KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY KUMASI-GHANA

ESTIMATING CONSUMPTION RISK OF STREET VENDED FUFU AND FRIED RICE

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A thesis submitted to the Department of Food Science and Technology Faculty of Biosciences, College of science in partial fulfilment of the requirements for the award of

DOCTOR OF PHILOSOPHY IN FOOD SCIENCE AND TECHNOLOGY

NOVEMBER 2017

DECLARATION

I hereby declare that this submission is my own work towards the award of a PhD and that, to the best of my knowledge, it contains no material previuously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ACKNOWLEDGEMENTS

My utmost gratitude goes to the Almighty God whose great mercies through my Lord Jesus Christ has made me come this far. I also express my profound gratitude to all my Supervisors, Prof. R.C. Abaidoo, Prof. W.O. Ellis and Dr. G. Darko for their guidance, patience and advice throughout my study. My sincere appreciation goes to my Provost, Prof I.N. Oduro, who really supported me with advice, a shoulder to cry on and words of encouragement during the period of study. To my office mates: Mr. Isaac Williams Ofosu and Dr. Herman Lutterodt for all the unrelenting support given me are deeply appreciated. I appreciate Dr. Apprey for assisting me with the statistical analysis of the data, to reach the logical conclusions. The entire staff and TAs of the Food Science and Technology Department are not left out. I appreciate all their support and assistance all the way. My gratitude also goes to all my siblings and my late mother, who were pillars of encouragement. My gratitude goes to my husband, Kojo Ankar-Brewoo, my children, Jessica, Juanita, William, Alicia and Zizi for their love and encouragement during my study. Finally, I acknowledge the funding support received from Danida through the Street Food Project and the entire team of the Street food Project in Ghana and Denmark.

ABSTRACT

Street food vending has for a long time been perceived as an unsafe source of food for the wider consumer population. The prevailing conditions of food preparation and handling is likely to introduce food safety hazards which can be detrimental to the health of the consuming population. Therefore, this study sought to contribute to improving upon the safety of the street vended foods under the prevailing conditions of food preparation and handling. The study also sought to determine vendor practices and challenges that introduce food safety hazards – chemical and microbiological, into the components of two ready-toeat street vended foods: fried rice and fufu. The hazards were identified through participant observation and informant (vendor and staff) interviews where interview guides and observation check list were used. Samples of the different components of the two street vended fufu and fried rice were bought separately from the vendors and analyzed for the presence and levels of the food safety hazards identified. Consumption characteristics of the street vended foods were also taken from regular consumers of the street vended foods of the vendors used in the study. Microbiological (*Bacillus cereus*, *Staphylococcus aureus, Escherichia coli* and the total plate counts) and chemical (metals - (Aluminum, Lead and Iron); polycyclic aromatic hydrocarbon

(PAH) (22 USEPA priority PAH) and Bisphenol A) hazards were evaluated using standard methods. The findings from the interviews and observations indicated high staff turnover, access to „good" location for vendors as major challenge to business with implications for food safety. Staff had very little knowledge on good food handling practices thus affecting safety since they are the main handlers of the vended foods. The microbiological analysis indicated high levels of bacterial contaminants in all the food samples. Levels of *E. coli* (5.49 – 2.53 log CFU/g), *S. aureus (*6.44 – 4.36 log CFU/g) and *B. cereus* (5.44–3.49 log CFU/g) were higher than the World Health Organization (WHO) limit of 3 log CFU/g for the rice, salad, chicken and macaroni ingredients of the fried rice meal sample. Fufu recorded very high levels of all the bacterial contaminants, *E. coli*, above 3 log CFU/g limit set by WHO. The total plate counts for all the sample meal ingredients were also above 6 log CFU/g. However, levels of bacterial contaminants in the soup were all below the limits set by the WHO. Assessing the level of risk associated with the consumption of these street vended foods using the quantitative microbial risk assessment approach, indicated high consumption levels of bacteria. It also showed that at all levels of consumption, consumers are at risk of microbial food borne illness. Sensitivity analysis showed that interventions must be focused on preventing or drastically reducing the levels of *E. coli* in the salad, macaroni and fufu ingredients and *S. aureus* and *B. cereus* in fried rice, salad and fufu. The levels of Iron (Fe) in the cooked samples, rice (2.33 $mg.kg^{-1}$), chicken (3.08 $mg.kg^{-1}$) macaroni (2.06 $mg.kg^{-1}$), fufu (3.05 $mg.kg^{-1}$) and soup (3.60 $mg.kg^{-1}$) were relatively higher than in the corresponding raw samples which suggested possible leaching from the utensils used in processing. Lead (Pb) levels (7.43 $mg.kg^{-1}$ to 11.25 $mg.kg^{-1}$) were highest in shito samples followed by mayonnaise with an average value of 7.08 $mg.kg^{-1}$. Leaching from the utensil best explains the levels of Pb in the shito samples as locally manufactured utensil is used for its preparation. Rice, shito, ketchup and macaroni also had very high levels of aluminum (Al), (above 5 $mg.kg^{-1}$) relative to the uncooked samples also implying possible leaching from utensils. The evaluated PAH of interest were BaP and DahA. These are the most potent carcinogens among the USEPA priority PAH. These PAH were detected in the chicken, shito and soup samples. Pyrene (Pyr), a precursor of BaP was detected in all the cooked food samples except fufu in levels between 4.8E-07 $mg.kg^{-1}$ and 2.0E-02 $mg.kg^{-1}$. Naphthalene, was detected in all the food samples in concentrations between 9.1E-06 $mg.kg^{-1}$ and 1.2E-02 $mg.kg^{-1}$. Chemical risk assessment revealed that the Hazard Index (HI) due to metals in the fried rice meal was 3.0 at 50^{th} percentile of consumption and 23.8 at the 95^{th} percentile, all above 1. Meaning the normal to heavy consumers of fried rice may be suffering the adverse health effects of the metals. The HI of fried rice due to PAH at the 95^{th} percentile and fufu meal at the 50^{th} percentile were also above 1. Sensitivity analysis indicates naphthalene having an impact on the risk levels with correlation coefficients ranging between 0.11 and 0.26 in all the food samples. Health risks due to BaP levels in the foods were above 10^{-4} from the 50^{th} percentile, which was unacceptable. The Bisphenol A (BPA) concentrations in the fufu and cooked rice samples were below 40 $\mu g.kg^{-1}$ lower the 4 $\mu g.kg^{-1}$ of $bw.day^{-1}$ limit set by EFSA in 2015. Risk assessment indicated that the consumers were not likely to suffer the adverse health effects of BPA in foods even at the 95^{th} percentile exposure level. Sensitivity analysis show that levels of BPA be reduced to the barest minimum. As a way forward towards the enhancement of the safety of street vended foods, training of vendors on personal hygiene and good food handling practices should be tied with food preparation skill to improve the taste/value of the vended foods. Emphasis on practices such as covering of boiling food with plastic must be replaced with that of cotton material such as *gray baft*, The use of stainless steel cooking pots and efficient personal hygiene practices be encouraged to improve the safety of the street vended

meals used in the study. Storage of cooked foods and cut up vegetables for long hours at ambient conditions should be discouraged. These practices if strongly adhered to would greatly improve safety of the vended foods.

CONTRIBUTION TO KNOWLEDGE

Key finding established from the study are

i. Street food vendors prioritized the business aspects of street vending relative to the food safety aspects ii. Established the preparation and vending practices contributing to contamination with the quantifiable hazards and intervention practices to improve safety of street vended fufu and fried rice ~~iii.~~ The application of quantitative risk assessment models in the assessment and improvement of street vended fufu and fried rice.

These findings have resulted in the following publications which forms part of the body of knowledge on street vended foods specifically fufu and fried rice:

1. **Ankar-Brewoo**, **G. M**., Darko G., Abaidoo, R C., Dalsgaard, A., Johnson P-N. T., Ellis W. O. and Brimer, L. 2017. Concentrations and health risk assessment of Fe, Pb and Al found in two commonly consumed street vended foods in Kumasi, Ghana, *Food Additives and contaminants Part A;* Manuscript ID TFAC-2017-395) *(under review).*

2. **Ankar-Brewoo**, **G. M.,** Darko G., Abaidoo, R C., Dalsgaard, A., Johnson P-N. T., Ellis W. O. and Brimer, L. 2017. Health risk assessment due to the consumption of polycyclic aromatic hydrocarbon in two commonly consumed street vended foods in Kumasi *(Food Chemical and Toxicology; (under review)*

3. **Ankar-Brewoo**, **G. M**., Larsen, M. H., Abaidoo, R C., Johnson P-N. T., Ellis W. O. and Dalsgaard, A. 2017. Microbiological and chemical hazard identification in the preparation and vending processes of two street vended foods. *(under internal review*)

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CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background

Street foods are ready-to-eat foods that are sold on the street. These are mass prepared consumer foods that are normally eaten without further processing or cooking (Mensah *et al*., 2002). The World Health Organization (WHO), refers to street foods as food and beverages prepared and sold by vendors in streets and other public places for immediate consumption (FAO/WHO, 2005a). This includes „ready-to-eat (RTE) foods and beverages prepared and/or sold from push-carts, buckets, and balance poles or stalls‟ (FAO, 2005). For this study, street food was defined as RTE foods that are prepared and sold by vendors (or their staff) in public places such as bus terminals and along the streets.

The types of street vended foods differ greatly between countries (Kok and Balkaran, 2014). However, most meals consist of staple foods served in various forms and have the diversity cutting across the various food groups in the food pyramid. In Ghana, some of the popular street vended foods on the menu are *koko* (non-alcoholic fermented cereal porridge); waakye (rice cooked with beans) and „omo tuo‟ (cooked rice balls) and fufu (pounded cooked cassava and plantain) eaten with assorted soups. Other foods include banku (non-alcoholic fermented heat-kneaded cereal product); fried rice (boiled rice stir-fried with vegetables); fried ripened plantains with cooked beans; and roasted ripened plantain with roasted groundnuts. Some various homemade drinks such as *asana* (malted maize drink), *bissap* (from *Hibiscus calyx*), and *pito* (beer from sorghum) are on the menu.

The vendors of street foods can be sedentary/stationary or itinerant. The sedentary ones are defined by Solomon-Ayeh *et al*. (2011) as having fixed locations on pavements, verandahs, stalls and tables. They either operate on the bare floors of large public areas such as markets places, school compounds, industrial sites, bus terminals and lorry parks or may be home-based. For the footloose or mobile vendors, they move throughout the city or business areas in search of customers (Solomon-Ayeh *et al*., 2011).

Street food vending is common in third world countries where there is high rate of unemployment, low salaries and very limited social work opportunities (Chukuezi, 2010). With growing urbanization of cities in third world countries, the street food vending activities have expanded to meet the growing demands of this informal sector (Hove *et al*., 2013). Street vending businesses make significant contribution to the societies in which they are found in by providing employment opportunities for people with low educational background who find it difficult to secure a job with the formal sector of the economy (Kok and Balkaran, 2014). Women with children are the most predominant active members of the society involved in the sale of street foods (Mensah *et al*., 2002; Adjrah *et al*., 2013). Large segments of the populations patronize these street vended foods, making it very popular in the urban communities.

Consumers of these street foods range from a variety of social backgrounds, cutting across income groups, gender, age and education. A study conducted in Accra on street vended foods involving 951 mothers observed that about 60 % of 951 mothers supplemented their children‟s diet with street food (Mensah *et al*., 2002). This may imply that the foods are nutritionally good and affordable, which is in line with the benefits of street vended foods as outlined by Ohiokpehai (2003).

Lack of basic infrastructure and utility services including water, electricity supply and waste disposal systems have created the perception that street vended foods (SVF) are a major public health risk (Barro *et al*., 2006; Lucca and da Silva Torres, 2006; Garode and Waghode, 2012). Studies have shown that these street foods contribute significantly to the number of food poisoning incidences (Amine *et al*., 2003; Bryce *et al*., 2005; Bahk *et al*., 2007). In a review article, Rane (2011), noted that foodborne bacterial pathogens that are commonly detected in street vended foods include *Bacillus cereus, Clostridium perfringens, Staphylococcus aureus* and *Salmonella* spp. In

Ghana, a study conducted among some 160 street food vending premises, in the Ga district, in Accra, using a five-point check list for basic hygiene showed that only three (1.8 %) of the vendors met the requirements (King *et al*., 2000). In another study where about 511 street food samples were collected and analyzed for the presence of pathogens, Mensah *et al.* (2002), reported that most of the foods which were analysed had acceptable limits of contamination. But, others such as red pepper had unacceptable levels of pathogens with *Staphylococcus aureus*, and *Bacillus cereus* being the predominant ones. In Kumasi, a study by Feglo and Sakyi (2012), also confirmed the presence of some pathogenic bacteria in levels higher than the acceptable limits, in street vended foods such as fufu‟, macaroni, salads, cocoa drink, red pepper and iced kenkey sold in the metropolis. This has fueled the perception that most ready-to-eat foods in Kumasi were contaminated with enteric bacteria and other potential food poisoning organisms.

In another consideration, few studies have been conducted on the possible chemical contamination in street vended foods. Research work by Tomlins and Johnson (2004) in Accra, Ghana, showed that the pots and other utensils used by street food vendors were from both formal and informal manufacturer/retailer source. In the foods cooked therein the levels of metal contaminants are higher than those cooked in stainless steel pots from households (Dan and Ebong, 2013). Available information on the chemical contaminations in street vended foods sold in Ghana is scanty. A myriad of chemical contaminants of toxicological importance could be present in street vended foods as a result of vendor practices in the food preparation, rendering it unsafe for consumption (Proietti *et al*., 2014).

Barro *et al.* (2007), in a critical review article argued that the application of the WHO/FAO Food

Safety Objective strategy is ideal in improving the safety of street vended foods. In India, when basic food safety training was given to street food vendors, some significant improvements in the safety of these foods were seen (Choudhury *et al*., 2011b). Barro *et al.* (2007), further argued that, to reach this goal, data on the Critical Control Points (CCP), Quantitative Risks Assessment (QRA), and hygienic status during street food preparation must be gathered. These data are needed to develop suitable intervention methods to improve the safety of street vended foods. There is evidence to show that hygienic status of street vended foods have been widely explored by various researchers (Barro *et al*., 2006; Baş *et al*., 2006; Lucca and da Silva Torres, 2006). Critical control point determination on street vended foods preparation has also been reported by Bryan *et al.* (1992). Furthermore, the application of the elements of QRA method has been explored up to exposure assessment by Mosupye and Van Holy (2000). However, very little has been done in quantifying the risk and magnitude of adverse effects due to these biological and chemical hazards associated with the consumption of street vended foods.

Risk assessment, management and communication tools are used in organizing available information, identifying data gaps, quantifying risk for specific pathogens and foods, and presenting strategies for improvement needed for education (Barro *et al.*, 2007). However, Rane (2011) has concluded in the article that scientific methods ought to be applied together with the social intervention methods to improve the safety of street vended foods so that the consumers would be protected and safely enjoy what they consume.

The Hazard Analysis Critical Control Point (HACCP) system is a scientific food safety management tool aimed at identifying and controlling food safety hazards (Walker *et al*., 2003). The HACCP has been widely acknowledged as the best approach to controlling hazards present in foods (Khandke and Mayes, 1998; Ehiri *et al*., 2001). The use of the HACCP system has gained international acceptance and is popular among the industrialized food processing units (Ehiri *et al.*, 2001).The use of this system allows for food safety regulation policy to be formed and adopted for food manufacturers to comply. However, the HACCP system is not popular with small and medium-scale food manufacturing and street food vending businesses even though in Nigeria, Ehiri *et al.* (2001), applied the HACCP system to identify critical control points in the preparation of some domestic complementary foods for babies. Toure *et al.* (2011), also applied the HACCP system to identify critical control points of two selected weaning foods in peri-urban Mali for control measures to be exerted. The HACCP experiment by Toure *et al.* (2011) improved significantly the bacterial safety of both types of weaning food studied. Bryan *et al.* (1992) applied the HACCP system to *Chat*, which is a street vended regionally popular food in Pakistan, which was deemed as a high risk street vended food. *Chat* is prepared from sliced cooked potatoes, fried graham and pulse dough, and chick peas or red beans garnished with lasi (fermented milk) and fruit syrup. In their study, the temperatures throughout the food preparation and display were measured to help identify critical control points (CCPs) and appropriate preventive measures. Even though CCPs were identified, they were not specific for the components of *Chat*, and the risk of consuming the individual component was not determined using the appropriate tools such as quantitative risk assessment (QRA).

Quantitative risk assessment (QRA) is a scientific evaluation of known or potential adverse health effects resulting from exposure to food borne hazards (McMeekin and Ross, 2002). This process is similar to the HACCP system but the QRA is an improvement composing of four steps. The first step in the development of an HACCP system is to identify hazards (Hoornstra *et al.*, 2001). The hazards are then quantified with the adverse health effects and the risks assessed by using the elements of QRA (steps 2, 3 and 4) (Gerba, 2000). The data obtained can be transformed into a meaningful managerial tool to avert the risk of consuming the contaminant (Gerba, 2000).

A quantitative risk assessment (QRA) study on street vended foods would therefore be a useful approach for improving the safety of the street vended foods. This can be done on the whole food per the organism involved or on the components of the food. It would help in the estimation of the risk of consuming these foods and the probability that illness would occur upon consumption. The magnitude of its adverse effects on the consuming population would as well be estimated (Gerba, 2000). Sensitivity analysis is conducted after risk assessment, to determine which input factor had the greatest impact on the risk of consuming the vended foods, where intervention will be focused (Zwietering and van Gerwen, 2000). This information will also give risk communicators and managers the ability to make informed decisions (Gerba, 2000).

1.2 Problem Statement

Safe street vended foods are required to among other things to boost tourism of a particular locality, increase patronage of vended foods by the consuming population, and increase the health status of consumers by reducing food borne illnesses. However, street vended foods are perceived to be of public health concern due to the food borne illness or outbreaks of diseases that have been associated with their consumption (Aluko *et al.*, 2014). High levels of pathogenic bacteria capable of causing food poisoning have been identified and quantified in these foods (Mensah *et al.*, 2002; Rane, 2011) and have been declared unacceptable for safe consumption. It is therefore important that efforts are made to bring down the high levels of bacterial contamination to acceptable levels.

Very little information about the chemical hazards on street vended food has been reported. Only one study so far has reported on the levels of metal (Al and Pb) contaminants in street vended foods, in Accra, Ghana (Tomlins and Johnson, 2004). This level of information on street vended food is thus not adequate as a myriad of toxicants could be present. Generally, the chemical contaminants upon consumption have cumulative effects until a level is reached where adverse health effects are seen in the health of the individual (Macrae, 1993).

Lack of information on vendor practices specific to the high risk street vended foods have made it difficult to determine intervention measures for its improvement. This possibly explains why training given to the vendors for improvement of the safety of the foods has not been food specific. Usually vendors are given broad training on good hygienic practices (GHP) in food handling and do not provide the desired capacity for improving the handling practices and consequently the safety of street vended foods.

Application of scientific methods such as the HACCP system has been difficult due to the prevailing conditions of street food preparation. Certain prerequisite systems, such as proper hygienic environment and good sanitation practices, must be in place for its effective implementation. Monitoring and record keeping are the strong pillars of the HACCP system, which may be a challenge to the vendors due to the low levels of education observed among them (Baş *et al*., 2007). Thus, there is the need to apply other scientific methods, such as quantitative risk assessment, whose objective would be to improve the safety of the high risk street vended foods.

Lack of consumption data on street vended foods has limited the application of QRA in determining the magnitude of the risk among the consuming population. This can be done on the various components of the meal to determine the components for which intervention would be applied. This information will assist risk managers to determine the magnitude of the adverse effects due to the hazard.

1.3 Justification

So much attention has been given to the microbiological hazards in street vended foods and there is very limited information on chemical hazards in street foods. The chemical hazards that could be present in street vended foods deserve comparable share of attention. This is because some food preparations and vending conditions are likely to introduce chemical hazards into the vended foods for consumption. For example the excessive repeated use of frying oils of more than three cycles coupled with high temperatures used by street food vendors in food preparations are likely to introduce polyaromatic hydrocarbons, acrolein and acrylamide (Proietti *et al.*, 2014). The chemicals are likely to have toxicological effects on the consuming population.

Application of QRA wholly to hazards (microbiological and chemical) present in the street vended foods will give evidence of the potential impact of the hazard based on the severity of its effects and the amount of exposure (Barro *et al.*, 2007; Proietti *et al.*, 2014). This information will be useful to risk communicators and managers as this is required to promote and update consumer safety (Proietti *et al.*, 2014).

Vendor practices that affect the levels of microbiological and chemical hazards in the SVF industry need to be fully known and used in determining applicable intervention practices. It is desired of the interventions to be user friendly for vendors and this will make them more willing to accept and implement and also easy to monitor (Baş *et al.*, 2007). In addition, the intervention has to be product specific and applicable under the prevailing conditions of street food handling.

1.4 General Objective

This study therefore seeks to use quantitative risk assessment (QRA) approach to assess the safety of two popular high risk street vended foods, fried rice and fufu.

1.4.1 Specific Objectives

1. To determine food safety considerations in citing business location and training of employees by vendors.

2. To determine the sources of chemical and microbiological hazards associated with vendor practices in the preparation and vending of two popular street vended foods

3. To determine the risk of consumption due to the identified hazards in the components of the two street vended foods.

1.5 Organization of study/ Scope of study

The first specific objective deals with vendor challenges in the street food business and its likely impact on the safety of the street vended foods. It seeks to determine if vendors have food safety on the priority checklist in selecting a food preparation and vending site, as well as hiring of staff.

The second specific objective deals with conducting a chemical and microbiological hazard analysis in the components of the two street vended foods. This will enable the researcher to determine vendor practices surrounding the entry points of the hazards. Based on the practices, intervention measures could be suggested which will be close to the practices of the vendors at the preparation point.

The third and fourth objectives deal with conducting a probabilistic risk assessment on the components of the street vended foods. To conduct the probabilistic assessment, consumption data is needed, which is done using information provided by the consumers of the two street vended foods. The risk assessment was conducted on the chemical and microbiological hazards present in the components of the street vended foods. It was done to determine which component contributes the most risk associated with the consumption of the two street vended foods. Based on the practices of vendors in the preparation of the components (Objective 2), possible intervention mechanisms or suggestions aimed at reducing the levels of the contaminants in the street vended foods, and to render them safe for consumption.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Street Vended Foods

Street vended foods (SVF) have been defined by the Food and Agriculture Organization of United

Nations (FAO, 2010) as “foods and beverages prepared and/or sold by vendors in the streets and other public places for immediate consumption or consumption at a later time without further processing or preparation”. This includes fresh fruits and vegetables, which are sold in unauthorized market areas for immediate consumption. SVF provides nutritionally balanced meal of consumer‟s choice which is affordable and convenient and usually the final preparations are made at the request of the consumer (FAO, 2010; Mensah *et al*., 2002; Ohiokpehai, 2003).

The food vendors promote tourism through the display of the food types, culture and eating habits of indigenes and preserving the culinary arts of their cuisine in and beyond their domicile (Nicolo and Bendech, 2012; Ohiokpehai, 2003). Demographic studies revealed that most of the vendors are poor women with low levels of education, and often lack appreciation of safe food handling (WHO 1996; Chukuezi, 2010). The married female food vendors having large families are also burdened with the responsibility of managing their homes. The low startup capital and skills required for this job as well as the flexibility of combining it with domestic responsibility, makes the vending business suitable (Nicolo and Bendech, 2012) and attractive. The street food is highly patronized in developing countries where high unemployment, low salaries, limited social programs and urbanization exist (Mensah *et al*., 2002).

2.2 Types of Street Vended Foods

The types of foods sold on the streets are diverse and peculiar to a given locality, country or region where the ready market and the expected economic gains of the vendor are assured (Muyanja *et al*., 2011). The ingredients for those foods are usually locally obtained, cheap and are selected to maximize bulk and value. In general, most vendors do not sell just one type of food; usually two or more foods are simultaneously sold. However, those new to the vending business will usually engage in specialized food products (Muyanja *et al.*, 2011). In the street food vending business in Kumasi, the types of foods on menu vary widely from breakfast meals to night meals. Examples of some prepared street vended food in some African countries are shown in Table 2.1.

2.3 Consumers of Street Foods

Given the low cost nature of SVF, the consumers vary ranging from commuters, travelers, workers and school children (Afele, 2006). People of different social background, across income groups, gender, age, and education patronize SVF (Nicolo and Bendech, 2012). In short, the types of consumers depend on the characteristics of residents within the given locality (Ehiri *et al*., 2001; FAO, 2005; Mensah *et al*., 2002). Since the consumers of SVFs include the vulnerable in society, especially babies, the safety of the foods must not be compromised. Every effort to improve the safety of SVFs is important (Kok and Balkaran, 2014).

Table 2.1: Examples of street-vended foods in some African countries

Country	Examples of some prepared street vended food

Ghana	Fufu, kenkey, banku, waakye, akamu, jollof rice, moi-moi, agidi, koko, koose, boiled rice, gari, yam and plantain, fried fish, light soup, groundnut soup, okra soup, palm nut soup, tomato stew, nkontmire
Zambia	Nshima, chicken/beef stew, fried vegetables, smoked sausages, buka buka fish, offals, (i.e. bovine stomach), vegetables (ifisashi - vegetable mixed with pounded groundnuts and beans)
Zimbabwe	Sadza, chicken, beef stew, boiled/fried vegetables, roasted beef/chicken/sausage, offal, boiled beans
South Africa	Maize porridge (pap), chicken/beef stew, gravy, salads
Kenya	Sausages, meat, fish, eggs (boiled), French fries, cereals, coffee, tea, porridge, root tubers (yams, cassavas, sweet potatoes, arrow roots), maize cobs, pumpkin pieces, bananas, potatoes, peeled carrots, onions, garlic, whole milk, yoghurt, ice cream, mangoes, water melons, pineapples, pawpaws, beef stew, African sausage
Malawi	Nsima, rice, sweet beer (beverage), meat, fish, eggs, fruits and vegetables, frozen foods
Benin, Togo, Senegal, Burkina Faso, Côte d‟Ivoire	Cereal or tuber based porridges (fermented or not), buttered bread, coffee/tea, bean purees, cowpea/cereal mixtures, maize/groundnut mixtures, pasta, salads, "monyo", potato chips, peanuts, cashew-nuts, etc.

Source: (Gadaga *et al.*, 1999)

2.4 Food Preparation Knowledge

The knowledge and skill for the preparation of SVF is acquired from various sources. A study conducted by Omemu and Aderoju (2008) in Nigeria, revealed that few (12 %) of the study population acquired the knowledge from catering schools. The majority (> 60 %) of the vendors acquired it on-the-job by being assistant vendors and so in most cases do not know more than their „masters". Most vendors have poor knowledge of safe food handling due to the inadequacy of the informal observation that inform their food preparation (Omemu and Aderoju, 2008). The inadequate knowledge about safe food practices could be so serious to the extent that some vendors tend to be horrified when informed that their food are potentially hazardous (Afele, 2006). Also, changing food handling practice is difficult especially if it has some financial implications. Many vendors resist change since they are comfortable with their established ways; hence find it difficult to be consistent with meal preparations even when change starts (Echols, 2001).

2.5 Safety of Street Foods

The problems of food safety in the industrialized world differ considerable from those faced by the developing countries. In the developing countries, a large proportion of ready-to-eat foods is sold on the street (Mensah *et al*., 2002). At these public places, infrastructural problems like the unhygienic states of the food stands, most of which lack protective covering leaving the food exposed to environmental conditions, such as dusty air, fumes from exhaust of moving vehicles and rain showers (Ekanem, 1998; FAO, 2010). The lack of basic facilities like running water, washing facilities and toilets makes it difficult for vendors to maintain hygienic practices. This has led to the general perception that street vended foods are unsafe due to contamination by pathogenic microorganisms, chemical and physical entities. It is suggested that foods prepared and sold by street food vendors are likely to have some zoonotic implications particularly in developing countries (King *et al.,* 2000).
Suggestions from epidemiological studies implicating street vended foods to a significant number of food poisoning incidences appear to be inadequate. This is due to paucity of data and deficiencies in knowledge about important parameters in the food chain and host pathogen interactions (Rane, 2011).

In addition, consumers‟ reporting to vendors or health officers about food poisoning incidences arising from the consumption of street vended foods is rare.

The safety of street foods is affected by several factors, starting from the quality of the raw materials, to food handling and storage practices. The scope of food safety is found in the domains of microbiological, chemical and/or physical contaminations. Such contaminations can considerably or are likely to cause acute, moderate or mild illnesses to an individual upon consumption of that food.

Microbiological food safety is of major concern to the street foods industry because of the successful isolation and identification of some pathogenic microorganisms in the foods (Feglo and Sakyi, 2012; Mensah *et al*., 2002). Various studies have identified the cause of microbiological safety issues as involving potentially hazardous microorganisms belonging to the genus *Bacillus*, *Staphylococcus, Clostridium, Vibrio, Campylobacter, Listeria, Salmonella, Pseudomonas and Proteus* (Garode and Waghode, 2012; Mensah *et al*., 2002; Rane, 2011; Rheinländer *et al*., 2008). The potential health risks have been reported to include associated diarrheal diseases (Rheinländer *et al*., 2008) stemming from contamination and/or cross contamination during preparation, postcooking and other handling stages (Garode and Waghode, 2012). The consumption of contaminated foods is among the leading causes of illness and death in low income countries (Dawson and Canet, 1991; Rheinländer *et al*., 2008). Underestimation or disregarding the risk of encountering harmful effects as well as having a knowledge of trust among the vendors are risk avoidance strategies consumers use (Garode and Waghode, 2012; Rheinländer *et al*., 2008). *Bacillus cereus*, *Clostridium perfringens*, *Staphylococcus aureus*, *Salmonella* spp, *Escherichia coli*, *Listeria monocytogenes* and *Campylobacter* are some of the bacterial pathogens that are mainly found in street vended foods (Mensah *et al*., 2002; Rane, 2011).

Escherichia coli (E. coli) is principally associated with fecal contamination, with a generation time of 20 min and able to survive outside the body for a short time (Oranusi *et al*., 2012). They mostly do not cause disease; however, the virulent strains cause gastroenteritis, urinary tract infections, and neonatal meningitis (Russo and Johnson, 2003).

Staphylococcus aureus (*S. aureus*),is a dangerous, commensal, bacteria pathogen found on the epithelial surfaces of humans and other mammals (Christensen and Bruggemann, 2014). It causes severe diseases like boils and impetigo, when they breach the epithelial barrier. The growth of *S. aureus* in foods is likely to produce a heat stable toxin (Christensen and Bruggemann, 2014). *Bacillus cereus* (*B. cereus)* is another toxin producing pathogen whose toxins cause two types of illness with one type characterized by diarrhea and the other by nausea and vomiting. The effects of the diarrheal illness are seen 6 – 15 h after consuming contaminated food with the toxin of *B. cereus*. In the emetic poisoning, vomiting is seen after 30 min and lasts up to 6 h after consumption. *B. cereus* in foods multiplies quickly with a doubling time of 30 min at optimum temperatures around room temperature (Houška *et al*., 2007).

Salmonella spp., is the most common in food poisoning cases. The symptoms of salmonella poisoning is seen between 12 – 72 h and lasts between 4 - 7 days and most people get better without treatment (Eley, 1996).

2.6 Some chemical contaminants in street vended foods

Much data exist on the microbiological hazards in street vended foods, however very little data exist on the chemical hazards and thus this area needs attention (Proietti *et al.*, 2014). Some of the chemical toxicants likely to cause deleterious effects among consumers will include metals, polycyclic aromatic hydrocarbon (PAH), heterocyclic amines, and acrylamide bisphenol A (BPA).

These compunds could be present in the street foods as a result of chemical quality of the food ingredients, vendor food handling practices and environmental contamination (Transportation and storage).

2.6.1 Metals and Pesticide Residues

The presence of some heavy metals and pesticide residues has been associated with food borne illnesses that arise from the consumption of these street vended foods (Tomlins and Johnson, 2004). This is due to the conditions under which these street foods are prepared and sold, which include leaching of the contaminants from the utensils into the foods (Proietti *et al.*, 2014), the chemical quality of the food ingredients (Odai *et al*., 2008), or the transport methods used, and also from the use of inappropriate storage facilities.

The utensils used are a possible source of chemical contamination. Most of the utensils used by the vendors especially the cooking pots are locally made. A study showed that the sources of the materials used for making the locally manufactured utensils are derelict cars, car batteries and old industrial and scrap machinery. These materials obviously are not suitable for making utensils to be used for cooking food to serve the public (Gadaga *et al*., 2008). Tomlins and Johnson (2004) reported that food samples from vendors using cooking pots from local manufacturers contained higher levels of lead, cadmium, arsenic, mercury and copper. This finding suggests possible leaching out of the metals from the locally made pots.

Some bad agricultural practices also pose a challenge to the street vended foods sector. It has been suggested that some banned chemicals are reported to be mixed and sprayed on vegetables to obtain maximum effects. Thus, some of the vegetables from some farms are already heavily contaminated with pesticides (Amoah *et al*., 2006). Most of these chemicals are insoluble in water but are lipophilic, hence, can accumulate in the adipose tissues upon consumption. The toxicological effects of the toxicants are not immediately felt; however, upon prolonged bio–accumulation, the liver may not be able to detoxify these chemicals leading to various kinds of diseases, which may cause morbidity and death. Amoah *et al.* (2006) reported that in a total of 180 vegetables (lettuce, cabbages and spring onions) samples purchased randomly from 9 major markets in 3 major cities in Ghana, the maximum residue levels (MRLs) of pesticides in lettuce, was exceeded.

2.6.2 Polycyclic Aromatic Hydrocarbons (PAH)

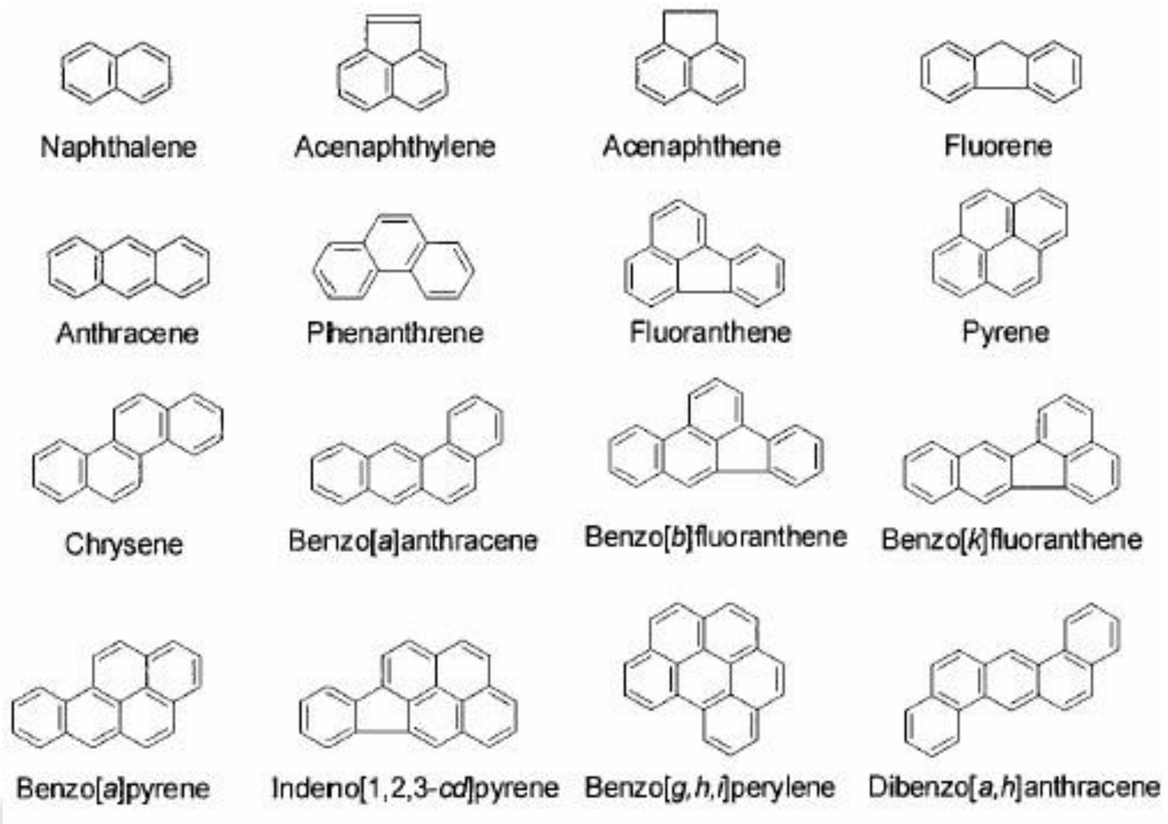
Polycyclic aromatic hydrocarbons (PAH) are a large group of over 100 organic compounds, which consist of two or more fused benzene rings in linear, angular or cluster formation. They are ubiquitous in the environment due to: industrial emissions in the form of smoke or particulates and intense thermal processing i.e. pyrolysis of organic matter or food nutrients (Bortey-Sam *et al.*, 2014; Orecchio and Papuzza, 2009; Ravindra *et al.*, 2008). The smallest member of the PAH group is naphthalene, which is a two-ring compound (Fig 2.1) (ATSDR, 2005a, 2005b). Three- to fivering PAH may occur as either gases or particles in air. PAH with five or more rings such as Benzo(a)pyrene (BaP) tend to attach themselves to the surface of particles or are a part of soot particles (Baek *et al.*, 1991).

