI (2.22,5.15), P<0.001 and 6.45,95% CI (3.22,13.15), P<0.001, respectively . The lung function which was assessed by recording the peak expiratory flow rate (PEFR) showed that fish smokers had a lowered average PEFR (321 ± 58.9+3 L/min) as compared to the non-fish smokers (400 ± 42.92 L/min)(Dienye et al., 2016) .

2.7 Mechanisms of biomass fuel exposure and anaemia

The link between exposure to biomass fuel smoke and anaemia in women and children is not widely known. It is believed that, as chemical substances from biomass fuel smoke enter the human body, it affects the haemoglobin formation process (Raub et al., 2000). According to Murray (2007), carbon monoxide a gas produced from the incomplete combustion of biomass fuel is able to bind more rapidly to haemoglobin than oxygen. When CO binds with haemoglobin it forms a compound called carboxyhaemoglobin (HbCO) which can decrease the amount of haemoglobin available for oxygen-transport and also decrease oxygen carrying capacity of haemoglobin (Fielding, Lang, & White, 2001; Prockop & Chichkova, 2007).

Also, particulate matter ($PM_{2.5}$), a compound from biomass fuel combustion has been shown to increase systemic inflammation and impact bone stimulation negatively (Cliff et al., 2016; Dabass et al., 2016; Page et al., 2015). Systemic inflammation leads to decreased haemoglobin or erythrocytes production and eventually anaemia by downregulation of erythropoietin production or continuous upregulation of hepcidin (Honda et al., 2017). In a study to determine the association of particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2) on haemoglobin concentrations and anaemia prevalence, increase in both $PM_{2.5}$ and NO_2 were significantly associated with lowered haemoglobin concentration and increased prevalence of anaemia (Honda et al., 2017).

Polycyclic Aromatic Hydrocarbons (PAHs) from smoke emission is associated with anaemia (Kamal et al., 2015). PAHs has been found to induce oxidative stress that affects erythrocytes. Due to the formation of Heinz body caused by the attack of PAH metabolites on haemoglobin, there is a change in the morphology of RBC and its ability to carry oxygen throughout the body. Finally, the erythrocytes go through a process called cell lyses which leads to a leakage of haemoglobin (Kamal et al., 2015).

2.8 Evidence of the association between biomass fuel smoke exposure and anaemia

Women are mostly involved in cooking and most of the times, their children are with them during the process. Exposure to smoke from biomass fuel has been linked to various health implications such as stunted growth Mishra & Retherford (2006), increased risk of respiratory disease Mishra (2003) and low birth weight Boy et al. (2002) among women and children.

Biomass smoke exposure may also be associated with anaemia among children. Few published studies have assessed the impact of exposure to biomass fuel on anaemia status of children (Accinelli & Leon-Abarca, 2017; Kyu et al., 2010; Machisa et al., 2013; Mishra & Retherford, 2006). An earlier research conducted by Mishra & Retherford (2006) suggests that the use of biomass fuel only for cooking and heating exposes children to moderate to severe anaemia. The study was based on the 1998-1999 national survey in India of over 29,000 children under 3 years. Weight, length/height were measured, haemoglobin concentration as well as their exposure to smoke based on the type of fuel used in their households for cooking and heating. About 50% of the children from households which use only biofuels such as wood and crop residues had a moderate to severe anaemia. The relative risk of moderate to severe anaemia was still significantly higher in children from households using biofuels only [RRR, 95% CI: 1.58 (1.28,1.94) P<0.001] than children who lived in households using only cleaner fuels after controlling for various confounders. This result was very similar to a much wider study by Kyu et al. (2010) where data on children under five years of age were gathered from the Demographic and Health Surveys of 29 developing countries between 2003 and 2007. The household use of biomass fuel per country level was used to categorize countries into high, moderate and low exposure level. Using multinomial logistic regression, moderate exposure and high exposure to biomass fuel smoke increased the odds of moderate to severe anaemia by 2.36 (OR, 95% CI 1.24, 4.36) and 2.80 (OR, 95% CI 1.37, 5.72) respectively (Kyu et al., 2010).

In a more recent study by Accinelli & Leon-Abarca (2017), the association of solid fuel use and anaemia among children under 5 years from 193 countries was assessed. Countries with higher biomass fuel use had a greater incidence of anaemia (Correlation=0.749, P<0.0001). The authors suggest that exposure to biomass fuel smoke is a significant independent predictor of anaemia (P-value=0.012) when the prevalence of measles immunization, anaemia in pregnant mothers, tobacco smoking, girls primary education and life expectancy were controlled (Accinelli & Leon-Abarca, 2017). Contrary to the three studies discussed above, there was no significant association observed between household biomass fuel use and anaemia among children (6-36 months) according to (Machisa et al., 2013). Data for the study were generated from the 2006-2007 Swaziland Demographic Survey. A major limitation to the study which could have underestimated the association between biomass fuel use and anaemia was the failure to assess exposure to biomass fuel smoke other than cooking. They argued that during winter, for example, it is a common habit for households to use biomass fuel for heating even for longer hours than cooking (Machisa et al., 2013)

Though very limited, anaemia has been linked with biomass fuel use among women of reproductive age. Page et al. (2015) proposed that chronic inhalation of smoke from biomass fuel contributes to anaemia in pregnant women. This study was based on a secondary analysis of data from the Maternal and Newborn Health Registry Study among 12,782 pregnant women in Nagpur, India. More than half (56%) of the study participants reportedly used biomass fuel while the remaining participants used cleaner fuel (44%). Anaemia was significantly higher in women who lived in households using biomass fuel as compared to women living in households using cleaner fuels (93% vs 88%: P<0.0001). Using multinomial logistic regression to control for age, educational level, BMI, household tobacco smoke exposure, trimester, parity, and prenatal iron and folate supplements among the women (Page et al., 2015). The adjusted relative risk of mild anaemia among women living in households using biomass fuel was 1.38 (95% CI: 1.19, 1.61) times greater than women using clean fuels. Moderate to severe anaemia was also 1.79 (95% CI: 1.53, 2.09) times greater in biofuel users than non-biofuel users (Page et al., 2015). A study was conducted in rural Nagpur in India to assess if anaemia and other morbidities were associated with the use of various types of cooking fuels among non-pregnant, non-smoking women of reproductive age (Sukhsohale et al., 2013). The exposure index (EI) of the women was assessed by multiplying the average number of years spent cooking and average hours spent cooking in a day. A total of 360 women had a low

(EI<50), 222 had moderate exposure (EI=50-100) and 178 women had a high exposure index (EI≥100). Women with the highest exposure index were more anaemic 53 (29.8%) compared to moderate exposure 46 (20.7%) and low exposure 46 (12.8%) at a $P<0.001$ (Sukhsohale et al., 2013)

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study design

This study was a comparative cross-sectional study.

3.2 Study site

Participants for the study were recruited from Biriwa in the Mfantseman Municipal District of the Central region. This research was part of The Invisible Fishers Project, a pilot project testing the feasibility of different interventions aimed at mitigating anaemia among women of reproductive age involved in fisheries value chains in the Central and Volta regions of Ghana. Biriwa was the largest of the Invisible Fishers project's six (6) study communities in the Central Region. It was selected as the study site for the current research because its relatively large population meant that it was more likely to obtain the target sample size from Biriwa alone, and thereby lessen the logistical demands of recruiting from more than one community. Fishing and fish-related activities are the main livelihoods in Biriwa. Other less common livelihoods include farming and petty trading. The community attracts fishermen from other parts of the country including Axim in the Western Region of Ghana.

3.3 Study participants

Participants were non-pregnant, non-lactating (NPNL) women of reproductive age (18-49 years) who were either engaged in fish smoking as their primary livelihood (FSL) or engaged in non-fish smoking livelihood (NFSL).

3.3.1 Inclusion and exclusion criteria for both groups

Inclusion and exclusion criteria for the two groups of study participants have been provided in the table below.

Table 1: Inclusion and exclusion criteria

	Engaged in fish smoking livelihood (FSL)	Engaged in non-fish smoking livelihood (NFSL)
Inclusion criteria	– At least 2 years in this livelihood – Willingness to participate	– At least 2 years involved in other livelihoods other than fish smoking – Willingness to participate
Exclusion criteria	– Must not be enrolled in Invisible Fisher's Project	– Living in a household where fish smoking occurs as a major economic activity

3.4 Sample size estimation

The sample size was estimated based on a confidence interval of 95% and a power of 80%. The expected prevalence of anaemia among women in fish smoking livelihood was estimated at 50% based on baseline anaemia prevalence among women in fish smoking livelihood selected to participate in the Invisible Fishers Project (Invisible Fishers, 2019). The expected prevalence of anaemia among women in non-fish smoking livelihood was estimated at 35% based on the prevalence of anaemia in the Upper West Region DHS (2015) since the Upper West region is not close to the ocean or any major fishing ground, and therefore fish-smoking in that region would be minimally low to make it a major livelihood. Using OpenEpi Software (version 3.01), the sample size was estimated at 175 (including 3% for contingency) per group for a total sample size of 350 for the two groups.

3.5 Sample selection

A census was completed in the community to list all NPNL, WRA (18-49 years of age), their primary livelihoods, years of living in the community and other eligibility criteria information. Based on the census data, all eligible women were categorized by livelihood type whether FSL or NFSL. All selected participants were visited in their homes and invited to participate.

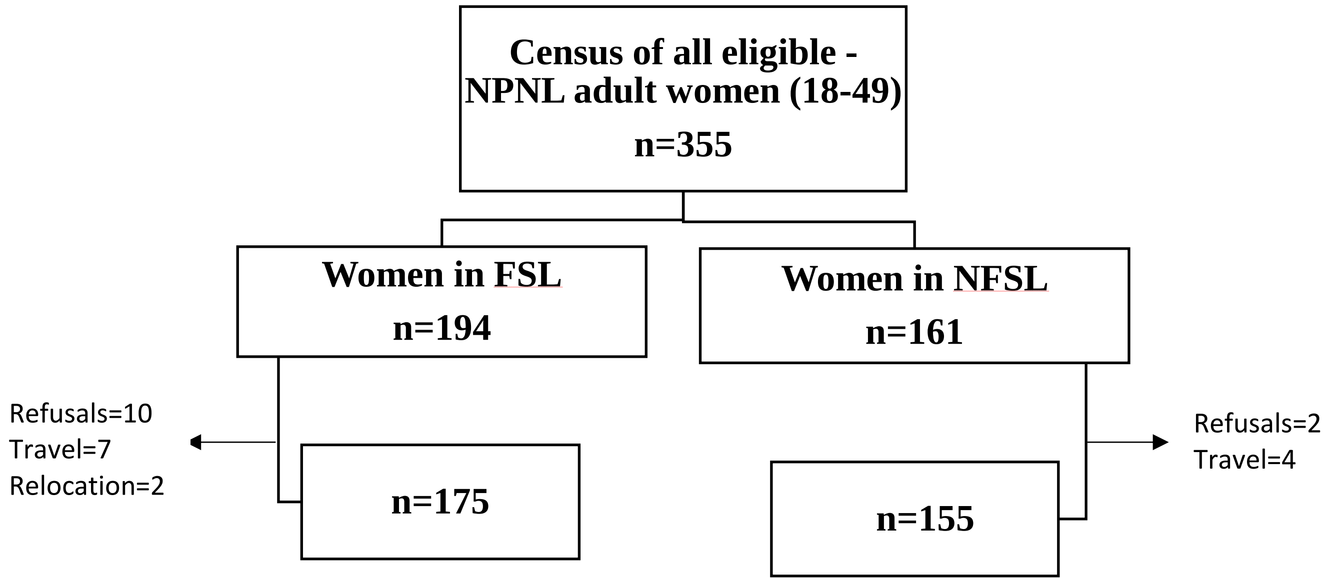

Figure 1: Study flow chart

3.6 Data collection

Data collection took place from December 2018 to February 2019 and included questionnaire administration, biochemical and dietary intake assessment.

3.6.1 Questionnaire administration

The questionnaire had four sections; socioeconomic factors, reproductive history, health information and use of biomass fuel. A face to face interview in Fante, Twi or English at the homes or working places of the eligible participants at a convenient time, was used to administer the questionnaire. Data were recorded with Android tablets by direct electronic data entry using the Open Data Kit (ODK).

Socioeconomic factors: Socio-economic information included women's marital status, type of occupation, average income per month, religion, educational level, source of drinking water, household size, toilet facility, etc.

Reproductive history: Questions about pregnancy history and parity were asked.

Health Information: Questions including sickling status, malaria in the past two weeks, dewormed within the last 3 months, intake of iron supplement in the past 6 months and use of mosquito net were asked.

Use of biomass fuel: Questions for women in fish smoking livelihood included, average years of smoking fish, average number of hours spent smoking fish in a day, number of months in the past year used for smoking fish, average number of days in a week spent smoking fish, type of oven for smoking fish and main fuel used for smoking fish. Questions for women in non-fish smoking livelihood included whether they helped someone in their fish smoking livelihood and the number of days in a week spent helping others to smoke fish. Questions about their exposure to cigarette smoke and main fuel used for household cooking were asked for both groups.