Although many different PAH have been identified, enough toxicological data exists for a few, with some classified as carcinogens. The United States Environmental Protection Agency (USEPA), has listed sixteen (16) of them as USEPA‟s Priority Chemical list. They are naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)flouranthene, benzo(a)pyrene, dibenzo(ah)anthracene, benzo(ghi)perylene, and indeno(1,2,3-cd)pyrene (Bortey-Sam *et al.*, 2015). This list of PAH is often targeted for measurement in environmental samples.This is because are persistent in the environments, do not breakdown easily and have varying carcinogenicity in humans upon consumption (Nisbet and LaGoy, 1992; USEPA, 2008). In addition to environmental concerns, there are concerns about levels of PAH in foods that we consume (Akpambang *et al.*, 2009; Lijinsky, 1991; Phillips, 1999), most especially SVF but data in this regard is limited. PAH are non-polar, hydrophobic compounds, which do not easily ionize; as a result they are only slightly soluble in water, ethanol, acetone and acid (Lijinsky, 1991). The low molecular weight

PAH are volatile, whilst the high molecular weight PAH are less volatile and chemically inert (Olatunji *et al*., 2014). Because of their high lipophilic nature, they are easily absorbed in the lung, gut and skin of mammals. The relative solubility of PAH in water and organic solvents decide their ease for transport and distribution between the different environmental categories (USEPA, 2008). Their chemical reactivity influences their adsorption onto organic material or their degradation in the environment. All these factors help to determine the persistence and ability of PAH to bioaccumulate in the food chain (European Commission, 2002).

Two- to three-ring PAH are very volatile and entirely in the vapor phase, while PAH with 4 or more rings show insignificant volatilization loss under all environmental conditions (USEPA, 2008). Those with five (5) or more aromatic rings are predominant on particulates and settle on vegetables with large leaves. Grazing cattle and poultry may ingest these leaves as food contaminated by PAH and thus join the food chain (European Commission, 2002). Washing of the leafy vegetables may remove up to 50 % of the total PAH that are on the leaves (Ashraf and Salam, 2012; European Commission, 2002). However, PAH particles that are bound are easily removed by washing off the surface, whereas those that are adsorbed into the waxy layer are not efficiently removed (European

Commission, 2002). The chemical structures of some PAH are shown in Figure 2.1:



Source: (https://www.researchgate.net/figure/27797700_fig1_Figure-1-The-chemical-structure-of-the-16target-PAHs)

Figure 2.1: Chemical structures of some PAH

Carcinogenic studies of PAH in humans

Individual PAHs found in the environment are not in isolation but as components of highly complex mixtures of other chemicals (Bortey-Sam *et al.*, 2015). Most of the data on carcinogenicity of PAH in humans have been established by research for mixtures of compounds containing PAH (Warshawsky, 1999). The most potent carcinogenic PAH to humans has been found to be benzo(a)pyrene, BaP (Nisbet and LaGoy, 1992).

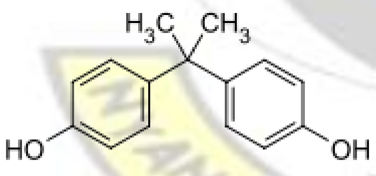
Food is considered to be one of the major routes of human exposure to PAH and they are formed during cooking, smoking and from atmospheric deposition (Akpambang *et al.*, 2009; Alomirah *et al.*, 2011; European Commission, 2002). Studies conducted on the levels of PAH in food substances reported a number of PAH in the foods (Olatunji *et al*., 2014; Šimko, 2002; Soceanu *et al*., 2014).

However, these foods did not include street vended foods and this is a cause for concern, since street vended foods are also subjected to all the sources of PAH contamination. The PAH do not exist in the environment in isolation therefore in conducting health risk assessment of PAH in a food complex all the PAH in the system must be used. The risk cannot be related to the sole total concentration or the most potent carcinogen amongst the list because each PAH has a different carcinogenic potential (Bortey-Sam *et al.*, 2015).

2.6.3 Bisphenol A (BPA)

Bisphenol A (BPA) is a carbon-based synthetic compound with the chemical formula $(CH_3)_2C(C_6H_4OH)_2$ belonging to the group of diphenylmethane derivatives and bisphenols. Bisphenol A is widely used in the production of epoxy resins, polycarbonate plastics and brominated flame retardants (BFRs) (Alaee *et al*., 2003). Bisphenol A is the monomer, and not an additive, for the production of polycarbonate plastic. This plastic is intended for food and beverages as well as resin that line metals in food and beverage cans (Alaee *et al.*, 2003).

The BPA is an organic chemical synthesized by condensation of two moles of phenol with one mole of acetone in the presence of an acid catalyst. It has the chemical formula $C_{15}H_{16}O_2$, with a molecular mass of 228.29 g/mol (Uglea and Negulescu, 1991).



Source: (http://organiceyourlife.com/bisphenol-a/)

Figure 2.2: Structure of Bisphenol A

Bisphenol A, is able to leach or migrate out of the plastic under elevated temperatures of between 100 ˚C and 120 ˚C (Alaee *et al.*, 2003). It has been found that the migration levels of Bisphenol A into food and water increase with high heat, acidic or basic contents, and increased age and usage of the plastic products (Brede *et al*., 2003; Howdeshell *et al*., 2003; Kang *et al*., 2006). These findings are significant because street food vendors use plastics in their food preparations at elevated temperatures of 100 °C and over. This will likely allow for the migration of the resins from the plastic into the foods for consumption, which is a major route for human exposure. However the types of plastics used by street food vendors are not known by the vendors, but everything is classified as „polythene‟.

Effects of BPA on humans

Through scientific studies on rodents, human health risks can be ascertained, but not fully quantified. This is because of the ethical dilemma of experimental human trials - all studies related to humans are epidemiological in nature. A study in Japan reported that women who are exposed to higher levels of BPA than a control group were more likely to have recurrent miscarriages. Patients were found to have an average of 2.59 ng/mL of BPA in their blood, where the control groups were found to have a mean quantity of 0.77 ng/mL of BPA in their blood. It was also found that in women who have autoimmune diseases, exposure to BPA can exacerbate the likelihood of a recurrent miscarriage (Sugiura-Ogasawara *et al*., 2005).

Another study reported that perinatal exposure to environmentally relevant doses of BPA may result in morphological and functional alterations of both sex genital tract and mammary glands. This could predispose those tissues to an earlier onset of disease, reduced fertility and increased mammary and prostate cancers (Maffini *et al.*, 2006). However, Haighton *et al.* (2002) reported that BPA is not likely to be directly carcinogenic to humans, unlike a chemical such as dioxin, but may have secondary mechanisms for carcinogenicity. Diel (2002) in another study concluded that BPA does not cause cancer cells to spread, but it inhibits natural cell death. Thereafter, it was found that BPA was not able to induce the proliferation of breast cancer cells, but may be a very potent inhibitor of cell apoptosis (Diel, 2002)

2.6.4 Environmental hygiene

The hygienic aspects of the vending of street foods are a major concern to food control officers (Mensah *et al*., 2002). The locations assigned for food vending usually lack facilities like refuse disposal units, toilet and hand washing facilities. Absence of these facilities lead to high pest infestation ultimately resulting in increased risk of contamination (Gadaga *et al*., 1999). Most often these vendors start the business without consulting the local authorities and then put up unauthorized structures (Solomon-Ayeh *et al.*, 2011). This leads to a constant battle between the regulatory authorities and the vendors when the authorities try to keep the city clean by removing the unauthorized structures. In many instances the removal actions begin when the activities of vendors heighten within a particular locality and are seen as disruptive. Despite all these situations, vendors are still found in such places. Why those places are preferred is yet to be understood. Current literature has little to say about why such areas are of choice to the vendors and how easily those places can be acquired despite all issues with authorities.

2.6.5 Personal hygiene of vendors

Vendors generally observe the concept of personal pureness that creates positive personal qualities such as neatness, friendliness and politeness as well as a front of good morals (Rheinländer *et al.*, 2008). Local perceptions of food safety and hygiene thus seemed to be highly influenced by values of neatness and appearance among both vendors and consumers, (Rheinländer *et al.*, 2008). This makes business sense, since customers" perceptions of food safety is also influenced by the appearance of the vendors. Other factors such as hand washing, talking whilst vending at the same time, using bare hands to serve the dishes were not considered as a matter of food safety (Rheinländer *et al.*, 2008). Observing these practices would be challenging for vendors since they are not perceived as food safety related. Therefore microbial contamination of street vended foods are likely to persist since these practices are sources of microbial contamination. There could be other practices which even though vendors may (not) perceive as food safety hence are likely to find difficulty practicing since no alternative practice is known or lack of food safety equipment (Donkor *et al*., 2009).

2.7 The Hazard Analysis Critical Control Point Approach

The Hazard Analysis Critical Control Point (HACCP) approach is a widely recognized system. Food industries use it as an effective approach for the elimination or reduction of identified hazard(s) by using critical control points (CCPs) to bring it to acceptable levels. The HACCP is a systematic approach which can be adopted at any stage of the food operation (Baş *et al.*, 2007; Billy, 2002). This system is a preventive approach seen more as a cost-effective method of food safety, rather than testing a product and then destroying or reworking it (Baş *et al.*, 2007).

However, prior to effective implementation of the HACCP system in any food business, certain practices known as the prerequisite programs must be in place. These include: ingredient and product specifications; staff training; cleaning and disinfection regimes; hygienically designed facilities and good hygienic practices (GHP) (Panisello and Quantick, 2001; Ra rez Vela and Martn Fernández, 2003). Once the HACCP system has been implemented, monitoring and

verification procedures form an integral part of the system to maintain the safety of the food. Small to medium sized enterprises (SMEs) as well as the less developed food businesses have found the application of the HACCP principles to be more difficult than it appears. Many researchers believe the size of the business is not an issue for difficult implementation of HACCP. The lack of knowledge and capability of the people who work within the business and the poor standard of existing systems such as good hygiene practice (GHP), determines the ease of implementation.

2.7.1 Street food vending and HACCP system

The HACCP concept has been applied in some food systems with the intention of identifying the critical control points in their preparation, and then suggesting possible control measures for their implementation. In a study conducted by Bryan *et al.* (1992), in Pakistan, the HACCP concept was applied to the preparation of *Chat,* a popular dish, to identify the CCPs in its preparation. The identified CCPs were handling after cooking and holding on display. Health agency personnel in developing countries, vendors, and consumers of these foods needed to be informed of the hazards and appropriate preventive measures (Bryan *et al.*, 1992). The HACCP concept applied was the hazard analyses including observing operations, measuring temperatures of foods throughout preparation and display, and sampling and testing for microorganisms of concern (Bryan, 1992). The control measures require that holding temperatures be measured and record kept at the identified CCPs. Vendors may not be in the position to make use of such interventions.

Ehiri *et al.* (2001) also applied the HACCP concept to complementary foods for children in Nigeria. The HACCP concept applied was to determine the microbial contamination and CCPs in the preparation and handling of complementary foods in 120 households in Imo state, Nigeria. They concluded that although unsafe environment poses many hazards for children‟s food, the hygienic quality of prepared food can be assured if basic food safety principles are observed (Ehiri *et al.*, 2001). When many factors contribute to food contamination, identification of CCPs becomes particularly important and can facilitate appropriate targeting of resources and prevention efforts (Ehiri *et al.*, 2001). The identified CCP for control was the purchasing of contaminated raw food stuff from vendors in the open market. This is one of the food handling practices, vendors do not consider as food safety (Rheinländer *et al*., 2008).

Toure *et al.* in 2011 also applied the HACCP concept step by step, to two selected weaning foods prepared by 15 volunteer mothers in peri-urban Mali with the aim to draw lessons on how to improve the microbiological safety of those two weaning foods (Touré *et al*., 2011). The lesson drawn in this study indicated that behavioural corrective actions by the food handlers were effective in controlling the hazards. This type of corrective action may be looked at when designing intervention for controlling food hazards in street vended foods since the use of food safety equipment is not ideal in controlling hazards in food vending. Thus the HACCP (Hazard Analysis, Critical Control Point) concept has been developed and widely applied to food hygiene in industrialized countries (Notermans *et al*., 1995a; Ra rez Vela and Martn Fern ndez, 2003) and adapted to small and less developed businesses (FAO/WHO, 2005b; WHO, 1996).

2.7.2 Implementing the HACCP concept at the street food level

There is an extensive literature suggesting the usefulness and effectiveness of HACCP in preventing food-borne diseases (Ehiri *et al*., 2001; Lucca and da Silva Torres, 2006; Touré *et al*., 2011). However, food operators especially the street food vendors, are yet to embrace it due to some challenges the food vendors have to overcome for the full implementation of HACCP at street food level, to ensure safe food preparation and its sale (Panisello and Quantick, 2001). Some of the challenges include:

1. **Low educational background of the street food vendors:**

Literature on the socio-demographic profile of vendors in the street food business has shown that the educational background or profile of some of the vendors in the street food business is very low (Adjrah *et al*., 2013; Gawande *et al*., 2013). The rural urban migration has led to a lot of people who come into the urban city to look for greener pastures with no educational background and hence cannot fit into the formal jobs (Draper, 1996). They therefore enter the street food industry which requires very little expertise. However, the HACCP plan, which is simply a document or folder, contains all the information related to the critical control points (CCPs) - together with the operating standards or critical limits. It also documents who is responsible for the monitoring of the CCPs and at what frequency, what corrective action should be taken if something goes wrong, the hazard that is being controlled (Panisello and Quantick, 2001), and a process flow diagram or stepwise drawing of each step in the process. The question now becomes, "how can people with little or no educational background effectively read, understand and apply the HACCP concept?" This would be a herculean task for the vendors who rely so much on culinary knowledge from ancestors or mothers or previous employment on the preparation and safety of the food.

2. **Knowledge on food safety and food borne diseases:**

Food-borne diseases constitute an important public health problem in both developed and developing countries (Abdul-Mutalib *et al*., 2012; Barro *et al*., 2007; Motarjemi *et al*., 1996). Given the inadequacies of traditional approaches to food safety control, being the inspection and endproduct testing, there is a need to apply the strategy of the proven effectiveness of the Hazard Analysis Critical Control Points (HACCP) system which has been described as the most viable means for the prevention of food-borne diseases yet devised (Motarjemi *et al*., 1996). Street food vendors" knowledge on food hazards relating to safety and its related diseases is again very low.

Due to the low educational background of vendors, knowledge on food related hazards could be a major challenge for their understanding. The lack of understanding and appreciation of the root causes of the problem will likely make it very difficult to solve food safety issues in street vending business. Behavioural intervention in relation to food safety, which this study seeks will be communicated to vendors. Policy briefs will be written to assist authorities implement to help mitigate the problem.

3. **Unhygienic operation and sanitation of the vending operation and facilities:** One of the key pillars for implementing the HACCP plan in any given food institution is a successful implementation of the Prerequisite programs (PRPs) (Mortimore, 2001). One of these PRPs is the designed hygienic facilities and good hygienic practices (GHP), a challenge for street food vending business. Extensive literature reveals that vendors operate under unhygienic conditions of food preparation and vending (Mensah *et al*., 2002). Some of these include the lack of infrastructure and crude existing stands or structures, lack of potable running water, toilets and adequate washing facilities (Lucca & da Silva Torres, 2006; Mensah *et al.*, 2002). Hand washing is even done in dish washing water (Barro *et al*., 2006; Mensah *et al*., 2002). No disinfection of premises or utensils, and insects as well as rodents are attracted to the sites where there is no organized sewage disposal (Mensah *et al*., 2002). Foods to be vended are not adequately protected from flies and refrigeration is usually unavailable. Under such conditions, it is very difficult for an HACCP plan to be successfully implemented. Therefore, training on the PRPs of the HACCP system for food operators and food regulatory officials would be a necessary condition for the realization of the fullest benefits of the HACCP concept in this food sector. Apart from these challenges to the effective implementation of HACCP in the street food vending business, other identified hindrances which include the lack of expertise and perception of benefits, absence of legal

requirements, as well as various attitude (wholeheartedly embracing the program) barriers and financial constraints (Ehiri *et al.*, 2001; Taylor, 2008) may affect the full implementation of the HACCP plan.

Evidently, the effective application of HACCP to small businesses, which includes the street food vending business, is a considerable challenge to both the food industry and enforcement agencies. Therefore, a more quantitative and practical approach to HACCP needs to be applied in these SMEs to improve the safety of the food they prepare or produce to be applied in a more quantitative manner (Notermans and Jouve, 1995). The solution may lie in the use of quantitative risk assessment (QRA). Quantitative risk assessment at the initial stages, identifies hazards which holistically identifies the sources and types of hazards as well as the effects (Gerba, 2000).

2.7.3 Risk Assessment in HACCP system

The international scientific community has over the period done an excellent work of developing and improving the HACCP tool, which is now widely known and in use to improve and have control over food borne safety hazards. However, there are still calls for refinement despite its international recognition as the accepted tool in the improvements for improving food safety. One of the topics that feature in the ongoing contemporary discussion is the application of the elements of risk analysis to food safety (Khandke and Mayes, 1998). Initially, HACCP contained the concept of risk categorization which was primarily done through qualitative means of ranking. A lot of the judgments which are made during the preparation of the HACCP plans are still based on qualitative measure and not quantitative data (Notermans *et al*., 1995b). The QRA has been proposed by a number of researchers as a quantitative means of hazard analysis to enable decisions to be made on quantitative basis when conducting hazard analysis and identifying the critical limits of the control points (Notermans *et al*., 1995b).

Quantitative risk analysis (QRA) can be defined as a stepwise analysis of hazards that may be associated with a particular type of food product, permitting an estimation of the probability of occurrence of adverse consequences from consuming that particular product (Gerba, 2000; Notermans *et al.*, 1995b). The QRA also consists of several logically successive elements, just like HACCP and these elements are:

1. **Hazard identification** is the first element which can be done in several ways and one of them is to do a qualitative indication of the presence of potential microbial/chemical hazards that may be associated with the consumption of a particular food product, or defining the hazard and documenting its toxic effects on humans (Gerba, 2000).

2. **Exposure assessment,** the second element, is a quantitative approach which leads to the estimation of the dose of the potentially hazardous organisms to which the consumer may be exposed to at the time of consumption (Notermans *et al.*, 1995b).

3. **Dose-response assessment,** the third element, is often termed as risk assessment, where information in terms of quantifying the negative health effects due to exposure to the organisms or chemical. Dose-response assessment translates exposure into possibility of disease and provides information about the probability (risk) that an adverse event will occur depending on the degree of exposure (Gerba, 2000).

4. **Risk characterization** is defined as the ranking of the probability of illness occuring according to severity and frequency, and this enables a decision to be made on the acceptance of a particular risk based on the degree of exposure. This step should include the determination of the most important factors that cause the risk (Gerba, 2000).

5. **Risk management** is the last element in the QRA process and the most complex of analysis and this requires judgments on the human perception, economic and social consequences of the risk from exposure to the hazard which aims at reducing the probability of the unacceptable risks (Notermans and Jouve, 1995). This step involves interaction and exchange of opinions and ideas among individuals, groups and institution.

The quantitative risk assessment can be conducted on the processing chain of a particular product or segments of the chain where deemed necessary. Upon completing the assessment, a particular process or step in the chain may be identified for intervention. The researcher then draws on the first step of the assessment, hazards identification, and then identifies the practice at that step and then puts in intervention measures. These measures do not necessarily require the use of food safety equipment as in the case of HACCP, it could be a behavioural change.

The application of elements of QRA in conjunction with HACCP will help change the HACCP plan into a quantitative system which will consequently improve the safety of the food (Notermans and Jouve, 1995).

2.7.4 Application of elements of QRA and HACCP

Quantitative risk assessment, (QRA) and HACCP are related, but fundamentally different processes. Some similarities exist between the inputs for the first elements of risk assessment (hazard identification) and HACCP (hazard analysis) (Coleman and Marks, 1999).

HACCP, which is a tool for safety management was conceptualized on two distinct processes, building safety into the product (hazard identification and CCP setting) and exerting strict process control (setting of critical limits and monitoring and validating the process). In other words, HACCP is a food safety management tool to minimize the occurrence of a hazard in a food product, whilst QRA assess the risk of the occurrence of adverse effects where the consumer is exposed to the hazard.

Careful combination of these two processes would lead to a high degree of confidence in the safety level of a product. So when QRA is used with HACCP principles it may help make the outcome of HACCP more defined where these two purposes are concerned (Notermans and Jouve, 1995). This study combined QRA with HACCP principles where vendor activities were linked with the occurrence of the hazard. Suggested interventions were based on vendor activities, which the vendors are more likely to relate withand may be willing to adapt the measures and bring about the needed results, i.e a reduction in the levels of the hazards.

Hazard analysis, which includes estimating the public health risk associated with the processing and marketing of a food product is one of the key basic processes of the HACCP plan. Therefore, it is important for consumables to be thoroughly analyzed for the presence of hazards and the levels of risks given by the hazards. The results of the analysis would be the basis for deciding the most appropriate intervention needed to keep (or to reduce) the risk under the tolerated (accepted) level (Gerba, 2000). In using the QRA approach, after the hazard has been identified, exposure assessment must be conducted, then the application of a dose-response assessment will finally provide information on risk levels given by the hazards due to exposure (Notermans *et al.*, 1995b). In the event of unacceptable risk, a formal risk characterization may be carried out to help risk managers to decide on what to do, which may include either modifying the processes and or product characteristics. If the risk is acceptable, studies to keep the risk at the level may be done through the confirmation of product/process characteristics and specifications, and with process control setting, that is, setting of critical limits at the control points.

In order to keep the process under control, HACCP team requires the establishment of documented evidence that the specific process will consistently meet the predetermined specifications of the product (Notermans *et al.*, 1995b). Therefore, the hazard identification process should identify what could possibly go wrong during production. Critical control points with critical limits must be determined, with monitoring system introduced. The documentation for the validation of the process must give evidence for compliance. Hence, processes or conditions that would lead to the unacceptable presence of the hazard such as contamination, re-contamination, growth or survival of micro-organisms must be critically examined for process or product failure (Notermans *et al.*, 1995b). This part of the analysis, that is, setting of critical limits is the most difficult part of HACCP and if the limits are not measurable then it is worthless, hence the need for QRA.

CHAPTER THREE

3.0 DILEMMA AND CHALLENGES OF STREET FOOD VENDORS: - FOOD SAFETY OR BUSINESS FIRST?

3.1 Introduction

The importance of street foods cannot be underestimated in developing countries where it serves as a large source of employment and income for many households (Choudhury *et al*., 2011a). Further, in countries and cities where the phenomenon is prevalent, street foods serve as an important component of the food distribution systems. Street food is defined by FAO as "ready-to-eat (RTE) food and beverages prepared and or sold by vendors and handlers in streets and other places for immediate consumption or at a later time without further processing or preparation"(FAO/WHO, 2005a).

The microbiological safety of street foods has received much attention from policy makers and scholars because of the risk these foods pose to the health of consumers. Various epidemiological studies conducted on street foods showed that, microbiological hazards like - feacal coliforms, *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* spp and *Bacillus cereus*, and chemical hazards like Pb and Al, were of levels higher than the acceptable levels set by the WHO (Kubheka *et al*., 2001; Mensah *et al*., 2002; Mohapatra *et al*., 2002; Osei-Kofi, 2003; Tomlins and Johnson, 2004; Baş *et al*., 2006; Rane, 2011; Dzotsi *et al*., 2014). Crucially, such levels (4.3 log CFU/g) have been linked with major outbreaks of fatal diseases such as cholera, diarrhea, typhoid fever and food poisonings (Tjoa *et al*., 1977; Umoh and Odobab, 1999; Mensah *et al*., 2002; Chizuru *et al*., 2008; Feglo and Sakyi, 2012) . Knowledge attitudes and practices of street food vendors have been widely studied around the world (Mosupye and von Holy, 2000; Mensah *et al*., 2002; Campbell-Platt, 2002; Barro *et al*., 2007; Omemu and Aderoju, 2008; Chukuezi, 2010; Ackah *et al*., 2011; AbdulMutalib *et al*., 2012; Feglo and Sakyi, 2012). These studies found that hygiene practices of vendors in handling foods are inadequate to ensure food safety and thus, represent a major threat to consumers‟ health. Vendors generally have inadequate knowledge on food safety and hygiene as majority of street food handlers are ignorant of basic food safety issues, hence, compromising food safety at all stages of food handling (Ekanem, 1998).

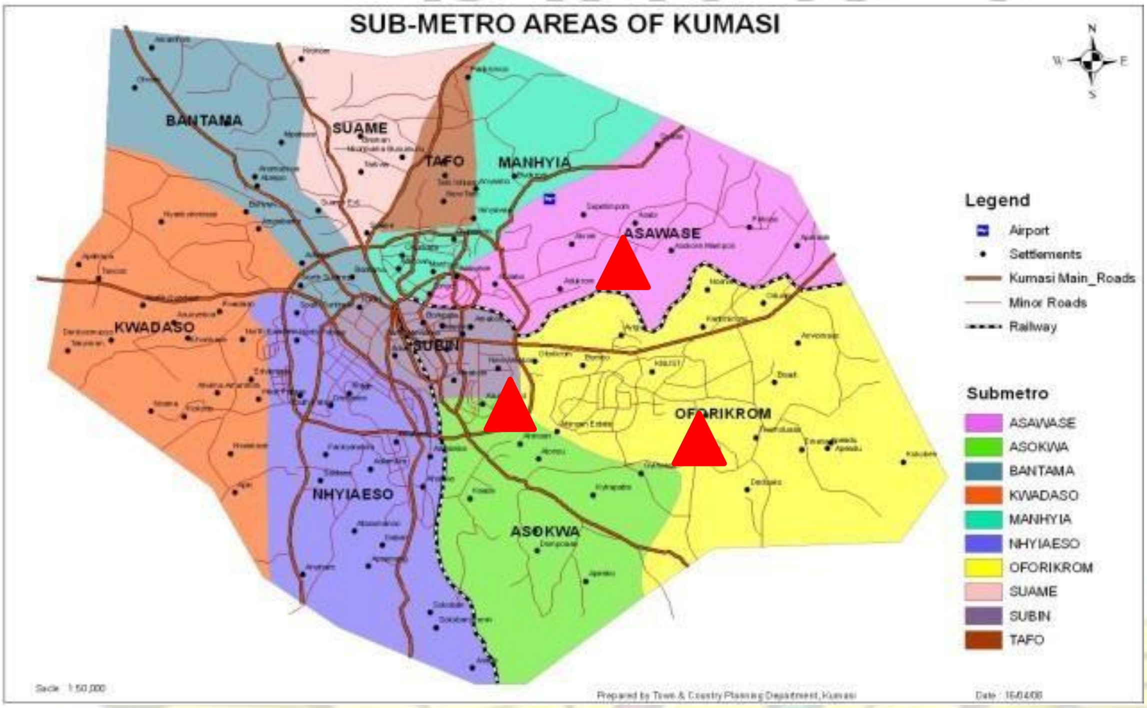
Recently, Ghana experienced major outbreaks of food borne diseases including cholera across the country, which was traced to victims‟ consumption of street water and food (Dzotsi *et al.*, 2014). The development has led to an ongoing nationwide campaign about food hygiene to improve street foods safety. Today, vendors are required to register and obtain certificates before operating a food service point. The registration process involves screening them for communicable diseases like Tuberculosis, Typhoid and Hepatitis, (Kosek *et al*., 2003; Soyiri *et al*., 2008).

Attempts on ways to improve safety of street vended foods through the vendor have largely focused on vendor‟s knowledge, attitudes and practices to street food vending using questionnaire based surveys. This aspect focused more on the preparation practices that compromise the safety of the vended foods. However, safe street food vending cannot be limited to only preparation practices. Factors such as environmental influences, vendor challenges in the business as well as the use of staff have a part to play on the safety of the vended foods. Vendor‟s own voice towards challenges they face which is likely to compromise safety of the vended foods have not been assessed. Thus the objectives of this study is how food safety considerations play out against business logic in citing business locations and training employees by vendors as well as the implications of the findings for policy on ensuring street food safety in Ghana. This information is needed when designing vendor based interventions to improve the safety of street vended foods with support of food safety authorities.

3.2 Methodology

3.2.1 Study site description

This study took place in Kumasi, the second largest city in Ghana, which is a trading and transport hub. It is a very busy city where people engage in different commercial activities; it has two large lorry stations with markets, where many travellers pass through with their merchandise to other parts of the country and beyond. Geographically, Kumasi is cited between latitude 6.35^o – 6.40^o and longitude 1.30^o – 1.37^o. The city has an elevation which ranges between 250 – 300 m above sea level and with an area of 254 sq. km and metro area of 299 sq. km. This study was conducted in three (3) of the ten (10) sub-metropolitan areas (Oforikrom, Asawase and Subin (red triangle inserts in Fig 3.1) within the Kumasi Metropolis. Of the three sub-metropolitan areas, two (2) locations each where street food vending is prevalent were selected for the study. Thus, the study covered six locations in three of the 10 sub-metropolitan areas in Kumasi.



(Source: www.mofa.gov.gh)

Figure 3.1: Map of Kumasi city showing all the metropolitan areas

3.2.2 Study population (vendor and staff)

In the three sub-metropolitan areas, six (6) sampling sites, where street food vending activities were highly concentrated were purposively selected for the study (Fig 3.1). The collection of data continued until a saturation point was reached – that is, when it became evident that, further information were only repetitions and at best, confirmatory, and had no or less value addition.

3.2.3 Data Collection methods

Individual recorded interviews were conducted with a total of 16 vendors and ten (10) staff (totaling 26). The interviews centered on how and why the vendors chose their current locations and the level of training they give to the supporting staff that assist in the food preparation (Appendix AI(B)). The idea behind this was to gauge how food safety considerations play out in their broad scheme of choosing locations for their businesses and employing people to assist the food preparation process. Averagely, the interviews lasted between 35 and 45 minutes. The interviews of the ten (10) staff focused on their roles in the day-to-day preparation of the food. They were also asked questions about employment, training, health and their challenges.

The participant observation method was also employed in the study, where the researcher spent a total of three (3) continuous days at each of the food preparation sites from as early as 0400 hrs for fufu vendors and 0600 hrs for fried rice vendors until vending was over at the fufu selling points that is 1600 hrs and at 1800 hrs, when the second batch of the fried rice has been sold out.

An observation guide was used to capture field notes, usually after observation sessions to avoid disturbing the operations of the vendors and the staff. In addition, occasional unannounced visits to the sites were done to verify if things were done differently from when the study subjects knew the researcher was coming around. This was done at least once for each of the study sites. The researcher also participated in a workshop organized for food handlers by the Kumasi Metropolitan Authority in conjunction with the Food and Drugs Authority on food safety and handling issues. The idea was to make observations on the program delivery and to enable the researcher to apprise herself with the content of the training given to participants.

3.2.4 Data management and analysis

The recorded interviews and the responses recorded as field notes were transcribed together by the researcher and two research assistants who had prior experiences in transcribing interviews. The interviews were conducted in English or „Twi" (a native language) depending on the preference of the interviewee according to her fluency level in either language.

The researcher collected all observational data in the form of field notes which were later compiled and kept for analysis. Notes from the unannounced visits to the vendors were used to verify observations made during the study period. These visits confirmed no differences in observations made during the study period.

The interview transcripts, unannounced visits and field observation notes were thoroughly read, the discerned patterns were organized into themes, which were further triangulated using the approach adopted by Rheinländer *et al.* (2008). The triangulation was done with literature, observations and the interview information.

3.2.5 Inclusion criteria

Vendors included in the study were fried rice and fufu vendors, who have established businesses and have been in operation for at least 3 years. These vendors had been in the business a minimum of three years and therefore had acquired enormous wealth of information and experience, which they brought to bare in the course of the study.

3.2.6 Ethical issues

Oral consents of the participants for the study were sought after their years of establishment of businesses were known. The vendors who were eligible but declined consent were not included in the study, only those who were willing to participate in the study were enrolled.

3.3. Results and Discussion

The study found that, while the vendors were largely aware of food hygiene and safety issues, factors such as the need for "good" locations, the fear of eviction by the authorities, and high rate of employee turnover impelled them to relegate food hygiene and safety considerations to the backburner.

3.3.1 Access to Good location

A „good" location according to the vendors is a place in proximity, maximum 500 m (FAO, 2016), to the customers. Obtaining a location of that sort was a huge challenge to the street food vendors.

This is because these „hot spots" are not usually public spaces, but areas already leased to certain individuals. City authorities have oversight of the use of public spaces The selling and food preparation points were all found around and within bus terminals. They are generally not planned into the overall architecture of the terminals as places for feeding. They are mostly pavements and other open spaces, which the vendors convert for their businesses. Some of these preparatory and vending places are busy hubs for people to board vehicles bound to various destinations. Such sites are squeezed out spaces enmeshed in places where other vendors and artisans like tailors, hairdressers, vulcanizers, „second -hand" clothe and shoe sellers, groceries sellers also operate. The inundation of such places by different swathes of people makes them strategic for the vendors since they could get them to patronize their food.

First, such places lack the essential facilities, such as kitchens with proper storage facilities, water supply, drainage and waste disposal sewers which are required to support hygienic and safe preparation and sale of safe food. The fact that such places are always overwhelmed by continual human and vehicular traffics even worsen the situation further. Most of the vehicles found in such places are old and not regularly and professionally maintained. Therefore, excessive emission of concentrated fumes from these over aged vehicles is likely to compromise the chemical safety of the food. This finding from the study in many ways confirm those of similar ones conducted in Ghana and other parts of Africa, which underscore the inadequacy of street food locations to support hygienic preparation, sale and consumption of food. For instance, FAO/WHO (1989) guidance to implementing food safety systems revealed that good hygienic practices tend to be lacking in street food vending activities as they face problems like inadequate location conditions.

Second, the tonnes of filth generated each day at these places are overwhelming and pose an intractable challenge for the authorities responsible for the cleaning and sanitization of such terminals. When it rains, the filth drains and chokes the gutters. They are mostly not cleared for a considerable period of time, leaving an eventual pungent stench. These spaces are also used as thorough fares by the several numbers of people who patronize the services of the many shops and poses additional challenge for safe food preparation and even consumption. In the night, these areas are usually infested with pests like rodents and cockroaches. Overall, the locations where the foods are prepared and (in some cases) sold, clearly pose health risks. These reasons make such places unfit for the preparation and sale of food. As reported by Muinde and Kuria (2005), the locations do not protect the prepared foods from dust and smoke from vehicles. This problem was also observed in a study conducted in Accra (Mensah *et al*., 2002) and Nairobi (Githahi *et al*., 2012) where street foods were sold in inappropriate vending stalls.

The general process of obtaining a location as was indicated by the vendors was to, first, identify the spot, and then negotiate with the owner for usage. But since they usually do not know the owner, they go through middlemen who negotiate on their behalf. The property owners charge rents and access is dependent on the vendors‟ ability to pay the rents, which are usually high. The spaces are temporarily leased to the vendors. Vendors can therefore be easily ejected when there is a change in ownership or by the city authorities leading to the loss of the hotspot.

In the course of the interviews, some of the vendors demonstrated awareness of the insanitary nature of the locations. Vendors cited factors that compromise safety of the vended foods of which they were aware of. Some of these factors are: being close to open and filthy gutters; open areas near fuel filling stations (dangerous location) and dirty surroundings (such as dirty markets). Others were inadequate size of the kitchen with no drains (basic hygiene facility); untarred areas generating dust and fumes from the vehicles. *The kitchen is an open place surrounded by basket weavers, vulcanizers and other sellers and this makes practicing hygiene very difficult,* (V05, Male FR).

Others were satisfied with their locations contending that, *if anything was wrong the Environmental Sanitary Officers would have pointed it out to us* (V15, Male FR). However, for the records, at the workshop organized for the vendors that the researcher attended, nothing was said about suitability of sites for food vending – the education mainly focused on some purchasing and hygienic practices of street food vendors. It mostly turns out that the locations, as noted by Solomon-Ayeh *et al.* (2011), have been approved by the environmental health authorities for such businesses. This may be so because the government generates revenue from these vendors and also it creates self employment. This lessens the government‟s burden of providing employment for them. Therefore may be forced to give out those places even though the place may not be appropriate for safe food vending. Thus the confidence by one of the interviewees in this study to argue that, if there were something wrong with where they prepared their food, the Environmental Sanitary Officers would have pointed out same to them.

Most studies have often reported that vendors were unaware of the effects these inappropriate locations can have on the health of the food and their consumers (Ekanem, 1998). However, the participants (13 out of 16 vendors) of this study clearly demonstrated such knowledge. A proxy of this argument is the high premium vendors put on the neatness or appearance of potential employees in the course of recruitment. Just as revealed in this study, other studies have also shown that these locations are usually infested with pests, dusty and smelling environment, non-cleanable surfaces and the old structures all of which contribute to microbiological contamination (Barro *et al.*, 2007). This makes it difficult to implement food safety systems, which would ultimately improve the hygienic conditions and safety of the vended foods. However, as found in this study and also reported by Solomon-Ayeh *et al.* (2011), the failure on the part of vendors to improve their food vending locations is borne neither out of their ignorance of the insanitary conditions of such places nor malice. The problem pertains to the vendors" perception that, their business locations are perpetually temporal in view of the imminent possibility that, they could lose the spots at any material time either through a change in location ownership or eviction by the authorities. They therefore did not find any economic sense in giving the places a facelift or putting up permanent structures.

3.3.2 Training of Employees/Supporting Staff

Street food vending usually involves the vendor (owner) and the staff, who just like the owners, are mostly (about 80%) females. Cooking is culturally gendered as female"s role (Ohiokpehai, 2003). Staff employment is very important to the vendors. Typically, the vendors go to the market, cook the foods and take charge of the vending process at the sale points. With the exception of going to the market, the rest of the works described below are done by the staff. These include all forms of cleaning, fetching water, doing errands and the disposal of waste. Some staffs are especially trained by the vendor in the food preparation so they do not compromise the „brand", which is tightly linked to the taste of the food.

Staffs, in some cases, lived on the food preparation premise some of which are old and worn out structures with leaking roof and small windows, with no basic facilities like bathrooms and toilets. They bath outside the premise in the night and access the public toilets when needed, but at a fee. The sleeping area is the same room where the utensils are stored along with other ingredients. They are usually crowded in the rooms in certain cases, with as many as five people sleeping in a very small room.

The staff indicated during the interviews that, their motivation is rooted in the fact that they were paid daily and got food to eat, at least, once a day. Even though they indicated that, they had never attended any food safety and handling training workshop, they said prior to their appointment confirmations, they received on the job training from vendors or senior staff, which lasted between 30 minutes to one week, depending on the job specification. All vendors had similar procedures of hiring staff: When an individual comes to them for a job and there are vacancies, the job seeker is taken through some screening process and subsequently employed when they are satisfied with their performance. The major criterion is appearance, which to the vendors, is an important proxy for evaluating the applicant"s neatness. However, other vendors may further interview applicants to explore their educational background, ability to demonstrate knowledge of food preparation for vending, and to correctly account for money, wash dishes and sweep floors.

Preparation activities start as early as 0300hrs and vending, from 0630hrs to around 2100hrs. The staff are generally fed once a day and in cases where an employee may arrive when all the food is sold out, she is given the monetary equivalent to enable her buy food elsewhere. The relationship between some vendors and their staff is cordial, whilst others are impolite. Where they are disrespectfully treated, it manifests in how they are yelled at. They are paid daily and according to the value the vendors place on the work they do. Usually if they learn of greener pastures elsewhere, from a colleague or get fed up with the vendors, they either leave unceremoniously or at short notice to the vendor.

Vendors expressed deep concerns about the high turnover of staff. At all the study sites, within a short period of three (3) months, four (4) vendors had changed all their staff, eight (8) of them had changed more than 50% of their staff, whilst the remaining four (4) vendors had changed at least one (1) employee. Vendors would ideally prefer the employee to stay on the job for about 3 years. *The older a person keeps at a job, the better s/he will learn and work well with you. They gain experience with* *time and they are able to do exactly how you want done. (V04, female FR).* While the employees studied complained of disrespectful treatments, the vendors also had their own set of issues against them, which included stealing and lack of respect on the part of some employees. The vendors were concerned about employing female employees with babies, *for food sellers we do not employ mothers with children, because at the time you really need them to work, that would be when their children would be crying for attention. Some of them are not clean and consumers do not want to see a mother with children as staff around a food vending site, because when the children poo, they will have to clean them up***,** (V02, Female, Fufu) as such; they mostly do not even employ such applicants.

During the interviews it was clear that 12 out of 16 vendors did not attend the workshop organized for them during the period of study. The non-compliant vendors argued that they already knew what was going to be said. Others indicated that the training was not effective because all vendors were „lumped‟ together, hence, it was not going to address specific needs; and as such, they were only *going to waste our time if we attended* (V07, male FR)

Despite the constraints of their locations, the vendors‟ try to inject some level of food safety considerations in their endeavors to the extent that, potential employees‟ ability for safe and hygienic preparation of food is made a condition precedent for employment, and they would even dishonor their applications on grounds of unkempt appearance. However, the caliber of personnel needed in the business sector put a serious limitation on how much they could insist in relation to potential employees‟ knowledge on hygienic and safe food preparation. Their employees just like some of them, generally are not highly literate and this may limit their knowledge levels on hygiene and food safety especially when they work on food in such large commercial quantities. This issue becomes even more problematic when viewed against their exclusion from the food safety training and workshops organized by the authorities for vendors.

The high turnover of staff was seen as a great source of worry to the vendors, hence, dissuading them from putting in the desired investment to train them on the requisite knowledge on safe handling of food. The vendors reasoned that they would not benefit from such investments as the employees may leave at any time, and in most cases, unceremoniously. Thus, they find it economically unwise to sink resources into training an employee who they are certain could quit to join their competitors, they have no recourse to take back from them such investments.

Some studies argue that staff training can have long term benefits, even with high staff turnover rates (Croucher *et al*., 2013; Jehanzeb and Ahmed Bashir, 2013). Any staff trained by a vendor will move to another business within the sector, and the training could lead to increased awareness of food safety practices in that area and even in the home. It is exceedingly likely that a vendor would employ another staff who might have been trained by another vendor, and subsequently become a vendor offering food for sale to the community (FAO/WHO, 2005b). While such arguments may be true, it was not clear, in this study, whether in the short term, individual vendors would want to shoulder the cost associated with training staff in terms of food safety.

Overall, the study shows how economic and business considerations compete fiercely against food safety and hygiene in street food vendors‟ decision processes relative to choosing locations for their business and training their employees. The vendors‟ desire to be closer to potential customers drives them to locations that could potentially, and in fact, compromise food safety. Just as pertains in the case of their employees, the glaring imminence that they could be evicted from such locations on any day serves as disincentive for improving the woeful insanitary conditions which, they are very much aware, adversely affect safe food preparation, sale and consumption.

3.4 Implications of findings

Customers who patronize street vended foods may never use their power of demand to force any changes in the status quo by withdrawing from consuming it. This argument is sound because as the study pointed out, the target groups of the vendors are the drivers and conductors, colleague hawkers, commuters, artisans and allied workers whose job locations are the very same places the vendors operate. If they find no health risk or are forced by circumstances to conduct businesses at such places, it may also be said that, they may not find problems with patronizing foods, prepared or sold at such places. Just as pertains in most developing countries, very few people could patronize the expensive foods sold at restaurants and other relatively well kept places – the majority of people are „forced‟ to patronize street foods due to their income levels and comparatively, the affordability of such foods. This means that, street foods would continue to be central to the food distribution systems in developing countries including Ghana. This then raises the serious question of how consumption safety of the street vended food can be ensured/ assured in the Kumasi Metropolis.

From the study, it came out strongly that vendors preferred business aspects over food safety aspects in the business. This led them to attend food safety training as mandated by the government officials alone, leaving behind the employees to undertake food preparation and possibly vending, so daily profits can be realized. This arrangement has been negotiated by the vendors with government offials incharge of food safety, to enable the business to continue in the day. Therefore, the authorities‟ exclusion of the employees‟ of vendors from their training and workshops is highly unprogressive and must be reviewed with the needed urgency. These employees are the main food handlers in the vending business and must have food safety training to enable safe handling of food for public consumption. The decision may be grounded in the trickling down mindset that, once the vendors are trained, they would eventually impart the training on their employees. While such reasoning may appear innocuous, it is however argued that, the business of ensuring public health relative to food safety is too serious to be left at the discretion of vendors. Sequential training of each staff once employed with refresher training yearly must be emphasized. Moreover, as underscored by FAO/WHO (2005), training vendors on food safety inures to the benefit of not just the street food industry; it also has the ripple effect of ensuring safe food preparation at the household and community levels since the trainees would send and apply the acquired skills in their various homes and communities.

In the study it was found that, the bundling of all vendors into single groups as if they were a homogenous group during trainings and workshops demotivates most vendors from participating in such rather important exercises. Accordingly, it is urged that the "one size fit all" training manuals and approach be abandoned. The training should be tailored to meet the specific needs of the vendors. There must be diversity of training where some vendors are made „trainer of trainers" in their communities. Communicating good hygienic practices to fellow vendors will be easier since they understand each other better rather than the authorities whom the vendors perceive as their

„enemies".

3.5 Conclusion

This study has shown that street food vendors prefer business aspects of street food vending over the safety aspects and this has implications in the implementation of a good food safety program to improve consumption safety of street food. This means business trainings can be tied to food safety training to ensure maximum participation of vendors.

CHAPTER FOUR 4.0 MICROBIOLOGICAL AND CHEMICAL HAZARD IDENTIFICATION IN THE

PREPARATION AND VENDING PROCESSES OF TWO STREET VENDED FOODS

4.1 Introduction

Street food is defined as “ready-to-eat” food and beverage prepared and sold by vendors and hawkers, especially in the streets and other public places (FAO/WHO, 2012)). Rapid urbanization and changing urban lifestyles have fuelled the street food vending business in many developing countries including Ghana. Street food vending provides complete meals and refreshments at relatively low prices, and provide an essential service to workers, shoppers, travellers, and people on low incomes (Lucca and da Silva Torres, 2006). The street food vendors operate from busy spots located all over the city, in streets, markets and even at traffic junctions with limited access to water and sanitation facilities (Mensah *et al*., 2002). Their operations are less formal and the food is mostly prepared elsewhere and brought to the vending site. The prominent varieties of dishes found on the menu are usually context determined and reflect the popular dishes of the locality where the food is sold. This notwithstanding, meals such as „waakye‟, „fufu‟, „banku‟, and „kenkey‟ are very common and could be vended in combinations. A typical street meal may cost less than USD 1
(GhC 4) making this enterprise a cheap source of meals. Estimates by the Ghana Statistical Service (2014), show that there were about 20,000 registered food vendors operating in Kumasi.

The consumption of street foods however presents public health risk. In Africa for example, WHO cited diarrhoea as one of the major causes of death in children under 5 years of age (Bryce *et al.*, 2005). In Ghana, for example, persistent diarrhea among children and adults has been cited as one of the major causes of hospital attendance (Feglo and Sakyi, 2012). Diarrhea may result from consuming foods contaminated with common food borne bacteria pathogens like *Escherichia coli*, *Shigella* spp., *Salmonella* spp., *Vibrio cholerae* and *Campylobacter jejuni, Bacillus cereus*, *Staphylococcus aureus*, *Clostridium perfringens*; protozoa such as *Giardia lamblia*, *Entamoeba histolytica*, *Cryptosporidium* spp, helminthes and enteric viruses and rotavirus (Motarjemi *et al.*, 1993). Infections due to pathogenic *E. coli* are probably the commonest illnesses in developing countries and produce up to 25% of all diarrheal episodes (Motarjemi *et al.*, 1993).

Street vended foods have extensively been analysed for the presence of microbiological contaminants and have been found to contain high levels of contaminants of microbiological origin (Mosupye & von Holy 2000; Kubheka *et al.* 2001; Mensah *et al.* 2002; Barro *et al.* 2006; Lucca & da Silva Torres 2006; Chukwuemeka *et al.* 2010; Feglo & Sakyi 2012). A number of risks factors including poor food handling practices like the use of bare hands in selling food (Mensah *et al.*, 2002), using dirty dishwashing water to wash plates and hands and the use of same hands to handle money (Barro *et al.*, 2006) have been reported. Also poor environmental conditions (Lucca and da Silva Torres, 2006), lack of clean water and toilets (Dzotsi *et al.*, 2014) and poor personal hygiene (Chukuezi, 2010) have been associated with the contamination of food at the vending site. However, some of these practices are likely to introduce chemical contaminants into the street vended foods. Some chemical contaminants such as heavy metals and pesticide residues have been quantified in street vended food and have been associated with food borne illnesses (Tomlins and Johnson, 2004; Amoah *et al*., 2006). Amoah *et al*. (2006), observed that pesticide residues were detected in only the vegetables as a result of the farming practice. So far there has been very little information on chemical contaminants in street vended foods, most especially chemical contaminants as a result of vendor and vending activity. It is therefore necessary to identify and quantify chemical contaminants in street vended foods whose presence are as a result of vendor practices (Proietti *et al.*, 2014). The associated practices will assist together with scientific approaches in determining interventions to mitigate the problem of much needed safe food handling practices during preparation and vending of street foods.

Hazard analysis with the preparation practices along the preparation and vending chain as well as the specific components of a meal type is not well documented. This study aims at hazard (of chemical and microbiological origin) identification along the preparation and vending processes of the components of fufu and fried rice. These foods in previous studies have been identified as containing unacceptable levels of microbiological hazards (Mensah *et al.*, 2002; Feglo and Sakyi, 2012).

4.2 Materials and methods

4.2.1 Description of study area

Please refer to Chapter 3.2.1 (Study site description)

4.2.2 Study population

At each location, two fufu and two fried rice vendors who have been in operation for at least three years were approached. A total of ten fufu and eight fried rice vendors voluntarily participated in the study with oral consent and they were assured confidentiality of the information provided. All the street food vendors who participated in this study operate at daytime; however, three „fufu‟ and five fried rice vendors extend their activities into the night (between 2200 hrs and 0000 hrs). All the vendors (owners of the business) had at least two engaged staff.

4.2.3 Hazard identification

An onsite verification of food preparation and vending practice was undertaken using the participant observation method as follows: The food preparation practices of each street food vendor were monitored and field notes taken for three weekdays (from 0700 hrs to 1600 hrs) using an observation guide covering the issues listed in Table 4.1. Routines at each food handling point were monitored and noted starting from 0700 hrs morning until 1600 hrs. In addition, at least, one unannounced visit was made to all vendors to verify the observations made during the three day routine visits. The duration of the cooking time was measured using a stopwatch. Unhygienic food preparation practices that were critical for both chemical and microbiological contaminations were noted for each vending business. Each vendor or staff was asked to show their health certificate issued by the Environmental Health Unit under the Metropolitan Authority of Kumasi.

4.2.4 Data Analysis

The information gathered from the field observations was used to construct the flow diagrams for the food preparation and vending (Figures 4.1 and 4.2) of fufu and fried rice meals, respectively. Hazard analysis was conducted at each stage of food preparation and vending using information from Tables A1 – A7 of tables in Appendices II and III.

Table 4.1: Observation guide for food preparation and vending sites.

Variable	Indicator	Method
Raw materials (Ingredie and Water	Source, quality, transportation and storage conditions; Sources and uses of water, storage of water, suitability of storage container;	Observation
Food preparation	Stages of preparation and practices; other foods prepared and sold; Place of preparation and vending; Preparation done by who and for how long?	Observation / Measurement
Equipment and utensils	Type, appearance, hygiene conditions, storage conditions, washing frequency.	Observation
Personal hygiene and Hygiene habits	Sex, covering of hair during food preparation. Frequency of hand washing, occasion of hand washing, coughing and sneezing over food	Observation
Waste disposal	Types of waste generated, time of disposal,	Observation
Pests	Types and presence of the pests as well as how they are dealt with	Observation
Vending unit conditions	Sale points and conditions, extra preparation practices through which the foods are taken through at the vending sites and possible contamination points. Other vending points	Observation
Vending process	By who, how often, vending time (duration) of each batch	Observation / Measurement
Conditions around the vending and preparation facility	Heavy vehicular movements, presence of toilet facility close by, presence of open gutters, and presence of refuse dump near the facilities.	Observation/ Interviews

4.3 Results and Discussion

4.3.1 Demographic profile of vendors and staff

The demographic characteristics of the vendors showed that 70 % of them were females and they were all above 31 years of age (Table 4.2). This finding was similar to that of other studies conducted on street foods in Nigeria (Muyanja *et al.* 2011; Aluko *et al.* 2014). In contrast, majority of the staff members enrolled in the study were below 30 years (Table 4.2). Most of the vendors had attained secondary level of education and all the vendors were in possession of a health certificate whereas 33 out of 36 employed staff did not have the health certificate. In a study conducted by Ohiokpehai (2003), it was revealed that female vendors sold nutritionally better food than their male counterparts. It is however not certain whether the predominance of women in the street food vending trade is advantageous to food safety. In the United States, safer food preparations were reported by persons who were female and at least 40 years of age with a high school education (Klontz *et al*., 1995)The vendors involved in the study had several years of work experience, which were obtained from their previous employment as assistant vendors (Table 4.2). Sixty five percent and 94 % of staff from fufu and fried rice vendors, respectively enrolled in the study had below 2 years of work experience in the street food business.

Table 4.2: Demographic characteristics of the 'Fufu' and Fried rice street food vendors and staff

Parameters	Levels	Vendors		Staff	
		„Fufu‟ n=10(100%)	Fried rice n=8 (100%)	Fufu n=20 (100%)	Fried rice n=16 (100%)
Age	<20	0 (0 %)	0 (0 %)	2 (10 %)	9 (56 %)
	21-30	0 (0 %)	3 (37.5 %)	11 (55 %)	4 (25 %)
	31-40	4 (40 %)	4 (50 %)	6 (30 %)	2 (12.5%)
	>40	6 (60 %)	1 (12.5 %)	1 (5 %)	1 (6 %)
Gender	Male	0 (0 %)	3 (37.5 %)	1 (5 %)	3 (19 %)
	Female	10 (100%)	5 (62.5 %)	19 (95%)	13 (81 %)
Educational Attainment	No schooling	4 (40 %)	0 (0 %)	6 (30 %)	2 (12.5 %)
	Primary school	1 (10 %)	0 (0 %)	6 (30 %)	1 (6 %)
	Secondary school	4 (40 %)	5 (62.5 %)	8 (40 %)	12 (75 %)
	Tertiary/Vocational	1 (10 %)	3 (37.5 %)	0 (0 %)	1 (6 %)
Health certificate	With	10 (100 %)	8 (100 %)	1 (5 %)	2 (12.5 %)
	Without	0 (0 %)	0 (0 %)	19 (95%)	14 (87.5 %)
Length of time spent vending (year)	0 to 2	0 (0 %)	5 (62.5 %)	13 (65 %)	15 (94 %)
	3 to 5	4 (40 %)	1 (12.5 %)	2 (10 %)	0 (0 %)
	5 to 7	2 (20 %)	2 (25 %)	0 (0 %)	1 (6 %)
	>7	4 (40 %)	0 (0 %)	4 (20 %)	0 (0 %)
Former vocation	Assistant vendors	7 (70 %)	5 (62.5 %)	11 (55 %)	6 (37 %)
	Artisans	1 (10 %)	1 (12.5 %)	1 (5 %)	0 (0 %)
	Others	2 (20%)	2 (25 %)	8 (40 %)	10 (63 %)
Attended any food handling training	Yes	5 (50 %)	5 (62.5 %)	0 (0 %)	2 (12.5%)
	No	5 (50 %)	3 (37.5 %)	20 (100 %)	14 (87.5 %)
Work Schedule (Staff)	Food preparation			12 (60 %)	7 (44 %)
	Food preparation/ vending			5 (25 %)	2 (12.5%)

Vending	0 (0 %)	2 (12.5%)
Food preparation and cleaning	1 (5 %)	4 (25 %)
Cleaning	2 (10 %)	1 (6 %)

*- %: Percent, n: Number of respondents

4.3.2 Fufu preparation

Fufu and „light‟ soup (meat based) is prepared according to Fig 4.1. Raw cassava and plantains are peeled, washed and boiled in a cooking pot with water for about 2 hours after which the water is drained and the cooked cassava and plantain are pounded together to make a batch of fufu. A portion of the batch is taken and molded in an earthenware to be served. Meat is spiced and boiled for about one hour to prepare a stock soup, light soup, as shown in Fig 4.1. A portion of boiled, milled vegetables like garden eggs, pepper, tomatoes and ginger is then mixed with the stock soup and boiled briefly to prepare the light soup. A portion of the light soup is taken and sent to the vending site to be served with the molded fufu.

The placing of cassava and plantain on the ground at the peeling stage (Fig 4.1) for „fufu‟ preparation are likely to get the peeled products contaminated with pathogens from the soil. For example, *Bacillus cereus* is a potential pathogen likely to be present on the foodstuff from the farm, during transportation and handling processes because *Bacillus cereus* has been commonly isolated from soils (Rane, 2011). Thus the potential pathogens likely to be present on the cassava includes *B. cereus*, *C. perfringens* and *E. coli*.

However, it is expected that during boiling (cooking) (for 2 hr and 30 min) of the peeled cassava and plantains, all vegetative forms of pathogens would not survive (Chizuru *et al.*, 2008); not even the spores of *B. cereus* and *C. perfringens,* are likely to survive (USDA, 2012). Therefore, the pounding and vending stage become very critical for monitoring since no other point exists after the cooking stage to reduce microbial load. At the pounding stage, the handling practices are similar to the vending process, where the „fufu" is extensively handled with the bare hand and lubricated with water as it is being pounded with mortar and pestle. The extensive handling of the fufu, the source of water as well as the hygienic state of the utensils are important factors for microbial contamination.

A WHO regional report (WHO, 2009) observed that the „hand is the most important vehicle for the transmission of microbes from feaces, nose, skin or other sites of the body and the environment into food". In general, hand washing practices of both the vendors and their staff are not sufficient to prevent the transfer of pathogens from hands to the food, as they do not adhere to the right protocol for hand washing given by WHO (2009). The hands are simply rinsed in dishwashing water, which might be already contaminated through previous dishwashing activities. Barro *et al.* (2006) carried out a study in Ouagadougou to assess the hygienic status of the dishwashing water used in vending businesses where about 10^4 coliforms/ mL were enumerated in the water after the second round of dishwashing. Proper hand washing has been reported to reduce the levels of pathogens by about 2 log units (Montville *et al*., 2002). Therefore hand washing basins, with running water from water storage containers fitted with a tap, and amply supplied antibacterial soap and paper towels should be provided at the vending and preparation sites. The sight of this is likely to remind vendors to wash their hands frequently (Baluka *et al*., 2015). During the boiling stage, it is anticipated that chemicals contaminants are likely to leach from the plastic film used to cover the cassava and plantain (Fig 4.1; Table 1A), and also from the use of locally manufactured pots (Gadaga *et al*., 1999).

Some high risk chemicals may include metals such as Al, Pb and Fe (from the locally made pots) (Tomlins and Johnson, 2004; Dabonne *et al*., 2010; Weidenhamer *et al*., 2014) and Bisphenol compounds (EPA, 2015) (from the plastic material) as reported by Willhite *et al.* (2008). These chemicals do not break down during food preparation conditions and hence, persist throughout the preparation chain until consumption. When asked their preference for the use of local pots over the foreign pots, vendors reported that the local pots are "durable", "affordable", "cook faster" and "easily accessible".

The nature of the mortar and pestle, (all wooden utensils), with the pestle having a brush like end (head) used in pounding the fufu, and the mortar, having hairline cracks in them. These features make it easy for the development of biofilms on them as they are difficult-to-clean. Dark spots around the brushes of the pestle indicates microbial growth probably of fungi origin, which are introduced into the fufu during the pounding process. The pestles could probably be dipped into NaCl solution after pounding, to provide saline conditions to prevent microbial growth (Amoah *et al*., 2007; Montville *et al*., 2002). This practice will most likely reduce the levels of microbial contamination and subsequently pathogens likely to be introduced through the pestle (Hui, 2015). The quality of the municipal source of water is very important, since vendors rely heavily on the municipal source of water for all food preparation and handling. Water is well known to be an important vehicle for pathogens like *E. coli*, *Salmonela* sp. and *Campylobacter* sp, (Rane, 2011). In times of water shortages, all the vendors store water but most of the storage containers are open barrels with no lids. Naphthalene (one of USEPA 16 top priority PAH) balls also known as „Camphor" is put in the stored water as a deodorant. In addition, vendors use unclean containers to fetch water from these storage barrels leading to further contamination of the stored potable water. The bacterial quality of the water used for street food vending has been noted to contain coliform and faecal coliforms and may contain species of pathogenic *Salmonella* and *Shigella* (Noor, 2016). During the vending process, another practice identified as a possible source of contamination, was the use of same hands to serve the meals and also to collect money. Money has also been implicated as a very good source of pathogens like *Staphylococcus aureus* and faecal coliforms (Bryan *et al*., 1992; Barro *et al*., 2006) because it travels through so many handling processes and these pathogens can therefore be easily transferred to the food. A possible intervention is the creation of points of payment after purchase.

FUFU PREPARATION

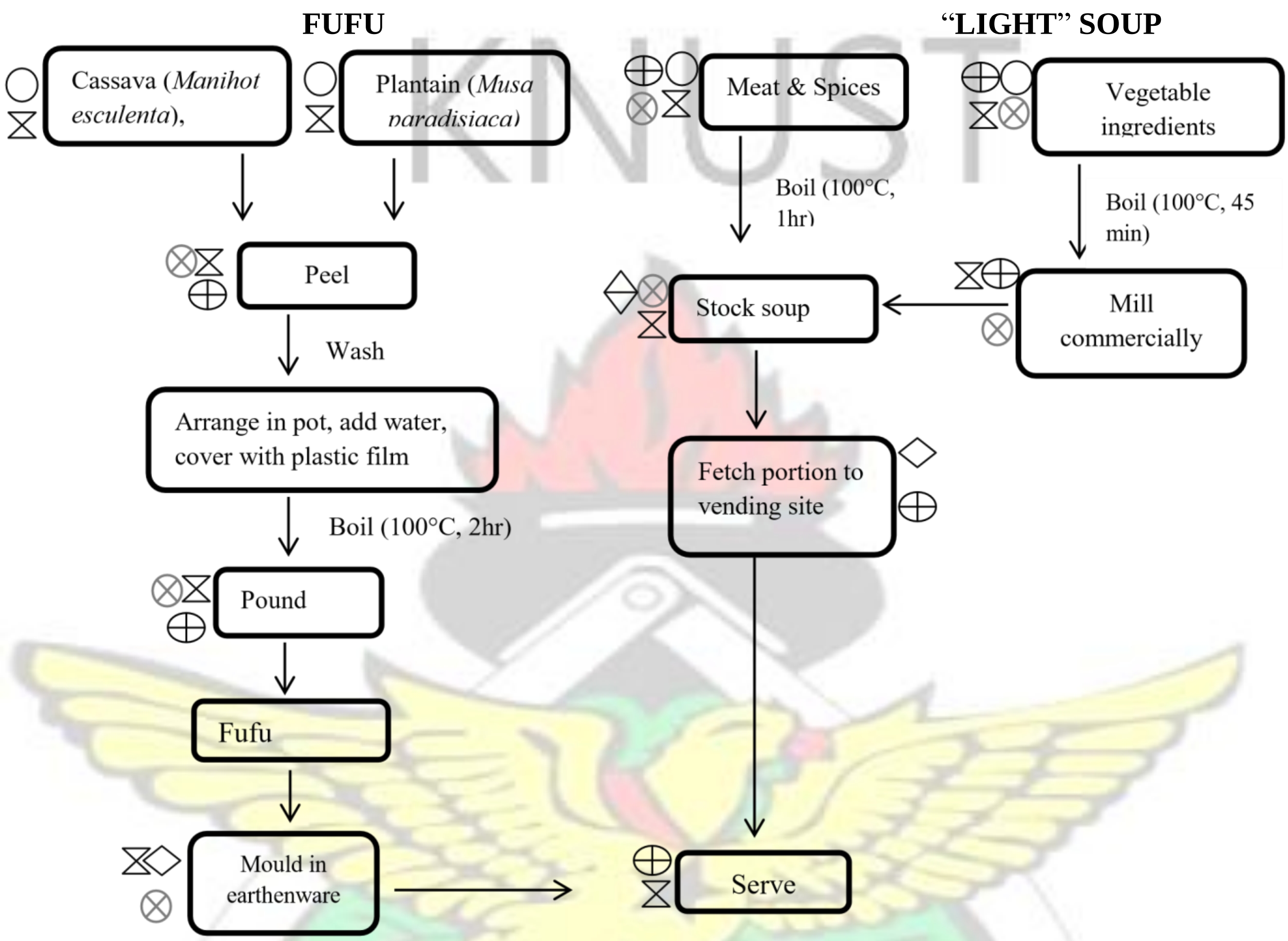


Figure 4.1: Preparation and vending process of fufu with 'light' soup

Legend

⊕ Utensil contamination

◇ Ingredient contamination

⧖ Hand contamination

○ Initial contamination

◇ Environment contamination

⊗ Water contamination

An additional risk factor observed is that the remaining batch of fufu which sits usually uncovered and sold on demand, usually lasts between 30 minutes to two (2) hours. This practice exposes this batch to flies, dust and soot in the environment (Lucca and da Silva Torres, 2006). This practice is therefore a potential source of microbial contaminants like *E coli*, *Staphylococcus aureus* and *Bacillus cereus* through aerosols (suspension of fine solid or liquid particles in air) generated from the ground through activities such as sweeping, dust from moving vehicles and pedestrians.

One risk factor in the soup preparation is associated with the use of the commercial mill base, where the ingredients can be contaminated with the metal Fe, resulting from the wear and tear of the grinder (Ojekale *et al.*, 2013). Also, cross contamination of bacteria and other microbes from previously milled foods due to improper cleaning of the grinding mill can occur. The use of personal blenders with stainless steel blades which can be kept in a hygienic manner is recommended as they are convenient and widely available on the market. Bare hands are used to pick up meat from the basket, containing previously cooked meat for soup preparation, and dip it momentarily into the boiling prepared soup before serving is a potential source of cross contamination due to the effects of poor hand hygiene (Jumaa, 2005) and could be a source of microbial contamination for the prepared soup.

The cooking fuel, used for making soup was either charcoal or burning wood with pieces of plastic waste thrown into the fire as a means of disposal but this produces smoke. This practice could introduce poly aromatic hydrocarbons (PAH) into the soup making it a risk factor for chemical contaminantion. The smoke saturates the cooking area and besides, PAH is lipophilic (Dennis *et al.*, 1983) and is likely to get dissolved into the oil layer on top of the soup. Food preparation and vending sites located at transport terminals and at the side of busy streets could lead to contamination by exhaust fumes from vehicles, another source of PAH.

Lead (Pb) residues also get into the soup as fumes from the exhaust. The source of Pb is as a result of the combustion of Pb-fuel (Rodríguez-Flores and Rodríguez-Castellón, 1982) or possibly corrosion of Pb from the locally manufactured utensils (Weidenhamer *et al*., 2014). The type of fuel used in Ghana predominantly by the public transport or commercial vehicles are the leaded types of petrol and diesel fuels (United Nations, 2001).

4.3.3 Fried rice preparation and vending

At the preparatory stage (Fig 4.2a), the raw rice is cooked by boiling with water for about 2 hours and packaged in food warmers. The raw cut chicken is seasoned, boiled, strained and fried, packaged separately in plastic containers. The vegetables are peeled, washed, sanitized and chopped. They are packaged into two separate containers; contents of one of the containers is used as salad and the other for stir frying with the cooked rice. The shito is prepared by frying the milled ingredients such as smoke-dried fish, onions, pepper and spices, in oil. The shito is either packaged in clean plastic or glass jars after cooling.

At the vending stage, a portion of the cooked rice is stir-fried with a portion of chopped vegetables and spices to prepare a batch of fried rice (Fig 4.2b). A portion of the fried rice is served with shito, chicken, salad, mayonnaise and ketchup in proportions according to the price being bought.

In the fried rice preparation, cutting and washing of the chicken in the facility leads to splashing of water around the preparation facility. The splashes are cleaned with an all-purpose cleaning napkin. This practice is a potential source of widespread facility contamination with pathogens such as *Campylobacter*, *Salmonella* spp, *E. coli*.