3.6.2 Dietary intake assessment

Information on the women's dietary intake was collected using the quantitative 24-hour recall method. The study participants were asked to recall every food and beverage except water consumed in the past 24 hours. Household measures (e.g. teaspoon, slices, etc.) and food models were used to help participants estimate the quantities of each food item consumed. A modified food frequency questionnaire which comprised a list of animal source food categories was used to solicit information on the frequency of consumption of different types of animal source foods in the past week.

3.6.3 Hematologic assessment

To assess the anaemia status of women, blood haemoglobin concentration was measured using a portable Urit12 HemoCue system. The forefinger of the participant was prepared by rubbing the tip with swabbing alcohol to sterilize the area and allowed to dry. A lancet was used to prick the area. The finger was pressed slightly to allow easy flow of blood to the sampling point. Cotton wool was used to wipe the first drop of blood to avoid any tissue fluid that may give false readings. The next drop of blood after wiping was collected into the hemocue to obtain a digital reading on haemoglobin concentration. Dried cotton wool was placed at the pricked area to stop the bleeding. The values obtained were recorded in grams per decilitres. The study participants were informed of their anaemia status. Participants with anaemia were given nutritional advice such as eating more green leafy vegetables and more diverse animal source foods to increase their Hb levels. Severely anaemic patients were encouraged to visit the nearest health facility for treatment.

3.7 Ethical Consideration

Ethical approval was obtained from the Ethics Committee for the College of Basic and Applied Science at the University of Ghana. The research was explained to study potential participants and those who agreed to participate thumb printed or signed an informed consent document before being interviewed. Consent forms were signed in duplicates: One was kept by the participants themselves and the other copy was kept for the researcher's records.

3.8 Quality Control Measures

The questionnaire used for the data collection was pre-tested on 4 women with similar characteristics in a neighbouring community (Moree) and revisions made to obvious shortfalls pertaining to the questionnaire before the study. The equipment was calibrated regularly to reduce errors. Field assistants were trained and supervised to ensure that all research protocols were followed during the data collection period. Completed questionnaires were reviewed for completeness at the end of each day of data collection. Data collected each day were uploaded unto the server to ensure that data were not lost.

3.9 Data Analysis

After cleaning, data were analysed using Statistical Software Package for Social Sciences (SPSS) version 22.0 (Chicago, USA) and SAS for Windows Release 9.4 (Cary, NC, USA). Using the WHO cut-offs, the women were classified as being anaemic if their Hb concentration was <12 g/dl (WHO, 2009). Starchy staple was defined as a combination of cereals, roots and tubers. Fish, poultry and meats were combined to form a single food group. Dietary diversity score was calculated by summing the different food groups (10 food groups) consumed by the study participants in the past 24 hours (FAO, 2016). These food groups were: starchy staples, fish poultry meat, Pulses, nuts and seeds, vitamin A rich fruits and vegetables, dairy, eggs, other fruits, other vegetables and dark green leafy vegetables. Thus, participants' dietary diversity scores ranged from 0 to 10. The ASF diversity score comprised 7 different animal food groups consumed in the past 7 days prior to the study. These food groups were: fish and seafood, milk and milk products, livestock meats, eggs, poultry, organ meats and bushmeats. Thus, participants' ASF dietary diversity score ranged from 0 to 7.

3.9.1 Generation of variables for bivariate and multivariate analyses

For the purposes of the regression models comparing outcome variables between the 2 groups of women (see below), the following binary variables were created:

- Having age below 35 years (code = 1) or otherwise (code = 0), using the median age of women in the sample as the cut-off point.
- Being in the Akan ethnic group (1) or otherwise (0), including Ewe ethnic group.
- Being married (1) or otherwise (0).
- Having attained primary educational level or higher (1) or otherwise (0).
- Having supplementary work (1) or otherwise (0); supplementary work is known to create other streams of income which helps improve their health and diet therefore decreasing risk of becoming anaemic (Kim et al., 2014).
- Earning < 500 GH₵ (1) or otherwise (0).
- Being the head of a household (1) or otherwise (0).
- Piped water as the main source of drinking water (1) or otherwise (0). Besides piped water, the other source of drinking water was sachet water.
- Having electricity in the residence (1) or otherwise (0).
- Having a cemented floor (1) or otherwise (0); a cemented floor may be a proxy for higher socioeconomic status.
- Having aluminium roofing (1) or otherwise (0); aluminium roofing may be a proxy for higher socioeconomic status.
- Having cemented walls (1) or otherwise (0); cemented walls may be a proxy for higher socioeconomic status.
- Using firewood as the main fuel for cooking (1), or otherwise (0), given that exposure to smoke from firewood can cause anaemia (Mishra & Retherford, 2006).

- Cooking indoors (1), or otherwise (0); indoor cooking may be associated with increased exposure or intensity of exposure to smoke.
- Responsible for cooking most of the time (1), or otherwise (0).
- Ever been pregnant (1), or otherwise (0); pregnancy is a known predictor of anaemia (Loy et al., 2019).
- Reportedly having sickle cell (1), or otherwise (0).
- Having malaria in the past 2 weeks (1), or otherwise (0); malaria is a known predictor of anaemia (White, 2018)
- Having dewormed in the past 3 months (1), or otherwise (0); deworming may help prevent anaemia (Girum & Wasie, 2018).
- Having taken iron supplements in the past 6 months (1), or otherwise (0); iron supplements may be associated with a lower risk of anaemia (Fernández-Gaxiola et al., 2011).
- Sleeping under an insecticide-treated mosquito net (1), or otherwise (0); use of insecticide-treated mosquito net may be associated with a lower risk of anaemia.
- Smoking fish more than 4 days in a week (1), or otherwise (0), using the median number of days women in the sample smoked fish as the cut-off point. Women in NFSL were categorized based on the number of days they usually helped someone in their fish smoking livelihood, women who did not help anyone were scored 0.
- Having someone who smokes cigarette in household (1), or otherwise (0); cigarette smoking has been found to increase haemoglobin concentration (Shah et al., 2012).
- Being exposed once or more to cigarette smoke outside work/home in the past 12 months (1), or otherwise (0); passive exposure to cigarette smoke may be associated with anaemia (Hong et al., 2007).

- Having ASF diversity score below 4 (1) or otherwise (0), using the median ASF diversity score in the sample as the cut-off point.

3.9.2 Analysis of baseline characteristics

Descriptive analysis was used to summarize sociodemographic variables: categorical variables were summarized as frequencies and percentages, and continuous variables were summarized as Means (± SD).

3.9.3 Comparison of continuous outcome variables

Continuous outcome variables (e.g. blood haemoglobin concentration, dietary diversity score, etc.) were compared between women in the two groups using general linear model for unadjusted comparisons (without any covariates), and ANCOVA for adjusted comparisons (with covariates). The SAS PROC GLIMMIX procedure was used in both cases. Unadjusted and adjusted means with their 95% CIs were calculated. Covariates for the ANCOVA models were selected as follows:

Step 1: For each outcome variable, potential covariates were each correlated with the outcome, so that only those covariates significantly associated with the outcome at alpha = 0.2 were selected for possible inclusion in the final model. According to Mickey & Greenland (1989), alpha levels of such preliminary tests should be set at 0.2 or more (i.e. well above conventional 0.05 or 0.01 levels) to minimize type II error in selection.

Step 2: To reduce collinearity between the independent variables, a Pearson's correlation matrix was constructed for independent variables selected in Step 1. Any two independent variables with a Pearson Correlation Coefficient > 0.500 were considered to be "highly correlated". In that case, the one variable which had the lower correlation coefficient with the outcome variable in Step 1 was excluded from the model.

In addition to the independent variables selected through correlation analysis, certain independent variables were selected for the final ANCOVA model if they were known to be associated with the outcome. For example, although the number of times per week women spent smoking fish, or helped someone smoke fish (i.e. in the case of women in NFSL group) had a p-value of 0.42 (i.e. $p > 0.2$) when correlated with blood haemoglobin concentration, that variable was included in the final ANCOVA model because of previous results showing that women living in households using biomass fuel for cooking had a greater risk for anaemia (Page et al., 2015).

3.9.4 Comparison of anaemia prevalence between groups

The anaemia prevalence between women in the 2 groups was compared using a simple logistic regression model for an unadjusted comparison, and multiple logistic regression model for an adjusted comparison. The SAS PROC GLIMMIX procedure was used in both cases. A binary distribution and log-link function were specified in the SAS procedures, so that relative risks between groups and their 95% CIs were calculated. Covariates for the multiple logistic regression models were selected as follows:

Anaemia was correlated with each potential independent variable so that only those independent variables significantly associated with the outcome at alpha = 0.2 Mickey & Greenland, (1989), were selected for the multiple logistic regression model. In addition to the independent variables selected through correlation analysis, certain independent variables were selected for the final multiple logistic regression model if they were known to be associated with the outcome. For example, although toilet facility had a p-value 0.28 (i.e. $p > 0.2$), when correlated with anaemia, it was included in the final logistic regression model because of research linking open defecation to anaemia (Coffey et al., 2018).

3.9.5 Sensitivity analysis

To assess whether the level of exposure to smoke (i.e. relatively low exposure versus relatively high exposure) was related to the risk of anaemia, a sensitivity analysis was conducted, which was restricted to women in fish smoking livelihood only. First, women's exposure index (EI) was calculated by multiplying the total number of years women had spent smoking fish by the average number of hours spent in a day smoking fish (Sukhsohale et al., 2013). Women below the 70th percentile EI (i.e. EI < 60) were categorized as having a lower biomass smoke exposure. Women above the 70th percentile EI (i.e EI ≥ 60) were categorized as having a higher smoke exposure. Next, blood haemoglobin concentration and anaemia prevalence where compared, by level of smoke exposure among women in fish smoking livelihood using unadjusted and adjusted analyses as described above.

3.9.6 Predictors of anaemia

Factors predicting anaemia in the study sample were determined using the same multiple logistic regression model used to compare anaemia prevalence between women in the two groups (SAS PROC GLIMMIX and specifying binary distribution and log-link). In addition to the livelihood type, the other independent class variables selected for inclusion in the prediction model were: Age, marital status, ever been pregnant, dewormed in the last 3 months, living in a household where someone smokes cigarette, had fever in the past 2 weeks, type of toilet facility, number of days used for smoking fish in a week, the main fuel used for cooking and animal source food diversity. A variable was considered as a significant and independent predictor if it was related to the anaemia prevalence at $p < 0.05$.

Table 2: Summary of data analysis

Objectives	Analysis
Socio-demographic characteristics	• Means ± SD (continuous variables) • n (%) (categorical variables)
Comparison of continuous outcome measures	• General linear model (unadjusted) • ANCOVA (adjusted)
Comparison the prevalence of anaemia	• Simple logistic regression (unadjusted) • Multiple logistic regression (adjusted)
Identification of predictors of anaemia	• Multiple logistic regression

CHAPTER FOUR

4.0 RESULTS

4.1 Background and household characteristics of women in the study

Data were collected within a period of 3 months (December to February). Overall, 355 women were enrolled in the study. A total of 25 women could not complete the study due to refusal, travel out of the study area and relocation. Of the total of 330 women who completed the study, 175 were women in fish smoking livelihood and 155 were women in non-fish smoking livelihood. Trading and vocational work were the primary occupations of most of the women in non-fish smoking livelihood. Women in fish smoking livelihood and women in non-fish smoking livelihood differed in most of the background and household characteristics presented (Table 3). For example, women in fish smoking livelihood were older, had spent more years in their occupation, had a greater parity and a larger household size compared with women in non-fish smoking livelihood. However, some of the characteristics that did not differ between women in the two groups were religion, ethnicity, use of electricity and the main fuel for cooking.

Table 3: Background and household characteristics of women in the study.

Characteristics	**Women in FSL (n = 175)**	**Women in NFSL (n = 155)**	**[1]P-value**
Sociodemographic characteristics			
Age, years	38 ± 8[2]	29 ± 8	<0.001
Years of stay in community	35 ± 11	24 ± 11	<0.001
Years in primary occupation	12 ± 7	6 ± 5	<0.001
Has supplementary income source	78 (45)	45 (29)	<0.001
Akan ethnicity	175 (100)[3]	154 (99)	0.290
Christian faith	174 (99)	155 (100)	0.350
Primary education or higher	88 (50)	137 (88)	<0.001
Average income < GH₵ 500/ month	103 (59)	130 (84)	<0.001
Married	143 (82)	89 (57)	<0.001
Ever been pregnant	170 (97)	107 (69)	<0.001
Parity	5 ± 3[2]	2 ± 2	<0.001
Household characteristics			
Household size	6 ± 3[2]	5 ± 3	<0.001
Head of household = Self	31 (18)	50 (32)	< 0.001
Sleeping place has cemented exterior walls	161 (92)	148 (96)	0.200
Sleeping place has cemented floor	170 (97)	154 (99)	0.130
Sleeping place has aluminium roofing	168 (96)	149 (96)	0.950
No toilet facility	131 (75)	92 (59)	<0.001
Piped water	166 (95)	135 (87)	<0.001
Electricity	103 (59)	128 (83)	<0.001
Firewood as main fuel for cooking	28 (16)	17 (11)	0.180
Cook indoors	83 (47)	85 (55)	0.180
Responsible for cooking most of the time	162 (93)	142 (92)	0.750
Someone smokes cigarette in household	9 (5)	5 (3)	0.390
Exposure to cigarette once or more in the last 12 months outside, aside home or office	32 (18)	30 (19)	0.804

[1]P-value is based on independent t-test for continuous variables, and chi-squared test for categorical variables
[2]All such values are Mean ± SD; [3]All such values are n (%)

4.2 Anaemia-related background characteristics of the study participants

The anaemia-related background characteristics refer to certain variables related to deworming, sickle cell trait, use of iron supplements, use of insecticide-treated bednets, and malaria (Table 4), which are known to be linked to increased or decreased risk of anaemia in many populations. There was no difference between women in the two groups with respect to most of these characteristics, except for the proportion of women who reportedly sleep under mosquito net usually, which was significantly greater in the women in fish smoking livelihood (61%) compared with women not in fish smoking livelihood (47%).