<u>FRIED RICE PREPARATION AND VENDING PROCESS FLOW DIAGRAMS</u>

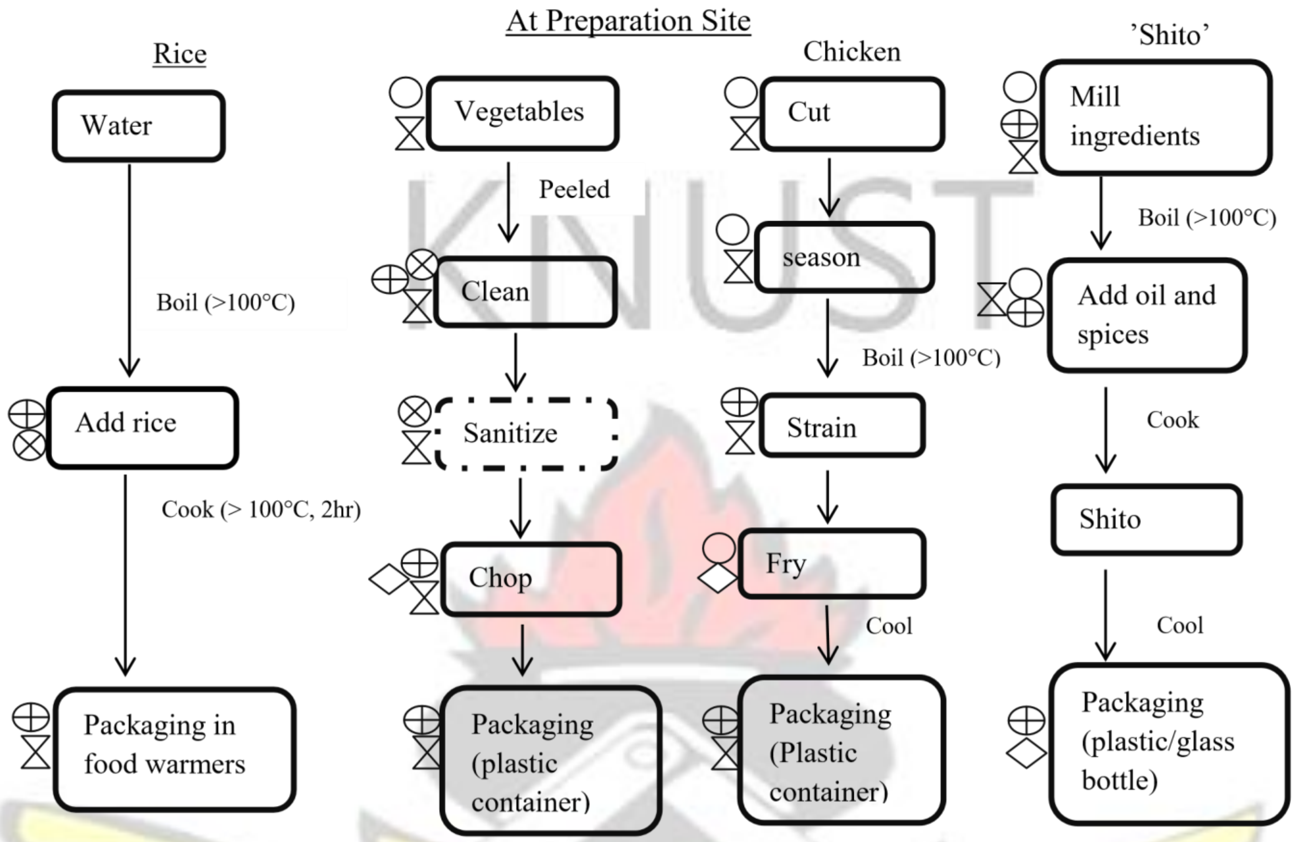


Figure 4.2a: Rice, vegetables, chicken and 'Shito' preparation steps for fried rice process flow diagram.

Legend

⊗ Water Contamination
○ Initial Contamination
⊕ Utensil Contamination
◇ Environmental contamination
⟠ Ingredient contamination
⧖ Hands Contamination
⬚ Optional step

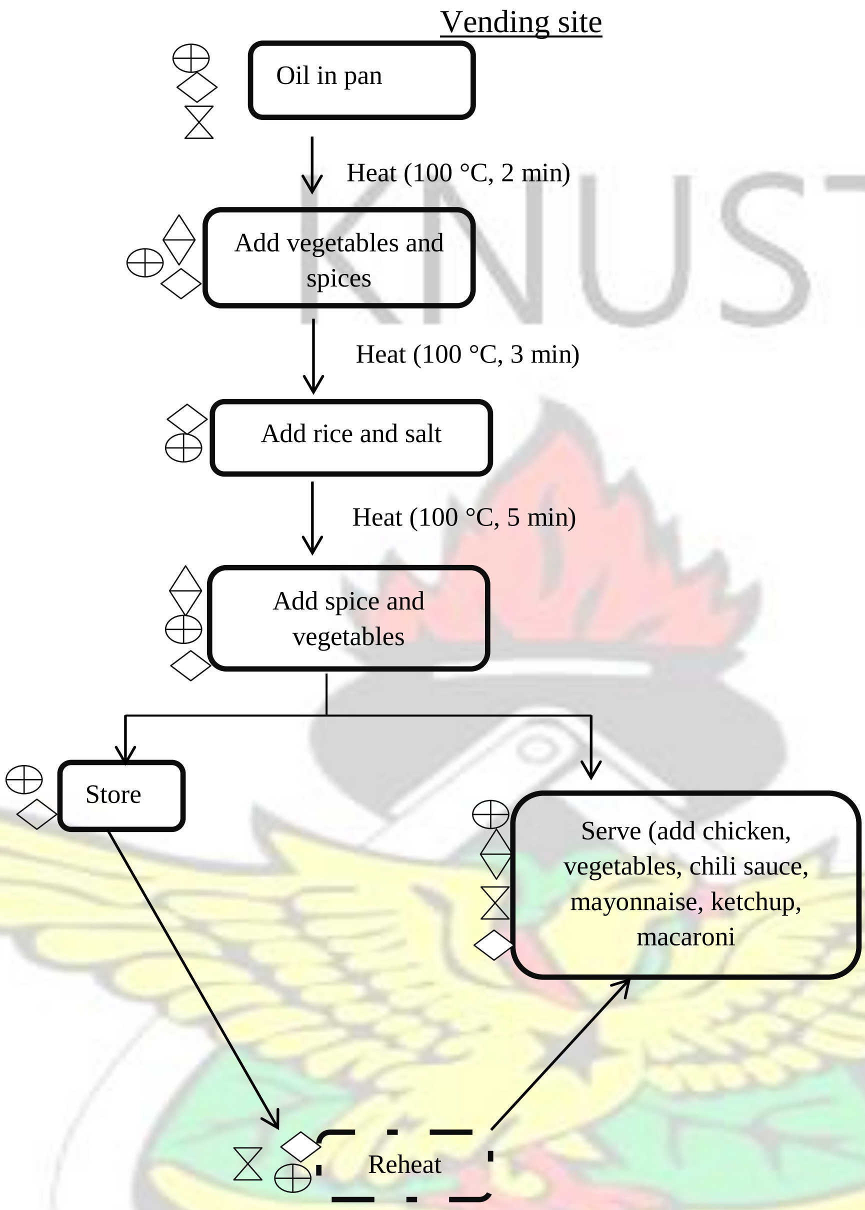
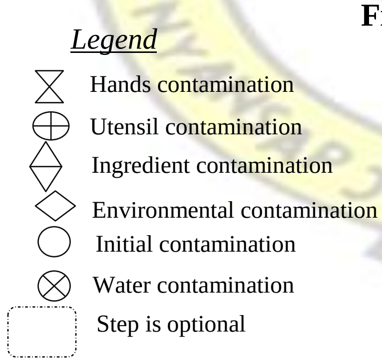


Figure 4.2b: Fried rice preparation steps process flow diagram.



The washing of chicken in the cooking area has been sternly warned against by food safety experts (Green Brown *et al*., 2013) as this practice helps spread infections easily through the splashes of water in the cooking area. The health experts also advise immediate cooking of chicken after defrosting, as this practice will reduce the spread of infections from such pathogens (FSA, 2014). Based on the vendors practices at this stage of preparation it is being proposed that separate containers should be acquired and used for the purposes of cleaning the chicken outside the cooking area. The all-purpose napkin used to clean working surfaces and other surfaces encourages cross contamination of pathogens to the working surfaces and the hands (Mensah *et al*., 2002). Vendors should be trained on the use of napkins so they can avoid cross contamination.

The vegetables, obtained from the market, or sometimes supplied (Table 4.3), is known to contain high levels of pathogens including food borne pathogens like *B. cereus*, *C. perfringens*, *E. coli* and *Salmonella* spp (Rane, 2011). Raw vegetables which usually contain high loads (between 3.3×10^6 and 1.1×10^7 g^{-1}) of pathogens (Amoah *et al*., 2006), such as faecal coliforms and thermo tolerant *E. coli*, are brought to the preparation sites and sanitized using various means by the vendors (Table 4.3). In this study, it was observed that the water used by vendors for washing vegetables was just enough to cover the vegetables in the bowl. The same water is used to clean a large volume of vegetables. Even though sanitizer is sometimes added to the water ostensibly to wash and sanitize the vegetables, the strength weakens after each washing. The WHO guidelines (2008), suggest that vegetables are to be washed under running tap water or copious amounts of water to remove as much pathogens from the vegetables as possible (WHO/FAO, 2008). Cleaning the uncooked vegetables well in copious amounts of clean water, is likely to reduce the microbial loads by 2.2 log units (Amoah *et al*., 2007).

Table 4.3: Types and origin of materials used to prepare and handle 'Fufu' and Fried rice

Parameters	Levels	Food types	
		„Fufu" (n*=10)	Fried rice (n=8)
Raw Materials source	Open market	6	6
	Supplier	0	0
	Both	4	2
Raw material quality (cassava, plantain, tomatoes, onions, pepper)	High (unbruised, firm, ripened)	0	1
	Medium (bruised, unripened)	7	5
	Low (bruised, rotting, foul smell)	3	2
Distinct room for storage of raw materials	Yes	1	1
	No	9	7
Sanitizing of vegetables	Salt (to taste)	-	6
	Vinegar	-	1
	Water only	-	1

*n-total number of respondents

According to Aluko *et al.* (2014), potable water in sufficient quantity is required in food vending operations; however observation showed that vendors used limited amount of water in their cleaning procedures which is inadequate and could lead to cross contamination. It was again observed that all the vegetables required for the day"s activity of vending are chopped and stored for as long as it lasts during the vending period at ambient temperatures and this will result in the growth of the remaining original microbial load on the vegetable nutritious exudates (Ameko *et al.*, 2012). Therefore, to reduce the levels of pathogens on the cut vegetables; batches sufficient for a 3 hr-period (WHO/FAO, 2008) should be cut and used. The rest of the washed vegetables can be kept away in containers until the initial stock runs out. The cutting increases the surface area of the vegetables for the growth of bacteria, and hence high numbers of bacteria are likely to be associated with cut vegetables.

Table 4.4: Food handling practices and left-over storage practices

Parameters	Categories	Food types	
		„Fufu‟(n*=10)	Fried rice(n=8)
Frequency of cleaning of hands	Low (no hand washing before touching foods. Drying of hands in clothes or napkin)	10	8
	Medium (hand washing, water only, before handling food, drying in napkin)	0	0
	High (hand washing with soap and water before touching food, drying in clean napkin)	0	0
Cooking of food by	Vendor	1	1
	Staff	3	0
	Both	6	7
Use of same hands to collect money and serving	Yes	10	8
	No	0	0
Estimated time frying rice with vegetables	0 -5 min	-	4
	5 – 10 min	-	3
	>10 minutes	-	1
Temperatures of vended Fried rice	<45˚C	-	3
	45˚C - 60˚C	-	4
	>60˚C	-	1
Temperatures of vended „Fufu‟	<45˚C	10	-
	≥45˚C - 60˚C	-	-
	>60˚C	-	-
Temperatures of vended soup	<45˚C	0	-
	≥45˚C - 60˚C	2	-
	>60˚C	8	-
Storage of left overs	Freezer (	2	1
	Fridge	4	2
	No storage	4	5
Use of left overs	Yes	6	3
	No	0	0

*n-total number of respondents

In practice, vendors added some more of the pre-cut vegetables to rice after frying with a little vegetable, just before serving as this was crucial to improving the aesthetic appeal of the fried rice.

It leads to the re-contamination of the fried rice. This assertion was found consistent with the research findings of Omemu and Aderoju (2008), who observed that the final stages of cooking street vended foods are often inadequate to destroy bacteria that may be present in the foods. All the rice to be fried in a particular day is cooked in the early hours of the morning, dispensed into food warmers and transported to the vending site. This practice is very risky since it can promote the growth of microorganisms like *Bacillus cereus* (USDA, 2012). The cooked rice in the food warmers keep the rice at temperatures between 15-50 °C. It takes close to 12 hours for the boiled rice to be fried and sold out. This period of time is optimum for the growth of the *Bacillus cereus* (USDA, 2012). Hence, vendors must be advised to cook the rice in batches, at intervals during the day, to prevent the rice from sitting for a long time. The frying of the rice (45 – 60˚C) (Table 4.4) for about five minutes, is not adequate in destroying all forms of vegetative bacteria (USDA, 2012; Aluko *et al.*, 2014). Mead *et al.* (1999), have also stated that „food intended for continuous serving should be protected from the environment and kept at 60˚C or above and served hot". This requirement was not met in the fried rice vending operations surveyed in this study.

During serving, from observations, mayonnaise and tomato ketchup are added to the vegetables as salad and used to serve with the fried rice. These products are not prepared by the vendors but are commercially obtained. Many researchers including Lucca and da Silva Torres (2006); Omemu and Aderoju (2008), have cautioned that sufficient attention must be given to the shelf life, source and storage of these products (Table 4.5). A small range of microorganisms can survive and cause spoilage in these products. The study however observed that there was low frequency of sanitization of the tubes in which these products were kept. Some vendors mixed the original mayonnaise with water in a container, before refilling the dispensing tube. This was to make it free flowing and easy to dispense, as well as increasing the volume for higher economic returns. The ketchup was also refilled in the dispensing tube but without mixing with water. Therefore recontamination of the mayonnaise and ketchup could arise from the utensils and water. Growth of the contaminants occurs through storage at ambient temperatures during vending stage (Omemu and Aderoju, 2008).

Table 4.5: Hygienic indicators of vending locations used in the study

Parameters	Levels	Food types	
		„Fufu" (n*=10)	Fried rice (n=8)
Distinct room for Storage of utensils	Yes	0	3
	No	10	5
Hygienic conditions of the utensils	High (quite new, fitting lids, easy to clean, neat)	0	0
	Medium (moderately used, fitting lids, easy to maintain)	6	3
	Low (Very old, not fitting lids, evidence of burnt foods around)	4	5
Tool for waste disposal	Garbage bin	5	7
	Plastic bag	4	1
	Outside	1	0
Frequency of waste disposal	Several times a day	0	0
	Once a day	5	8
	Less than once a day	5	0
Heavy vehicular movements around vending facility	Yes	10	8
	No	0	0
Presence of open choked gutters	Yes	3	4
	No	7	4
Refuse damp site in vicinity	Yes	2	0
	No	8	8
Distance of KVIP* toilets from vending facility	0-5m	0	0
	5-10m	3	3
	>10m	7	5
Pests found in the facility	Rodents	5	4

Flies	2	6
Cockroaches	9	0
None	0	0

*KVIP: Kumasi ventilated improved pit laterine; n-total number of respondents

4.4 Conclusion

Chemical and microbiological hazards are likely to be introduced through vendor practices. These may include PAH, BPA, metals and *B. cereus*, *E. coli* and *S.aureus*, for the two street vended foods, fufu and fried rice. The associated practices should be looked at when designing interventions for the identified activities with hazards. This should be done after the risk of consumption of these foods is at an unacceptable value among the highest consumers of the street vended foods.

CHAPTER FIVE 5.0 CONSUMPTION CHARACTERISTICS, PATTERNS AND PREFERENCES FOR TWO

HIGH RISK STREET VENDED FOODS

5.1 Introduction

Consuming street vended foods is very common in many developing countries due to the variety of dishes available on the menu, affordability, indigenous nature of the dishes and suitably consumed by people of all ages (Ekanem, 1998). These factors of convenience, availability, cost, familiar taste and some nutritional implications of street vended foods have made impact on the food intake of large portions of the population of most African countries (Steyn *et al*., 2011). The food may be eaten on site or taken elsewhere for consumption. Lifestyle changes and socio economic factors have given consumers other alternatives to the patronage of preparing one‟s own meals at home (Ohiokpehai, 2003).

A lot of studies worldwide on street vended foods have emphasized on its contribution in terms of nutritional status, economic impacts and social interventions in relation to food security. Consumption patterns of street vended as well as fast foods were studied in South Africa by Steyn *et al.* (2011). In their study it was observed that frequent (2 ≥ times/week) street food and fast food consumption varied among towns with the highest being 20.6 % in Limpopo for street food and 14.7 % in Gauteng for fast foods. They also observed that the consumption was affected by socio demographic factors with the highest intake of street food being associated with those in the medium socio-economic category (14.7 %) and that for fast foods in the high socio-economic category (13.2 %). The research was not specific for individual street vended foods. Another research in Ghana focused on the consumption characteristic of street vended foods across various consumer characteristics (Mensah *et al*., 2013). It was also observed that averagely, a high income household expenditure on street vended foods was GhS 476.91; and those for the middle and low income groups were GhS 403.3 and GhS 390.23, respectively. The report further stated that low income groups spent about 85 % of their income on street vended foods. It was also noted that low educated people spent a greater portion of their income on street foods as well as families with large sizes (Mensah *et al*., 2013). There is paucity of data on the consumption characteristics of individual street vended foods such as fufu and fried rice which this chapter seeks to address. Fufu is a native Ghanaian meal whilst fried rice is not native to Ghanaians. The consumption characteristics cover the rates (quantities and frequency) of consumption of the street vended foods. This data is necessary in determining the risk associated with the consumption of the individual street vended foods.

Quantitative risk assessment tools make use of the consumption patterns and dose response models to determine the consumption risk in any food product (Gerba, 2000; Hoornstra *et al.*, 2001). Food safety interventions are desired if the risk estimate is unacceptable. For street vended foods, interventions must be vendor friendly for it to be adapted. Based on the risk estimate, interventions can be consumer based, hence consumption characteristics, or production based, hence processing activities, are required. There is dearth of information on the consumption characteristics of street vended foods in general in Ghana.

This chapter will serve to collect consumption data for exposure assessment and dose response modelling of specific hazards in the street vended fufu and fried rice in Kumasi, Ghana.

5.2 Materials and methods

5.2.1 Description of study site

Please refer to Chapter 3.2.1 (Description of study site)

5.2.2 Study population /Data collection

Regular consumers of the eighteen (18) vendors for each of the selected meal type were selected and recruited for the study. A total of 187 consumers comprising of 115 consumers for fufu and 72 consumers for fried rice were interviewed using a structured interview guide (Appendix I). The topics covered the demographics, purchasing habits, consumption preferences and post purchase practices about the two street vended foods. The purpose of this interview was to obtain in-depth information and explanations concerning the consumption patterns and vendor preference.

5.2.3 Data management and analysis

The information from the regular consumers is needed to conduct the risk assessment due to the regular consumption of the hazard in the street vended foods (worst case scenario). The responses from the interviews were recorded, transcribed into a Microsoft excel spreadsheet and analyzed using excel data analysis tool and the @Risk (6) software (from Palisade). Some parts of the data such as the ages, ingestion rates, and exposure frequency were initially fitted into a distribution curve using the best fit model based on the Akaike information criterion (AIC). This was then iterated (simulated) at 10,000 times in the first order Monte-Carlo to obtain the stochastic distribution over a 10,000 population size and the results presented in the distribution information at the 5th, 50th and 95th percentile values. The 5th, 50th and 95th percentile values represent the various levels of consumption according to Gerba (2000) depending on their consumption rates. However the 50th percentile represents the median value. The 5th and 95th percentile represents a vulnerable group in the society, who consumes low weights and excessively high weigts of the street vended foods (Montgomery, 2009), respectively.

5.3 Results

5.3.1 Consumer characteristics

In this study, it was observed that more males (76 % for fried rice and 68 % for fufu) were the major patrons of the meal types (Table 5.1). Four main categories of professions were identified in the consumer category in this study. These were trade workers, public servants, students and other professions who did not fit any of the three categories.

Table 5.1 Demographic characteristics of the consumers

Parameters	Levels	Fried rice, *n (* %)	Fufu, n (%)
Gender	Male	54 (76)	78 (68)
	Female	17 (24)	37 (32)
Profession	Civil servants	6 (8)	24 (21)
	Students	22 (31)	8 (7)
	Trade workers	41 (57)	80 (70)
	Others	3 (4)	3 (2)
Site consumption	Onsite	20 (28)	84 (73)
	Off site	9 (12)	18 (16)
	*Sometimes	43 (60)	13 (11)
How long to reach destination? (take away, N=43)	0 - 15 min	38 (88)	15 (88)
	15 -30 min	1 (2)	0 (0)
	> 30 min	4 (10)	2 (12)

***n** – number of respondents; % - percent value; *sometimes – about 50% of the time eat at vending site.

The consumption of the street vended foods assessed on a weekly basis, indicated the 95th percentile consumers patronized the fried rice on a daily basis (7 days) per week (Table 5.2). The 50th percentile of the population consumes fried rice four (4) days per week and the 5 percentile represents those who consume the meals once a week (Table 5.2).

The stochastic age of the consumers who participated in this study are as shown in Table 5.2. The 5th percentile age for fried rice consumers was below 16 yrs. The 95th percentile consumers also had their ages above 44 yrs of age.

Table 5.2: Stochastic distribution of some consumer characteristics of fried rice meal in the three chosen metropolitan areas

Parameter (units)	Distribution models (model characteristics)	Percentiles		
		5th	50th	95th
Age (yr)	Triangle (11,835; 22;51,357)	16	27	44
Consumption frequency (day/wk*)	IntUniform (1;7)	1	4	7
Dist from res* (km)	Expon(5,1731, Shift(0,42279)	0.69	4.01	15.92
Dist from wkpl* (km)	Pareto(0,82406;0,5)	0.53	1.16	18.96
Cost of food (GhS)	Exponential (2,1111); Shift (1,9707)	2.08	3.43	8.30

*Res – residence; wkpl- work place, GhS – Ghana cedi, yr – years; wk _ week

The distances (km) commuted from the workplace and residence to the vending sites for the 5th percentile fried rice consumers was less than one (1) km. At the 95th percentile consumption level distance travelled was about 15.92 km from residence and 18.96 km from workplace to the vending sites. At the 50th percentile, distance commuted was about 2 km away from work place and 4 km from residence to the vending site (Table 5.2 and 5.3).

The 95th percentile level of consumption for the fufu was above 56 yr of age and the 50th percentile level of consumption for the fufu were 33 yr of age (Table 5.3). The distance commuted by 50th percentile of the consumers of the fufu from residence and work place was about 2 km and less than one (1) km, respectively.

Table 5.3: Stochastic distribution of some consumer characteristics of Fufu meal from the three metropolitan areas

Parameter (units)	Distribution models	Percentiles		
		5th	50th	95th
Age (yr)	Negbin (15;0,30052)	21	33	56
Consumption frequency (day/week)	IntUniform (1;7)	1	4	7
Dist from res (km)	Pareto(0,5447;0,5)	0.55	1.78	122.32
Dist from workplace (km)	Pearson5(1,2295;0,82814); Shift(-0,02291))	0.21	0.94	12.34
Cost of Fufu (GhS)	Laplace (2;0,42799)	1.30	2.00	2.70
Cost of Soup (GhS)	Invgauss (1,7457;7,8333); Shift (-0,048368)	0.52	1.53	3.27

*res – residence; *Dist- Distance; GhS – Ghana cedi

5.3.2 Consumption patterns

The stochastic distributions of some consumption characteristics of the two street vended foods are as shown in Table 5.4. These are important parameters that are needed in completing the exposure assessment in the quantitative risk assessment models, be it chemical or microbiological. Different ingestion rates (IR) distributions were observed for each component of the two meal types (Table 5.4). The fufu component of the meal type had the highest ingestion rate with a mean rate of 0.44 kg day^{-1}, however the 95th percentile consumer, consumes 0.59 kg day^{-1}. This was closely followed by the soup component of the meal type with mean ingestion rate of 0.37 kg day^{-1}. The rice component of the fried rice meal recorded the highest mean IR of 0.41 kg day^{-1}. This was followed by the chicken component with mean IR of 0.08 kg day^{-1}. The macaroni component had the least mean IR value of 0.01 kg day^{-1}. Consumers had a mean exposure duration time of 4.01 yrs and 2.48 yrs for fufu and fried rice, respectively. The mean consumption period for fufu consumers in a year is 210 days yr^{-1} whilst that for fried rice is 182 days yr^{-1} (Table 5.4).

Table 5.4: Probabilistic distribution of some consumption characteristics of the street vended as input variables for risk assessment

Food samples	Parameters (units)	Distribution model	Data ranges Mean	5th	50th	95th
Fufu	IR (kg/day)	Loglogistic(-0,039534;0,45583;5,3792)	0.44	0.26	0.42	0.59
Soup	IR (kg/day)	Logistic(0,372538;0,050994)	0.37	0.22	0.37	0.52
Fried Rice	IR (kg/day)	Weibull(1,7367;0,17127;Shift(0,25874)	0.41	0.29	0.40	0.58
Vegetables	IR (kg/day)	Uniform(-0,00097183;0,069972)	0.03	0.03	0.05	0.07
Chicken	IR (kg/day)	Weibull(1,2182;0,039238;Shift(0,047147)	0.08	0.05	0.08	0.14
Shito	IR (kg/day)	ExtvalueMin(0,027724;0,004255)	0.02	0.02	0.03	0.03
Ketchup	IR (kg/day)	Triang(0,007;0,007;0,044151)	0.02	0.01	0.02	0.04
Mayonnaise	IR (kg/day)	Triang(0,01;0,01;0,048084)	0.02	0.01	0.02	0.04
Macaroni	IR (kg/day)	Expon(0,014389;Shift(-0,00019985)	0.01	0.02	0.03	0.06
Fufu	ED/years	Lognorm(4,036;8,7655;Shift(-0,055694)	4.01	0.14	1.63	14.75
	EF/ (days/year)	Weibull(1,8115;265,86;Shift(-26,107)	210	25	191	461
Fried rice	ED/years	Expon(2,5048;Shift(-0,018385)	2.49	0.11	1.72	7.48
	EF/ (days/year)	Uniform(-5,1408;370,14)	183	23	135	338

*IR- Ingestion rate; ED – Exposure duration; EF – Exposure frequency

5.3.3 Consumer preferences

Figure 5.1and 5.2 represents absolute figures for the primary, secondary and tertiary reasons for consumer preference for street vended fufu and fried rice at the area of study. Chi-square test was used to determine associations between the primary, secondary and tertiary reasons of choice. The first three highly ranked reasons why consumers patronize the fufu meal type are as shown in Fig 5.1. Taste was ranked highest among the primary (45 %) and secondary (43 %) reasons why consumers patronize street vended fufu. Environmental conditions surrounding the vending premise ranked highest among the tertiary reasons. This was followed by the cost (27 %) of the vended fufu and healthy eating habits of consumers. Upon conducting a chi square analysis due to the discreetness of data with more than two attributes at 95 % level of confidence, significant differences existed among the different levels of choices made by the consumers.

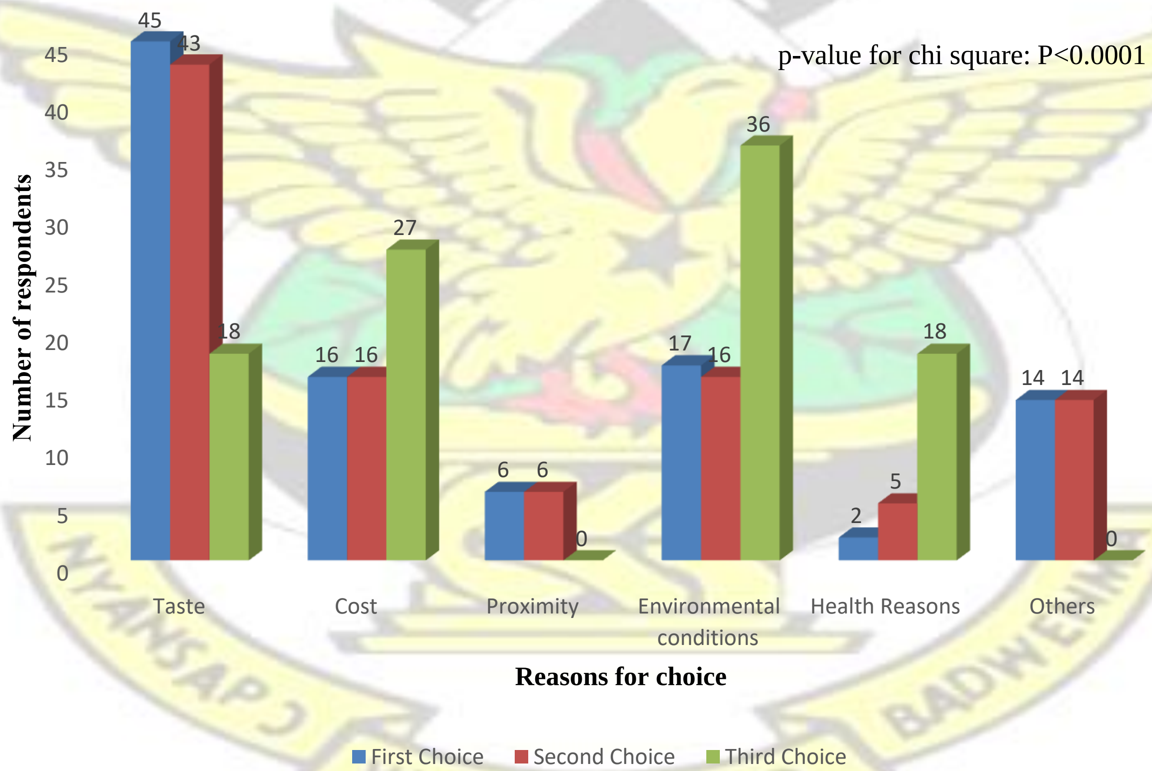


Figure 5.1: Reasons for consumer preference for street vended fufu

The highest ranked reason why a fried rice consumer would opt for the meal at any given time is taste for both the primary (55%) and secondary (41%) levels of choice. Environmental condition was the most (40%) ranked among the tertiary reasons why a consumer would patronize street vended fried rice meal.

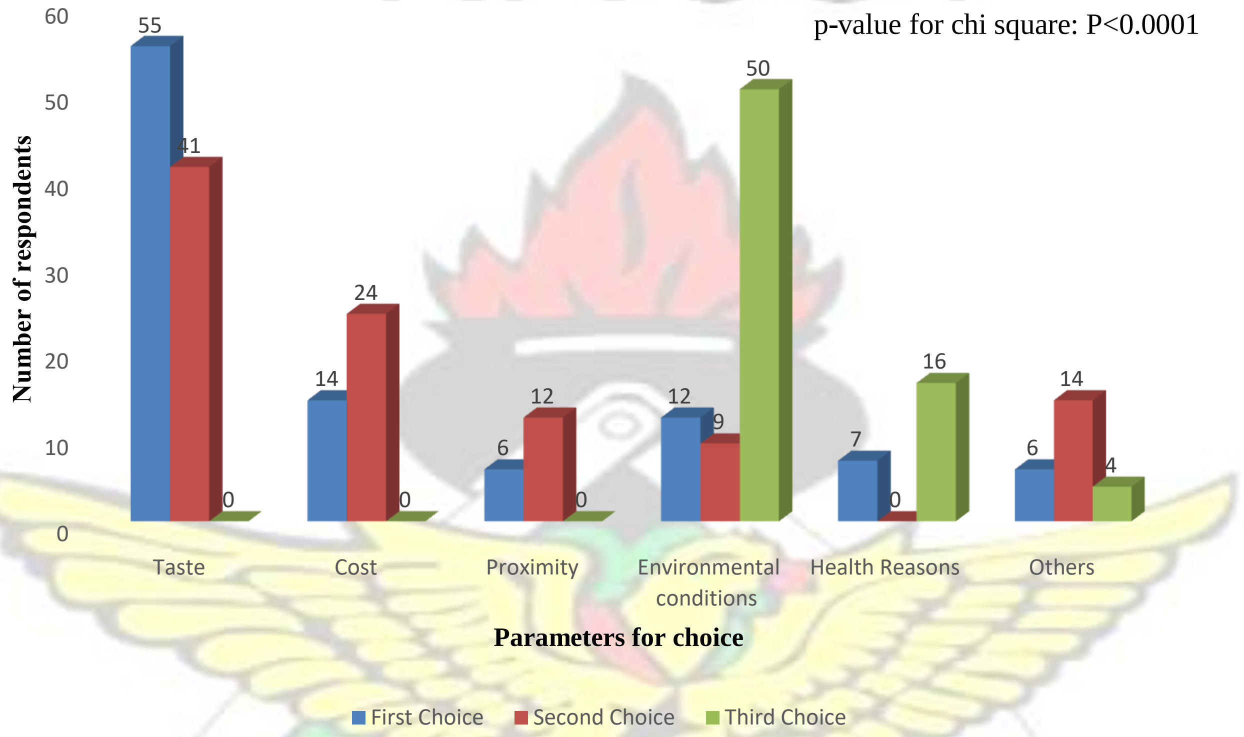


Figure 5.2: Reasons for consumer preference for street vended Fried rice

5.4 Discussion

Males were the highest patrons (133 out of 187) of the two street vended meal types used in the study. This finding was similar to that of the study conducted by Mensah *et al.* (2013), who also observed males as major patrons of street vended foods. However, according to the Housing and Population census conducted in Ghana for 2010, there are more females in Kumasi metropolis (52.2%) than males (47.8%). In Africa, and for that matter Ghana, there is a generally held view that women are responsible for cooking foods (Ackah *et al.*, 2011) at home to feed the family, hence must not be seen patronizing street vended foods. For this reason, women are mostly trained in the homes by their mothers, on how to cook foods for her family (Ohiokpehai, 2003), thereby handing down traditions of the art of cooking foods to generations. There is a perception in Ghana that women who patronize street vended foods are „lazy‟ because it is their responsibility to cook foods for families (Ohiokpehai, 2003). The males who patronize street vended foods are less likely to cook at home either because they lack the culinary skills or simply do not have the time (Mensah *et al*., 2013). It is however uncertain from literature if males consume more food in terms of quantity than females and by extension may stand a greater risk of illness due to consumption of the street vended foods.

The 50th percentile of fried rice consumers moved a maximum of 2.19 km from their workplace for fufu and 1.96 km for fried rice. This indicated that 50 % of the consumers preferred vendors who were located close to them. This could be the possible reason why vendors were located at every imaginable space in the major cites (Ghana Statistical Service, 2014). They prefer to be located at places close to the consumers, usually called the hot spots, offering the convenience of not moving far to get something to eat. Longer distances moved by consumers to purchase foods can impact on the microbial safety of the food, in that, growth of bacteria is likely to occur and double the original numbers of the bacteria present in the food samples at the time of purchase. The growth of bacteria is not only influenced by time, other factors such as temperature, media and aerobic conditions all have a role to play (Powell, 1956; Maier, 2009). However short distances moved by the consumers indicate a short travel time of less than 20 min. This does not however affect chemical contamination since these chemical are not biological in nature thus having a growth rate.

People of all ages patronized the street vended foods, according to the results shown in Table 5.2 and 5.3. However the modal age of the consumers was 29 years. According to the Population and housing census conducted in Ghana (Ghana Statistical Service, 2014), the modal age for this study, 29 yr, ranked the 5th highest age in the population of Kumasi for both males and females. This age of the youth is more unlikely to be married for males than for females. These unmarried males according to Mensah *et al.* (2013) lack culinary skills and therefore less likely to cook, hence being high in numbers as street food consumers.

Table 5.4 shows consumption patterns of the street vended foods used in the study. The ingestion rates (IR) were highest in all the carbohydrate based meals such as the rice component of fried rice (0.41 kg day^{-1}) and the fufu (0.44 kg day^{-1}) component of fufu and soup. With the exception of soup with meat (protein) having an IR of 0.31 kg day^{-1}, the rest of the fried rice components had values less than 0.1 kg day^{-1}. This meant that low quantities of the components of fried rice were being ingested. It could possibly mean a low contribution to the levels of hazards at the time of ingestion.

Consumer preference for eating fufu meal at the vending site was high (73 %) as shown in Table 5.1, whilst those of the fried rice was low (27 %) indicating consumers preferred taking away the fried rice. The reason for the observed phenomena could be varied; by observation the fufu vendors provided an eating area for the consumers, whilst a few fried rice vendors provided small eating area. Also taking fufu away is an inconvenient process, so most consumers prefer eating/consuming the fufu at the vended site rather than as take away packages. Generally, longer distances moved meant longer time to reach their destinations implying enough time for the multiplication of microorganisms. Most fufu consumers (73 %) preferred eating the fufu at the vending site, which took less than 5 min to start eating once food is served. Most consumers (88 %) for both fufu and fried rice indicated that it took less than 15 min (Table 5.1) to get to their destinations if the meal was not consumed on site. This time is less than the generation time for *E. coli* which is 20 min and would not be likely for *Staphylococcus aureus* and *Bacillus cereus* to grow since their generation time is about 30 min under optimum conditions (AFO, 2009).