Table 4: Anaemia-related background characteristics of the study participants

Characteristic	**Women in FSL (n=175)**	**Women in NFSL (n=155)**	**[1]P- value**
Reportedly dewormed in past 3 months	47 (27)[2]	47 (30)	0.490
Reportedly had sickle cell trait	0 (0)	2 (1)	0.130
Reportedly used iron supplements in past 6 months	25 (14)	27 (17)	0.440
Reportedly sleep under mosquito net usually	106 (61)	72 (47)	**<0.001**
Reportedly had malaria in past 2 weeks	47 (27)	29 (19)	0.079

[1] P-value is based on chi-squared test for categorical variables
[2] All values are n (%).

4.3 Hb concentration and anaemia prevalence, by livelihood type

In the (unadjusted) analysis in which the mean hemoglobin concentrations of women in the FSL and NFSL groups were compared without controlling for any other variables, there was no significant difference in the means at alpha = 0.05 (Table 5). However after adjusting for potential confounders including marital status, toilet facility, fever, main fuel used for cooking, someone smokes cigarette in household, exposure to cigarette smoke outside the home once or more in the past 12 months, number of days spent smoking fish in a week and ASF diversity, women in FSL had a mean blood haemoglobin concentration that was significantly lower (by 0.6 g/dl) compared with that of women in NFSL.

Without any adjustments for background characteristics, the prevalence of anaemia was 32.0% among women in FSL and 27.0% among women in NFSL. These percentages did not differ significantly at alpha = 0.05. However, after controlling for potential confounders including age, marital status, someone smokes cigarette in household, dewormed, fever, ever been pregnant, toilet facility, main fuel used for cooking, number of days in a week for smoking fish and animal source food diversity, the prevalence of anaemia was significantly greater (P = 0.023) among women in FSL (37.0%) than women in NFSL (20.3%). These percentages translated into 80% increased relative risk for anaemia in women in the FLS group, compared with those in the NFSL group.

Table 5: Mean ± SD haemoglobin concentration and anaemia prevalence of study participants

	Women in FSL (n=175)	Women in NFSL (n=155)	Difference in means or Relative Risk and 95% CIs	[1]P-value
Haemoglobin concentration (g/dl)				
Unadjusted	12.3 ± 1.9[3]	12.6 ± 1.8[3]	-0.3 (-0.7, 0.1)[4]	0.174
Adjusted[5]	12.2 ± 0.2[6]	12.8 ± 0.2[6]	-0.6 (-1.2, -0.1)[4]	**0.018**
Anaemia prevalence[2]				
Unadjusted	32.0	27.1	1.2 (0.8, 1.7)[7]	0.331
Adjusted[8]	37.0	20.3	1.8 (1.1, 3.1)[7]	**0.023**

[1] P-values are based on general linear model and ANCOVA (SAS PROC GLIMMIX) for haemoglobin concentration (continuous variable) and Poisson regression for anaemia prevalence (categorical variable).
[2] Anaemia was defined as Hb concentration <12.0 g/dL
[3] Values are mean ± SD
[4] Values are difference in means (95% CIs)
[5] Adjusted for marital status, toilet facility, fever, fuel used for cooking, someone smokes cigarette in household, exposure to cigarette smoke outside the home once or more in the past 12 months, number of days spent smoking fish in a week and ASF diversity.
[6] Values are mean ± SE
[7] Values are Relative Risks (95% CIs)
[8] Adjusted for age, marital status, someone smokes cigarette in household, dewormed, fever, ever been pregnant, toilet facility, main fuel used for cooking, number of days in a week for smoking fish and ASF diversity

4.4 Hb concentration and anaemia prevalence among women in fish smoking livelihood, by level of exposure to smoke

In a sensitivity analysis restricted to women in fish smoking livelihood (Table 6), those with relatively high exposure to smoke (≥70th percentile Exposure Index calculated by multiplying the total number of years woman had been in fish smoking livelihood by average number of hours spent in a day smoking fish) had a point estimate for unadjusted or adjusted mean haemoglobin concentration which was lower than that of women who had relatively low exposure to smoke (<70th percentile Exposure Index). However, between the two sub-groups of women, the difference in the unadjusted mean haemoglobin concentration (-0.5 g/l; 95% CI: -1.1, 0.1) or the adjusted mean haemoglobin concentration (-0.2 g/dl; 95% CI: -0.9, 0.4) after controlling for marital status, toilet facility, fever, main fuel used for cooking, someone smokes cigarette in household, exposure to cigarette smoke outside the home once or more in the past 12 months, number of days spent smoking fish in a week and ASF diversity was not significant at alpha = 0.05. Similar results were obtained for unadjusted or adjusted point estimate for the proportion of women with anaemia in the two sub-groups. That is, a greater percentage of women in FSL who had relatively high exposure to smoke were anaemic (unadjusted percentage = 36.1%; adjusted percentage = 33.1%) compared with women in the FSL group who had a relatively low exposure to smoke (unadjusted percentage = 29.8%; adjusted percentage = 27.8%), although these percentages did not differ significantly.

Table 6: Mean ± SD haemoglobin concentration and anaemia prevalence of women in fish smoking livelihood by, exposure index

	High exposure Index (n=61)	Low exposure Index (n=114)	Difference in means or Relative Risk and 95% CIs	[1]P-value
Haemoglobin concentration				
Unadjusted	12.0 ± 2.0[3]	12.5 ± 1.8[3]	-0.5 (-1.1, 0.1)[4]	0.108
Adjusted[5]	12.2 ± 0.2[6]	12.4 ± 0.2[6]	-0.2 (-0.9, 0.4)[4]	0.425
Anaemia prevalence[2]				
Unadjusted	36.1	29.8	1.2 (0.8, 1.9)[7]	0.395
Adjusted[8]	33.1	27.8	1.2 (0.7, 2.0)[7]	0.502

[1] P-values are based on general linear model and ANCOVA (SAS PROC GLIMMIX) for haemoglobin concentration (continuous variable) and Poisson regression for anaemia prevalence (categorical variable). Exposure Index = Total number of years woman has been in fish smoking livelihood × average hours spent in a day smoking fish

[2] Anaemia was defined as Hb concentration <12.0 g/dL

[3] Values are mean ± SD

[4] Values are difference in means (95% CIs)

[5] Adjusted for marital status, toilet facility, fever, fuel used for cooking, someone smokes cigarette in household, exposure to cigarette smoke outside the home once or more in the past 12 months, number of days spent smoking fish in a week and ASF diversity.

[6] Values are mean ± SE

[7] Values are Relative Risks (95% CIs)

[8] Adjusted for age, marital status, someone smokes cigarette in household, dewormed, fever, ever been pregnant, toilet facility, the main fuel used for cooking, number of days in a week for smoking fish and ASF diversity

4.5 Mean dietary diversity and ASF diversity among women in the study

In unadjusted analysis, women in FSL group had a significantly lower mean ± SD dietary diversity score compared with women in NFSL (Table 7). This significant difference in the dietary diversity in the unadjusted analysis however disappeared after controlling for potential confounders including marital status, educational level, average monthly salary, total members in the household and supplementary work. In the 7 days prior to the study, women in FSL had a lower mean ± SD animal source foods dietary diversity compared to women in NFSL, and this difference remained significant after controlling for potential confounders in the study.

Table 7: Mean ± SD dietary diversity and ASF diversity among women in the study

	Women in FSL (n=175)	Women in NFSL (n=155)	Difference in means (95% CI)	[1]P-value
Dietary diversity[5]				
Unadjusted	3.0 ± 1.0[2]	3.3 ± 1.0[2]	-0.3 (-0.4, -0.0)[3]	**0.032**
Adjusted[7]	3.1 ± 0.1[4]	3.2 ± 0.1[4]	-0.1 (-0.3, 0.1)[3]	0.388
ASF diversity[6]				
Unadjusted	2.7 ± 1.3[2]	3.4 ± 1.2[2]	-0.7 (-1.0, -0.4)[3]	**<0.001**
Adjusted[7]	2.8 ± 0.1[4]	3.3 ± 0.1[4]	-0.5 (-0.8, -0.2)[3]	**0.002**

[1] P-values are based on general linear model and ANCOVA (SAS PROC GLIMMIX) for Hb concentration (continuous variable).
[2] Values are mean ± SD
[3] Values are Difference in means (95% CIs)
[4] Values are mean ± SE
[5] Dietary diversity comprised 10 different food groups consumed in the past 24-hours (including starchy staples, fish poultry meat, Pulses, nuts and seeds, vitamin A rich fruits and vegetables, dairy, eggs, other fruits, other vegetables and dark green leafy vegetables.
[6] ASF diversity comprised 7 different animal food groups consumed in the past 7 (including fish and seafood, milk and milk products, livestock meats, eggs, poultry, organ meats and bushmeats.
[7] Adjusted for marital status, educational level, average monthly salary, total members in household and supplementary work.

4.6 Food groups consumed by women in the study

Figure 1 shows the proportions of women in the FSL and NFSL who consumed foods from the different food groups in the 24 hours preceding the interview. There was no significant difference in the consumption from the fish, poultry or meat food group between the two groups of women. A greater proportion of women in FSL consumed nuts and seeds than women in NFSL. Significantly lower proportion of women in FSL consumed from the dairy and pulses food groups compared to the women in NFSL. Though not significant, fewer women in FSL livelihood consumed fruits, vegetables and eggs than women in NFSL. Figure 2 presents the proportion of women consuming ASF in the past 7 days. With the exception of fish and seafood, a lower proportion of women, in FSL consumed milk and milk products, livestock meats, eggs, poultry and organ meats than women in NFSL. Only 3 women in the study consumed bushmeat.