None of the consumers had experienced any symptom of food borne illness as a result of consuming any of the meals despite the long periods of exposure (2 years) to the meals (Table 5.4). In the gastrointestinal tract are resident microorganisms called commensal microbiota. These organisms protect the lining of the gut to prevent infection by pathogens through mechanisms that regulate the ability of the microbiota to restrain pathogen growth. Some of the mechanisms include competitive metabolic interactions, localization to intestinal niches, and induction of host immune responses (Kamada *et al*., 2013). There is thus an interplay between the pathogen and the commensals which is needed for controlling diseases and infections. Since consumers of both fufu and fried rice meals were not experiencing any symptom of food borne illness, this could imply that the minimum dose for infection by 3 log CFU for *B. cereus*, *S. aureus* and enterobacteriaceae, as well as 5 log CFU for total counts (Mensah *et al*., 2002), should be looked at. Possibly the consumers did not know symptoms of food borne illness of all contaminants of street vended foods.

The primary, secondary and tertiary reasons why consumers would patronize the fufu and fried rice have been shown in Figures 5.1 and 5.2, respectively. The highest ranked reason given by the fried rice consumer is taste for both the primary (55 %) and secondary (41 %) levels of choice.

According to the Merriam-Webster online dictionary definition of taste, it is „to have a particular taste" or „to sense the flavor of something that you are eating or drinking" (www.merriamwebster.com). Most of the consumers cited taste possibly because they are acquainted with the flavor of the meals under study. Fufu is a traditional meal which has high patronage, therefore given any option; most consumers would prefer fufu over all the other foods on a menu. Also the consumers of fried rice have acquired the taste of fried rice given the period they have been exposed to it. The vendors are more concerned with the taste and thus would prefer to attend training programs aimed at teaching them skills to improve the taste of the meals rather than food safety. Pricing of meals was the next highest reason after taste for the primary and secondary choice for the street vended foods. The ability to purchase a meal, to consume and be satisfied is of primary concern to consumers (Andreyeva *et al*., 2010). These findings were also consistent with findings by Mensah *et* *al.* (2002) that consumers of the street vended foods were interested in the convenience and not the safety of the meals provided. Environmental conditions featured strongly in all the reasons why the consumers of the fufu patronized the meal. Some of the consumers patronized the vendors because of the neat appearance of the vendor and the vending place, which gave them some form of risk avoidance strategy concerning the safety of the vended foods (Rheinländer *et al.*, 2008). For the fried rice consumers, neatness did not feature strongly, partly because they mainly take the food away to eat at their places of convenience.

5.5 Conclusion

These street vended foods were mostly patronized by males and trade workers. The ingestion rates of the carbohydrate components of the street vended foods were observed to be highest. Taste of street vended foods motivated the patronage of consumers. These findings have implications for interventions and exposure levels of hazards to consumers.

These findings need to be taken into consideration when determining the risk estimate due to the associated hazards with the consumption of these street vended foods.

CHAPTER SIX

6.0 A PROBABILISTIC EXPOSURE ASSESSMENT OF MICROBIAL CONTAMINANTS IN TWO COMMONLY CONSUMED STREET VENDED FOODS

6.1 Introduction

The street foods trade has reached a new dimension as a result of growing urbanization. This activity provides, complete meals and refreshments at relatively low prices to low income workers, shoppers, travellers but it may also present risks to people‟s health (Lucca and da Silva Torres, 2006). People who depend on such food are often more interested in its convenience than in questions of its safety, quality and hygiene (Mensah *et al*., 2002). In Ghana, it has attracted great economical, sociocultural and sanitary importance.

However, these foods have been associated with major food borne disease outbreaks that have occurred in the world during these past few years. Food borne illnesses of microbial origin are a major international health problem associated with food safety and could be an important cause of death in developing countries (Mead *et al.*, 1999). The main factor that currently compromises food quality is the hygienic-sanitary aspect. The sale of food in public places is highly controversial from a health standpoint and represents a serious threat to consumer health. Based on the high levels of pathogenic bacteria isolated from food samples collected on streets (Boye *et al*., 2007; Feglo and Sakyi, 2012; Mosupye and von Holy, 2000) many studies have established epidemiological links between street food and disease (Rane, 2011). Considering all the problems relating to handling, inadequate or insufficient storage and poor hygienic conditions, the risk of contracting food-borne diseases is considered high. Foodborne bacterial pathogens commonly detected in street vended foods are *Bacillus cereus*, *Clostridium perfringens*, *Staphylococcus aureus* and *Salmonella* spp. Consumers of such foods have been reported to suffer from food borne diseases such as diarrhea, cholera, typhoid fever and food poisoning (Rane, 2011).

In Ghana, street foods are mostly prepared and processed manually and sold to the public at various lorry terminals, by the roadside or by itinerant vendors (Mensah *et al*., 2002). Diarrheal disease, which is one of the recognized major causes of hospital attendance, has been directly attributed to 16 % of deaths in African children, who are younger than five years (Bryce *et al.*, 2005). Recently, in 2014, Cholera, a fatal diarrheal disease, hit the cities of Accra, resulting in several deaths of its residents. This was linked to the consumption of contaminated street vended foods (Dzotsi *et al.*, 2014). This type of disease outbreak does not occur only in Ghana, but in places where street vended foods are sold. This means there is an inherent risk of getting food borne illness due to the consumption of contaminated street vended foods. The risk associated with the consumption of some foods has been documented for some bacteria such as *Bacillus cereus,* in a cooked chilled vegetable product but not with the consumption of street vended foods (Nauta, 2003). *Bacillus cereus* and other pathogenic microorganisms have been quantified in the street vended foods at levels exceeding the WHO safe limits for consumption. Therefore there is the need to determine the risk of consumption by determining the level of exposure to the pathogens by the consumer.

The exposure assessment gives the quantities a contaminant is absorbed by an exposed target organism, in what form, at what rate and how much of the absorbed amount is actually available to produce a biological effect. This determination is conducted on a population and the effects on the various consumer segments can be estimated using the stochastic determinations. The assessment is usually conducted on the exposure pathways of the hazard. Therefore the aim of this chapter is to determine stochastic concentrations of microbiological hazards (exposure) and the risk of consumption of the components of two commonly consumed street vended foods.

6.2 Materials and Methods

6.2.1 Study area description

Refer to Chapter 4.3.1 (*Description of study area*)

6.2.2 Description of Food samples used

Two street vended foods, fufu and fried rice, which are most commonly consumed in Kumasi were selected for this study. Fufu is a major food staple, which is highly patronized and native to the people of the Ashanti region. It is made from cooked cassava (*Manihot esculenta*) and plantain, (*Musa paradisiaca*) and pounded together into a thick dough-like consistency. This is usually served with different, but often tomato-based (light) soup with meat or fish. Other soups served with fufu include, palm fruit base soup, ground nut butter soup, *werewere* soup and *Abunuabunu* (leafy vegetable soup) Fried rice is a dish not native to people in Ghana but also highly patronized. It is prepared from cooked rice stir-fried with vegetables, and is served with chicken or fish and salad.

6.2.3 Sampling

Two (2) locations within each of the three (3) selected sub-metropolitan areas (Oforikrom, Sibin and Asawase) in Kumasi city were chosen for the study. At each location, three (3) street food vendors each of fufu and fried rice that had been in operation for at least three (3) years were selected for the study. All the vendors (owners of the business) who participated in the study had at least two engaged staff and operated during the day time even though some had their activities extending to the night time.

6.2.4 Sample collection

Food samples were bought from the eighteen (18) vendors each of Fufu and Fried rice and separated into their various components by the vendors at the point of sale. They were collected in vendor"s packaging materials and transported into the laboratory immediately after purchase. A maximum of one hour was spent between the point of sale and the laboratory. All samples were analyzed the same day and within two hours of reaching the laboratory.

6.2.5 Sample preparation

Five (5) g each of the food components was weighed into separate stomacher filter bag and topped up to 50.0 g with sterile Saline Diluent solution (CM0733 Oxoid: Thermoscientific, Roskilde, Denmark). The mixture was pulsified for five (5) min. One (1) milliliter of the pulsified food samples was taken from the filtered side of the stomacher bags and serial dilutions were prepared up to the sixth dilution and inoculated on the appropriate agar for the specific microbial analysis. All the media used for the analysis were prepared according to the manufacturer"s instructions.

6.2.6 Microbiology methods

Bacteria counts

Total bacterial counts were made by means of pour plating using plate count agar (Oxoid CM463). Counts of *E. coli*, *Staphylococcus aureus*, and *Bacillus cereus* were made using rapid *E. coli* 2 agar base (356-4024, Bio-rad Ltd, France), Baird–Parker agar (Oxoid Ltd., Basinstoke, Hampshire, England, CM0961 and SR0122) and *B. cereus* selective agar base (Oxoid CM0617 and SR0099), respectively. After the appropriate incubation, plates with 30–300 colonies were selected and counted. The number of colony-forming units per g (cfu/g) of food was calculated by multiplying the number of bacteria colonies by the dilution factor.

Pure cultures of the bacteria and the Peptone Saline diluent were also prepared and inoculated like the food samples and enumerated. This was to aid in identifying the strains of interest and also to make sure that the media are not contributing to the contamination or numbers of the colonies that would be enumerated.

6.2.7 Consumption studies

Please refer to Chapter 5.2.2 (Study population /Data collection)

6.2.8 Data analysis

Distribution fitting for input data

Please refer to Chapter 5.2.3 (Data management and analysis)

Total daily dose consumption

The daily dose of the ingested pathogens was calculated for each component and the associated pathogen quantified by multiplying the numbers of the microbial counts per unit weight, g, of the foods samples by the total weight in grams of the component in question.

6.3.9 Sensitivity Analysis

Sensitivity analysis was done on the total daily dose by ranking the correlations coefficients of the output mean between each input variable and the output (risk). The sensitivity of each variable relative to one another was assessed by calculating rank correlation coefficients between each input and output during simulations and then estimating each input contribution to the output variance by squaring the output variance and normalizing to 100 percent. The input factor with correlation coefiicient above 0.02 (US EPA Technical Panel, 1997) was earmarked for intervention.

6.4 Results and Discussion

The stochastic concentrations ($\log_{10}$CFU/g) of the bacterial contaminants of the components of the street vended fried rice are as shown in Table 6.1. Among all the components of the fried rice, salad recorded high concentrations of all the pathogens at the 5^{th} percentile level of consumption for *S. aureus* above 4 log CFU/g. The level of exposure due to *E. coli* was 4 log CFU/g for the 5^{th} percentile salad consumers, whilst that for *B. cereus* was 4.5 log CFU/g. These values were higher than the recommended WHO value of 3 log CFU/g for *B. cereus*, *E. coli* and *S. aureus* (Mensah *et al*., 2002). The exposure levels of the bacterial contaminants for ketchup, mayonnaise were the lowest among all the components of the fried rice meal. The exposure level due to *E. coli* at the 95th percentile level of consumption was 3.2 log CFU/g, whilst those for *S. aureus* and *B. cereus* was 4.2 and 4.0 log CFU/g, respectively. At the 95^{th} level of consumption the exposure due to all the contaminants in the street vended meals were above the WHO recommended value of 3 log CFU/g (Mensah *et al*., 2002).

Staphylococcus aureus concentrations in the salad samples were the highest, with exposure level at the 5th percentile consumption being 5.0 log CFU/g. This was followed by the exposure due to *B. cereus* at 5th percentile consumption level of 4.5 log CFU/g and that for the salad was 4.0 log CFU/g for *E. coli*.

The high levels of exposure due to *E. coli*, in the salads could be from the cultivation sources, where practices such as the use of highly polluted water for irrigation (Mensah *et al*., 2002; Keraita *et al*., 2002), and untreated manure from poultry and human feces (Amoah *et al*., 1998) as fertilizers in cultivation are rampant. After harvesting, the vegetables are packed in sacks and kept for days on the farm, with intermittent sprinkling with water to moisturize the vegetables leading to growth of the resident bacteria on the vegetables (Amoah *et al*, 2014). Vegetables are poured onto sacks on the bare ground in the major market places (Amoah *et al*, 2014) for sale. Some vendors do not peel the vegetables especially the cabbage and lettuce and they are washed with limited quantity of water in a basin against the recommended practice prescribed by WHO (WHO/FAO, 2008) The vegetables are then left exposed to the unhygienic environment (King *et al*., 2000; Lucca and da Silva Torres, 2006; Chukuezi, 2010; Rane, 2011).

Table 6.1: Stochastic concentrations (log CFU/g) of bacterial contaminants in the components of fried rice

Bacteria	Food type	Distribution model	Data Ranges(log CFU/g)			WHO limit (logCFU/g)
			5th	**50th**	**95th**	
E. coli	Rice	Geomet (0,00021784)	2.4	3.5	4.1	3.0
	Salad	Geomet (0,00000497869)	4.0	5.1	5.8	
	Chicken	Geomet (0,00012006)	2.6	3.8	4.4	
	Shito	Geomet (0,00054609)	2.0	3.1	3.7	
	Macaroni	Geomet (0,000044055)	3.1	4.2	4.8	
	Ketchup	Geomet (0,0027432)	1.3	2.4	3.0	
	Mayonnaise	Geomet (0,0020647)	1.4	2.5	3.2	
B. cereus	Rice	Geomet (0,000027573)	3.3	4.4	5.0	3.0
	Vegetables	Negbin (2;0,0000101607)	4.5	5.2	5.7	
	Chicken	Geomet (0,0000641937)	2.9	4.0	4.7	

	Shito	Geomet (0,0000465295)	3.0	4.2	4.8
	Macaroni	Geomet (0,0000398903)	3.1	4.2	4.9
	Ketchup	Geomet (0,0003635)	2.1	3.3	3.9
	Mayonnaise	Geomet (0,00030787)	2.2	3.4	4.0
S. aureus	Rice	Geomet (0,00000267677)	4.3	5.4	6.0 3.0
	Vegetables	Geomet (0,000000501322)	5.0	6.1	6.8
	Chicken	Geomet (0,00000425792)	4.1	5.2	5.8
	Shito	Geomet (0,00000612477)	3.9	5.1	5.7
	Macaroni	Geomet (0,00000837047)	3.8	4.9	5.5
	Ketchup	Geomet (0,0000619199)	2.9	4.0	4.7
	Mayonnaise	Geomet (0,00018634)	2.4	3.6	4.2
TPC*	Rice	Geomet (0,00000056027)	5.0	6.1	6.7 5.0
	Vegetables	Geomet (0,0000000685768)	5.9	7.0	7.6
	Chicken	IntUniform (100000;6480000)	5.6	6.5	6.8
	Shito	Geomet (0,000000859735)	4.8	5.9	6.5
	Macaroni	IntUniform (160000;960000)	5.3	5.7	6.0
	Ketchup	IntUniform (13300;560000)	4.6	5.5	5.7
	Mayonnaise	Geomet (0,0000278838)	3,3	4,4	5,0

*TPC- Total plate count, 5th - Fifth percentile, 50th - Fiftieth percentile; 95th - Ninety-fifth percentile

Dirty clothes worn by vendors during the preparation of foods serve as a source of *S. aureus* contamination (Omemu and Aderoju, 2008). There is also possible cross contamination of *S. aureus* on vegetables from the utensils (Barro *et al.*, 2006; Boye *et al.*, 2007). Unhygienic handling of food with bare hands coupled with improper cleaning of dishes are likely to contribute to the high levels of *S aureus* on the vegetable samples (Boye *et al.*, 2007; Feglo and Sakyi, 2012; Mensah *et al.*, 2002). The cut vegetables for use as salad are packaged in plastic containers and left partially covered during the vending hours. At this ambient temperature, 30 °C and time of about 12 hours of vending, the growth of the bacteria in the vegetables will occur with *E. coli* doubling faster (Seow *et al.*, 2012).

The rice samples also had mean levels of the bacterial contaminants higher than 3 log CFU/g limit given by WHO (Mensah *et al.*, 2002). The rice component sample is cooked rice stir-fried with vegetables for about five (5) minutes. More vegetables are immediately mixed with the fried rice to improve its aesthetic appeal. The cooked rice usually stays for a maximum of 12 hr to be sold out.

This time period is long enough for the vegetative forms of *B. cereus* to multiply (doubling time of 30 min). The high levels of the bacterial contaminants recorded in the fried rice could be due to the addition (for aesthetic purposes) of the raw cut vegetables to the rice after stir frying and the long hours the cooked rice stays before it is stir fried. The stir-frying time is not adequate to destroy all forms of bacterial life in the rice. For example, the point of sale condition and practices (Lucca and da Silva Torres, 2006) such as leaving the fried rice uncovered or partially covered exposes the fried rice to the environmental conditions leading to the further contamination of the fried rice (Mensah *et al*., 2002). Therefore the rice needs to be cooked in batches for stir frying, and foods need to be covered to reduce contamination by aerosols.

Macaroni also had high exposure levels of bacterial contaminants in the food samples. Cooked macaroni in its preparation is strained and remain exposed for periods between 30 min to one hour. The exposure levels of all the bacterial contaminants were higher than the limits set by FAO/WHO of 3 log CFU/g. This finding is consistent with findings from studies conducted by Mensah *et al. (*2002) and Feglo and Sakyi (2012). According to Mensah *et al.* (2002), macaroni together with the salads carried the greater risk of transmitting diarrheal pathogens. Initial contamination occurs when the cooked macaroni is washed with low quality water after cooking to prevent it from sticking together. The macaroni sits for long hours (2 – 12 hr) at ambient conditions during the vending period until it is sold out and with a generation time of 20 min for *E. coli,* the mean levels are likely to increase with the long hours of storage. As also noted by Feglo and Sakyi (2012) as well as Mensah *et al. (*2002), the vendors use bare hands to dish out food and as well as simultaneously handle currency as they provide change to the buyers (during payment). This practice is commonly implicated in introducing bacterial pathogens such as *S. aureus* and *E. coli* into the cooked macaroni (Barro *et al.*, 2006; Kubheka *et al.*, 2001). It was also reported in Manila, Philippines that, the consumption of such food served with bare hands led to cholera outbreak (Michaels, 2002). Another observation was that cooked macaroni was placed in proximity to the chopped vegetables, and served with bare hands used to serve the vegetables. Therefore cross contamination could occur in the safe and also during the serving process whereby bare hands that have handled money and other contaminated surfaces (Barro *et al.*, 2006) are used.

Ketchup and mayonnaise are commercial products which offer low risk of bacterial contamination due to their low pH (below 4.5). The likelihood of bacterial growth in such media is low. Only a small range of microorganisms can survive and cause spoilage in this type of medium due to its acidic pH (Radford and Board, 1993). The levels of bacterial contamination of these products are controlled at the industries where they are manufactured. However, the volume and cost of these products are of importance to the vendors (Abdussalam and Käferstein, 1993). Therefore some vendors mix the mayonnaise and ketchup with some amount of water to increase the volume and flow ability of the products to allow for easy dispensing (Abdussalam and Käferstein, 1993; Omemu and Aderoju, 2008). The source of water and the utensil in which the mixing is done become sources of contamination. The frequency of sanitization of the tubes from which the mayonnaise and ketchup are dispensed is low (Lucca and da Silva Torres, 2006). This finding is consistent with findings by Lucca and Torres (2006), when they assessed the safety of hot-dogs on the streets of Sao Paulo in Brazil. Therefore, the tubes which are used to dispense these products must be frequently sanitized and fresh samples must be put inside these containers daily. These are industrial products which are used with no further processing, hence bacterial contaminants takes its source from the industry (Ohiokpehai, 2003; Omemu and Aderoju, 2008).

The fufu samples also had very high exposure levels of bacterial contaminants of above 3 log CFU/g as shown in Table 6.2. Fufu is excessively handled during the pounding and serving stages. The source of bacterial contamination in the fufu is the water used to turn and help soften the stiff dough. In the observations made, unhygienic containers are used to fetch water from the storage containers which are not frequently cleaned and this leads to the water becoming contaminated. Water is known to be a source of bacterial contaminants in foods (Barro *et al.*, 2006).

Table 6.2: Stochastic concentrations (log CFU/g) of bacterial contaminants in the components of fufu

Bacteria	Food type	Distribution model	Percentiles (log CFU/g)			WHO limit
			5^{th}	50^{th}	95^{th}	(logCFU/g)
E. coli	Fufu	Geomet (0, 0000212946)	3.4	4.5	5.1	3.0
	Soup	Geomet (0, 0010869)	1.7	2.8	3.4	
B. cereus	Fufu	Geomet (0,0000390074)	3.1	4.2	4.9	3.0
	Soup	Geomet (0,003443)	1.1	2.3	2.9	
S. aureus	Fufu	IntUniform (21000;616000)	4.7	5.5	5.8	3.0
	Soup	Geomet (0,0001268)	2.6	3.7	4.4	
TPC*	Fufu	IntUniform (220000;9840000)	5.8	6.7	7.0	5.0
	Soup	Geomet (0, 00000844648)	3.8	4.9	5.5	

*TPC – Total plate count, 5^{th} - Fifth percentile, 50^{th} - Fiftieth percentile; 95^{th} - Ninety-fifth percentile

The utensils used in preparing the fufu could also be a very good source of bacterial contamination (Barro *et al*., 2006; Mosupye and von Holy, 2000). The mortar and pestle used are wooden in nature and is pervious to water. The mortar, after pounding the fufu is cleaned with water and scouring sponge and kept upturned on the pounding floor (usually cemented) to allow the water to drain till the next day. The presence of pests (rats and cockroaches) in the storage rooms in attempt of finding food crawl all over the utensils. Pests are known as carriers of pathogenic bacteria which would lead to contamination of the mortar and pestle. The mortar and pestle are rinsed with water, when ready to be used in pounding the fufu. The pestle is a wooden stick, which is about 15 cm in diameter. The pounding edge of the pestle is brush-like with difficult to clean. Therefore the debris of fufu in the pestle which act as biofilms, re-contaminate the next batch of fufu that is prepared. Also the brush like nature of the head of the pestle traps dust and dirt during storage which has the potential of contaminating the fufu during pounding.

Bare hands are used to turn the stiff dough with some water to soften the dough as it is being pounded. The hands are the most important vehicle for the transfer of organisms from faeces, nose, skin or other sites to food (WHO, 1989); therefore hand hygiene is important in feacal coliform transmission into the foods. The use of bare hands in handling ready to eat foods (Barro *et al.*, 2006), has been rated as one of the high risk factors in transmitting diarrheal pathogens (Mensah *et al*., 2002). In a study conducted by Mensah *et al.* (1999), in Accra, Ghana, it was observed that vendors were carriers of a variety of bacterial enteropathogens, including *Salmonella typhi* and that defective personal hygiene can facilitate the transmission of these pathogens via food to humans.

These enteropathogens can survive on the human hands for three (3) hours or longer (Mensah *et al*, 1999; Barro *et al*, 2006). The hand washing frequency of the vendors were observed to be low and hand washing was done not following the appropriate protocol. This finding is consistent with other studies on the hand hygiene of street food vendors which were also found to be inappropriate (Barro *et al*., 2006; Chukuezi, 2010; Ekanem, 1998; Feglo and Sakyi, 2012; Lucca and da Silva Torres, 2006; Mensah *et al*., 2002; Omemu and Aderoju, 2008).

The soup samples on the other hand had counts lower than the 3 log CFU/g as specified by WHO (ICMSF, 1986). This mean value was unexpected because the soups are prepared by boiling the ingredients together for about two (2) and half hours. After this, a portion of the soup is taken and put in stainless steel pans or aluminum pans and left boiling on fire beside the vendor at the vending site. It is refilled from the main cooking pot to replenish the stock. Since the soups are left boiling, throughout the vending period (12 hr), lower levels of pathogens were expected in the soup samples. However some quite high levels of the enteric pathogens were found in the soup. Since the exposure levels were lower than the 3 log CFU/g limit set by the WHO at the 5th and 50th percentiles, the soups were considered to be generally safer than the fufu.

6.4.1 Total daily dose

Quantitative Microbial Risk Analysis can be a useful tool to estimate the risk of pathogen growth in foods and to make decisions to manage food safety. The lack of data on the dose-response model for some bacterial contaminants like *S. aureus* and *B. cereus*, implies that risk estimates of the bacterial pathogens are uncertain (Hoornstra *et al*., 2001; Oscar, 2004). Therefore, in situations like these, the use of a specific cell concentration to determine if a food is safe may be the best course of action (Lindqvist *et al.*, 2002; Stewart *et al*., 2003). A concentration of *S. aureus* equal to or exceeding 5 log CFU/g was assumed to be unsafe in the current study. The incorporation of studies which provide a dose–response assessment of *S. aureus* toxin in food would improve the accuracy of the results presented here so that the full impact assessment of the bacterial pathogens to an individual and the society can be known. The probabilistic total dose per serving (exposure assessment) of the bacterial contaminants determined using the quantitative risk assessment models for both meal types are as shown in Tables 6.3.

Table 6.3: The probabilistic total dose per serving (log CFU/g) of the bacterial contaminants in the components of the street vended meals

Meal types	Bacteria	Maximum	Percentiles 5th	50th	95th
Fried rice	*E coli*	2.44E+01	5.79E+00	6.89E+00	8.88E+00
	S aureus	1.03E+01	7.68E+00	8.22E+00	8.90E+00
	B cereus	1.02E+01	6.53E+00	7.21E+00	7.95E+00
Fufu	*E coli*	1.30E+01	6.34E+00	7.15E+00	7.79E+00
	S aureus	8.46E+00	7.05E+00	7.90E+00	8.23E+00

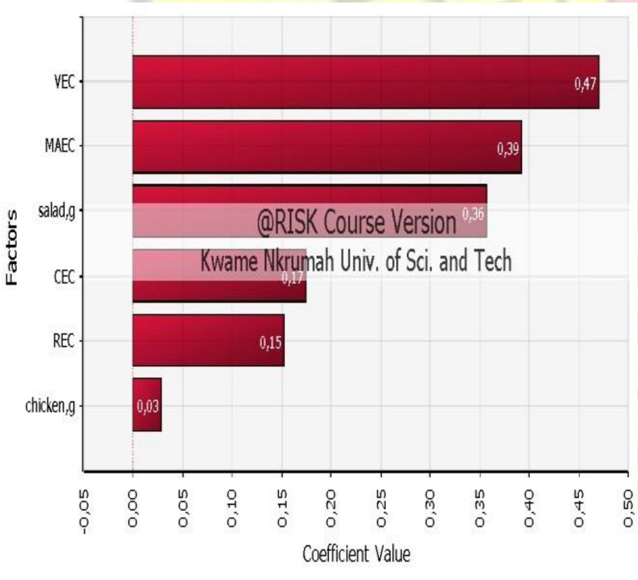
B cereus	8.14E+00	6.25E+00	6.84E+00	7.54E+00

Results from Table 6.3 indicates that all the consumers of the fried rice and fufu meals used in this study were exposed to unsafe levels of bacterial pathogen upon consumption of the meals. Based on the 3 log CFU/g (limit set by WHO) or 5 log CFU/g, limit according to Lindqvist *et al.* 2002.

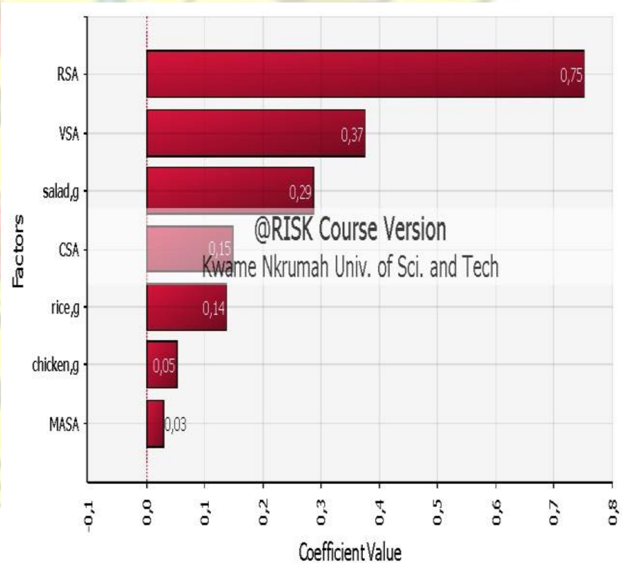
6.4.2 Sensitivity analysis

Spearman Rank correlation coefficient for the number is used to express the relevance of a varying factor for *N* (the number of organisms, i.e. the exposure). This was performed on the total daily doses of the components of the meal.

For each of the bacterial contaminants, a sensitivity analysis was performed to determine which of the components had a major impact on the total daily dose of the meals.



a. Total *E. coli* in fried rice meal



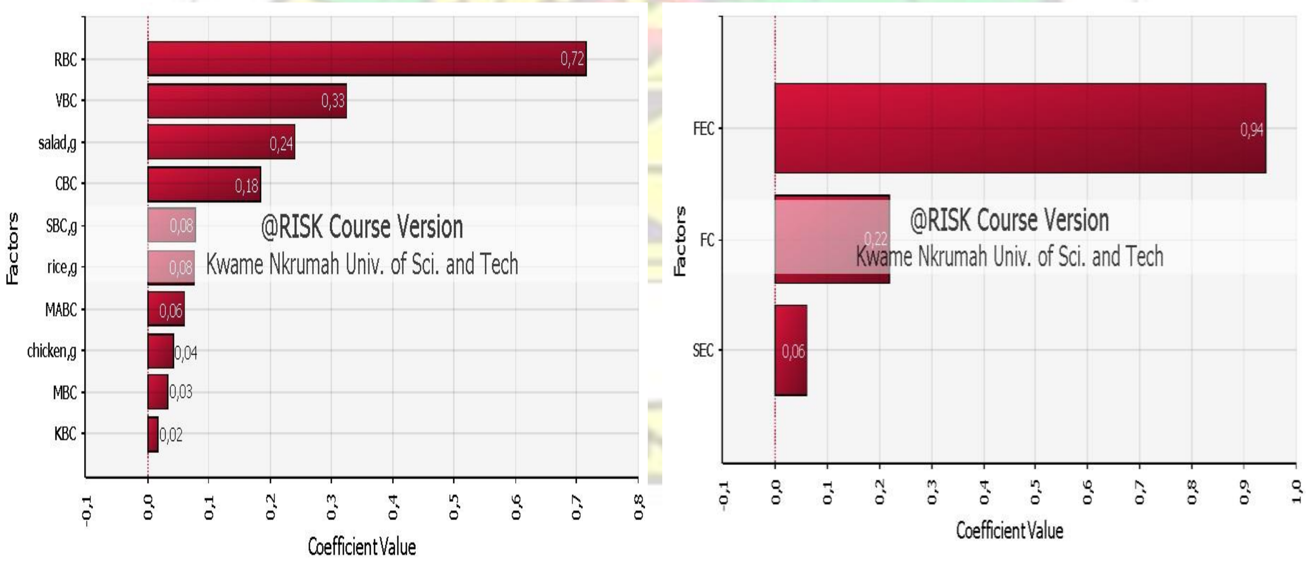
b. Total *S. aureus* in fried rice meal

Figure 6.1: Sensitivity profile (Spearman's coefficient) for (a) total *E. coli* and (b) *S. aureus* in fried rice meals upon consumption

Legend: VEC: *E.coli* in vegetable:MAEC-*E. coli* in macaroni, CEC-*E.coli* in chicken, REC-*E. coli* in rice; RSA- *S.aureus* in rice, VSA- *S.aureus* in vegetables, CSA-*S.aureus* in chicken, MASA- *S.aureus* in macaroni

The factors that impacted the total daily dose of *E. coli* in the fried rice samples were levels of *E. coli* in the vegetables for consumption with a coefficient value of 0.47 (Fig 6.1a), followed by the levels of *E. coli* in the macaroni, 0.39, the weight of the salads consumed, 0.36, and levels of *E. coli* in chicken, 0.17. The focus for intervention for the total daily dose of *E. coli* in fried rice is the handling of the vegetable and in the preparation processes of macaroni (Fig 6.1a). The focus for intervention in the total daily dose of *S. aureus*, according to the spearman rank correlation coefficient analysis (Fig 6.1b) is the rice and vegetables components.

Figure 6.2a shows the sensitivity profile for *B. cereus* in the fried rice. The profile implicates rice, vegetable as well as the fried chicken component as having the strongest impact on the overall daily dose. *Bacillus cereus* is commonly found in cooked rice, and if it is kept for a long time after cooking allows the pathogen to proliferate and produce the emetic poisons of *B. cereus*. In this light, the rice must be cooked in smaller quantities which will be sold in the shortest possible time to prevent the growth of *B. cereus*.

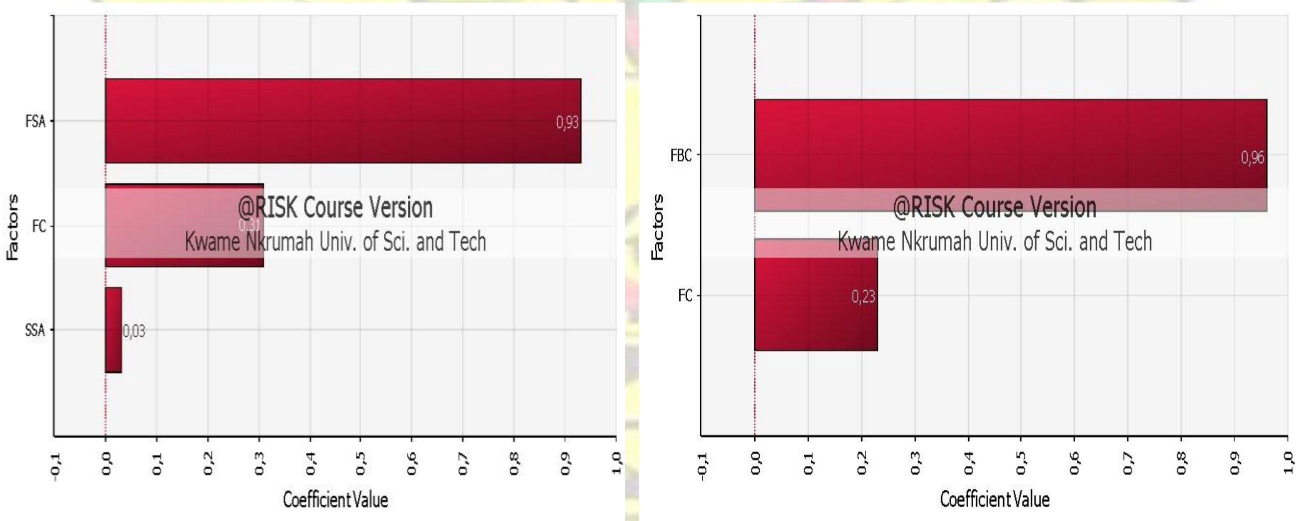


a. Total *B cereus* in fried rice meal **b. Total *E. coli* in fufu meal**

Figure 6.2: Sensitivity profile (Spearman's coefficient) for total *B. cereus* in fried rice meal and *E. coli* fufu meals upon consumption

Legend: RBC- *B.cereus* in rice, VBC- *B.cereus* in vegetables, CBC- *B.cereus* in chicken, MABC-*B.cereus* in macaroni, KBC- *B.cereus* in ketchup, FEC- *E.coli* in Fufu, SEC, *E.coli* in soup

Levels of *E. coli, S. aureus and B cereus* in fufu were the focus for intervention (Figs 6.2b, 6.3 a and 6.3b). The sensivity profile showed the strongest impact on the daily dose for the respective organisms. *Escherichia coli* is an indicator for poor hand hygiene having it‟s source possibly in the water used to turn the fufu. The water quality and the hand hygiene conditions are the sources of *E. coli* contamination in the fufu. The intervention would be for the vendors to manintain good hand hygiene practice. The quality of the water must be looked at before using to turn the fufu. *Staphylococcus aureus* is an indicator for extensive handling of the fufu which also stems from using unclean clothes and unclean hands. Hence vendors should wear clean clothes, maintain proper hand hygiene when handling fufu.



a. Total *S. aureus* in fufu meal **b. Total *B. cereus* in fufu meal**

Figure 6.3: Sensitivity profile (Spearman's coefficient) for total *S. aureus* and *B. cereus* in fufu meal upon consumption

Legend: FSA-*S. aureus* in Fufu, SSA- *S.aureus* in Soup, FC- Consumption Frequency, FBC- *B.cereus* in Fufu, Presence of *Bacillus cereus* in foods can also be an indicative of an unhygienic environment, possibly dusty. The practice of exposing the mortar and pestle to the environment must be stopped. An alternative would be to have two sets of mortar and pestle to be used alternatively, as one is being sanitized.