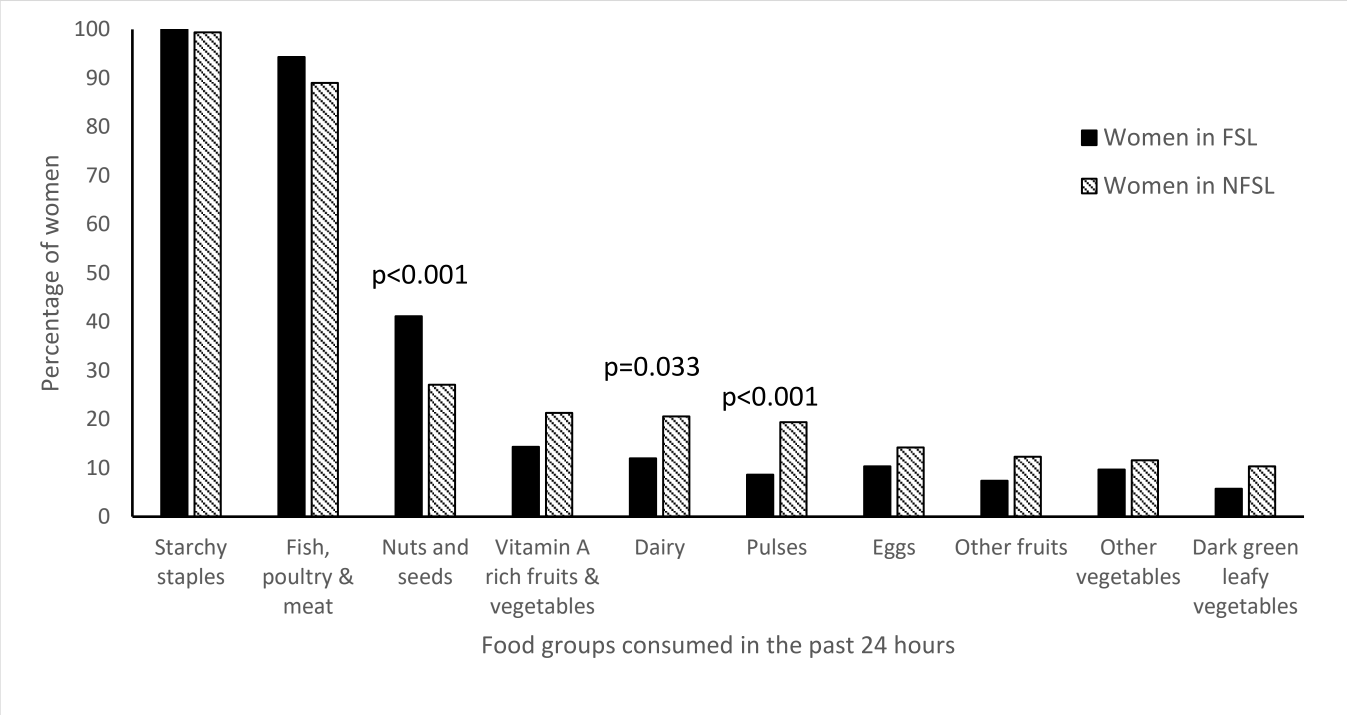

Figure 2: Food groups consumed by women in the study in the past 24 hours

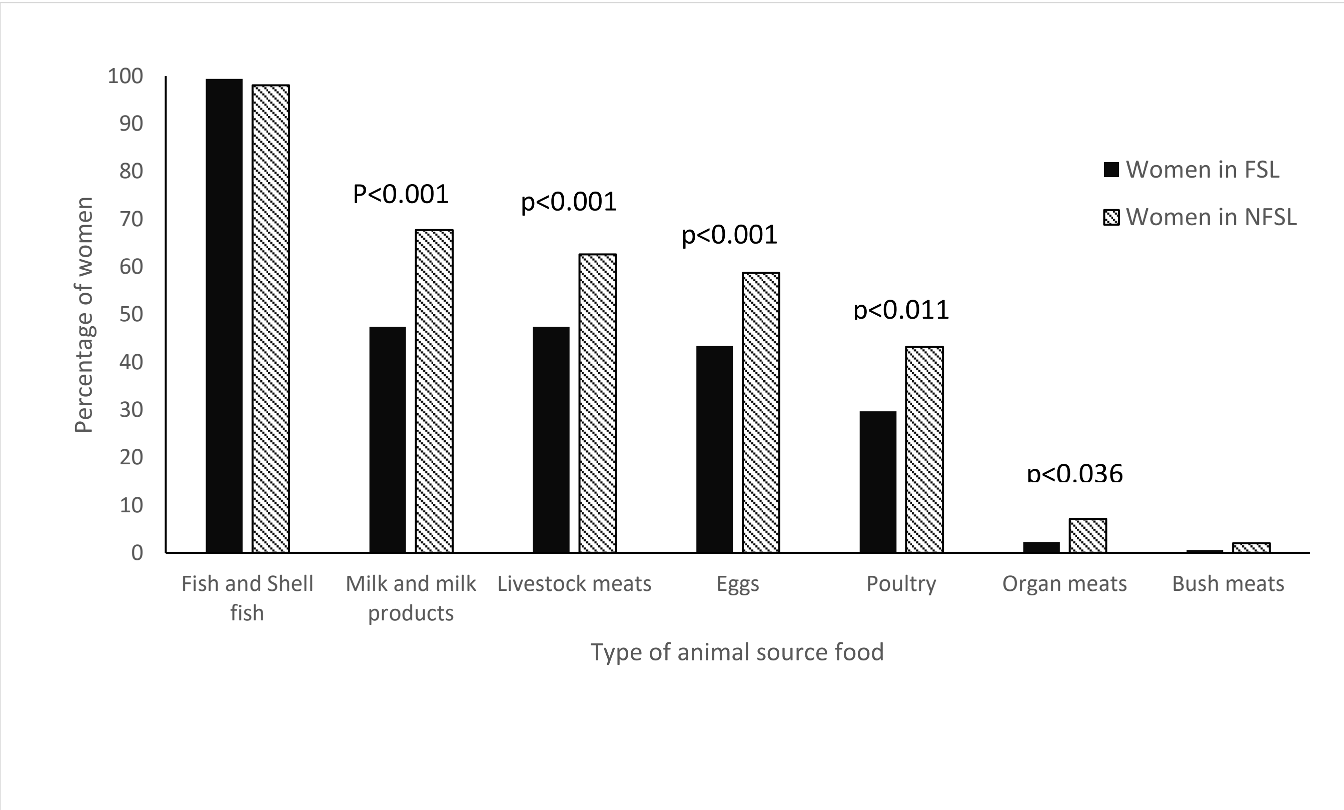

Figure 3: Consumption of animal source foods in the past 7 days by women in the study

4.7 Predictors of anaemia among women in the study

In a logistic regression model that included 11 potential predictors (Table 8), being in a fish smoking livelihood independently predicted anaemia when adjusting for all the other variables in the model. The relative risk of anaemia was 1.8 (95% CI = 1.1, 3.1) times greater among women in fish smoking livelihood than women in non-fish smoking livelihood. However, age, marital status, someone smokes cigarette in household, ever been pregnant, dewormed, fever, toilet facility, use of biomass as main fuel for cooking, the number of days in a week spent smoking fish, or ASF dietary diversity score did not independently predict anaemia when adjusting for all other variables in the model.

Table 8: Predictors of anaemia among women in the study

Characteristics	Relative Risks (95% CI)[2]	[1]P-value
Age		
Older (≥35 years)	1	
Younger (<35 years)	1.3 (0.9, 2.0)	0.165
Marital status		
Single	1	
Married	0.9 (0.6, 1.3)	0.529
Livelihood type		
Non-fish smoking livelihood	1	
Fish smoking livelihood	1.8 (1.1, 3.1)	**0.023**
Someone smokes cigarette in household		
No	1	
Yes	1.9 (1.0, 3.4)	0.051
Ever been pregnant		
No	1	
Yes	0.7 (0.4, 1.3)	0.311
Dewormed		
Yes	1	
No	0.8 (0.5, 1.1)	0.215
Fever		
No	1	
Yes	1.2 (0.8, 1.7)	0.416
Toilet facility		
Yes	1	
No	0.7 (0.5, 1.1)	0.092
Use of biomass fuel for cooking		
Other fuel	1	
Firewood	1.3 (0.8, 2.0)	0.315
Number of days in a week for smoking fish		
Fewer days	1	
More days	1.4 (0.9, 2.2)	0.163
ASF diversity		
High	1	
Low	1.4 (1.0, 2.1)	0.067

[1] P-value is based on logistic regression; dependent variable = anaemia (Yes/No)
[2] 95% CI = 95% confidence interval

CHAPTER FIVE

5.0 DISCUSSION

5.1 Background

This chapter discusses the findings of the study. The main aim of the study was to assess the relationship between anaemia and livelihood type of non-pregnant, non-lactating women of reproductive age (18-49 years), living in Biriwa. The difference between their animal source food intakes was also investigated. This section begins by discussing the prevalence of anaemia between the two groups of women, followed by reviewing their animal source food intake and ended with the predictors of anaemia among women in the study.

5.2 Prevalence of anaemia among women in the study

Almost a third of the women involved in the study were suffering from anaemia and based on the WHO cut-offs, this is classified as a moderate public health problem (WHO, 2009). This value is lower compared to the prevalence of anaemia among non-pregnant, non-lactating women in Ghana during the 2014 Demographic and Health Survey (41.3%). The prevalence in this study is however similar to the current value reported by the Ghana Micronutrient Survey in 2017, where anaemia prevalence among non-pregnant women of reproductive age in Ghana was about 22% (GMS, 2017). This overall lower anaemia prevalence among women in this study may have been as a result of majority of the women usually sleeping under treated mosquito nets as a result of the awareness created by health workers in the community about the health implication of malaria.

As our first specific objective, we set out to compare the mean haemoglobin concentration and anaemia prevalence between women in fish smoking and non-fish smoking livelihoods. The prevalence of anaemia among women in FSL was higher than women in NFSL after controlling for potential confounders in our study. The significant difference ($p=0.023$) of the adjusted anaemia prevalence in our study between the exposed group (women in FSL=37%) and the unexposed group (OL women= 20.3%) was similar to that of a study by Page et al. (2015) which found anaemia prevalence to be higher among rural pregnant women using biomass fuel for cooking (93%) than women who used cleaner fuel for cooking (88%) in Nagpur, India ($p<0.0001$). The higher prevalence in the Page et al. (2015) study may be due to the study participants being pregnant women therefore predisposing them to increased risk of anaemia. Pregnant women have been found to have a higher risk of anaemia due to the increased iron required for the development of the foetus (Siddiqui et al., 2017).

Women in FSL recorded lower mean haemoglobin concentration after controlling for potential confounders in our study compared to women in NFSL. This means that being in fish smoking livelihood irrespective of factors such as marital status, use of biomass for cooking, exposure to cigarette smoke, number of days spent smoking fish, and ASF diversity led to a 0.6 g/dl decrease in haemoglobin concentration. Actually, Particulate matter ($PM_{2.5}$), a compound from biomass fuel combustion which has been shown to increase systemic inflammation, was responsible for a 0.81 g/dL decrease in average haemoglobin among old American adults (Honda et al., 2017). Contrary to our study, there was no significant difference in haemoglobin concentration between women using smoky stoves for cooking and non-pregnant women who used the smokeless stove in a study in Guatemala (13.8 g/dl vs 13.7 g/dl; $p=0.20$) (Neufeld et al., 2004). A major limitation to this study acknowledged by the authors was the power used to calculate the sample size (0.65), which might have hindered the ability to detect a difference in haemoglobin concentration between the two groups of women.

5.3 Intake of animal source foods

In Ghana, diversity of diet is usually low due to the heavy reliance on starchy roots and cereals. Based on the 24-hour recall, women in this study relied mainly on starchy staples; as a matter of fact, only one person did not consume any starchy staple. A similar study in the Ashanti Region of Ghana revealed that starchy staples formed well over 60% of their total energy intake (Wald et al., 2019). This high intake of starchy staples might be explained by the availability and low cost of these food. The overall dietary diversity score of women in both groups was below the minimum requirement of ≥5 food groups according to the FAO (FAO, 2016).

The second specific objective of this study was to compare the animal source food diversity between women in fish smoking livelihood and women in non-fish smoking livelihood. Our results showed that the common animal source food consumed by the women was fish and seafood. Almost all women in the study had consumed fish and seafood in the past seven days prior to the interview. This supports the claim by FAO (2017) that fish is the most vital animal protein source which forms a significant portion of a typical Ghanaian diet. Gordon et al. (2013) emphasized that in coastal nations such as Ghana, fish forms over 60% of their animal source food supply. The average consumption of fish in Ghana is currently 28 kg per capita per annum which is greater than the world's mean per capita consumption of 18.9 kg and Africa's mean consumption of 10.5 kg (Tall & Failler, 2012). Contrary to our results, a study in Ethiopia by Workicho et al. (2016) showed that fish was part of the foods which were least consumed by the various households. In the present study, we have found out that there was no significant difference in the consumption of fish and seafood between the two groups of women in the study within the past week. Since Biriwa is a fishing community, it may be that access to fish is easier and less expensive even for the women who are not involved in any kind of fish processing livelihood.

Intake of variety of ASF even in small amounts is widely known to improve health and nutritional status. From our results, compared with women in FSL, women in NFSL consumed a wider variety of animal source foods. The difference between the intakes of both groups remained significant after controlling for confounders such as marital status, the total number of household members, average monthly income, supplementary work and educational level. Fish and seafood which was the major ASF of the women in FSL is not a known rich source of iron as compared to meat and poultry which was consumed more by the women in NFSL. Studies have found a positive correlation between the intake of red meat and iron (Blanco-Rojo et al., 2014; Blanton, 2013). Blanton (2013) found that young women who consumed beef had increased levels of serum ferritin and iron concentration compared to women who ate a non-beef meal after 16 weeks of the controlled trial. Also in the Blanco-Rojo et al. (2014), high intake of red meat was found to be a strong predictor of better iron status of women.

Milk is a rich source of protein and minerals such as phosphorus and calcium. Increased consumption of milk may inhibit the absorption of iron in the body which can lead to iron-deficiency anaemia due to its high calcium concentration (Beck et al., 2014). Although almost 50% of the women in FSL had consumed milk in the past 7 days, the 24-hour recall shows a picture of their poor intake of other vitamin C rich foods which aids the absorption of iron in foods. It was observed in a study among girls that, those who usually consumed high vitamin C rich diet had normal haemoglobin compared with those consuming low vitamin C rich diet (Safwan, 2017). From our study more women in NFSL consumed eggs within the past 7 days compared to women in FSL. In a study by Workicho et al. (2016), it was revealed that the consumption of eggs actually depends on the socioeconomic status of a particular household unlike our study which was based on the type of livelihood. As revealed by our study, only 3 women consumed bushmeat within the past 7 days. This result was possibly due to Biriwa being a coastal town, therefore, more people particularly the men are mostly involved in fishing rather than hunting which makes the meat rarely available for consumption.

The overall frequency of consumption of animal source foods in our study may have been due to cost, food preference and health reasons. Similar reasons were stated by Cornelsen et al. (2016) where households who usually consumed animal source foods were driven by the taste followed by the nutritional value. The cost of the ASF was stated as the main barrier in most of the households who did not usually consume ASF, followed by the taste. Some households also stated accessibility as a hindrance (Cornelsen et al., 2016). Although more women in FSL received more than GH₵500 per month, it did not reflect on their diet. This may be due to women in FSL having a bigger household size and majority of them being married. A bigger household size means a lot of people to feed which may affect food choices, distribution and its availability (Gitagia et al., 2019). According to Chai et al. (2019) married women usually have poor nutritional status because they often neglect their own needs due to their roles as both a mother and a wife.

5.4 Predictors of anaemia

In our study livelihood type was the only factor which independently predicted anaemia among women in this study. The relative risk of anaemia was 1.8 times greater among women in FSL than women in NFSL. That is, there was an 80% increased relative risk of anaemia among women in FSL compared with women in NFSL. Our result was consistent with the multivariate analysis of the Page et al. (2015) study which showed that the adjusted relative risk of moderate to severe anaemia among pregnant women was 1.79 (95% CI = 1.53 – 2.09) times greater in biomass fuel users than among pregnant women who were clean fuel users (Page et al., 2015)

There have been four other studies which have looked at the association of exposure to biomass smoke and anaemia among children. All four studies were based on secondary analysis of already existing data (Accinelli & Leon-Abarca, 2017; Kyu et al., 2010; Machisa et al., 2013; Mishra & Retherford, 2006). Our results were similar to the Mishra & Retherford (2006) study which used national data of about 29,000 children under three years. Their results showed that the relative risk of moderate to severe anaemia was 1.58 (95% CI = 1.28 – 1.94) greater among children from households using only biomass fuel than children living in households using cleaner fuels even after controlling for confounders such as age, sex, maternal education and recent episodes of illness of the child and other factors. A common confounder in their study which was also controlled in our study was household exposure to cigarette smoke, which did not significantly affect the risk of being anaemic. There was an association between moderate to severe anaemia and biomass fuel use among children under 5 years from 29 developing countries after controlling for various covariates in the Kyu et al. (2010) studies. According to studies by Accinelli & Leon-Abarca (2017), irrespective of the prevalence of measles immunization, anaemia in pregnant mothers, tobacco, girls' primary education and life expectancy, exposure to biomass fuel smoke was a significant independent predictor of anaemia (P-value=0.012) among children under 5 from 193 countries. However, addition of sanitation access and income per capita to the model rendered it insignificant. This may be due to the fact that most of the under-developed countries have sanitation as a greater cause of anaemia compared with exposure to biomass fuel. Also, the income per capita may determine the use of biomass fuel or cleaner fuels (Accinelli & Leon-Abarca, 2017). Contrary to our studies, Machisa et al. (2013), revealed that there was no significant association between household biomass fuel use and anaemia among children (6-36 months) in Swaziland.

However, a major limitation to this study was the failure to assess exposure to biomass fuel smoke other than cooking which may have been higher especially during winter seasons.

Our study suggests that women who use firewood for smoking fish in their occupation have an increased risk of anaemia irrespective of age, marital status, fever, dewormed, ever been pregnant, exposure to cigarette smoke from household, fuel used for cooking, the number of days spent smoking fish in a week and ASF diversity. Though the mechanism is not clear, according to Padhy & Padhi (2009) smoke from biomass fuel can induce oxidative stress and cause adverse health effect among children. Some studies have shown that $PM_{2.5}$, a major compound produced by the combustion of biomass fuel triggers inflammations which negatively impact bone simulation leading to decreased haemoglobin production (Cliff et al., 2016; Dabass et al., 2016; Page et al., 2015). Engagement in FSL in our study may have independently predicted anaemia among our study population due to the long hours and days spent by women in FSL smoking fish compared with women in NFSL. In a sensitivity analysis among women in fish smoking livelihood only, it was observed that women who were highly exposed (Exposure Index = ≥60) had point estimate for unadjusted or adjusted mean haemoglobin concentration which was lower than that of women in FSL who had low exposure (Exposure Index =< 60). Again, women highly exposed had point estimate for unadjusted or adjusted anaemia prevalence greater than women who had low exposure. However, these associations were not significant. In a similar study by Sukhsohale et al. (2013) among non-pregnant women in Nagpur, India, women who were exposed to biomass fuel smoke through cooking for a longer time (EI= >100) were more anaemic ($p<0.001$). Since there was a level of exposure by all women in our study, the length of exposure to smoke and the heavy reliance on fish and seafood as their main source of ASF may be the main factors for the increased risk of anaemia among women in FSL.

5.5 Limitations of the study

A limitation to this study was grouping women by livelihood type using questionnaire which may have over- or under-estimated exposure to biomass smoke. Since fish smoking is a common livelihood among women in Biriwa, passive inhalation of smoke from the environment by women who do not smoke fish as their primary livelihood may be high. The smoke produced due to the combustion of biomass fuel emits certain concentration of pollutants, therefore direct measurement would have shown a better exposure and association. Though self-reported, our study failed to directly screen for malaria, sickle cell trait and worm infection for the women since these factors are well-known contributors to low haemoglobin concentration in humans.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Almost a third of women in this population were suffering from anaemia. The prevalence of anaemia was higher in women in fish smoking livelihood compared with women in non-fish smoking livelihood after controlling for confounders in the study. Women in non-fish smoking livelihood consumed a wider variety of animal source foods than women in fish smoking livelihood. Fish smoking livelihood independently predicted anaemia in our study. That is, the relative risk of anaemia was 1.8 (95% CI = 1.1 – 3.1) times greater among women in fish smoking livelihood than women in non-fish smoking livelihood irrespective of, age, marital status, living in household where someone smokes cigarette, ever been pregnant, dewormed, fever, toilet facility, use of biomass as main fuel for cooking, the number of days in a week spent smoking fish or ASF diversity.

6.2 Recommendation

Our study could be improved by directly measuring biomass smoke exposure and thoroughly assessing the history of biomass fuel use. Also, further studies in which control women are selected from non-fishing communities should be done, since women who do not smoke fish as a livelihood in our study were also somehow exposed to smoke just as consistently as women in fish smoking livelihood. Compared to the 2014 Demographic Health Survey, the anaemia prevalence among women in our study is lower, however, it is still classified as a moderate public health problem among our population. Therefore, to improve the health status and decrease the prevalence of anaemia of women in our study, we suggest the following;

- Women, especially women in fish smoking livelihood should diversify their diets and eat more iron-rich foods, given that they mainly consumed fish as a source of protein.
- Women in fish smoking livelihood, switch to the use of more improved ovens which has chimneys installed for their fish smoking business.
- Interventions should be put in place to improve the sanitation and hygienic conditions of the community. Women should also be educated to avoid open defecations, washing of hands and proper food preparation to avoid the loss of nutrients and to reduce worm infestation due to poor sanitation.

REFERENCES

Accinelli, R. A., & Leon-Abarca, J. A. (2017). Solid fuel use is associated with anemia in children. *Environmental Research*, *158*(January), 431–435. https://doi.org/10.1016/j.envres.2017.06.032

AFDB. (2016). Empowering Women in Africa through Access to Sustainable Energy. Retrieved May 27, 2019, from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/AfDB-Gender_and_Energy_Desk_Review-EN-2016.pdf

Akca, S., & Bostanci, M. (2017). The impact of anemia and body mass index (BMI) on neuromotor development of preschool children. *Scielo Analytics*, *63*(9), 779–786.

Attimogge, H. P. K., & Devi, G. (2014). Utilization pattern of biomass energy and socioeconomic dimensions associated with Yelandur , Karnataka , India. *International Journal of Energy and Environmental Engineering*, *5*(2–3), 95. https://doi.org/10.1007/s40095-014-0095-3

Beck, K. L., Conlon, C. A., Kruger, R., & Coad, J. (2014). Dietary determinants of and possible solutions to iron deficiency for young women living in industrialized countries: A review. *Nutrients*, *6*(9), 3747–3776. https://doi.org/10.3390/nu6093747

Blanco-Rojo, R., Toxqui, L., López-Parra, A. M., Baeza-Richer, C., Pérez-Granados, A. M., Arroyo-Pardo, E., & Vaquero, M. P. (2014). Influence of diet, menstruation and genetic factors on iron status: A cross-sectional study in Spanish women of childbearing age. *International Journal of Molecular Sciences*, *15*(3), 4077–4087. https://doi.org/10.3390/ijms15034077

Blanton, C. (2013). Improvements in iron status and cognitive function in young women consuming beef or non-beef lunches. *Nutrients*, *6*(1), 90–110. https://doi.org/10.3390/nu6010090

Boy, E., Bruce, N., & Delgado, H. (2002). Birth weight and exposure to kitchen wood smoke during pregnancy in rural Guatemala. *Environmental Health Perspectives*, *110*(1), 109–114. https://doi.org/10.1289/ehp.02110109

Bruce, N., Dherani, M., Liu, R., Hosgood, H. D., Sapkota, A., Smith, K. R., … Pope, D. (2015). Does household use of biomass fuel cause lung cancer? A systematic review and evaluation of the evidence for the GBD 2010 study. *Thorax*, *70*(5), 433–441. https://doi.org/10.1136/thoraxjnl-2014-206625

Castellanos-Sinco, H. ., Ramos-Penafiel, C. ., Santoyo-Sanchez, A., Collazo-Jaloma, J., Martinez-Murillo, C., Montano-Figueroa, E., & Sinco-Angeles, A. (2015). Megaloblastic anaemia : Folic acid and vitamin B12 metabolism Megaloblastic anaemia : Folic acid and vitamin B12. *Revista Médica Del Hospital General de México*, *78*(3), 135–143. https://doi.org/10.1016/j.hgmx.2015.07.001

CDC. (2015). Nbs_Hemoglobinopathy-Testing. Retrieved June 7, 2019, from https://www.cdc.gov/ncbddd/sicklecell/documents/nbs_hemoglobinopathy-testing_122015.pdf

CDC. (2019). Soil-Transmitted Helminths. Retrieved June 7, 2019, from https://www.cdc.gov/parasites/sth/index.html

Cecelski, E., & Matinga, M. (2014). Cooking with gas: Why women in developing countries want LPG and how they can get it. Retrieved June 12, 2019, from https://www.wlpga.org/wp-content/uploads/2015/09/2014-cooking-with-lp-gas-women-report.pdf

Chai, Z. F., Gan, W. Y., Chin, Y. S., Ching, Y. K., & Appukutty, M. (2019). Factors associated with anemia among female adult vegetarians in Malaysia. *Nutrition Research and Practice*, *13*(1), 23–31. https://doi.org/10.4162/nrp.2019.13.1.23

Cliff, R., Curran, J., A. Hirota, J., Brauer, M., Feldman, H., & Carlsten, C. (2016). Effect of diesel exhaust inhalation on blood markers of inflammation and neurotoxicity: A controlled, blinded crossover study. *Inhalation Toxicology*, *28*(3), 145–153. https://doi.org/10.3109/08958378.2016.1145770

Coffey, D., Geruso, M., & Spears, D. (2018). Sanitation, Disease Externalities and Anaemia: Evidence From Nepal. *Economic Journal*, *128*(611), 1395–1432. https://doi.org/10.1111/ecoj.12491

Cornelsen, L., Alarcon, P., Häsler, B., Amendah, D. D., Ferguson, E., Fèvre, E. M., … Rushton, J. (2016). Cross-sectional study of drivers of animal-source food consumption in low-income urban areas of Nairobi, Kenya. *BMC Nutrition*, *2*(1), 1–13. https://doi.org/10.1186/s40795-016-0109-z

Dabass, A., Talbott, E. O., Venkat, A., Rager, J., Marsh, G. M., Sharma, R. K., & Holguin, F. (2016). Association of exposure to particulate matter (PM2.5) air pollution and biomarkers of cardiovascular disease risk in adult NHANES participants (2001-2008). *International Journal of Hygiene and Environmental Health*, *219*(3), 301–310. https://doi.org/10.1016/j.ijheh.2015.12.002

Dienye, P., Akani, A., & Okokon, I. (2016). Respiratory effects of biomass fuel combustion on rural fish smokers in a Nigerian fishing settlement: A case control study. *African Health Sciences*, *16*(2), 516–523. https://doi.org/10.4314/ahs.v16i2.20

Dongmo Keumo Jiazet, J. H. (2019). Potential Impact of Fish Smoking on Mangrove Resources in Southwest Cameroon. *Tropical Conservation Science*, *12*, 194008291983330. https://doi.org/10.1177/1940082919833300

Energy Commission. (2006). Woodfuels and renewables. *Danish International Development Agency*, 36. Retrieved from http://energycom.gov.gh/files/snep/WOOD FUEL final PD.pdf

FAO. (2016). Minimum Dietary Diversity for Women A Guide to Measurement. Retrieved June 26, 2019, from http://www.fao.org/3/a-i5486e.pdf

FAO. (2017). Fishery and Aquaculture Country Profiles (Ghana). Retrieved June 26, 2019, from http://www.fao.org/fishery/facp/NGA/en

FAO. (2018). The State of World Fisheries and Aquaculture. Meeting the sustainable development goals. Retrieved May 28, 2019, from http://www.fao.org/3/i9540en/I9540EN.pdf

Fernández-Gaxiola, A. C., De-Regil, L. M., & Nasser, M. (2011). Intermittent iron supplementation for reducing anaemia and its associated impairments in menstruating women. *Cochrane Database of Systematic Reviews*, (1). https://doi.org/10.1002/14651858.cd009218

Fielding, J., Lang, W., & White, O. B. (2001). Carbon Monoxide Poisoning. *Cognitive and Behavioral Neurology*, *23*(4), 256–261. https://doi.org/10.1097/WNN.0b013e3181c5e2c1

Figueiredo, A., Cruz, S., Lyrio, A., Silva, R., Mata, F., Pereira, P., … Souza, E. (2018). Maternal Anemia and Low Birth Weight: A Systematic Review and Meta-Analysis. *Nutrients*, *10*(5), 601. https://doi.org/10.3390/nu10050601

GDHS. (2014). *Ghana Demographic Health Survey*. *[GSS, GHS, AND ICF INTERNATIONAL]*. Retrieved from https://dhsprogram.com/pubs/pdf/FR307/FR307.pdf

Ghana Statistical Service. (2012). 2010 Population and Housing Census. *Ghana Statistical Service*, 1–117. https://doi.org/10.1371/journal.pone.0104053

Girum, T., & Wasie, A. (2018). The Effect of Deworming School Children on Anemia Prevalence: A Systematic Review and Meta-Analysis. *The Open Nursing Journal*, *12*(1), 155–161. https://doi.org/10.2174/1874434601812010155

Gitagia, M. W., Ramkat, R. C., Mituki, D. M., Termote, C., Covic, N., & Cheserek, M. J. (2019). Determinants of dietary diversity among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru, Kenya. *Food & Nutrition Research*, *63*(0), 1–12. https://doi.org/10.29219/fnr.v63.1553

GMS. (2017). *Ghana Micronutrient Survey*. Accra. Retrieved from http://groundworkhealth.org/wp-content/uploads/2018/06/UoG-GroundWork_2017-GHANA-MICRONUTRIENT-SURVEY_Final_180607.pdf

Gopalakrishnan, S., Eashwar, V. M., Muthulakshmi, M., & Geetha, A. (2018). Intestinal parasitic infestations and anemia among urban female school children in Kancheepuram district, Tamil Nadu. *Journal of Family Medicine and Primary Care*, *7*(6), 1395–1400.