6.5 Conclusion

The total daily dose of the two meal types showed unsafe consumption levels of the bacterial contaminants at all levels of consumption. The total daily dose for fried rice was impacted most by the levels of bacteria present in the vegetables, fried rice and chicken component. The fufu component impacted the total daily dose for fufu meal. Activities surrounding vegetable (salad) preparation and storage of cooked rice, as well as handling the fufu, from the sensitivity analysis

should be focused on for intervention.

CHAPTER SEVEN 7.0 HEALTH RISK ASSESSMENT DUE TO THE CONSUMPTION OF POLYCYCLIC

AROMATIC HYDROCARBON CONTAMINATED STREET VENDED FOODS

7.1 Introduction

There is a general perception that street vended foods are unsafe for consumption, considering the conditions under which they are prepared, sold or consumed (Mosupye and von Holy, 2000). Unhygienic conditions at the location of vending and poor knowledge on food safety among vendors can result in the foods becoming exposed to contamination and thereby rendering them unsafe for consumption (Lucca and da Silva Torres, 2006). Epidemiological data mostly from microbiological origin indeed points to the incidence of food borne diseases resulting from the consumption of popular street vended foods (Ekanem, 1998; Rane, 2011). Thus, the safety of the street vended food is of concern since it is likely the conditions of food preparation and handling, are likely to expose them to hazardous chemical contaminants such as poly aromatic hydrocarbons (PAH), which very information exists for street vended foods (Proietti *et al.*, 2014).

Polycyclic aromatic hydrocarbons are a group of compounds which are ubiquitous as environmental contaminants (Bortey-Sam *et al.*, 2014). They are produced mainly as a result of oil spillage and/or incomplete combustion of organic materials including wood, fossil fuels and petroleum products (Ravindra *et al.*, 2008). Many of the PAH are mutagenic (Martena *et al*., 2011) whilst some have also been proven to be carcinogenic (Menzie and Potocki, 1992; USEPA, 2008). This raises concerns about their presence in the environment and in foods (Cornelissen and Gustafsson, 2006; Thorsen *et al*., 2004). The most potent carcinogenic PAH identified are BaP and DahA (Bishnoi *et al*., 2006; Collins *et al*., 1998, 1991). PAH are lipophilic and generally have a very poor aqueous solubility, hence they can be adsorbed on atmospheric particles like dust and transported over distances (Bortey-Sam *et al.*, 2014) and can accumulate in lipid tissues of plants and animals used as food (European Commission, 2002). However, processing procedures, such as smoking, drying, and cooking (Proietti *et al.*, 2014) are commonly thought to be the major source of PAH contamination in food (USEPA, 2008). Depending on a number of parameters such as time, fuel used, distance from the heat source, type of cooking (grilling, frying, roasting) and drainage of fat, (European Commission, 2002), a number of compounds including PAH thus are produced. There are several mechanisms for the formation of PAH such as melted fat that undergoes pyrolysis when it drips onto the heat. Also the pyrolysis of the meat due to the high temperatures during roasting (Menzie and Potocki, 1992). Overall, consumption of food containing PAH is believed to be the major route of human exposure to PAH (Ashraf and Salam, 2012; Bishnoi *et al*., 2006; Menzie and Potocki, 1992), inhalation and dermal exposures are other routes by which PAH can enter into the human body (Boffetta *et al*., 1997; Bortey-Sam *et al*., 2015; Chen and Liao, 2006; Liao and Chiang, 2006).

Street food vending activity is very high at transport terminals and they are seen along the busy streets in the major cities of Ghana (Mensah *et al*., 2002). These places are characterized by high levels of PAH in the air as a result of the smoke from the exhaust fumes of vehicles (Bortey-Sam *et al.*, 2014).

Preparation of street vended foods are characterized by such processes as grilling, smoking, over-cooking of some starch and protein rich foods at high temperatures (Proietti *et al.*, 2014). The processes are likely to introduce PAH and information on the levels of PAH in street vended foods as well as the possible risk it poses to the consuming population is scanty. In this work the concentrations of twelve USEPA priority PAH in two commonly consumed street vended foods were evaluated. The level of risks being posed to consumers at the 5^{th}, 50^{th} and 95^{th} levels of consumption were also assessed.

7.2 Materials and Methods

7.2.1 Sampling

Please refer to Chapter 6.2-3 (Sampling)

7.2.2 Sample collection

Please refer to Chapter 6.2.4 (Sample collection)

The food samples were stored in a -20 °C deep freezer prior to analysis. Raw (uncooked) samples (rice, chicken, vegetables and smoked fish) and processed samples such as mayonnaise and ketchup were bought from the market and used control samples.

7.2.3 Consumption studies

Please refer to Chapter 5.2.2 (Study population and data collection)

7.2.4 Sample preparation and PAH analysis

All analysis was done on a wet weight basis of the sample. Sample was extracted according to the method described in AOAC, (2007), where 10 mL of acetonitrile (HPLC grade) was added to 5 g portion of each of the food samples in a 50 mL centrifuge tube and vortexed for 1min. Agilent Bond

Elut QuEChERS AOAC extraction salt packet containing 6 g of anhydrous magnesium sulphate ($MgSO_4$) and 1.5 g of anhydrous sodium acetate (NaOAc) was added and vortex for 1min after which the tube and its contents were centrifuged at 4000 rpm for 5 min. About 6.0 mL aliquot of the upper acetonitrile layer was transferred into a Bond Elut QuEChERS AOAC Dispersive SPE 15 mL tube which contains 400 mg of primary and secondary amines (PSA), 40 mg of C18 EC and 1200 mg of anhydrous $MgSO_4$. The mixture was vortexed for 1 min and then centrifuged at 4000rpm for 5 min. A 4 mL aliquot of the extract was filtered through a 0.45 µm polyvinylidene fluoride (PVDF) syringe filter and then 0.1 mL of the extract was injected into the HPLC system (AOAC 2007). The standard mix of PAH was purchased from Sigma Aldrich (catalogue number, 861291), in methylene chloride:methanol (1:1). The analysis was based on Shimadzu Application Note (LC022) Demuro protocol with some modifications: A Cecil-Adept Binary Pump HPLC coupled with

Shimadzu 10AxL fluorescence detector (Excitation: 254 nm, Emission: 390 nm) with Phenomenex HyperClone BDS C18 Column (150 x 4.60mm, 5µm). Mobile phase composition was Pump A (Acetonitrile) and Pump B (Deionized Water) at 0.8mL/min. Gradient elution was used with the following combination, 0min – 5min = 60% A, 40% B; 5min - 15min = 90% A, 10% B; 20min 100% A, 0% B; 28 – 30min = 60% A, 40% B. PAH in samples were identified using the retention times against the standards and quantified using the calibration curve obtained. Quantitation was performed using the internal standard calibration method (five-point calibration), and the correlation coefficients (r^2) for the calibration curves were all greater than 0.98. Limits of detection (LOD) were calculated based on 3SD/S (SD is the standard deviation of the response of five replicate standard solution measurements and S is the slope of the calibration graph). LOD of PAH were in the range of 0.05–6.46ng/g. Recovery assessment was done by spiking matrix prior to extraction with standard mix. Average recovery was 114±1.42%. The final PAH concentrations were not corrected from the recoveries of the internal standards. Blanks were run periodically and contained no detectable amounts of target analyte. The coefficients of variation of PAH concentration in duplicate samples were less than 15 percent.

7.2.5 Data analysis

Please refer to Chapter 5.2.3 (Data management and analysis)

7.2.6 Health Risk assessment

According to Billiard *et al.* (2007), health risk assessment due to PAH cannot be solely related to their total concentrations, since each PAH exert different toxicological effects. The risks assessment due to PAH consumption was categorized into cancer risks and non-cancer risks according USEPA (USEPA, 2008). The incremental life cancer risk (ILCR) was calculated for each PAH with carcinogenic potential (Equation 4) and hazard quotient (HQ) calculated (Equation 1) for noncancer PAH (Gerba, 2000). An HQ less than 1 means the exposed population is unlikely to experience adverse effects of the hazard; whereas an HQ above 1 means that there is a chance of adverse effects of the hazards, with an increasing probability as the value increases (Akoto *et al*., 2014).

$$\boldsymbol{HQ = \frac{CDI}{RfD}} \qquad \text{Equation (1)}$$

Where the oral reference doses (R_fD) for naphthalene (Naph), (2.0×10^{-2} mg kg^{-1}day^{-1}), Imethylnapthalene (1MN) (7.0×10^{-2} mg kg^{-1}day^{-1}), 2-methylnaphtahlene (2MN) (4.0×10^{-3} mg kg^{1}day^{-1}), acenaphthene (Ace) (6.0×10^{-2} mg kg^{-1}day^{-1}), fluorene (Fle) (4.0×10^{-2} mg kg^{-1}day^{-1}), antracene (Ant) (3.0×10^{-2} mg kg^{-1}day^{-1}), fluoranthene (Flu) (4.0×10^{-2} mg kg^{-1}day^{-1}) and prene (Pyr) (1.0×10^{-3} mg kg^{-1}day^{-1}) (USEPA, 1996, 1993, 1986); and the Chronic daily intake (CDI) for each PAH was calculated using the Equation (2).

$$\boldsymbol{CDI = \frac{Cs \times IR \times EF \times ED}{BW \times AT}} \qquad \text{Equation (2)}$$

Where the CDI represents the amount of chemical (hazard) intake per kilogram of body weight per day (mg $kg^{-1}day^{-1}$); where Cs represents the average concentration of a particular PAH (mg kg^{-1}); IR (kg day^{-1}) represents the ingestion rate (given in the stochastic determination from the consumption studies); EF represents the exposure frequency (days $year^{-1}$) of consumption, ED represents the exposure duration (yr), total number of years the consumers have been exposed to the hazard and BW represents the body weight of the consumer (a 70 kg body weight of the reference man was assumed for the adult consumers) and AT represents the pathway-specific period of exposure, for non-carcinogenic effects, (ED x 365 days $year^{-1}$) and 70-yr lifetime for carcinogenic effects (i.e 70 yr x 365 days $year^{-1}$), averaging time (Gerba, 2000).

It has been reported that exposure to two or more pollutants may result in additive and/or interactive effects (Akoto *et al.*, 2014). Therefore the HI of the non-declared carcinogenic PAH for individual foodstuff was treated as the arithmetical sum of the individual PAH (Equation 3) (Gerba, 2000).

$$HI = HQ_{(n=1)} + HQ_{(n=2)} + \quad HQ_{(n)} \qquad \text{Equation (3)}$$

Where n refers to the HQ of the individual PAH

For the USEPA declared carcinogens, Incremental Lifetime Cancer Risk (ILCR), in humans can be determined by multiplying the CDI of the PAH with the respective potency factor (PF) according to the USEPA guidelines (Gerba, 2000) using the Equation 4. The equation for estimating ILCR is given as follows:

$$ILCR = (CDI) \times (PF) \qquad \text{Equation (4)}$$

The potency factor (PF), for the benzo-b-fluoranthene (BbF), benzo-k-fluoranthene (BkF), benzo-apyrene (BaP) and dibenz-a,h-anthracene (DahA) are 7.3E-01, 7.3E-02, 7.3E+00 and 7.3E+00 respectively.

7.2.7 Sensitivity Analysis

Please refer to Chapter 6.3.9 (Sensitivity Analysis)

7.3 Results and Discussion

The stochastic concentrations (mg kg^{-1}) of the non-carcinogenic PAH in the components of the meal types used in the study are as shown in Tables 7.1. The non-carcinogenic PAH detected in no particular order were naphtahlene (Naph), 1-methylnaphtahlene (1MN), 2-methylnaphtahlene (2MN), acenaphthene (Ace), fluorene (Fle), antracene (Ant), fluoranthene (Flu) and pyrene (Pyr). The predominant PAH detected in all the food samples of the two meal types was Naph. The stochastic concentration was as high as 6.5mg kg^{-1} in rice and shito samples at 95^{th} percentile consumption of the components (Table 7.1). The presence of Naph could be due to naphthalene balls (moth balls) used in the water and as insect repellent in the storage rooms (Soghoian *et al*., 2012) by some vendors. Water in storage is used for the all cooking and vending processes. In fufu preparation, for instance, excess raw cassava is stored in water for use the next day therefore Naph in the water gets imbibed into the raw cassava leading to the high levels, Alternate means of water storage would be by having an airtight lid storage container fitted to a tap. The container could be fitted with a tap for drawing water from the storage container; this could eliminate the use of naphthalene balls for water purification. Good house-keeping practices such as proper disposal of waste, instead of accumulating waste on premise and keeping tidy operations, could prevent the use of naphthalene as insect repellent and hence reduce the levels of naphthalene present in the food samples.

Pyrene (Pyr), was detected PAH in fried chicken and shito samples with concentrations of 4.0E-05 mg kg^{-1} and 2.9E-03 mg kg^{-1} respectively. Pyrene is of concern because it is believed to act as a precursor to BaP (USEPA, 2010), the most potent carcinogenic PAH (Nisbet and LaGoy, 1992). However, no safe limits have been established for dietary concentration of Pyr. Emphasis on PAH analysis was placed on the detection of BaP and DahA, due to its known carcinogenicity (Nisbet and LaGoy, 1992).

Table 7.1: Stochastic concentration ($mgkg^{-1}$) of the non-carcinogenic PAH Percentiles

Food Sample	PAH	5th	50th	95th
Rice	Naphthalene	3.3E-01	1.7E+00	6.5E+00
	1-methylnaphthalene	0.00	1.8E-04	8.4E-04
	2-methylnaphthalene	0.00	3.9E-03	1.8E-02
	Acenaphthene	0.00	2.7E-02	1.2E-01
	Fluoranthene	0.00	2.0E-02	9.5E-02
	Antracene	0.00	8.8E-04	4.1E-03
	Fluorene	0.00	2.7E-02	1.3E-01
	Pyrene	0.00	5.8E-04	2.7E-03
Chicken	Naphthalene	3.8E-04	1.8E-02	2.3E+00
	1-methylnaphthalene	0.00	4.2E-02	2.0E-01
	2-methylnaphthalene	0.00	5.0E-02	2.3E-01
	Acenaphthene	0.00	9.4E-03	4.4E-02
	Fluoranthene	0.00	1.1E-02	5.2E-02
	Antracene	0.00	7.7E-03	3.6E-02
	Fluorene	0.00	8.6E-06	4.0E-05
Shito	Naphthalene	3.3E-01	1.7E+00	6.5E+00
	1-methylnaphthalene	0.00	6.6E-02	3.1E-01
	2-methylnaphthalene	0.00	3.7E-01	1.7E+00
	Acenaphthene	0.00	4.6E-02	2.1E-01
	Fluoranthene	0.00	3.6E-02	1.7E-01
	Antracene	0.00	5.2E-03	2.4E-02
	Fluorene	0.00	9.9E-02	4.6E-01
	Pyrene	0.00	6.3E-04	2.9E-03

Fufu	Naphthalene	2.7E-05	1.3E-02	1.7E+00
	1-methylnaphthalene	0.00	2.1E-02	9.5E-02
	2-methylnaphthalene	0.00	1.1E-01	5.3E-01
	Acenaphthene	0.00	5.0E-03	2.3E-02
	Fluoranthene	0.00	3.5E-04	1.6E-03
Soup	Naphthalene	9.8E-04	2.2E-02	2.8E+00
	1-methylnaphthalene	0.00	6.4E-02	2.9E-01
	2-methylnaphthalene	0.00	1.7E-01	8.0E-01
	Acenaphthene	0.00	4.2E-02	8.5E-02
	Fluoranthene	0.00	2.8E-04	1.3E-03
	Antracene	0.00	6.3E-04	2.9E-03
	Fluorene	0.00	4.1E-02	1.9E-01
	Pyrene	0.00	4.3E-04	2.0E-03

PAH- Polycyclic aromatic hydrocarbon;

Benzo-a-pyrene, BaP, was detected in fried chicken, shito and soup component samples of the two meal types with concentrations of 1.2E-02 mg kg^{-1}; 2.0E-02 mg kg-1 and 6.3E-03 mg kg^{-1} respectively at the 95th percentile consumption (Table 7.2). The 95th percentile consumers of the fried rice meal were exposed to DahA at concentrations of 3.2E-03 mg kg^{-1}. The presence of BaP and DahA is not desired in the food samples because of their carcinogenic property (Phillips, 1999). These possible human carcinogens do not have safe levels of exposure, so all exposure routes should be reduced to the barest minimum (USEPA, 2011). By observation, nine of the vendors were located at the major transport terminal and six were located beside busy road. At these locations, exhaust from the vehicles could contaminate the fried chicken as they are exposed to the environment during cooling. About six vendors actually grilled the chicken on fire which leads to fat of the chicken dripping into the charcoal fire. The fumes that develop are known to be rich in benzo-a-pyrene can condenses on the grilled chicken.

Table 7.2: Stochastic concentration (mg kg^{-1}) of carcinogenic PAH

Food Sample	PAH	Percentiles		
		5th	50th	95th

Rice	BbF	-8.8E-06	7.4E-04	3.4E-03
	BkF	-7.7E-05	6.4E-03	3.0E-02
Chicken	BbF	-1.0E-07	8.4E-06	3.9E-05
	BkF	-1.8E-07	1.5E-05	6.9E-05
	BaP	-3.1E-05	2.6E-03	1.2E-02
	DahA	-8.3E-06	7.0E-04	3.2E-03
Shito	BbF	-2.7E-04	2.3E-02	1.1E-01
	BkF	-5.1E-05	4.3E-03	2.0E-02
	BaP	-7.0E-05	5.8E-03	2.7E-02
Soup	BaP	-9.1E-06	1.4E-03	6.3E-03

PAH- Polycyclic aromatic hydrocarbon; BbF – Benzo-b-fluoranthene; BkF – Benzo-k-flouranthene; BaP – Benzo-a pyrene; DahA – Dibenzo-a,h-Anthracene

Polycyclic aromatic hydrocarbon was not detected in some components of fried rice, namely, vegetables, ketchup mayonnaise and macaroni for all the samples as well as in the control samples.

The salad samples in this study consisted of chopped cabbage, onions, lettuce leaves and grated carrots and sometimes sliced cucumbers. However, a study conducted in Romania detected 15 PAH in different parts of potato, celery, dill, parsley, carrot, cucumber, onion, garlic, cabbage and spinach grown in rural and urban areas (Soceanu *et al.*, 2014). The absence of PAH in the vegetables used in this study can possibly be explained by the fact that preparation procedures such as peeling of the carrots and onions, the removal of the outer layer of the cabbage before shredding, could have helped reduce the concentration of the PAH on the vegetables (Ashraf and Salam, 2012).

Usually, PAH are stored in the lipid tissues which vegetables lack. The waxy surface of vegetables and fruits can concentrate low molecular mass PAH through surface adsorption (European Commission, 2002). The concentrations of PAH are generally higher on plant surface (peel, outer leaves) than in internal tissue (Ashraf and Salam, 2012). Particle bound high molecular mass PAH which remain on the surface are easily washed off whereas low molecular mass compounds which are in the vapor phase can penetrate the waxy layer of fruits and vegetables and, therefore, are less efficiently removed by washing (European Commission, 2002). Consequently, careful washing and cleaning may remove up to 50% of the total PAH on the average.

The mayonnaise and ketchup are industrial products that are obtained from the market and used as toppings on the salads. They are poured into refill bottles after mixing it up with some water to increase the volume and flow (Omemu and Aderoju, 2008). At the vending site, these are not left exposed but in bottles or containers used for dispensing, thus environmental contact with these products is minimal (Lucca and da Silva Torres, 2006). The boiled macaroni, a component of the fried rice meal did not contain PAH. No studies have been published on PAH levels in macaroni. However, the expected PAH are Flu, Pyr and BaP, because they are known to be associated with domestic combustion of wood charcoal (Olabemiwo, 2014), which is the primary fuel used in cooking by the street food vendors. The presence of all the PAH in the rice and chicken were as a result of vendor practices because none of them was detected in the uncooked rice and water.

The oral reference dose (R_fD) is a simple indicator of potential risk in practice where the stochastic chronic daily intake (CDI), is compared with the R_fD (Gerba, 2000). If the CDI is below the R_fD, then it is assumed that the risk is negligible for almost all the members of the exposed population. The stochastic chronic daily intake, CDI, due to PAH in the components of the two meal types are shown in Table 7.3. The levels of exposure due to PAH at the 5th and 50th levels of consumption were lower than the respective oral reference doses, R_fD (Table 7.3). This indicates that the foods being consumed at the 5th and 50th percentile were within safe levels (Akoto *et al.*, 2014). The CDI of the non-carcinogenic PAH found in the fufu meal are as shown in Table 7.3. At the 95th percentile, The CDI for Naph and 2MN in the fufu and soup samples was higher than the R_fD. This indicates that the 95th percentile consumers stands a chance of possible risk due to Naph and 2MN.

Table 7.3: Stochastic chronic daily intake (mg.kg^{-1} .day^{-1}) due the non-carcinogenic PAH

		Percentiles		RfD*
Rice	Naphthalene	0.0 0.0	7.1E-05	
	1-methylnaphthalene	0.0 0.0	4.9E-06	
	2-methylnaphthalene	0.0	1.1E-04	
	Acenaphthene		7.8E-04	
	Fluoranthene		5.6E-04	
	Antracene	0.0	2.5E-05	
	Fluorene	0.0	8.0E-04	
	Pyrene	0.0	1.7E-05	
Chicken	Naphthalene	3.1E-07	1.3E-04	
	1-methylnaphthalene	0.0 0.0	2.4E-04	
	2-methylnaphthalene	0.0	2.8E-04	
	Acenaphthene		5.2E-05	
	Fluoranthene	0.0	6.2E-05	
	Antracene	0.0	4.3E-05	
	Fluorene	0.0	4.9E-08	

Food Sample	PAH	5th	50th		
Shito	Naphthalene	1.1E-04	3.5E-03		
	1-methylnaphthalene	0.0 0.0	1.2E-04		
	2-methylnaphthalene	0.0	6.5E-04		
	Acenaphthene	0.0	8.1E-05		
	Fluoranthene		6.2E-05		
	Antracene	0.0	9.2E-06		
	Fluorene	0.0	1.7E-04		
	Pyrene	0.0	1.1E-06		
Fufu	Naphthalene	0.0 0.0	6.9E-04		
	1-methylnaphthalene	0.0	8.3E-04		
	2-methylnaphthalene		4.8E-03		
	Acenaphthene	0.0	2.1E-04		
	Fluoranthene	0.0	1.5E-05		
Soup	Naphthalene	4.2E-06	1.1E-03	2.3E-01	2.0E-02
	1-methylnaphthalene	0.0 0.0	2.3E-03 6.6E-	5.9E-02	7.0E-02
	2-methylnaphthalene	0.0	03 1.4E-03	1.6E-01	4.0E-03
	Acenaphthene	0.0	1.1E-05	2.6E-02	6.0E-02
	Fluoranthene			2.6E-04	4.0E-02
	Antracene	0.0	2.3E-05	5.8E-04	3.0E-01
	Fluorene	0.0	1.5E-03	3.6E-02	4.0E-02
	Pyrene	0.0	1.6E-05	3.7E-04	3.0E-02

Food Sample (mg.kg-1.day-1) PAH 95

1.4E

9.0E-05 7.0E-02 1.9E-03 4.0E

6.0E-02 9.5E-03 4.0E-02 4.3E-0

01 1.3E-02 4.0E-02

2.7E 3.0E-02

2.3E 2.0E-02

-04 4.3E-03 7.0E-02 5.0E-03

-02 04 6.0E-02 1.1E-03

04 4.0E-02

8.3E 3.0E-02

4.4E 2.0E-02

2.0E-03 7.0E-02 1.1E-02 4.0E

6.0E-02 1.1E-03 4.0E-02 1.6E-0

01 2.9E-03 4.0E-02 -07

th -02

-02 2.0E-02

1.9E 3.0E-02

1.5E 2.0E-02 2.1E-02 7.0E-02 1.2E-01 4.0E-03 5.2E-03 6.0E-02 3.6E 4.0E-02 -04

-05

-01

PAH- Polycyclic aromatic hydrocarbon; RfD- Oral reference dose

7.4.1 Health Risk Assessment

The results of the hazard index (HI) of the non-carcinogenic PAH are shown in Table 7.4. The components of the fried rice meal had HI less than 1 for the 5th and 50th percentile levels of exposure. However, the 95th percentile consumers of all the meal types used in the study had an HI more than

1, with the HI of shito being the highest. This was interesting considering the quantities of shito consumed (0.03 kg.day^{-1} for 95th percentile consumers, Table 6.4) per mealThis implies that even though small quantities of shito are added to the fried rice meal, its effects may be felt in the heavy consumers (95th percentile consumers) standing the risk of the non-carcinogenic effects due to PAH in shito. However, HI, greater than 1 was observed for the 50th percentile consumers of the fufu meal. This indicates that about 50% of the study consumers of fufu may be experiencing noncancer effects due to the PAH in the meal. Meanwhile fufu, is a predominantly consumed meal, native meal of the people in Ashanti region, the areas of study.

Table 7.4: Stochastic hazard index (HI) of the non-carcinogenic PAH

	Percentiles		
	5th	50th	95th
HI (rice)	5.87E-03	1.50E-01	1.94E+00
HI (chicken)	3.12E-03	1.30E-01	2.77E+00
HI (shito)	1.58E-02	4.49E-01	4.71E+00
HI (fried rice)	3.86E-02	9.69E-01	1.12E+01
HI (fufu)	4.76E-03	1.65E+00	4.78E+01
HI (soup)	1.61E-02	2.29E+00	6.46E+01
HI (Fufu)	1.11E-01	5.33E+00	1.30E+02

*fufu implies fufu component alone; Fufu = fufu with soup components

The results of the mean incremental life cancer risks (ILCR), for the clearly labeled carcinogenic PAH by USEPA, are shown in Table 7.5. The 5th percentile consumers had ILCR values for the PAH of $\leq 10^{-6}$. Those for the 50th percentile was within $\leq 10^{-6}$ to 10^{-4}. Benzo-a-pyrene, BaP, for all the components of the fried rice meals had high levels at the 95th percentiles with values above 10^{-4}. These values represent the risk of getting cancer due to BaP in the consumption of the components in the fried rice meals. The risk of getting cancer in the chicken component of the fried rice meal is

2 out of a 1000 people in the study population. The cancer risk for shito was approximately 1 out of 1000 people in the study population (Table 7.5).

Table 7.5: Stochastic incremental life cancer risk (ILCR) carcinogenic PAH

Food Samples	PAH	Percentiles 5th	50th	95th
Rice	BbF	0.0	1.6E-05	2.5E-04
	BkF	0.0	1.3E-05	2.2E-04
Chicken	BbF	0.0 0.0	3.4E-08	6.1E-07
	BkF	0.0	6.1E-09	1.1E-07
	BaP		1.1E-04	1.8E-03
	DahA	0.0	2.9E-05	5.0E-04
Shito	BbF	0.0 0.0	3.0E-05	5.0E-04
	BkF		5.3E-07	9.1E-06
	BaP	0.0	7.3E-05	1.3E-03
Soup	BaP	0.0	3.7E-04	9.0E-03

PAH- polycyclic aromatic hydrocarbons; BkF – benzo-k-fluoranthene; BbF – benzo-b-fluoranthene; BaP – benzo-a-pyrene; DahA – dibenz-a,h-anthracene

The ILCR due to BaP in the soup samples had values above 10^{-3}, where the risk was 9 people out of 1000 in the study population may be experiencing the effects of cancer. According to Whipple (1987), the de-minimis for cancer risk is 10^{-6}, meaning, one (1) out of a million people in any risk calculation was acceptable. The safe limit for PAH cancer risk according to Bortey-Sam *et al,* (2015), is $\leq 10^{-6}$ to 10^{-4}. The 95th percentile consumers of soup and fried rice from the study may be classified to be at risk of cancer.

7.4.2 Sensitivity Analysis

A sensitivity analysis was performed on the overall hazard index to determine which input factors have the greatest effect on risk estimate. The results of the sensitivity analysis are as shown in the tornado plots illustrating the spearman rank order correlation coefficients (Fig 7.1). Exposure duration and exposure frequency were the most influential variables for the fufu risk estimate (HI) with correlation coefficients of 0.69 and 0.42 respectively (Fig 7.1). These figures show the extent to which the two variables are linearly related. If the relationship is perfectly linear, then the correlation coefficient is +1 if there is a positive correlation and -1 if the line has a negative slope. There is no linear relationship between the variables if the correlation coefficient is zero (Hoare *et al*., 2008). The exposure duration had a more positive linear relationship with the risk estimate.

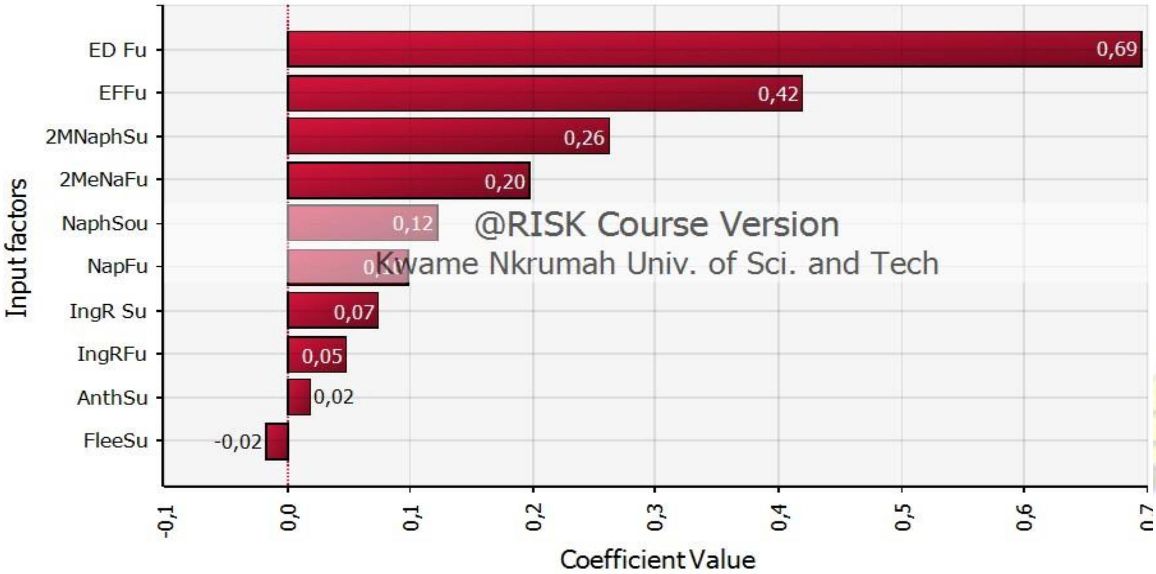


Figure 7.1: The relationship between the input factors on the hazard index of fufu meal

Legend: EDFu- Exposure duration for fufu consumption, EFFu-Exposure frequency in fufu consumption, 2MNaphSu-2-methylnaphthalene in fufu, 2MeNaFu-2-methylnaphthalene in soup, NaphSou-Naphthalene in soup, NapFu-Naphthalene in Fufu, IngRSu-Ingestion rate for soup, IngRFu-Ingestion rate for fufu, AnthSu-Anthracene in soup, FleeSu-Fluoranthene in soup

This implies that duration of consumption puts the consumer at risk as well the frequency of consumption. So the exposure duration and frequency must be reduced, however, this meal is a traditional meal of the area under study, so reducing the duration as well as frequency would be a monumental task, therefore the next target for intervention is the presence of naphthalene and its derivatives the fufu and soup components. The naphthalene balls should be removed from the stored water, as a means of intervention, since that is the most likely source in the meals.

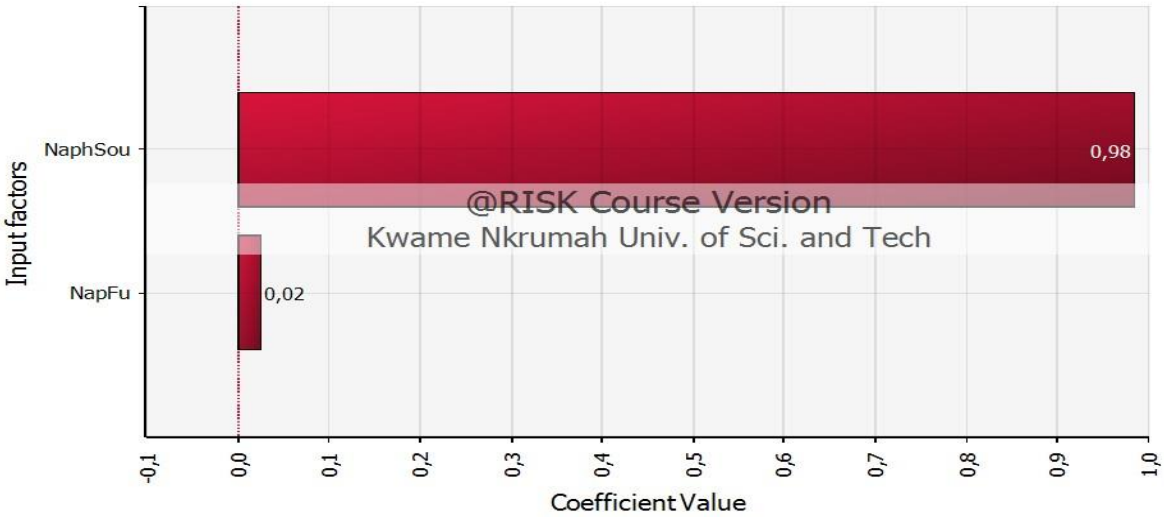


Figure 7.2: The regression coefficient of input factors on overall hazard index for Fufu meal
Legend: NaphSou- Naphthalene in soup, NapFu-Naphthalene in Fufu

Figure 7.2 shows the regression coefficient on the hazard index for the fufu. The Naph in soup had the most linear relationship with the hazard index. This indicates that the Naph in soup must be focused on for intervention. All possible exposure routes of Naph in the consumption of the soup must be reduced. The main source of Naph and its derivatives in the fufu meal is the use of Naph also known as moth ball or camphor in the stored water (Soghoian *et al.*, 2012).

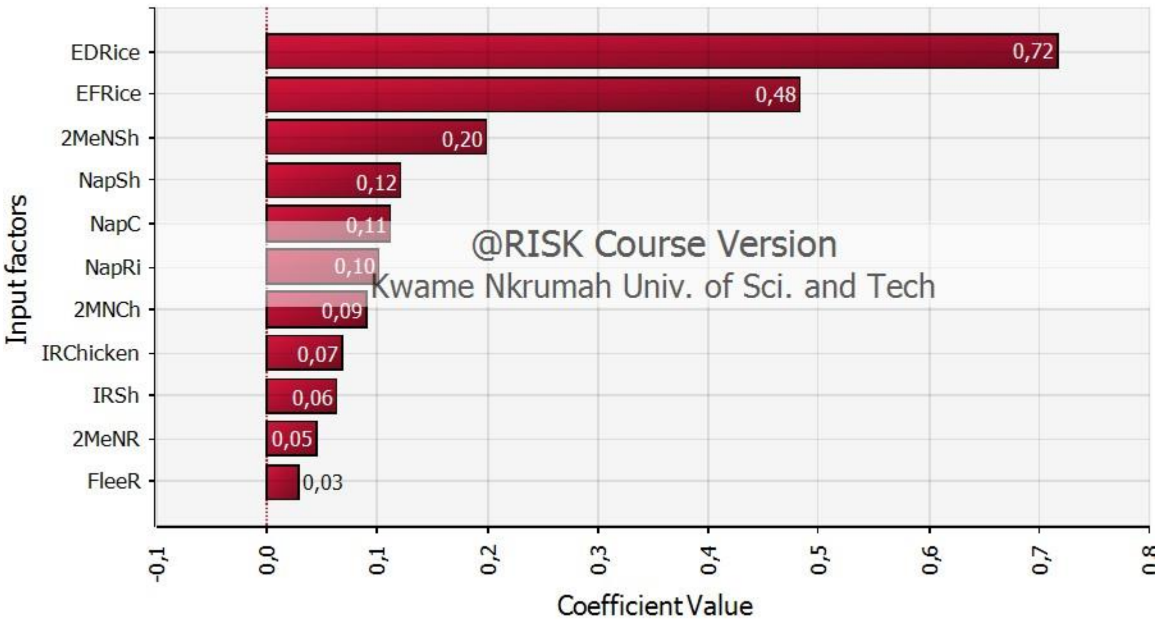


Figure 7.3: The Spearman's ranking correlation coefficient of the input factors on the hazard index of fried rice meal

Legend: EDRice-Exposure duration for rice consumption, EFRice- Exposure frequency for rice consumption, 2MeNSh-2-methylnaphthalenein shito, NapSh-naphthalene in Shito, NapC-naphthalene in chicken, NapRi-naphthalene in rice, 2MNCh- 2-methylnaphthalene in chicken, IRSh-Ingestion rate of shito, 2MeNR-2-methylnaphthalene in rice, FleeR-Fluoranthene in rice

The sensitivity analysis for the HI on the Fried rice meals also implicated exposure duration, exposure frequency, concentrations of naphthalene and its derivatives in shito, chicken and rice components. The reduction in exposure duration and frequency are consumer based interventions as stated above. The presence of naphthalene in the rice and chicken and shito components of the fried rice meals are all as a result of the vendor and raw material supplier practices, which can be intervened by stopping the use of moth balls for various reasons, such as controlling pest infestation or purifying and deodorizing stored water for cooking purposes. Alternative would be the avoidance of improper storage of food and proper disposal of waste eliminates the feeding sites of pests and thus help control pests. However, Figure 7.4 which shows the correlation coefficients of the input factors on the HI suggests the presence of naphthalene in rice and chicken as the main regression factors affecting the HI and that the exposure duration had no correlation with the HI.

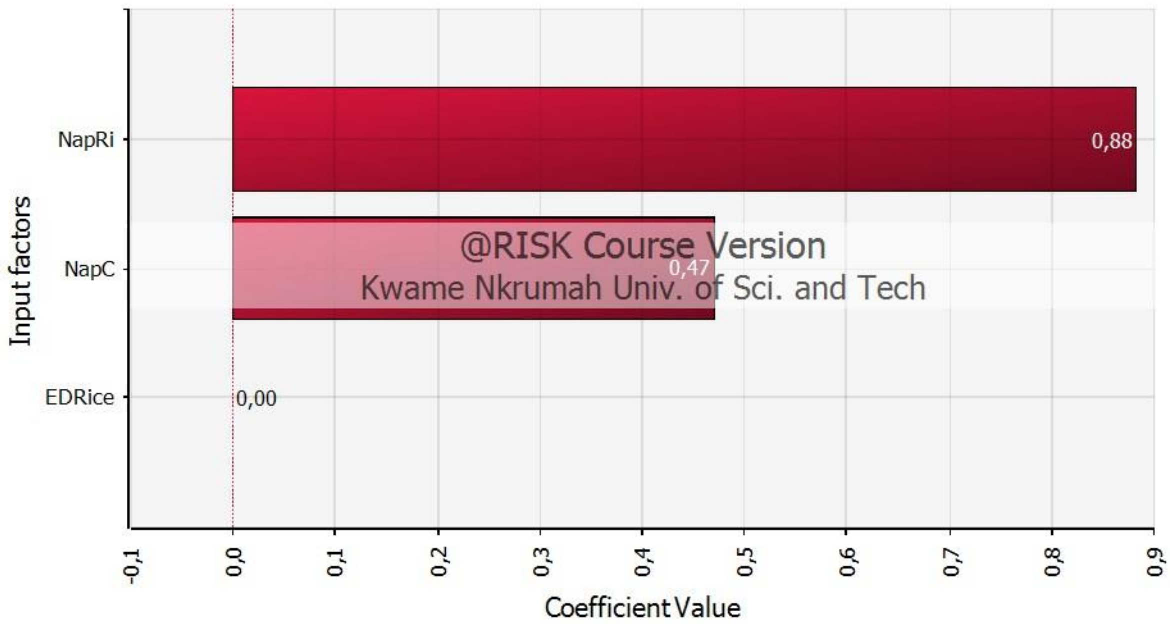


Figure 7.4: Correlation coefficients of the input factors on the overall hazard index for fried rice meal

Legend: NapRi- naphthalene in rice, NapC- naphthalene in chicken, EDRice- Exposure duration of rice consumption

7.5 Conclusion

The findings from this study have shown clearly the presence of polycyclic aromatic hydrocarbons in all the components of the "Fried rice" except Vegetables, Ketchup, Mayonnaise and Macaroni samples. Shito samples recorded the highest levels of PAH including the USEPA declared carcinogens, making it unsafe for human consumption. The chronic daily intakes (CDI) of the fried rice meal at all levels of exposure were lower than the Oral reference doses (R_fD) indicating consumption at safe levels. Generally, the ILCR revealed that meals were consumed within safe levels or acceptable levels. The hazard index (HI) for both fufu and fried rice meals suggested that fried rice meals at 95th percentile and fufu at the 50th percentile consumption levels were not safe. The main intervention for the HI for both street vended meals was eliminating the use of

naphthalene balls in water and as pest control agent.

CHAPTER EIGHT 8.0 ASSESSMENT OF METAL EXPOSURE AND HEALTH RISKS ASSOCIATED WITH

STREET FOODS CONSUMPTION.

8.1 Introduction

The sale and consumption of street vended foods in third world countries is one of the major drivers of the informal sector of the economy (Ekanem, 1998). Mostly engaged in the business of street food are women with low educational background who are the major breadwinners for their families, since they are mainly single mothers (Draper, 1996). The business finds them lined along the major streets of the city where they are together with the vended foods exposed to the fumes from the exhaust of moving vehicles and this poses a risk of Pb contamination (Omemu and Adeosun, 2010). Main utensils used in the preparation of these foods are usually locally manufactured utensils, which are made from scrap metals of batteries and especially aluminum from different sources of waste materials (Weidenhamer *et al*., 2014). Coupled with these, the process of preparation of street vended food includes milling of the ingredients from local commercial mills (Panduwawala *et al*., 1988) and the use of scouring sponges to clean the utensils after food preparation (Proietti *et al*., 2014). This situation may expose consumers to the risk of possible metal contamination from street environment and practices related to the preparation of the meals. *Fufu* (pounded cooked cassava and plantain) and fried rice, (cooked rice stir-fried with cut vegetables) are two very popular street vended meals whose preparation and handling are similar to most of the street vended meals in Ghana. However, information on the levels of metals in these foods as a result of the use of local utensils is scanty and therefore the need to research into levels of some toxic metals in them.

Aluminum (Al) is a metal which, for a long time, has been considered as non-toxic because of its ubiquitous nature. The environment acts as the main source. However, orally consumed aluminum is now considered a contaminant in the food chain due to the role it plays in the aetiology of diseases like Alzheimer‟s and amytrophic lateral sclerosis (Dabonne *et al*., 2010; Muller *et al*., 1998). Ogawa and

Kayama, (2015) stated that, Aluminum has low toxicity to humans; however, it is still important to try to reduce aluminum exposure as much as possible. Source of Aluminum in cooked foods include, the food material (plant origin) itself, other food ingredients, the cooking pan used to prepare the food, water used during cooking and the packaging material (Dabonne *et al.*, 2010; Weidenhamer *et al.*, 2014).

Lead (Pb) serves no purpose in humans and its presence leads to toxicity regardless of the exposure pathway. Lead accounts for 674,000 deaths annually (Radwan, 2005). It is responsible for attention behavior disorders in children (Radwan, 2005). It is also responsible for a lot of renal, cardiovascular, reproductive and endocrine effects in human adults. Possible sources of lead (Pb) in food samples include; food samples of plant origin grown in lead contaminated soils preparation practices like the milling or cooking procedures, though not in high levels (Panduwawala *et al*., 1988). Use of pesticides that are contaminated with heavy metals during the cultivation or storage of crops may also be a source of lead contamination in the final product (Galal-Gorchev, 1991). Some other studies reported that traffic density due to the use of leaded petrol in automobiles also increases the burden of lead in the environment thereby increasing the lead content in the vegetation (Buszewski *et al*., 2000; Nabulo *et al*., 2006; Rodríguez-Flores and Rodríguez-Castellón, 1982) and in foods that may be exposed to the environment.

Iron, is an essential mineral needed by the body for blood production and is naturally present in many foodstuffs in varying concentrations. However, consumption of excessive amounts of iron can lead to adverse health effects such as enlarged liver due to deposition of the iron, joint diseases, multisystem organ failure, convulsions, coma and even death (Darko *et al*., 2014). Apart from it being naturally present in foodstuffs, certain food preparation practices may increase iron concentration, e.g. grinding of cereals at commercial mills. Fe concentration can increase by 3 to 5 folds due to wear and tear of the machine parts (Panduwawala *et al*., 1988). Dabonne *et al*. (2010) found that traditional utensils used for food preparation contained high Fe levels and that Fe could leach into the food, e.g. during cooking. Copper, iron and nickel are considered essential metals at low concentrations but are toxic at high levels (Chen *et al*., 2009; Rignell-Hydbom *et al*., 2009).

FAO and WHO have established tolerable levels known as the Recommended Daily Allowance (RDA) and Permitted Tolerable Daily Intake (PMTDI) for most of these elements, where the RDA of Fe is 14.8 $mg.day^{-1}$ for a 60 kg body weight and its PMTDI is 5 $mg.kg^{-1}$ body weight (FAO/WHO, 2010). Aluminum on the other hand is considered a safe metal with no recommended daily allowance (RDA) as suggested by the United States Environmental Protection Agency
(USEPA) but with provisional tolerable weekly intake (PTWI) levels established by the World Health Organization (WHO) as 7000 $\mu g.kg^{-1}$ $week^{-1}$ (FAO/WHO, 1989). The PWTI for Pb is 25 $\mu g.kg^{-1}$ $week^{-1}$ (JECFA, 1993).

The exposure of street food consumers to the metals in the meals and associated health risks is determined not only through analyzing metal concentrations in street vended foods. In addition, the risk could also be assessed through the consumption of the metals in the street vended meal with the use of the hazard quotient calculations for non-cancer risks. The preparation of street vended food relies mostly on the use of local cookware and utensils. This study therefore aimed to determine the levels of Pb, Fe and Al as well as the health risk associated with the consumption of two commonly vended street foods in Kumasi, Ghana.

8.2 Materials and methods

8.2.1 Study area, sampling and sample size and consumption interviews

Please refer to Chapter 6.2-3 (Sampling); Chapter 6.2.4 (Sample collection); Chapter 5.2.2 (Study population and data collection)

8.2.2 Metal Analysis

Ten milliliters of freshly prepared Acqua regia (HNO_3: HCL, 1:3) reagent was poured onto one (1) gram of the food samples in appropriately labeled digestion tubes and placed in a water bath (Labline, Imperial IV, USA) set at 100 ºC for approximately 12 hr. Following the digestion, the solution was filtered into pre-labeled graduated 50 mL falcon tubes through ashless filter paper (Whatman no.42, 125 mm diameter). The filtrate was made up to the 50 mL mark with distilled water.

Determination of Iron (Fe) and Lead (Pb) determination

The Fe and Pb contents were determined using the Atomic Absorption Spectrophotometer (AAS) (Buck Scientific, USA, model: 210 VGP). The basic setup was as follows: air pressure at 50 – 60 psi; acetylene pressure at 10 – 15 psi and voltage at 208 – 240 V. The file for the type of analysis and hollow cathode lamps were selected with appropriate wavelengths - 248.3 nm for Fe, and 283.3 nm for Pb, slit for both elements was at set 0.7 nm. A calibration curve was plotted for each of the elements to be analyzed from the stock standards (Buck Scientific, USA). The limit of detection for Fe was set at 0.03 mg/L and that for Al, 0.10 mg/L. The standard curves for both elements are shown in Appendix IV.

Aluminum (Al) determination

Aluminium determination was done using the graphite furnace atomic absorption spectrophotometer (GFAAS). Calibration standards were made in concentrations of 50, 100, 150 and 200 µg/L by auto-calibration from a stock of 200 µg/L under the following graphite furnace atomic absorption spectrometry (GFAAS) conditions: 15 uL loads of standards and samples were injected at 309.3 nm wavelengths, D2 Background correction, Peak Height, Argon purge (~50 mL/min), auto-zero off, in the grooved furnace tube. The analysing conditions were as follows: drying: ambient to 120 ^{o}C in 10 s ramp, 5 s holding**;** ashing at 120 ^{o}C to 1000 ^{o}C in 45 s ramp, 20 s holding; and atomizing at 1000 ^{o}C to 2500 ^{o}C in fast ramp or step followed by 2 s holding.

8.2.3 Data analysis and handling

All analysis were made in triplicate and mean concentrations of Fe, Pb and Al in each of the component of the food samples together with the standard error of mean (SEM) were calculated. Two-way analysis of Variance (ANOVA) was performed at 95% confidence interval (CI) to determine if there were significant differences to check for equal and random distribution between the contaminants in the components of fried rice and fufu meals from the different metropolitan areas and among the vendors using GraphPad Prism version 6, USA.

8.2.4 Health risk assessment

The chronic daily intake (CDI) of the metals over the exposure period was determined first in the health risk assessment. The CDI, for each component of the meals was calculated as follows:

$$\text{CDI} = \frac{Cs \times IR \times EF \times ED}{BW \times AT} \qquad \text{Equation 1}$$

Where, CDI is the chronic daily intake, the intake amount per kilogram of body weight per day (mg kg^{1} day^{-1}). Cs represents the stochastic distribution of the concentration of the metal (mg kg^{-1}, wet weight basis); IR (kg day^{-1}) is the ingestion rate of the metals; EF is the stochastic distribution of the exposure frequency (days yr^{-1}), ED is the exposure duration (yr) representing the stochastic distribution of the total number of years the consumers have been exposed to the hazard and BW represents the body weight of the consumer, where an assumed average body weight of 70 kg (reference man) for adult consumer was used, and AT is the specific period of exposure, for noncarcinogenic effects (30 yr x 365 days yr^{-1}) (Gerba, 2000).

The health risk assessment for the metals which pose no cancer risks, were expressed in terms of hazard quotient (HQ) for a single substance, or hazard index (HI) for multiple substances (Gerba, 2000). The Hazard Index (HI) was calculated for the individual metal in the fried rice meal. An HI less than 1 means the exposed population is unlikely to experience adverse effects of the hazard. An HI above 1 means that there was a chance of adverse effects of the hazards, with an increasing probability as the value increases (Akoto *et al.*, 2014).

$$HQ = \frac{CDI}{\mathrm{RfD}} \qquad \text{Equation 2}$$

$$\mathbf{HI = HQ\ (n=1) + HQ\ (n=2) + \quad HQ\ (n)} \qquad \text{Equation 3}$$

The oral reference doses (RfD) for Iron (Fe) and Lead (Pb) are 0.7 and 0.14 $mgkg^{-1}day^{-1}$ respectively (Akoto *et al.*, 2014). No oral RfD value has been provided for Al. Therefore the

Provisional Tolerable Weekly Intake (PTWI) level established by the World Health Organization (WHO) was used in place of RfD for the Aluminium (Al), being 7000 $\mu g\ kg^{-1}week^{-1}$ (FAO/WHO, 1989).

8.2.5 Sensitivity analysis

Please refer to Chapter 6.3.9 (Sensitivity Analysis)

8.3 Results and discussion

Relatively high mean levels of the metals were seen in all the food samples. Aluminum (Al) however had higher mean levels in the food samples than Iron (Fe) and Lead (Pb) (Table 8.1). Significant differences were seen in the mean levels of Fe and Pb in the rice samples from the three metropolitan areas. All the samples that were cooked in the local cooking pots (rice, chicken, shito and macaroni) had higher levels of metals than their corresponding control samples (raw samples) (Table 8.1). Pb content in all food samples were higher than the 0.3mg kg^{-1} levels specified by FAO/WHO Joint Expert committee on food additives (JECFA) (FAO/WHO, 1989).

8.3.1 Fried rice

In general the mean concentrations (mg kg^{-1}) of the Aluminum in the fried rice and chicken were about 6.15 mg kg^{-1} (Table 8.1). The maximum value obtained for Al in the cooked rice (11.34 mg kg^{-1}) was lower compared with a mean value of 18 mg reported by Dabonne *et al.* (2010). The fried chicken samples had mean Al levels of 3.9 mg kg^{-1} which was higher than the control chicken sample (uncooked) with a mean value of 3 mg kg^{-1}. This implies that leaching of aluminum from the local utensils could have had an impact on the final aluminum content of the chicken. However the varying concentration of the aluminum seen in the rice and chicken samples could also be as a result of the varying cooking and frying times of chicken in the aluminum pots and frying pans (Weidenhamer *et al.*, 2014). The time of exposure can influence the rate of leaching of metals from the cookware into the food materials (Dan and Ebong, 2013). There were no statistical differences $p<0.05$ between mean values of samples from the different metropolitan areas.

The mean concentrations of Pb in the fried rice and chicken samples ranged between 3.3 mg kg^{-1} to 11.25 mg kg^{-1} (Table 8.1). The raw chicken had values of 5.45 $mgkg^{-1}$ quite close to the cooked and fried chicken samples. The high levels of Pb in the cooked rice samples could be due to the cooking in the locally manufactured aluminum pots which contains Pb as impurities (Weidenhamer *et al.*, 2014). The uncooked rice samples had higher levels of Pb (6.8 mg kg^{-1}) than the cooked samples whose mean concentration ranged between 3.30 mg kg^{-1} to 9.32 mg kg^{-1}. These low values were not expected because in the study conducted by Dabonne *et al.* (2010), the cooked rice samples still had higher levels of Pb than their corresponding uncooked ones, indicating that the utensils used had impact on the levels Pb in the cooked food samples in their study. Irrespective of this, all the fried rice and chicken samples had mean Pb concentration higher than the 0.3 mg kg^{-1} limit set by FAO/WHO, Joint Expert Committee of Food additives, 2003

The mean levels of the Fe in the fried rice and chicken samples ranged from 2.33 mg kg^{-1} to 4.53 mg kg^{-1} and most of the samples had levels below the 5 mg kg^{-1} tolerable daily intake by (FAO/WHO, 2010). The reason for the levels of Fe in the rice samples were due to the fact that the vendors used the stock from boiling the chicken to actually cook the rice. The spices in the stock have been shown by to have high iron content (Darko *et al*., 2014) due to milling of the spices using the commercial mills (Panduwawala *et al*., 1988). Statistically, significant differences existed between the rice samples from the Subin sub-metropolitan areas and the other two sub-metropolitan areas. The Fe levels in the in the control rice and chicken samples were relatively low (0.65 mg kg^{-1} and 1.5 mg kg^{-1}, respectively) than in the cooked rice and chicken samples which were between 2.33 mg kg^{-1} to 4.53 mg kg^{-1}, indicating the possibility of leaching of the Fe from the utensils as suggested by Dabonne *et al.* (2010). Statistically no significant differences existed among the different chicken samples from the vendors

The mean values of Al, Pb and Fe in the vegetables used as salad were about the 4.04 mg kg^{-1} (Table 8.1). The salad component of the fried rice is not cooked in any of the cooking pots. The different levels of metals in the samples could be as a result of agricultural management practices in the different locations where the vegetables were grown. Location of growth featured strongly on the levels of metals present in vegetable, in a research conducted on the impact of location on the metal contaminants of some vegetables grown in the Kumasi city (Odai *et al*., 2008).

Table 8.1: Mean concentrations (± SEM) of some metals contaminants in the components of the meals

Food sample	Metro Area	Fe ($mg.kg^{-1}$)	Pb ($mg.kg^{-1}$)	Al ($mg.kg^{-1}$)
Rice	Oforikrom	2.33 ± 0.19^{a}	3.30 ± 0.42^{a}	11.34 ± 7.53^{a}

(n=18)	Subin	4.53 ± 0.55[b]	4.40 ± 0.54[ac]	7.87 ± 3.52[a]
	Asawase	2.62 ± 0.44[a]	9.32 ± 1.56[bc]	6.04 ± 0.85[a]
Vegetables (n=18)	Oforikrom	2.25 ± 0.34[a]	4.23 ± 0.36[a]	3.04 ± 1.25[a]
	Subin	2.47 ± 0.21[a]	6.23 ± 0.81[a]	6.12 ± 3.34[a]
	Asawase	1.83 ± 0.25[a]	5.89 ± 0.79[a]	4.33 ± 1.53[a]
Chicken (n=18)	Oforikrom	3.08 ± 0.24[a]	4.91 ± 0.58[a]	3.35 ± 0.61[a]
	Subin	2.94 ± 0.18[a]	4.20 ± 0.44[a]	3.31 ± 0.67[a]
	Asawase	3.22 ± 0.49[a]	9.22 ± 1.08[b]	5.05 ± 2.22[a]
Shito (n=18)	Oforikrom	6.74 ± 1.27[a]	11.25 ± 1.81[a]	5.27 ± 0.91[a]
	Subin	7.82 ± 0.47[a]	7.43 ± 1.44[a]	18.49 ± 9.63[a]
	Asawase	7.73 ± 0.55[a]	8.99 ± 1.10[a]	12.21 ± 6.66[a]
Ketchup (n=18)	Oforikrom	1.44 ± 0.10[a]	7.15 ± 1.52[a]	10.96 ±0.51[a]
	Subin	2.57 ± 0.55[a]	6.14 ± 0.79[a]	13.47 ± 0.95[a]
	Asawase	2.33 ± 0.49[a]	4.14 ± 0.35[a]	13.29 ± 3.23[a]
Mayonnaise (n=18)	Oforikrom	2.42 ± 0.24[a]	8.46 ± 1.68[a]	8.59 ± 1.27[a]
	Subin	1.82 ± 0.50[a]	6.47 ± 0.92[a]	9.23 ±1.42[a]
	Asawase	1.82 ± 0.15[a]	6.31 ± 1.10[a]	8.54 ±1.34[ab]
Macaroni (n=18)	Oforikrom	2.06 ± 0.46[a]	4.30 ± 0.44[a]	9.15 ± 6.68[a]
	Subin	3.95 ± 0.10[a]	6.58 ± 1.39[a]	6.15 ± 0.87[a]
	Asawase	3.57 ± 0.56[a]	8.23 ± 2.20[a]	3.24 ± 1.33[a]
Fufu (n=18)	Oforikrom	2.23 ± 0.33[a]	6.02 ± 0.87[a]	35.05 ± 28.65[a]
	Subin	2.27 ± 0.37[a]	3.35 ± 0.59[ab]	24.69 ± 6.55[a]
	Asawase	3.05 ± 0.43[a]	7.53 ± 0.78[ac]	21.90 ± 18.10[a]
Soup (n=18)	Oforikrom	4.27 ± 0.25[a]	7.80 ± 1.11[a]	13.72 ± 8.49[a]
	Subin	3.60 ± 0.30[a]	4.63 ± 0.60[a]	4.58 ± 1.43[a]
	Asawase	2.24 ± 0.32[b]	6.61 ± 1.09[a]	17.62 ± 12.77[a]
Control	Rice	0.65	6.80	
	Vegetable	1.20	5.65	5.12
	Chicken	1.50	5.45	3.2
	Fish	9.65	6.50	11.53
	Ketchup	0.40	5.90	32.83
	Mayonnaise	0.80	6.45	20.05
	Macaroni	1.70	7.95	3.59
	Salt	2.00	9.70	4.79
	Fufu	0.80	7.10	3.90
	Soup	1.15	7.65	4.68

*Same letters (a,b,c) in the superscript in a column indicate non-significance at 95 % Confidence Interval.

Significant differences, $p > 0.05$, however did not exist between the means for all metals even though the concentrations Al, Pb and Fe were 14 mg kg^{-1} for ketchup and 9 mg kg^{-1} for the mayonnaise, Table 8.1. These are commercial products some vendors mix with some water to enable them dispense the product easily and also to increase the volume of the product (Omemu and Aderoju, 2008). The original undiluted mayonnaise and ketchup had higher mean values of Aluminum, of 20 mgkg^{-1} and 32 mg kg^{-1} respectively. The levels seen could be from the source of raw materials used to produce these products. However exposure levels of toxic and heavy metals in the commercial products should be investigated since they could be sources of nationwide metal intoxication. There was no significant difference $p > 0.05$ between similar samples from the metropolitan areas used in the study.

The test metals were detected in shito and macaroni samples varied across vendors ranging from 2.06 mg kg^{-1} to 18.49 mg kg^{-1}. The high levels >0.03 mg kg^{-1}, reported in this study for macaroni may be due to exposure to the environment, especially in traffic dense areas where Pb contamination will be most likely. The levels of Fe in the shito samples could be due to the use of the dried fish powder, with mean concentration of 9.65 mg kg^{-1}, dried spices (anise, rosemary, curry, ginger and dried pepper powder), with high Fe concentration as reported by Darko *et al.* (2014). The utensils used to prepare the shito had evidence of pitting (Weidenhamer *et al.*, 2014) indicating possible leaching of the utensils into the hot pepper sauce. The level of Fe in the dried fish powder may be due to the milling of the dry fish after smoking, in a commercial mill (Panduwawala *et al.*, 1988). There was no significant difference ($p > 0.05$) between all the „shito" samples from the different metropolitan areas.

8.3.2 Fufu

For the fufu and soup samples, the mean concentration of Al (between 21.90 mg kg^{-1} and 35.05 mg kg^{-1}) were relatively higher than the mean concentration of Fe and Pb (between 2.23 mg kg^{-1} and 7.53 mg kg^{-1}) (Table 8.1). These values were correspondingly higher than the control samples in each case. The phenomenon could be attributed to possible leaching from the cooking pot. (Dabonne *et al.*, 2010; Weidenhamer *et al.*, 2014) before pounding. The use of metal scouring sponge in cleaning the pots could also enhance the leaching of the metals into the food samples. There was no significant difference ($p > 0.05$) in the mean concentration of the metals in fufu and soup samples (Table 8.1).

8.3.4 Hazard index (HI)

The hazard index represents estimates of non-cancer risks for single hazard or substance, and a multiple of the substances, in the same exposure pathway. The hazard index due to the different metals in the street vended meals at the 5th, 50th and 95th percentiles of consumers in the population used in the study is shown in Table 8.2.

The 5th percentile consumers in this study had very low hazard indices for all the meals (Table 8.2). This indicates that consumers exposed to low consumption weights of the meals were not likely to suffer the adverse effects due to the presence of Al, Pb abd Fe in the street vended meals. The 50th percentile population were likely be suffering the adverse effects due to Pb in the meals, because the HI > 1. The consumers were not likely to suffer the adverse effects due to Fe and Al because HI < 1. However the 95th percentile consumers were likely to suffer the adverse effects due to all the metals in the street vended meals as the HI > 1, with an increasing probability as the HI increases.

Table 8.2: Hazard index (HI) due to metal in Fried rice and Fufu meals

Percentiles

Fried rice	5th	50th	95th
Fe	0.01	0.27	2.08
Pb	0.10	2.30	19.07
Al	0.02	0.36	3.46
Fufu	5th	50th	95th
Fe	0.01	0.39	5.06
Pb	0.09	3.82	50.20
Al	0.02	0.90	42.05

8.3.5 Sensitivity Analysis

Figure 8.1 shows the effects of the input factors on the overall mean risk estimates in terms of the HI due to the presence of the metals in the fufu meal. These are expressed as correlation coefiicients ranked in Spearman‟s rank order correlation. The analysis indicates that the exposure duration of 0.76 and exposure frequency of 0.45 having the highest impact on the overall mean estimate of the HI (Fig 8.1). The concentration of Al in the fufu samples ranked third with correlation coefficient of 0.18 and levels of Pb in both the fufu and soup samples, 0.11. These are the factors that interventions must be focused on according to this study. The results indicate the first two factors, exposure duration and frequency need behavioral change in consumers. The concentration of Al in the fufu implicated the utensils used for cooking. Alternatively, the vendors can change the utensils from local pots to the use of stainless steel pots (Hauser *et al.*, 2004). This is the recommended food grade utensils by WHO as the safest for food preparation purposes. Stainless steel is corrosion resistant, non-toxic and mechanically stable (Hauser *et al.*, 2004). Even though Al was not generally considered as a toxic metal, it can become toxic due to the high levels of exposure such as in the meals. Leaching of Al and Pb have been shown to be influenced by the presence of salt, low pH and period of use (Al Zubaidy *et al.*, 2011).

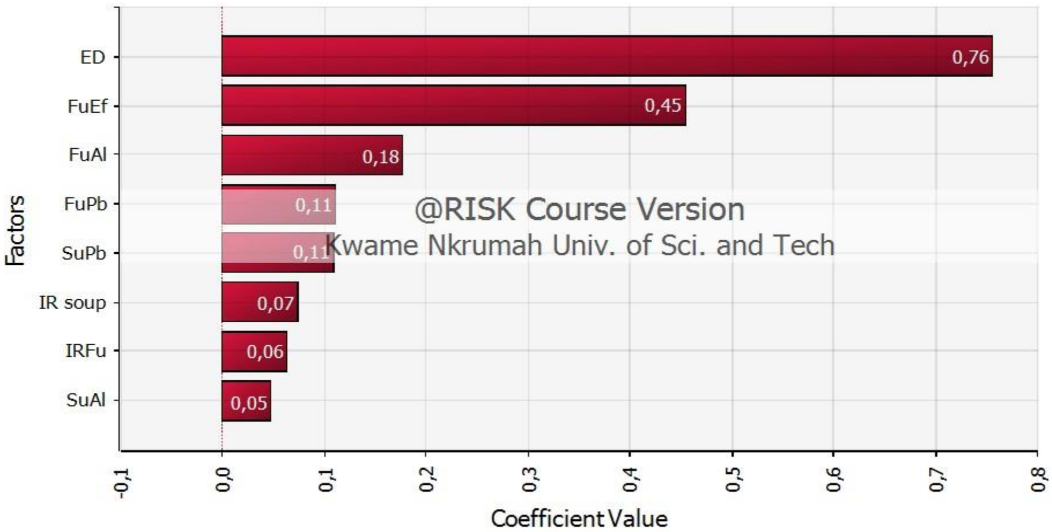


Figure 8.1: The impact of the input factors on the overall HI due to metals in fufu meal.
Legend: ED-Exposure duration for fufu consumption, FuEf- Exposure Frequency for fiufu consumption, FuAl- Aluminum in fufu, FuPb, Lead in fufu, SuPb- Lead in soup, IR soup: Ingestion rate for soup consumption, IRFu- ingestion rate for fufu consumption, SuAl-Aluminum in soup

The Spearman‟s rank correlation coefficients of the HI of fried rice meal featured the exposure frequency and duration as having the strongest impact on the overall risk estimate (Fig 8.2).

The levels of Pb in the rice and chicken components also affected the impact on the overall risk estimate. These components are prepared or cooked in the locally manufactured cooking pots and the leaching effects as discussed earlier are likely to be the cause (Weidenhamer *et al.*, 2014).

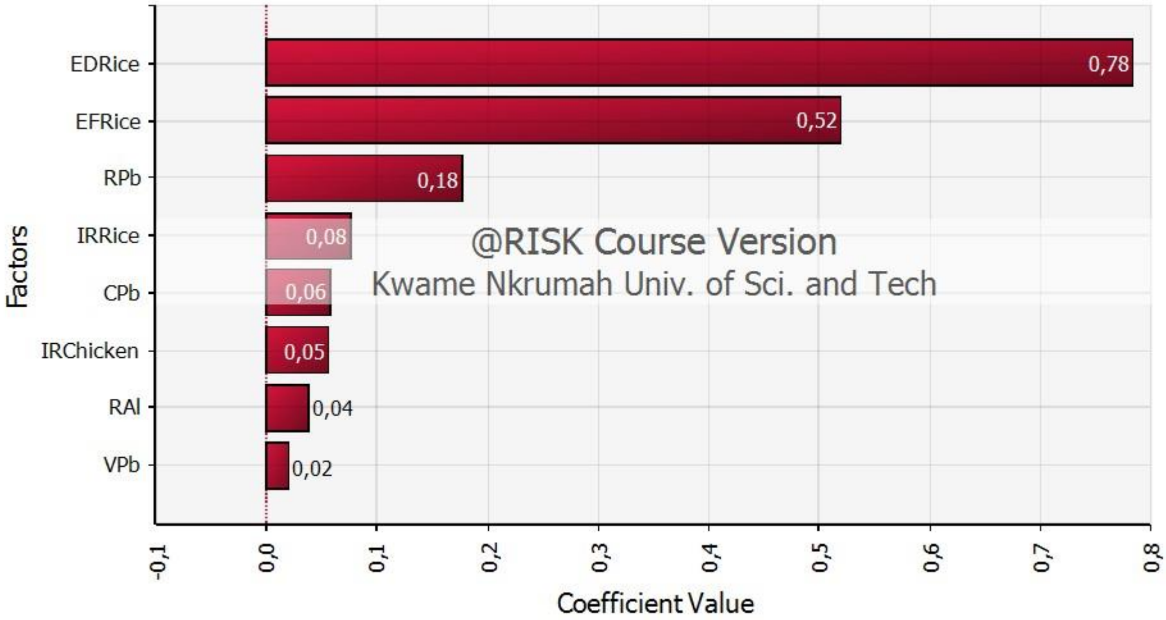


Figure 8.2: The impact of the factors on the overall hazard index due metals in fried rice
Legend: EDRice-Exposure duration for rice consumption, EFRice-Exposure frequency for rice consumption, RPb- Lead in rice, IRRice- Ingestion rate in rice consumption, CPb- Lead in chicken, IRChicken-ingestion rate for chicken consumption, RAl- Aluminum in rice, VPb-Lead in vegetables

8.4 Conclusion

The findings from this study has clearly established that street vended fufu and fried rice in Kumasi have high levels of metals, specifically aluminum, iron and lead suggested possible leaching from the utensils used in cooking/processing. The results also indicate that the 95th percentile consumers are likely to be suffering the adverse effects of the metals in the foods..

CHAPTER NINE

9.0 HEALTH RISK ESTIMATE DUE TO BISPHENOL A, BPA, IN TWO STREET VENDED MEALS

9.1 Introduction

A critical observation in the preparation of fufu and fried rice, the boiling of the cassava and plantain for the fufu and the rice for the fried rice, revealed that raw materials are covered with plastic film in the cooking pot to trap steam during the cooking process which may lasts about 2 hr. Exposure of the plastic film to this temperature over such a time is likely to allow certain chemicals, possibly the plastic monomer and plasticizer, to leach out of the film into the food. Various studies have shown that BPA may be present in urine, breast milk, blood, serum and plasma as well as pregnancy associated fluids of humans who may have been exposed to this chemical (Vandenberg *et al*., 2007). Karalius *et al.* (2014) found BPA in109 human urine and the drinking water from three different geographical regions in the world, including Nkwantakese, a rural community in the Ashanti region in Ghana. Oral exposure routes of BPA include drinking water or eating foods contaminated with BPA.