Gordon, A., Finegold, C., Charles, C., & Pulis, A. (2013). FIsh Production, Consumption, and Trade in Sub-Saharan Africa: A Review Analysis, 1–51. Retrieved from http://pubs.iclarm.net/resource_centre/WF-3692.pdf

Gordon, A., Pulis, A., & Owusu-Adjei, E. (2011). Smoked marine fish from Western Region , Ghana : a value chain assessment, (July), 1–45.

Gupta, A., & Gadipudi, A. (2018). Iron Deficiency Anaemia in Pregnancy : Developed Versus Developing Countries. *European Medical Journal*, *6*(1), 101–109.

Haidar, J. (2010). Prevalence of anaemia, deficiencies of iron and folic acid and their determinants. *J Health Popul Nutr*, *28*(4), 359.

Hariz, A., & Bhattacharya, P. T. (2019). Megaloblastic Anemia. *StatPearls Publishing*, 1–14. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK537254/

Honda, T., Pun, V., Manjourides, J., & Helen, S. (2017). Anemia prevalence and hemoglobin levels are associated with long-term exposure to air pollution in an older population. *Environment International*, *101*(2), 125–132. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L614272295%0Ahttp://dx.doi.org/10.1016/j.envint.2017.01.017

Hong, R., Betancourt, J. A., & Ruiz-beltran, M. (2007). Passive smoking as sa risk factor of anemia in young children aged 0-35 months in Jordan. *BMC Pediatrics*, *10*, 1–10. https://doi.org/10.1186/1471-2431-7-16

Horton, S., & Ross, J. (2003). The economics of iron deficiency. *Food Policy*, *28*, 51–75. https://doi.org/10.1016/S0306-9192(02)00070-2

Invisible Fishers. (2019). The Invisible Fishers Project: Summary of Key Findings. *Unpublished Manuscript*.

Jangjoo, S., & Hosseini, L. (2016). The Prevalence of Iron-Deficiency Anemia in Non-Pregnant Women of Reproductive Age [14-45] with Anemia in Marvdasht ' s Shahid Motahari Hospital in 2012-2013. *Electronic Journal of Biology*, *12*(3), 294–299.

Jáuregui-lobera, I. (2014). Iron deficiency and cognitive-functions. *Dove Medical Press Limited*, *10*, 2087–2095.

Joosten, E., & Lioen, P. (2015). Iron deficiency anemia and anemia of chronic disease in geriatric hospitalized patients: How frequent are comorbidities as an additional explanation for the anemia? *Geriatrics and Gerontology International*, *15*(8), 931–935. https://doi.org/10.1111/ggi.12371

Kalasuramath, S., Vinodkumar, C. S., Kumar, M., & Ginnavaram, M. V. (2015). Impact of anemia , iron deficiency on physical and cardio respiratory fitness among young working women in India. *Indian Journal of Basic and Applied Medical Research*, *4*(4), 119–126.

Kamal, A., Cincinelli, A., Martellini, T., & Malik, R. N. (2015). A review of PAH exposure from the combustion of biomass fuel and their less surveyed effect on the blood parameters. *Environmental Science and Pollution Research*, *22*(6), 4076–4098. https://doi.org/10.1007/s11356-014-3748-0

Karakochuk, C. D., Whitfield, K. C., Barr, S. I., Lamers, Y., Devlin, A. M., Vercauteren, S. M., … Green, T. J. (2015). Genetic Hemoglobin Disorders Rather Than Iron Deficiency Are a Major Predictor of Hemoglobin Concentration in Women of Reproductive Age in Rural Prey Veng, Cambodia. *The Journal of Nutrition*, *145*(1), 134–142. https://doi.org/10.3945/jn.114.198945

Karimi, M., Cohan, N., & Parand, S. (2015). Thalassemia and Women ' s Health, *2*(3), 2–3.

Keles, S., Bilgen, S., & Kaygusuz, K. (2017). Biomass energy source in developing countries. *Journal of Engineering Research and Applied Science*, *6*(1), 566–576.

Khaskheli, M., Baloch, S., Sheeba, A., Baloch, S., & Khaskheli, F. (2016). Iron deficiency anaemia is still a major killer of pregnant women. *Pakistan Journal of Medical Sciences*, *32*(3), 630–634.

Kiggundu, V. L., O'Meara, W. P., Musoke, R., Nalugoda, F. K., Kigozi, G., Baghendaghe, E., … Wools-Kaloustian, K. K. (2013). High prevalence of malaria parasitemia and anemia among hospitalized children in Rakai, Uganda. *PLoS ONE*, *8*(12), 8–13. https://doi.org/10.1371/journal.pone.0082455

Killip, S., Bennett, J. M., & Chambers, M. D. (2007). Iron deficiency anemia. *American Family Physician*, *78*(8), 671–678. https://doi.org/10.1177/0884533608314536

Kim, J. Y., Shin, S., Han, K., Lee, K. C., Kim, J. H., Choi, Y. S., … Ko, B. J. (2014). Relationship between socioeconomic status and anemia prevalence in adolescent girls based on the fourth and fifth Korea National Health and Nutrition Examination Surveys. *European Journal of Clinical Nutrition*, *68*(2), 253–258.

Kohne, E. (2011). Hemoglobinopathies: Clinical manifestations, diagnosis, and treatment. *Deutsches Arzteblatt*, *108*(31–32), 532–540. https://doi.org/10.3238/arztebl.2011.0532

Kwarteng, E., Nsiah, A., Samey, B., Boateng, L., & Aziebor, E. (2016). Livelihood Options Synthesis Report, The USAID/Ghana Sustainable Fisheries Management Project (SFMP), 84. Retrieved from http://www.crc.uri.edu/projects_page/ghanasfmp/

Kyu, H. H., Georgiades, K., & Boyle, M. H. (2010). Biofuel Smoke and Child Anemia in 29 Developing Countries: A Multilevel Analysis. *Annals of Epidemiology*, *20*(11), 811–817. https://doi.org/10.1016/j.annepidem.2010.07.096

Lahner, E., & Annibale, B. (2009). Pernicious anemia : New insights from a gastroenterological point of view. *World Journal of Gastroenterology*, *15*(41), 5121–5128. https://doi.org/10.3748/wjg.15.5121

Lopez, A., Cacoub, P., Macdougall, I. C., & Peyrin-biroulet, L. (2016). Iron deficiency anaemia. *The Lancet*, *387*(10021), 907–916. https://doi.org/10.1016/S0140-6736(15)60865-0

Loy, S. L., Lim, L. M., Chan, S., Tan, P. T., Chee, Y. L., Quah, P. L., … Chi, C. (2019). Iron status and risk factors of iron deficiency among pregnant women in Singapore: a cross-sectional study. *BMC Public Health*, *19*(1), 397. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L627363247%0Ahttp://dx.doi.org/10.1186/s12889-019-6736-y

Macciò, A., Madeddu, C., Gramignano, G., Mulas, C., Tanca, L., Cherchi, M. C., … Ganz, T. (2015). The role of inflammation, Iron, And nutritional status in cancer-related anemia: Results of a large, Prospective, Observational study. *Haematologica*, *100*(1), 124–132.

Machisa, M., Wichmann, J., & Nyasulu, P. S. (2013). Biomass fuel use for household cooking in Swaziland: Is there an association with anaemia and stunting in children aged 6-36 months? *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *107*(9), 535–544. https://doi.org/10.1093/trstmh/trt055

Mann, S. K., Kaur, S., & Bains, K. (2002). Iron and energy supplementation improves the physical work capacity of female college students, *23*(1), 57–64.

Mengist, H. M., Zewdie, O., & Belew, A. (2017). Intestinal helminthic infection and anemia among pregnant women attending ante-natal care (ANC) in East Wollega, Oromia, Ethiopia. *BMC Research Notes*, *10*(1), 1–9. https://doi.org/10.1186/s13104-017-2770-y

Mickey, R. M., & Greenland, S. (1989). The impact of confounder selection criteria on effect estimation. *American Journal of Epidemiology*, *129*(1), 125–137. https://doi.org/10.1093/oxfordjournals.aje.a115101

Mishra, V. (2003). Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe. *International Journal of Epidemiology*, *32*(5), 847–853. https://doi.org/10.1093/ije/dyg240

Mishra, V., & Retherford, R. (2006). Does biofuel smoke contribute to anemia and stunting in early childhood. *International Journal of Epidemiology*, *36*(1), 1–33.

Modell, B., & Darlison, M. (2008). Global epidemiology of haemoglobin disorders and derived service indicators. *Bulletin of the World Health Organization*, *86*(6), 480–487. https://doi.org/10.2471/BLT.06.036673

Morandi, M. T., Ward, T. J., & Workgroup, A. (2009). Wood smoke risk assessment : Defining the questions. *Inhalation Toxicology*, 1–5. https://doi.org/10.3109/08958370903008854

Muoneke, V., Ibekwe, R., Nebe-Agumadu, H., & Ibe, B. (2012). Factors Associated with Mortality in Under-Five Children with Severe Anemia in Ebonyi, Nigeria. *Indian Pediatrics*, *49*(2), 119–123.

Murray-kolb, L. E., & Beard, J. L. (2007). Iron treatment normalizes cognitive functioning in young women. *American Journal of Clinical Nutrition*, *85*(3), 778–787.

Murray, B. M. L. (2007). *Antepartal and Intrapartal Fetal Monitoring* (3rd ed.). Springer Publishing Company.

Nemeth, E., & Ganz, T. (2014). Anemia of nflammation. *Hematology/Oncology Clinics of North America*, *28*(4), 671–681. https://doi.org/10.1016/j.hoc.2014.04.005

Neufeld, L. M., Haas, J. D., Ruel, M. T., Grajeda, R., & Naeher, L. P. (2004). Smoky indoor cooking fires are associated with elevated hemoglobin concentration in iron-deficient women. *Pan Am J Public Health*, *15*(2), 110–118. https://doi.org/10.1590/S1020-49892004000200006

NIH. (2019). Anemia of Inflammation or Chronic Disease | NIDDK. Retrieved June 9, 2019, from https://www.niddk.nih.gov/health-information/blood-diseases/anemia-inflammation-chronic-disease

NORD. (2018). Anemia of Chronic Disease - NORD (National Organization for Rare Disorders). Retrieved June 9, 2019, from https://rarediseases.org/rare-diseases/anemia-of-chronic-disease/

Padhy, P., & Padhi, B. (2009). Effects of biomass combustion smoke on hemotological and antioxidant provile among children (8-13 years) in India. *Inhalation Toxicology*, *21*(8), 705–711.

Page, C. M., Patel, A., & Hibberd, P. L. (2015). Does smoke from biomass fuel contribute to Anemia in pregnant women in Nagpur, India? A cross-sectional study. *PLoS ONE*, *10*(5), 1–13. https://doi.org/10.1371/journal.pone.0127890

Pasricha, S., Caruana, S. R., Phuc, T. O., Casey, G. J., & Jolley, D. (2017). Anaemia , Iron Deficiency , Meat Consumption and Hookworm Infection in Women of Reproductive Age in Northwest Vietnam, *78*(3), 375–381.

Pemberton, Pigott, C., Robinson, J., Kwarteng, E., & Boateng, L. (2016). Low PAH Improved Fish Smoking Stove Design Development Report. Retrieved May 10, 2019, from http://www.crc.uri.edu/projects_page/ghanasfmp/

Petrou, S. (2003). Economic consequences of preterm birth and low birthweight. *International Journal of Obstetrics and Gynaecology*, *110*, 17–23. https://doi.org/10.1016/S1470-0328(03)00013-2

Petry, N., Olofin, I., Hurrell, R. F., Boy, E., Wirth, J. P., Moursi, M., … Rohner, F. (2016). The proportion of anemia associated with iron deficiency in low, medium, and high human development index countries: A systematic analysis of national surveys. *Nutrients*, *8*(11), 1–17. https://doi.org/10.3390/nu8110693

Piddock, K. C., Gordon, S. B., Ngwira, A., Msukwa, M., Nadeau, G., Davis, K. J., … Mortimer, K. (2014). A cross-sectional study of household biomass fuel use among a periurban population in Malawi. *Annals of the American Thoracic Society*, *11*(6), 908–914. https://doi.org/10.1513/AnnalsATS.201311-413OC

Prockop, L. D., & Chichkova, R. I. (2007). Carbon monoxide intoxication: An updated review. *Journal of the Neurological Sciences*, *262*(1–2), 122–130. https://doi.org/10.1016/j.jns.2007.06.037

Raub, J. A., Mathieu-nolf, M., Hampson, N. B., & Thom, S. R. (2000). Carbon Monoxide Poisoning {\textemdash} a public health perspective. *Toxicology*, *145*(1), 1–14. https://doi.org/10.1016/s0300-483x(99)00217-6

Rizvi, A., Ariff, S., Hussain, I., Habib, A., Kureishy, S., Khan, G. N., … Umer, M. (2017). Prevalence and possible factors associated with anaemia, and vitamin B 12 and folate deficiencies in women of reproductive age in Pakistan: analysis of national-level secondary survey data. *BMJ Open*, *7*(12), e018007. https://doi.org/10.1136/bmjopen-2017-018007

Safwan, A. (2017). Association between Hemoglobin status with Vitamin C Intake. *Advances in Obesity, Weight Management & Control*, *6*(1), 25–28. https://doi.org/10.15406/aowmc.2017.06.00145

Saloojee, H., & Pettifor, J. M. (2002). Iron deficiency and impaired child development. *BMJ*, *323*(7326), 1377–1378. https://doi.org/10.1136/bmj.323.7326.1377

Salvi, S., & Brashier, B. (2014). Fish smoking and COPD: A fishy affair. *Lung India*, *31*(2), 105. https://doi.org/10.4103/0970-2113.129807

Santos, J., Rates, S., Lemos, S., & Lamounier, J. (2009). Consequences of anemia on language development of children from a public day care center. *Rev Paul Pediatr*, *27*(1), 67–73.

Scott, S. P., Chen-edinboro, L. P., Caulfield, L. E., & Murray-kolb, L. E. (2014). The Impact of Anemia on Child Mortality: An Updated Review. *Nutrients*, *6*(12), 5915–5932. https://doi.org/10.3390/nu6125915

Sen, A., & Kanani, S. J. (2006). Deleterious Functional Impact of Anemia on Young Adolescent School Girls. *Indian Pediatrics*, *43*(3), 219–226.

SFMP. (2016). Testing Of Low PAH Improved Fish Smoking Stove (Ahotor Oven). The USAID/Ghana Sustainable Fisheries Management Project (SFMP), 19.

Shah, B., Nepal, A., Agrawal, M., & Sinha, A. (2012). The Effects of Cigarette Smoking on Hemoglobin LEvels Compared Between Smokers and Non Smokers. *Sunsari Technical College Journal*, *1*(1), 42–44.

Shaw, J. G., & Friedman, J. F. (2011). Iron Deficiency Anemia : Focus on Infectious Diseases in Lesser Developed Countries. *Hindawi Publishing Corporation*, *2011*, 1–6. https://doi.org/10.1155/2011/260380

Siddiqui, M. Z., Goli, S., Reja, T., Doshi, R., Chakravorty, S., Tiwari, C., … Singh, D. (2017). Prevalence of Anemia and Its Determinants Among Pregnant, Lactating, and Nonpregnant Nonlactating Women in India. *SAGE Open*, *7*(3), 1–10.

SNV. (2019). Introducing the Ahotor Oven In the Volta Region of Ghana. Retrieved June 13, 2019, from www.snv.org/update/introducing-ahotor-oven-volta-region-ghana

Stevens, G. A., Finucane, M. M., De-Regil, L. M., Paciorek, C. J., Flaxman, S. R., Branca, F., … Ezzati, M. (2013). Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: A systematic analysis of population-representative data. *The Lancet Global Health*, *1*(1), 16–25. https://doi.org/10.1016/S2214-109X(13)70001-9

Sukhsohale, N., Narlawar, U., & Phatak, M. (2013). Indoor Air Pollution from Biomass Combustion and its Adverse Health Effects in Central India: An Exposure-Response Study. *Indian Journal of Community Medicine: Official Publication of Indian Association of Preventive and Social Medicine*, *38*(3), 162–167.

Sung, E., Choi, C., Kim, N., Kim, S., & Shin, M.-H. (2018). Association of Coffee and Tea with Ferritin : Data from the Korean National Health and Nutrition Examination Survey (IV and V), 178–183.

Tall, A., & Failler, P. (2012). Fishery and aquaculture industry in Ghana. *Series Report N°1 of the Review of the Fishery and Aquaculture Industry in the 22 ATLAFCO Member States*, (October 2012), 44. https://doi.org/10.13140/RG.2.1.1624.3362

Torres-Duque, C., Maldonado, D., Perez-Padilla, R., Ezzati, M., & Viegi, G. (2008). Biomass Fuels and Respiratory Diseases: A Review of the Evidence. *Proceedings of the American Thoracic Society*, *5*(5), 577–590. https://doi.org/10.1513/pats.200707-100rp

UNDP. (2001). Improved fish smoking: Ghana. Retrieved June 13, 2019, from http://tcdc2.undp.org

Viana, M. (2011). Anemia and infection: a complex relationship. *The American Journal of Medicine*, *52*(2), 242–253. https://doi.org/10.1016/0002-9343(72)90073-3

Wald, J. P., Asare, E., Nakua, E. K., Nohr, D., Lambert, C., Riedel, S., … Biesalski, H. K. (2019). Validation of a computer-based analysis tool for real-time dietary assessment within a Ghanaian region. *NFS Journal*. https://doi.org/10.1016/j.nfs.2019.06.002

Weiss, G., & Goodnough, L. T. (2005). Anemia of chronic disease. *The New England Journal of Medicine*, *352*(10), 1011–1023. https://doi.org/10.1056/NEJMra041809

WHA. (2012). WHA Global Nutrition Targets 2025 : Anaemia Policy Brief. Retrieved April 2, 2019, from https://apps.who.int/iris/bitstream/handle/10665/148556/WHO_NMH_NHD_14.4_eng.pdf?ua=1

White, N. J. (2018). Anaemia and malaria. *Malaria Journal*, *17*(1), 1–17. https://doi.org/10.1186/s12936-018-2509-9

WHO. (2006). Household Energy and Health Household Energy and Health.

WHO. (2009). Worldwide prevalence of anaemia, WHO Vitamin and Mineral Nutrition Information System, 1993-2005. *Public Health Nutr.*, *12*(4), 444–454. https://doi.org/10.1017/S1368980008002401

WHO. (2011). Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. *Vitamin and Mineral Nutrition Information System, World Health Organization*, 1–6. https://doi.org/2011

WHO. (2015). the Global Prevalence of Anaemia in 2011. *WHO Report*, 48. https://doi.org/10.1017/S1368980008002401

WHO. (2017). Nutritional Anaemias: Tools for effective Prevention. Retrieved June 7, 2019, from https://apps.who.int/iris/bitstream/handle/10665/259425/9789241513067-eng.pdf

WHO. (2019a). Genes and human diseases. Retrieved June 9, 2019, from https://www.who.int/genomics/public/geneticdiseases/en/index2.html

WHO. (2019b). Malaria. Retrieved June 7, 2019, from https://www.who.int/news-room/fact-sheets/detail/malaria

WHO. (2019c). Soil-transmitted helminth infections. Retrieved June 7, 2019, from https://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections

Workicho, A., Belachew, T., Feyissa, G. T., Wondafrash, B., Lachat, C., Verstraeten, R., & Kolsteren, P. (2016). Household dietary diversity and Animal Source Food consumption in Ethiopia: Evidence from the 2011 Welfare Monitoring Survey. *BMC Public Health*, *16*(1), 1–11. https://doi.org/10.1186/s12889-016-3861-8

World Bank. (2017). Wood-Based Biomass Energy Development for Sub-Saharan Africa. *Wood-Based Biomass Energy Development for Sub-Saharan Africa*. https://doi.org/10.1596/26149

Yadav, M. K., Manoli, N. M., & Madhunapantula, S. V. (2016). Comparative assessment of vitamin-B12, folic acid and homocysteine levels in relation to p53 expression in megaloblastic anemia. *PLoS ONE*, *11*(10), 1–17.

Yang, R.-Y., & Tsou, S. C. S. (2006). Enhancing Iron Bioavailability of Vegetables through Proper Preparation−Principles and Applications. *J. International Cooperation*, *1*(108), 107–119.

APPENDICES

APPENDIX I: Individual Consent form for Census

UNIVERSITY OF GHANA

Official Use only Protocol number

COLLEGE OF BASIC AND APPLIED SCIENCES

Ethics Committee for the College of Basic and Applied Sciences (ECBAS)

PROTOCOL CONSENT FORM

Section A- BACKGROUND INFORMATION

Title of Study:	Comparison of anaemia prevalence between women in fish smoking and non-fish smoking livelihoods in Biriwa in the Central Region of Ghana
Principal Investigator:	Daniel Armo-Annor
Certified Protocol Number	

Section B– CONSENT TO PARTICIPATE IN CENSUS

General Information about Census

We are going to undertake a research in Biriwa to assess whether the type of livelihood women engage in makes them vulnerable to certain health conditions such as anaemia. To do this we need to first identify women with certain characteristics who we can invite to participate in the study. We are therefore conducting this census to list households with non-pregnant, non-lactating adult women of reproductive age (18-49 years) from Biriwa to help us know those who will be eligible to take part in the research. . If you agree to participate in this activity you will be asked to indicate all women (18-49 years) who are part of this household, how long they have lived in the community, their livelihood and how long they have been doing that work, and whether they are currently participating in the Invisible Fishers project. The questions will take about 10 minutes to complete and you can skip any questions you do not wish to answer. The information gathered from this census will help us identify all potentially eligible women for the study.

Benefits of the study

You receive no direct benefits from participating in this census. However the census will help the research we will do, which may inform future interventions to improve the well-being of Ghanaian women.

Risk of the study

There are no risks involved in taking part in this census.

Confidentiality

Be assured that whatever information you provide will be kept strictly confidential and will not be shown to other people. The information provided will not be shared with anyone other than members of our survey team.

Compensation

Your participation in this interview is very important and we do appreciate the time you made available. You will receive no compensation for taking part in this census.

Withdrawal from Study

Your participation in this census is fully voluntary. You are free to refuse to answer any question without any penalty.

Contact for Additional Information

If you have any questions or concerns about the survey you may contact any of the following:

Daniel Armo-Annor (Graduate Student), Department of Nutrition and Food Science, P. O. Box LG 134, Legon, Accra. Tel: +233 50 639 7047

Dr. Esi Colecraft (Supervisor), Department of Nutrition and Food Science, P. O. Box LG 134, Legon, Accra. Tel: +233 24 410 7633

Dr. Seth Adu-Afarwuah (Co-supervisor), Department of Nutrition and Food Science, P. O. Box LG 134, Legon, Accra. Tel: +233 20 593 3805

Administrator, Ethics Committee for Basic and Applied Sciences, College of Basic and Applied Sciences University of Ghana, P. O. Box LG 68, Legon – Accra. Tel: + 233 207684121. Email:ethicscbas@ug.edu.gh

Section C- VOLUNTEER AGREEMENT

"I have read or have had someone read all of the above, asked questions, received answers regarding participation in this study, and I am willing to give consent for me, my child/ward to participate in this study. I have not waived any of my rights by signing this consent form. Upon signing this consent form, I will receive a copy for my personal records."

_________________	_________________	_________________
Name of Volunteer	Signature or mark of volunteer	Date

If volunteers cannot read the form themselves, a witness must sign here:

I was present while the benefits, risks and procedures were read to the volunteer. All questions were answered and the volunteer has agreed to take part in the research.

_________________	_________________	_________________
Name of witness	Signature of witness	Date

I certify that the nature and purpose, the potential benefits, and possible risks associated with participating in this research have been explained to the above individual.

_________________	_________________	_________
Name of Person who obtained Consent	Signature of Person who obtained Consent	Date

APPENDIX II: Individual consent form for research

UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

Ethics Committee for the College of Basic and Applied Sciences (ECBAS)

Official Use only Protocol number

PROTOCOL CONSENT FORM

Section A- BACKGROUND INFORMATION

Title of Study:	Comparison of anaemia prevalence between women in fish smoking and non-fish smoking livelihoods in Biriwa in the Central Region of Ghana
Principal Investigator:	Daniel Armo-Annor
Certified Protocol Number	

Section B– CONSENT TO PARTICIPATE IN RESEARCH

General Information about Research

We are doing a study to assess whether the type of livelihood women engage in predispose them to certain health conditions such as anaemia. The information from the study will help us make recommendations on how to prevent anaemia among women. You are being invited to participate in the study because you are a woman of reproductive age working and living in Biriwa and you are not part of the Invisible Fishers project. If you agree to participate in this research, someone will interview you about your background, household characteristics, reproductive history, health and dietary habits. In addition we take small sample (about a drop) of blood by finger prick so we can assess whether or not you have anaemia. We may also take picture of the data collection processes that may be used in presentations reports without personally identifying information. Everything will take about 50 minutes of your time.

Benefits of the study

You receive no direct benefits from participating in this research. However we will inform you of your anaemia status so you can seek appropriate treatment for yourself. Our study may also inform interventions to improve nutrition and health of women in Ghana including Biriwa.

Risk of the study

We do not anticipate any risks to you in taking part in this study. However, you may experience slight discomfort when the finger prick is made to get the blood sample. Persons taking the sample will be well-trained and take all necessary precautions to minimize any potential discomfort.

Confidentiality

Whatever information we obtain from you will be kept strictly confidential. We will use codes on all data collection forms so that no-one besides the research team can link your name directly with your information. The data we collected will also be protected by password on a secure laptop accessible only to the research team. The information collected will be disseminated in aggregate so individual participant information will not be identifiable. So you will never be identified personally in any report published from the study.

Compensation

You will receive one kitchen napkin and a bar of toilet soap as a token of appreciation to you for completing the interview.

Withdrawal from Study

Your participation in this study is completely voluntary. You are free to leave the study at any point in time or refuse to answer any question you do not wish to answer without any penalty to you

Contact for Additional Information

If you have any questions or concerns about the research you may contact any of the following:
Daniel Armo-Annor (Graduate Student), Department of Nutrition and Food Science, P. O. Box LG 134, Legon, Accra, Tel: +233 50 639 7047

Dr. Esi Colecraft (Supervisor), Department of Nutrition and Food Science, P. O. Box LG 134, Legon, Accra.Tel: +233 24 410 7633.

Dr. Seth Adu-Afarwuah (Co-supervisor), Department of Nutrition and Food Science, P. O. Box LG 134, Legon, Accra, Tel: +233 20 593 3805.

Administrator, Ethics Committee for Basic and Applied Sciences, College of Basic and Applied Sciences, University of Ghana, P. O. Box LG 68. Legon – Accra. Tel: + 233 207684121

Email: ethicscbas@ug.edu.gh

Section C- VOLUNTEER AGREEMENT

"I have read or have had someone read all of the above, asked questions, received answers regarding participation in this study, and I am willing to give consent for me, my child/ward to participate in this study. I have not waived any of my rights by signing this consent form. Upon signing this consent form, I will receive a copy for my personal records."

______________________________ ______________________________ ____________________

Name of Volunteer Signature or mark of volunteer Date

If volunteers cannot read the form themselves, a witness must sign here:

I was present while the benefits, risks and procedures were read to the volunteer. All questions were answered and the volunteer has agreed to take part in the research.

______________________________ ______________________________ ____________________

Name of witness Signature of witness Date

I certify that the nature and purpose, the potential benefits, and possible risks associated with participating in this research have been explained to the above individual.

______________________________ ______________________________ ____________

Name of Person who obtained Consent Signature of Person who obtained Consent Date

Appendix III: Questionnaire for census

SCREENING QUESTIONNAIRE

Name of Interviewer: ______________________________ Date: ________________

Household Number: __________________________ Participant ID ______________________.

1. How old are you? ______________.

2. Do you live in Biriwa? _______________

   [1] Yes [2] No

3. How long have you lived in Biriwa? _____________

4. What is the main work you do for income? ___________________

   [1] Fish Smoking [2] Vocational [3] Trading [4] Farming [5] Not working [6] Other (specify)

5. How long have you been in this occupation? ______________

6. Are you enrolled in the invisible fisher's project? ______________

   [1] Yes [2] No

7. If not a fish smoker, does anyone in your household smoke fish as a business in the house? ______________

   [1] Yes [2] No

8. Are you currently pregnant? ______________

   [1] Yes [2] No

9. Are you currently lactating?

   [1] Yes [2] No

Appendix IV: Research Questionnaire

QUESTIONNAIRE ON THE COMPARISON OF ANAEMIA PREVALENCE BETWEEN WOMEN IN FISH SMOKING AND NON-FISH SMOKING LIVELIHOODS IN BIRIWA IN THE CENTRAL REGION OF GHANA

Interviewer's name: ______________________ Interview date: __________

Household No.: __________ Participant ID: ________

SECTION A

PART A: BACKGROUND INFORMATION *I would start by asking you some personal questions about yourself*		
Socio-demographic Characteristics		
1	How old are you?	_________ years
2	How many years have you lived in this community?	__________ years
3	What is your ethnic background?	1= Akan 2= Ga/Adangbe 3= Ewe 4= Northern ethnicity 5= Other (specify)
4	What is your religion?	1= Christian 2= Muslim 3= Traditional religion 4 = Other (specify)
5	What is your current marital status	1= Single/Never been married 2= Married 3= Divorced 4= Widowed
6	What is the highest level of formal education you have completed?	1=< Primary 2= Primary

		3= JHS 4= SHS 5= Vocational training 6= Tertiary
7	What is the main work you do for income?	1= Fish smoking 2= Other fish related activity 3= Farming 4= Trading 5= Vocational 6= Not working 7= Other (specify)
8	How long have you been in this line of work?	__________ years
9	Do you have a supplementary source of income?	1= Yes 2= No
10	If yes, what is the supplementary work you do for income?	1= Fish smoking 2= Other fish related activity 3= Farming 4= Trading 5= Vocational 6= Other (specify)
11	During this time of the year, how much do you earn monthly?	1=<500 GH₵ 2= 500-999 GH₵ 3= 1000-1999 GH₵ 4= 2000-3999 5= 3000-4999 GH₵ 6=≥5000 GH₵

Household Characteristics *I would like to ask you a few questions about your household*		
12	Who is the head of this household?	1= Myself 2= Husband 2= Father or father in-law 3= Mother or mother in-law 4= Other male household member 5= Other female household member
13	How many people in total are part of your household?	________
14	How many of your household members are children (<18 years)?	________
15	How many of your household members are adults (≥ 18 years)	________
16	What is your household's main source of drinking water?	1= Pipe 2= borehole 3= Well 4= River/stream 5= Rainwater 6= Sachet water 7= Other (specify)
17	How do you treat your household's water before drinking?	1= No treatment 2= Boil 3= Filter 4= Chlorine/bleach 5= Let it stand and settle 6= Other (specify)
18	What kind of toilet facility does your household use?	1= Water closet (WC)

		2= Public toilet/KVIP 3= Nearby (Bush/beach/field) 4= Pit latrine with slab 5= Pit latrine without slab 5= Other specify
19	Do you share your household's toilet facility with other members who are not part of your household?	1=Yes 2=No
20	What is your main source of light?	1= Electricity 2= Kerosene lamp 3= Candle 4= Solar lamp 5= Other (specify)
21	Does your household have any of the following assets?	1= Electricity 2= Radio 3= Black/white television 4= Color television 5= Mobile phone 6= Refrigerator 7= Generator 8= Video deck/DVD/VCD 9= Bed 10= Table 11= Access to internet in any 12= Motorcycle 13= Car or truck
22	Main material of the floor (sleeping place) Record Observation	1= Cement 2= Earth/sand 3= Ceramic/tiles/terrazzo

		4= Carpet 5= Other (specify)
23	Main material of the roof. Record Observation.	1= Palm leaf 2= Palm/Bamboo 3= Wood planks 4= Roofing sheets 5= Ceramic/brick tiles 6= Cement 7= Other (specify)
24	Main material of the exterior walls Record Observation.	1= Bamboo with mud 2= Plywood 3= Stone with mud 4= Cement 5= Bricks 6= Other (specify)
Now I would like to ask you some questions about cooking in your household and other household practices		
25	What is the main fuel used for cooking in your household?	1= Electricity 2= LPG 3= Charcoal 4= Kerosene 5= Wood 6= Animal dung 7= No food cooked in household
26	Is the cooking usually done in the house, in a separate building, or outdoors?	1= In the house 2= In a separate building 3= Outdoors
27	Who spends most of the time cooking for the household?	1= Myself 2= Another household member

		3= A non-household member
PART C: HEALTH INFORMATION *At this point I will ask questions about your health*		
28	Have you ever been pregnant?	1= Yes 2= No
29	If yes, how many live births have you had?	______
30	Do you have sickle cell trait?	1= Yes 2= No 3= Don't know
31	Have you had fever in the last two weeks?	1= Yes 2= No
32 b.	If yes, what did you do to treat it?	1= Hospital 2= Medicine from pharmacy 3= Herbal medicine 4= Nothing 5= Other (specify)
34	When was the last time you dewormed?	1= Less than one month ago 2= Within 6 months 3= Less than a year ago 4= More than 2 years ago 5= Don't know
35	Do you usually sleep under a mosquito net at night?	1= Yes 2= No
36	Did you sleep under a mosquito net last night?	1= Yes 2= No
37	Do you smoke cigarettes, cigars or tobacco?	1= Yes 2= No
38	If yes, during the past 30 days, did you smoke cigarettes, cigars or tobacco?	1= Yes

		2= No
39	Does anyone in your household smoke cigarette?	1= Yes 2= No
40	Have you taken iron supplements in the last 6 months?	1= Yes 2= No
42	Over the past 12 months, how often have you gone to places other than your home or work where people smoked around you indoors, close enough to see or smell the smoke? *(Applicable to women engaged in non-fish smoking occupation)*	1= More than once a week 2= More than once a month 3= Less than once a month 4= Never
PART D: USE OF BIOMASS FUEL *Now I will ask you some questions about your exposure to smoke from biomass fuel*		
43	Do you help someone in her fish smoking business? *Applicable to women in NFSL only*	1= Yes 2= No
	On an average, about how many days in a week do you help someone who smokes fiish in her business during this season? *Applicable to women in NFSL only*	_______ days
44	During the past 12 months, about how many months did you participate in fish smoking? *Q44 to Q48 Applicable to women in FSL only*	_______ months
45	On average, about how many times in a week do you smoke fish during this time of the year?	_______ days
46	On average, how many hours in a day do you spend smoking fish?	__________ Hours

47	What kind of smoke oven do you use?	1= Chorkor 2= Ahotor 3= Round clay oven = 4= Metal drum = 5= Traditional kiln = 6= Frismo/Cosmos stove 7= FTT = 8= LPG Gas Burner = 9= Other (specify)
48	What is the main source of fuel you use for smoking fish?	1= Firewood 2= Charcoal 3= Animal waste (cow dung) 4= Other (specify)

SECTION 2: DIETARY INTAKE

24 HOUR RECALL

I would like to ask you about all the foods and beverages except water you consumed in the past 24 hours along with further descriptions of the food.

Time of eating event	*Type of eating event*	*Actual foods eaten*	*Preparation method*	*Household amount*	*Total amount*

FOOD FREQUENCY

Next I would like to ask you some questions about intake of animal source foods you ate in the last seven days, since last [SAY DAY, SAME AS INTERVIEW DAY]. *For each food I ask about, please tell me how many times in the last seven days you think you ate that food*

FOOD ITEMS	Number of days
Livestock meats (All types of red meat e.g. goat, cow, lamb, pork)	____________
Bushmeats (E.g. Grass cutter, antelope, rat, squirrel and other wild animals)	____________
Organ meats (Blood-based foods e.g. liver, kidney, heart, gizzard, lung etc.)	____________
Poultry (Chicken, guinea fowl, duck and other birds)	____________
Fish and seafood (Fresh or dried fish e.g. Anchovies, one-man-thousand or other small fish eaten whole, either fresh or dried, shrimps/amonkor, adode, crabs)	____________
Milk and milk products (Milk, cheese, yogurt or other milk products)	____________
Eggs (Any type of egg e.g. chicken eggs, duck eggs etc.)	____________

HB TEMPLATE

SECTION 3: Hb Concentration reading

Name of Interviewer_________________________________ Date of Interview_______

Household number____________ Woman’s ID________

Hb Concentration = ___________g/dl

APPENDIX V: Ethical Approval

UNIVERSITY OF GHANA
ETHICS COMMITTEE FOR BASIC AND APPLIED SCIENCES (ECBAS)

P. O. Box LG 1195, Legon-Accra

Ref. No: ECBAS 003/18-19

8th November, 2018.

Mr. Daniel Armo-Annor
Department of Nutrition and Food Science
P. O. Box LG 134
University of Ghana
Legon, Accra

Dear Mr. Armo-Annor,

ECBAS 003/18-19: COMPARISON OF ANEMIA PREVALENCE BETWEEN WOMEN INVOLVED IN FISH-SMOKING AND NON-FISH SMOKING LIVELIHOODS IN BIRIWA IN THE CENTRAL REGION OF GHANA

This is to inform you that the above referenced study has been presented to the Ethics Committee for Basic and Applied Sciences for a full board review and the following actions taken subject to the conditions and explanation provided below:

Expiry Date:	07/11/19
On Agenda for:	Initial Submission
Date of Submission:	19/09/2018
ECBAS Action:	Approved
Reporting:	Quarterly

Please accept my congratulations.

Yours sincerely,

Professor Daniel Bruce Sarpong
ECBAS Chairperson

ETHICS COMMITTEE FOR BASIC AND APPLIED SCIENCES
APPROVED
08 NOV 2018
UNIVERSITY OF GHANA

IP No.: 3014

Email:ethicsecbas@ug.edu.gh