The European Food Safety Authority in January, 2015 published a press release on its latest comprehensive re-evaluation of BPA exposure and toxicity. It reported that the current exposure levels of BPA in Europe, poses no health risk to the consumers of any age. However, with the refining of the methodologies for BPA, EFSA‟s experts have changed the safe level of BPA from

50 micrograms per kilogram of body weight per day (μg kg^{-1} of bw day^{-1}) to 4 μg kg^{-1} of bw day^{-1} (EFSA, 2015). In other studies, BPA in blood has been associated with a variety of conditions in women such as obesity, endometrial hyperplasia, recurrent miscarriages, abnormal karyotypes and polycystic ovarian syndrome (Vandenberg *et al.*, 2007). Other research works have indicated possible carcinogenicity of BPA through perhaps secondary mechanism for carcinogenicity (Haighton *et al.*, 2002). Therefore this study sought to determine the levels of BPA as an indicator of plastic monomer leaching into the food components as a result of vendor activity and to determine the risk estimate upon consumption.

9.2 Materials and methods

9.2.1 Study area description, sampling and consumption interviews

Please refer to Chapter 6.2-3 (Sampling); Chapter 6.2.4 (Sample collection); Chapter 5.2.2 (Study population and data collection)

9.2.2 Bisphenol A analysis

Sample Preparation

Sample Preparation was based on the United Chemical Technologies (UCT) protocol (2013) with some modification. Five (5) grams of homogenized samples were weighed into glass tubes and 15 mL of acetonitrile added. The tube was then agitated at 400 rpm for 20 min after which 10 mL of hexane was added to the supernatant and allowed to stand for 30 min after agitating for 5 min at 400 rpm. The acetonitrile layer was dried at 40 °C under vacuum, reconstituted in one (1) milliliter of deionized water and a 100 uL portion injected into the HPLC.

HPLC determination

Stock solutions of BPA (Fluka Analytical, Denmark) were prepared in acetonitrile at final concentration of 1 ug mL^{-1}. Working standards were made by serial dilution from the stock and calibration standards of 5 – 25 ng g^{-1} were prepared accordingly. The HPLC analysis was based on Lafee (2011) and Hadjimohammadi and Saeidi (2010) with some modifications: A Cecil-Adept Binary Pump HPLC coupled with Shimadzu 10AxL fluorescence detector (Ex: 275 nm, Em: 313 nm) and a Supelco Discovery C18, 5 µm, 4.6 mm x 100 mm column was used for the analysis. Mobile Phase composition was water/methanol (35:65v v^{-1}) at 0.9 mL min^{-1} with column temperature maintained at 40 °C.

9.2.3 Statistical analysis

Please refer to Chapter 5.2.3 (Data management and analysis); Chapter 6.3.9 (Sensitivity Analysis)

9.3 Results and Discussion

Bisphenol A was detected in the fufu and the fried rice components of the meal types (Table 9.1). This was as a result of the use of plastic film by the vendors to cover the respective raw materials during the high temperature at boiling stage (refer to figures 4.1 and 4.2 a) for about 2 hrs at the preparation process. The plastic films are used to trap steam to enhance the boiling. The plastics films are not discarded after a single use, but used daily, sometimes, twice in a day for boiling different batches, until the film is partly melted or visibly torn.

Table 9.1: Stochastic concentrations of BPA (μgkg^{-1}) in the rice and fufu

Food samples	Distribution model	Data ranges (μg kg^{-1})				
		Minimum	Maximum	Mean	*Std Dev	Mode
Fufu	Laplace (38,5625;14,3276)	0.00	134.12	38.56	14.33	38.66
Rice	Expon (18,363); Shift (8,3999)	8.40	191.46	26.76	18.36	8.49

*Std dev – standard deviation

The stochastic concentrations for the fried rice ranged from 8.40 μg kg^{-1} to 191.46 μg kg^{-1}. There were no significant differences ($p>0.05$) observed among the BPA concentrations in the fried rice samples from the different metropolitan areas. Assuming an adult body weight of 70 kg (standard reference man) the reference dose for BPA would be 280 μg kg^{-1} which is higher than the maximum quantified levels of BPA in the food samples. Therefore the quantified values are very low compared with the recent tolerable intake of 280 μg kg^{-1} for the standard reference man. The levels of BPA observed in the fried rice samples is as a result of the migration of the monomer, BPA, from the plastic into the foods during the cooking process conditions of temperature ≥ 100 °C and time of about 2 hr. According to EPA (2015), migration of BPA from polycarbonate plastics is low at temperatures 0 - 70 °C, high temperatures of 100 °C, the rate of migration greatly increases. The type of plastic under consideration is unknown, however generally, BPA was thought to have migrate from only polycarbonates, however Guart *et al*. (2011) detected BPA in other types of plastics such as low and high density polyethylene. Bisphenol A is used to improve plastic properties as a plastic additive (EPA, 2015; Guart *et al*., 2011). Repeated use of the same plastic film is likely to release different concentration of BPA into the food due to the different residual polymer after each use and also the degradation of the polymer (EPA, 2015). This could be the reason why varying concentrations of the BPA was observed among the fried rice samples from the different vendors.

The stochastic concentrations of the BPA in the fufu samples are as shown in Table 9.1. Varying concentrations of BPA were recorded for samples from the different metropolitan areas ranging from about 8μg kg^{-1} to 39μg kg^{-1}. Statistically no significant difference ($p > 0.05$) was observed among the fufu samples. The values were lower than the tolerable daily intake by EFSA (2015) of 280 μg kg^{-1} for reference man. This means that the streetfood fufu is consumed within the safe limits of BPA. The varying concentrations of the BPA observed in all the fufu samples, could be as a result of the use of repeated use of the plastic film as Bisphenol A was not detected in the water and the uncooked cassava and plantain, used as control samples.

Table 9.2: Stochastic exposure concentrations of BPA (μg kg^{-1}) in the rice and fufu

		Percentiles		
Food sample	Distribution model	5_{th}	50^{th}	95^{th}
Fufu	Laplace (38,5625;14,3276)	15.23	38.56	61.88
Rice	Expon (18,363); Shift (8,3999)	9.34	21.13	63.40

Stochastic exposure concentrations for the consumers were also determined for the two food types and are as shown in Table 9.2. The 5^{th} percentile consumers for the fufu consumers were exposed to a higher level of Bisphenol A (15.23 μg kg^{-1}) than the fried rice consumers with exposure level of 9.34 ug kg^{-1}. The differences could be due to the different mean concentrations of BPA in the fufu and fried rice (Table 9.1). The trend was again similar for the 50^{th} percentile consumers however at the 95^{th} percentile, the fried rice consumers were exposed to a higher concentration of BPA than the fufu consumers. This could be attributed to the distribution of BPA in each food matrix. All the different segments of the consumers were exposed to safe levels of BPA. However due to the bioaccumulating nature of BPA, every level of exposure is important. Bisphenol A at doses lower than the reference dose has been shown in animal models to have adverse health effects such as prostate weight and cancer, mammary gland organization and cancer, onset of estrus cyclicity and earlier puberty, body weight, genital malformations and others (Vandenberg *et al*., 2007; Willhite *et al*.,

2008). At „low doses‟ of exposure it is uncertain what adverse health effects consumers might be experiencing (Vandenberg et al., 2007). It will be of interest to eliminate BPA entirely in the diet.

9.3.1 Health risk assessment

Table 9.2: Chronic daily intake (CDI) and hazard quotient (HQ) due to BPA in street vended fufu and rice.

Parameter	Mean	SD	5th	50^{th}	95^{th}	RfD* (µg kg^{-1})
CDI (µg kg^{-1})*						280*
Fufu	3.8E+00	1.1E+01	2.8E-02	1.1E+00	1.5E+01	
CDI (µg kg^{-1})						280*
Rice	1.6E+00	2.7E+00	2.7E-02	6.6E-01	6.5E+00	
HQ* Fufu	1.4E-02	4.0E-02	9.8E-05	3.8E-03	5.5E-02	-
HQ Rice	5.8E-03	9.7E-03	9.5E-05	2.3E-03	2.3E-02	-

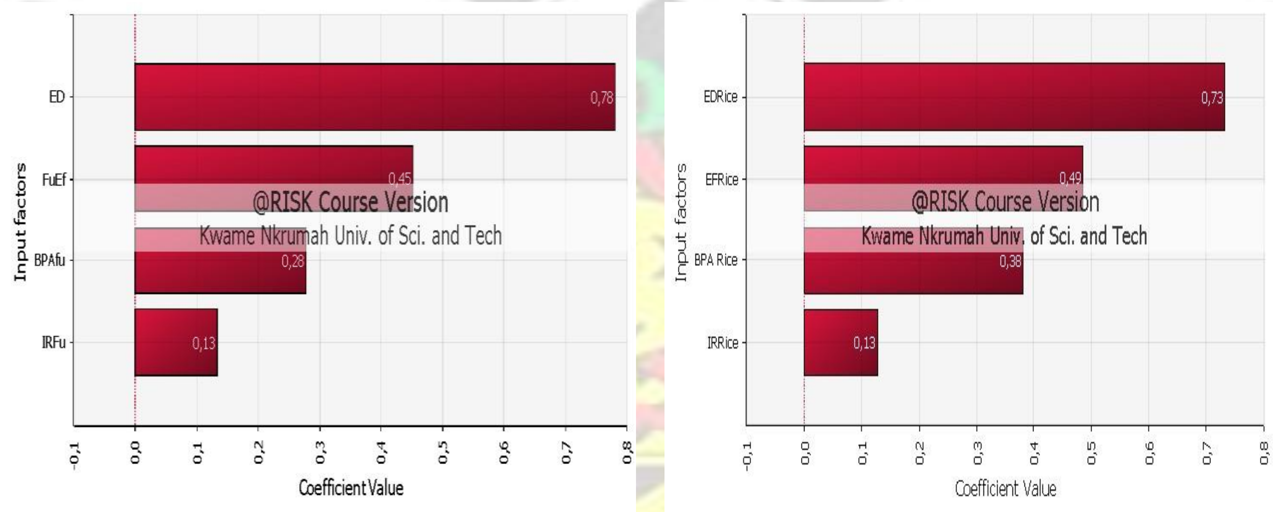
*CDI – Chronic Daily Intake; HQ – Hazard Quotient; SD – Standard deviation; RfD – Oral reference dose * Figure represents RfD for a 70 kg man

The mean CDI of BPA in the fufu and rice component of the street food vended meals used in the study, were far below the oral reference dose, RfD, values recommended by the European Union Food Safety Authority (EFSA, 2015). The RfD represents the threshold estimation of the daily exposure of the hazard to which the human population, including the vulnerable in the society, may be continually exposed over a lifetime without an appreciable risk of harmful effects. Though the concentration of BPA was below the limit set by EFSA, 2015, it was important to determine the risk associated with the consumption of the foods, to be assured that the population is not likely to be suffering the adverse effects of BPA.

The health risk assessment in the form of the hazard quotient, (HQ) of BPA considered in the study is presented in Table 9.2 shows HQ value > 1 indicative of the fact that the consumers may not be experiencing any significant health risk.

9.3.2 Sensitivity analysis

The input factors that affected the risk estimate were exposure duration and frequency in the consumption of the components in the meal are shown in Figure 9.1.



a. Impact factors for Fufu **b. Impact factors for Rice**

Figure 9.1: Spearman's correlation coefficient ranking of the impact of input factors on the risk estimate of BPA.

Legend: ED- exposure duration for fufu consumption, FuEF- exposure frequency for fufu consumption, BPAfu- bisphenol A in fufu, IRFu – ingestion rate for fufu consumption, EDRice – exposure duration for rice consumption, EFRice – exposure duration for rice, BPA Rice – bisphenol A in rice, IRRice – ingestion rate for rice consumption

Exposure duration and frequency featured strongly as input factors affecting the risk estimate.This was followed by the BPA concentrations in the food matrix. Hence the interventions are, first the duration and frequency of consumption of the meals must be reduced through behavioral change of consumers. Secondly, the levels of the BPA in the rice be reduced to the barest minimum by changing the use of the plastic film to cover the foods. The use of alternative materials such as the *gray baft* in place of plastic film. The *gray baft* is a plain cotton based material with no printing, and used as a packaging material for wheat flour.

9.4 Conclusion

The levels of BPA in the food samples suggest possible leaching from the plastic film used to cover the foods during food preparation. However, the concentration levels indicate that the amount of leakage was very low. The exposure level suggests that the foods were being consumed at safe limits. The risk estimate, HI, for the two components of the street vended meals used in the study was less than 1 at all levels of exposure, indicating that the consuming population may not be suffering any potential adverse effects as a result of BPA, provided these foods were the only source of exposure.

CHAPTER TEN

10.0 GENERAL CONCLUSION AND RECOMMENDATION

10.1 General Conclusion

Street vended foods have long been a part of the food basket of majority of people especially in developing countries. However, its consumption has been perceived as unsafe and a lot of microbiological studies conducted on them have confirmed higher than acceptable levels of pathogens. This study therefore sought to determine ways of improving the safety of street vended foods, using model foods that were determined in previous studies as unsafe for consumption such as fufu and fried rice. Quantitative microbial and chemical risk assessments were conducted on fufu and fried rice, commonly consumed street vended foods. Direct stakeholders of these foods namely, vendor and consumers, were the primary target for the study. Practices and reasons affecting the safety of the street vended foods were also investigated using informant interviews.

The outcomes of the vendor interviews and observations showed that access to good location and high staff turnover have impact on the safety of the street vended foods. Also, vendors prioritized the business aspects of their enterprise over the safety of the consumption of the foods. These challenges have implications in the implementation of a good food safety program. Through hazard identification processes on the preparation and sale of street vended foods, the results of the study showed that chemical and microbiological hazards are likely to be introduced through vendor practices. These practices should be critically looked at when designing interventions. Some of these practices included improper sanitization of the vegetables for stir-frying with the rice and for salads. Pounding of fufu must be done in the strictest hygienic means possible, where the lack of hand washing plays a crucial role in transmitting bacterial pathogens like *S. aureus* and *E. coli*. Consumption studies revealed high ingestion rates of the carbohydrate components of the street vended foods. These findings have implications for the exposure levels of hazards to the consumers.

Results of the incremental life cancer risks (ILCR) revealed that the fufu and fried rice meals were consumed within safe levels or acceptable levels. From the sensitivity analysis, the main intervention for the hazard index (HI) due to PAH specifically naphthalene for both street vended meals is to eliminate the use of naphthalene balls in water storage which is a common practice with most of the vendors. High levels of the metals observed in the food samples suggested possible leaching from the utensils with highest consumers likely to suffer the consequences. The levels of bisphenol A (BPA) in the food samples suggested possible leaching from the plastic film used to cover the cassava and the rice during boiling however the exposure levels suggest that the foods were being consumed at safe limits. The risk estimate, HI, for the two components (raw fufu without soup and fried rice) of the two meals were less than one at all levels of exposure, indicating that the consuming population was not risk in suffering the adverse effects of BPA, provided these foods were the only source of exposure.

It is therefore recommended that to improve the safety of these two street vended foods, food handling training programs should be linked with good food preparation skills and business enterprise development. This is very important since the interest of most of the vendors is more towards the business aspects of the street food enterprise.

Critical areas in the vending process should reduce the holding time for some components of the meals like the fufu, the rice and the vegetables. Proper sanitization of the vegetables should be enforced and the use of naphthalene balls should be discouraged. Finally boiling using plastic film should be abolished and replaced with cotton cloth such as *gray baft* which is likely to reduce the levels of BPA. The introduction and implementation of these practices would help ensure the safety of street vended fufu and fried rice.

10.2 Recommendations

From the outcomes of this work, I will want to make the following recommendations for further research work:

- It would be important to determine the extent of the impact of environmental PAH on street vended foods. Insights on the levels of PAH in the use of recycled oil for cooking.

- The exposure assessment due to the consumption of metal contaminants in commercially processed products used in the preparation of street vended meals.

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APPENDICES

APPENDIX I (QUALITATIVE STUDY)

A. OBSERVATION GUIDE FOR STREET FOOD VENDORS

1. Raw materials: Types of raw materials, Source, cost, time of purchase, conditions of purchase, purchase of food additives, which ones and why? Transportation and storage
2. Water used: Source of water, uses of the water, availability of the water, storage systems, when and how it is fetched, cost of water, cleaning of the storage system, quantities used daily, Re-use of water
3. Preparation and processing: steps of preparation, practices at each step of preparation, preparation of vegetables – possible avoidance of cross contamination. Addition of spices. Storage of cooked foods prior to vending, left overs (storage), length of time taken to prepare and sell prepared foods, temperatures (possibly), time intervals between preparation of each batch, time taken to finish selling each batch.
4. Transportation, handling and storage of prepared food: state of vehicle used to transport foods, storage of foods in the vehicle, time required to transport food between the preparation site and vending units, if not at the same place, Left overs generated, temperature of storage, storage facilities and their condition
5. Vending units, equipment and utensils: design and construction of units, equipments and surfaces used for food preparation, storage of equipments i.e free from contamination from environment, materials used to make the equipments, state of equipment, i.e presence of grooving, pitting, sculptured surface, for foods that will not be cooked. Single use of equipments such as cutting board for vegetables and meat, person(s) responsible for sale.
6. Point of sale conditions: Lighting, protection from strong winds, dust, sun, rain and pests. Must have a waste disposal system, hand washing facility, toilet facility.

7. Cleaning and sanitizing: Availability of cleaning programs, types of soaps and detergent used for cleaning, availability of clean napkins, disinfection of site and surfaces, cleaning of utensils, plates, napkins, waste disposal units (Liquid and solid waste), pest and control activities. Storage of cleaning equipments.
8. Around facility: Description of site about 20 m around the facility, i.e presence of Waste disposal facility, open gutters, KVIPS, Open fields, tarred and untarred busy roads, foot paths, car washing bays, presence of other vendors,
9. Other observations: Cooking fuel used, Staff and vendor relationship, staff – staff relationships, vendor/owner participation in cooking and vending, motivation for the business

B. FINAL INTERVIEW GUIDE FOR VENDORS

1. Demographic information such as: age, sex, marital status, number of dependents, years of vending, acquisition of knowledge, number of vending sites, number of staff, vendor and staff possession of health certificates, member of an association,

2. Motivations and constraints for starting up the business

   a. Can you tell me how you started up the business?

   b. What were your motivations to start up the business?

   Probe: Money/Increase income (for what?), Likes to cook/wanted to become a cook, Wanted to try a new business etc. (why?)

   c. What were the main challenges for you to start up the business?

   d. Did you have any difficulties in terms of gaining permission for getting a place to vend from? Or finding kitchen facilities?

   e. Did you have any challenges in terms of getting a health license?

   f. How did you overcome these challenges?

   g. What are your main challenges in running the business as a vendor today?

   h. How do you feel working as a vendor in Kumasi today?

   i. What do you think is most important in running a successful business?

3. Employment and Training of staff

   a. How do you employ the staff you need?

   b. What criteria do you use to choose them?

   c. What do you want them to be able to do when they start work?

   Probe: have training, have licenses, e.t.c.

   d. What will (do) you teach/ train them to do?

   e. What work can they do as staff and what do you do as the vendor?

4. General food handling:

   a. What type of training have you received? (to be asked openly for all types of training)

   b. Have you attended any food training workshops (Which, describe?)

c. What were you taught there? (What do you remember?)

d. Did you have to pay?

e. Of all the things you learnt what have you used in your business?

f. What has been difficult to apply in your business and why?

5. Follow up questions on observations

   a. Why do you use recycled water to wash plates for customers to use?

   b. Is there any advantage of using the locally manufactured utensils like the pots over the foreign ones?

   c. How often do you have left overs in a week?

   d. How are the left overs treated?

6. Food hygiene and sanitation questions.

a. In terms of hygiene and sanitation of the kitchen and the surroundings; what are the main challenges to you in your business? Why?

b. What about the hygiene of foods. What are the main challenges?

c. What about hygiene of the staff and the handling of the food? What are the main challenges?

d. What about availability of water? (Probe; how much do you pay, how often?)

e. What can you do to overcome these challenges?

f. What is difficult to change?

<u>C.</u> <u>FINAL INTERVIEW GUIDE FOR STAFF</u>

1. Demographic information: Age sex educational background and possession of health certificate.

2. Cooking experiences:

   a. How were you employed here?

   b. How long have you been working with cooking food?

   c. For how long have you been working here?

   d. What were you doing before coming into this work?

3. Daily work life:

   a. Can you tell me what you do on a normal working day starting from morning till evening?

   b. Where do you live, sleep and normally eat when you work here? Where can you take your bath, go to toilet etc.?

4. Work motivations and challenges:

   a. Please tell me, why would you want to work in a food business like this?

   b. What do you think about this type of work

   c. What do you like about the job?

   d. What do you think is difficult about the work?

5. Training

   a. What were you taught to do here as a staff.

Probe :(By whom, how were you taught, how long did it take you t learn that skill)

   b. What have you learned on the job?

   c. Have you ever attended any training workshops or meetings? (Probe: Which ones, how many times, when and organized by whom?)

   d. Did you have to pay for them?

   e. What did or have you learned from the training?

   f. What are you doing differently now after the training?

   g. Can you correct other staffs when they do things differently from what you have learned? (Why /why not, describe)

   h. Any other concerns about the work.

a. Do you have any other concerns or thoughts about this work as a food vendor staffs that you would like to share with me?

D. INTERVIEW GUIDE FOR THE CUSTOMERS

1. Demographic information: Age, Religion, job, place of residence, place of work
2. Food purchasing preferences:
   a. How long have you been purchasing from this particular vendor
   b. How often do you purchase from this vendor?
   c. What makes you like buying from this vendor?
   d. Have you ever brought people here to buy food?
   e. How much do you often buy?

3. Food handling after purchasing
   a. What do you do with the food after buying? Eat here or take away?
   b. How long does it take you to eat the food after you have bought it? Especially for the takeaways!
   c. What do you do to it before eating? Heating soup again, or microwaving?
   d. How often do you take food away after purchasing?
   e. Have ever been ill after consuming food from here?

APPENDIX II: DECISION MAKING TABLE: FUFU PROCESSING

Table A1: COOKING PROCESS

PRACTICES	FLOW DIAGRAM	ASSOCIATED RISKS	POSSIBLE HAZARDS PRESENT
Poured on the ground	Cassava (about 50kg), Plantain (between 20 – 25 fingers)	Microbial pathogens in soil	*B cereus*
Uses knife to peel, the cassava one after the other, into a bucket of water	Peeling	Metals contaminants from knives, water contaminants	Al, Fe,
Uses hands to rub cassava against each other in the bucket	Washing	Water used	Al from the water treatment *E.coli, B. cereus, S. aureus* Naph in water
Jute sack is put at the base of pot, then the cassava arranged on top, in order if sizes, with the biggest at the bottom. After that the plantain is placed on top of cassava.	Arranged in pot size 20	Utensil used	Al, *E coli, B cereus, S aureus*
Plastic film is used to cover the plantain and then a jute sack is used to cover the plastic on the cassava. They are tucked into the sides of the pot, all round it to be held firmly to the pot.	Covered with plastic film and jute sack covering	Jute covering storage, washing/cleaning before use, Smoke from burning fuel	Al from water, *B cereus* from sack, PAH
Water boils and cooks cassava and plantain	Cooked (2 hr)		BPA from plastic, leaching of metals (Al, Pb) from utensils. Naph in water
Pot is taken off fire a	Ready for pounding		

Table A2: POUNDING PROCESS

PRACTICES	FLOW DIAGRAM	ASSOCIATED RISKS	POTENTIAL HAZARDS PRESENT
Mortar and pestle taken from storage area to pounding area		Storage conditions of utensils, pesticide application in storage	Cleaning soap used, Naph, *B cereus, E coli*
They are pre rinsed with fresh water	Rinsed with water	Source of water, storage conditions, difficult to clean areas of utensils (Biofilm)	Al, *E coli*, *S. aureus* and *B cereus*
The water is drained and they are allowed to stay as the cassava is being drained.	Allowed to dry		*B. cereus*
Plantains are pounded first. It is mixed stirred slowly until the desired consistency is achieved with the help of water.	Plantains are pounded first (30 min)		*S. aureus*, *E. coli*, and *B. cereus*
Storage of part of pounded plantains in portions	Divided and rolled into portions (5)		Growth of organisms
One portion pounded with some cassava into fufu, with addition of water	Pounding fufu	hand hygiene, sweat source of water	*B. cereus, S. aureus, E. coli.* Al from water
Pounded fufu is put either stainless steel or aluminum pan, more water added		Source of water,	Al from water
Taken to the vending site for selling uncovered	Ready for vending		Chemical from the environment (air, aerosols)

Table A3: VENDING PROCESS

PRACTICES	FLOW DIAGRAM	ASSOCIATED RISKS	POSSIBLE HAZARDS PRESENT
Fufu in pan at vending site (sometimes covered)	Fufu in vending bowl	Pests (Houseflies) if not covered	Environmental PAH
Vendor dips hands into water and picks a portion of the fufu, adds some more water to remove the paste taken	Portion taken	Hand hygiene, source of water	*S aureus, E. coli,* Al
Water is used to rinse the earthen ware first and then the fufu is placed in it for moulding process.	Put earthenware	Condition of earthenware, source of water, hand hygiene	Soap used to wash utensils, chemicals on hands and in water
Fufu is moulded in earthenware with water as lubricant	Moulding process	Source of water, hand hygiene, earthen ware	Al, *S. aureus, E. coli*
Bowl is rinsed with the water for moulding the fufu, Fufu is placed in bowl afterwards.	Put into serving bowl (rinsed with water)	Source of water	Al, *S. aureus, E. coli*
The desired soup is added to it for the customer.	Soup added.		Hazards from soup

APPENDIX III: DECISION MAKING TABLE FOR FRIED RICE

Table A4: COOKING RICE:

PRACTICES	**FLOW DIAGRAM**	**ASSOCIATED RISKS**	**POSSIBLE HAZARDS PRESENT**
Cooking pot with water (8 – 12 L) is put fire, some amount (200 mL) of oil and a handful of salt is added	Put water on Fire, add oil and salt	Source of water, and oil, leaching of utensil, type and amount of salt	Presence of Ketones, aldehydes, (rancidity profile of oil), Pb, Al, Salt impurities
Cover the pot, increase heat and allow the water to boil	Bring water to boil.		
Add about 10 – 15 kg of rice	Add rice		*B. cereus*
Cover and allow to boil for 30 min	Boil for 30 min		
Rice is stirred intermittently, and covered with clean plastic film and metal lid.	Stir at interval, while covering the rice with clean plastic film	Smoke from fire	PAH
Heat is lowered, until rice is well cooked	Lower heat; continue cooking	Burning of rice	PAH
It is then dispensed into a food warmer (50 L) or 30 L capacity plastic container with a flat plastic plate	Dispense into food warmer or plastic containers	Source of water, Use of napkins, Hand hygiene	BPA from plastic, *S.aureus*, *E.coli*

Table A5: VEGETABLE PREPARATION

PRACTICES	FLOW DIAGRAM	ASSOCIATED RISKS	POSSIBLE HAZARDS PRESENT
Vegetables are purchased from the market	Vegetables used: Spring Onions, Cabbage, Green pepper, Onions, Carrots, (Lettuce optional	Quality of vegetable, farm practices	Presence of pesticides, Pathogens
Cleaned by peeling (removal of outer layer), deseeding or de-coring	Clean vegetables		Fe
Treatment by washing twice or thrice in (water containing small amount of salt, or, vinegar)	Wash and treat vegetable,	Source of water , quantity of water	Impurities from the salt, Al
Air dry to drain off the water	Allow to air dry, to drain off water	Presence of dust in air, chemicals like exhaust fumes, DDT in air	PAH fumes from exhaust of cars, *B cereus* in dust
Chopped into respective containers	Chop vegetables and put in containers		Biofilm on table, metal deposits from knife
	Transportation	Exhaust fumes from cars	PAH

Table A6: FRIED RICE PREPARATION

PRACTICES	FLOW DIAGRAM	ASSOCIATED RISKS	POSSIBLE HAZARDS PRESENT
The frying pan is wiped dry with a napkin and put on fire	Put pan on fire	Type of pan (aluminum)	Al,
About 100 mL of oil is put in and allowed to heat, and then a ladle full of the sauce is added and stirred with a wooden ladle.	Add oil, and sauce, and stir	Type of oil used	Rancidity products
A portion of spring onions with green pepper is poured from their respective containers and added to the mixture and stirred for about 5 min	Add a little spring onions and green pepper and stir	Hand hygiene	*S. aureus*, *E. coli*
Add portion of boiled rice / left overs then vegetables, salt and spices are added and stirred, with wooden ladle or flat metal plate for about 5 min	Add boiled rice, vegetables and spice. Then fry	Insufficient cooking time and temperature, hand hygiene	Metals scrapped from the pans, Al, *B cereus*, *S aureus*, Salts from spice
Soy sauce is also added and stirred for another 5 min; the heat is then lowered, then more vegetables are added, mixed and then put off.	Add soy sauce	Contaminant from soy sauce, expiry dates	Contaminant from soy sauce, expiry dates
It is then covered	Dispense to customers		

Table A7: FOOD SERVING TO CUSTOMERS:

PRACTICES	FLOW DIAGRAM	ASSOCIATED RISKS	POSSIBLE HAZARDS PRESENT
Transparent polythene spread on a paper	Spread transparent polythene bag on paper	Dust in the air, exhaust from fumes	PAH from fumes from cars
A portion of fried rice is put on the polythene	Add fried rice	Hand hygiene, utensil used	
The additives such as macaroni, vegetables (salad), pepper sauce, sauce, fried chicken, mayonnaise, ketchup and chopped onions are taken with thongs and sprinkled on it.	Add vegetables, macaroni, sauce, fried chicken, pepper sauce, mayonnaise, ketchup and sprinkle chopped onions	Cross contamination	
Fried rice meal is wrapped and served	Wrap with paper	Hand hygiene	*S. aureus*, *E.coli*
It is then put in a take away bag, and money collected.	Put in take away polythene	Money ,	Inks from money,

APPENDIX IV: CALIBRATION CURVES

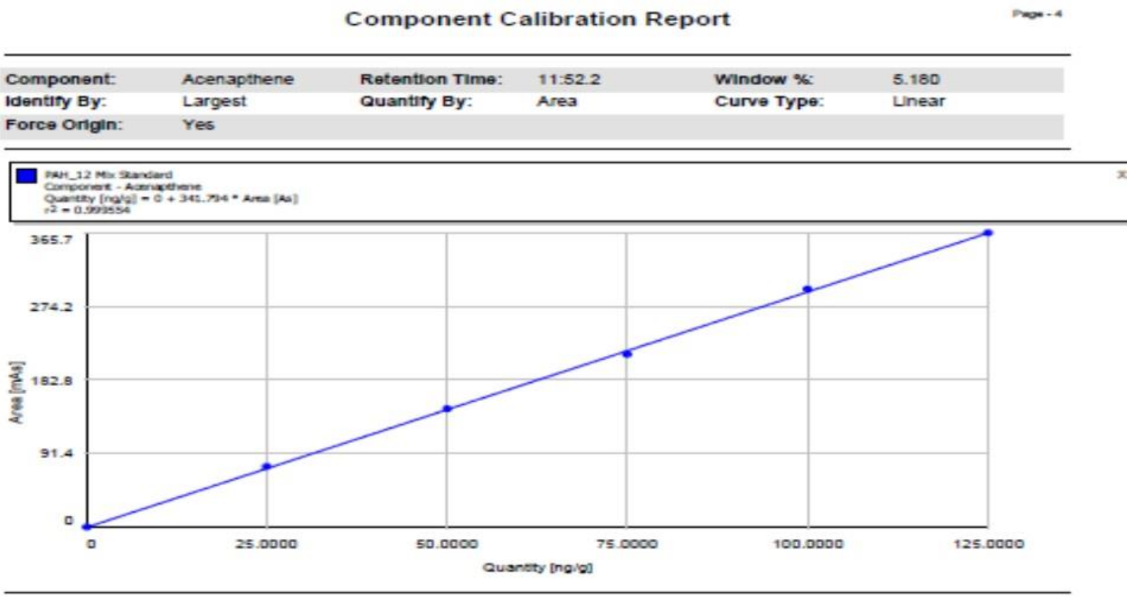


Figure A1: Calibration curve for the PAH compounds

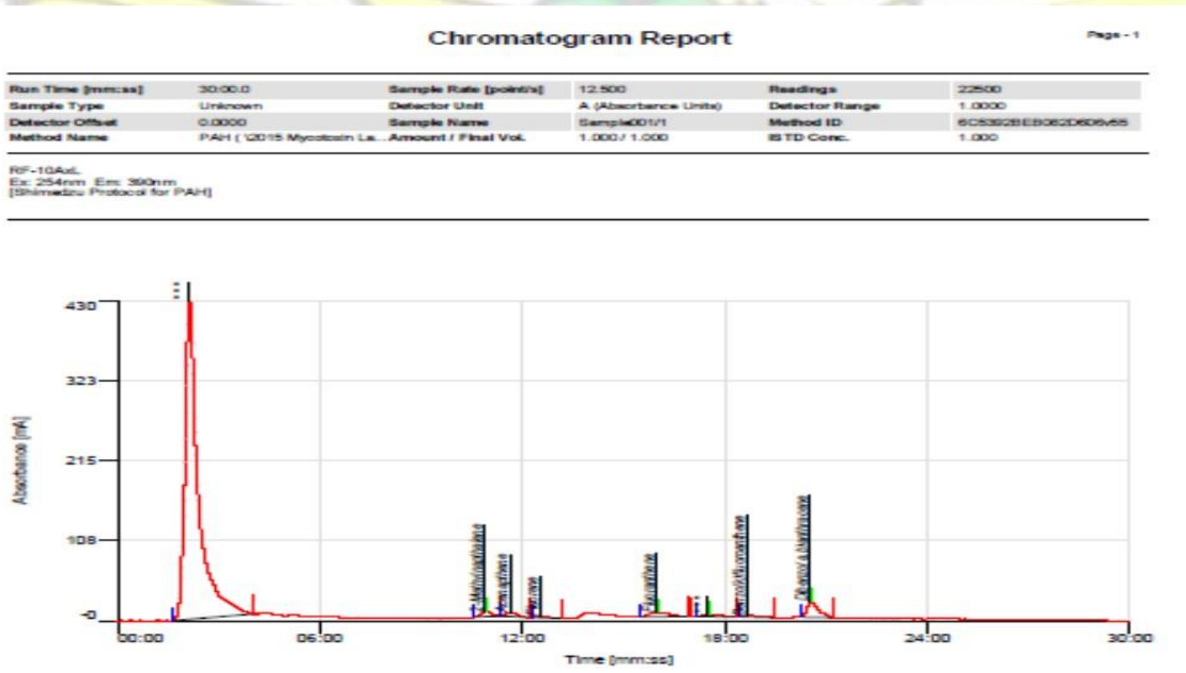


Figure A2: Chromatogram report of PAH compounds

<u>Table A8: Limit of detection</u> of PAH standards

PAH	LOD (ppb)	Equation of line
Naphthalene	0.45	$0 + 3634.91 \times area$
1-Methylnaphthalene	0.61	$0 + 1374.9 \times area$
2-Methylnaphthalene	0.10	$0 + 2173.5 \times area$
Acenaphthene	2.35	$) + 341.794 \times area$
Fluorene	4.15	$) + 17.3113 \times area$
Anthracene	3.79	$) + 99.4051 \times area$
Fluoranthene	2.17	$) + 969.388 \times area$
Pyrene	4.68	$) + 19.0336 \times area$
Benzo[b]fluoranthene	0.05	$) + 150.865 \times area$
Benzo[k]fluoranthene	6.46	$) + 173.631 \times area$
Benzo[a]pyrene	2.28	$) + 226.709 \times area$
Dibenz[a,h]anthracene	3.18	$) + 773.936 \times area$

BPA Calibration curve

Component Calibration Report

Page - 1

Bisphenol_Supelco_Discovery 18 (10cm x 4.6mm, 5um)

Component:	Bisphenol A	Retention Time:	02:10.1	Window %:	14.830
Identify By:	Largest	Quantify By:	Area	Curve Type:	Linear
Force Origin:	Yes				

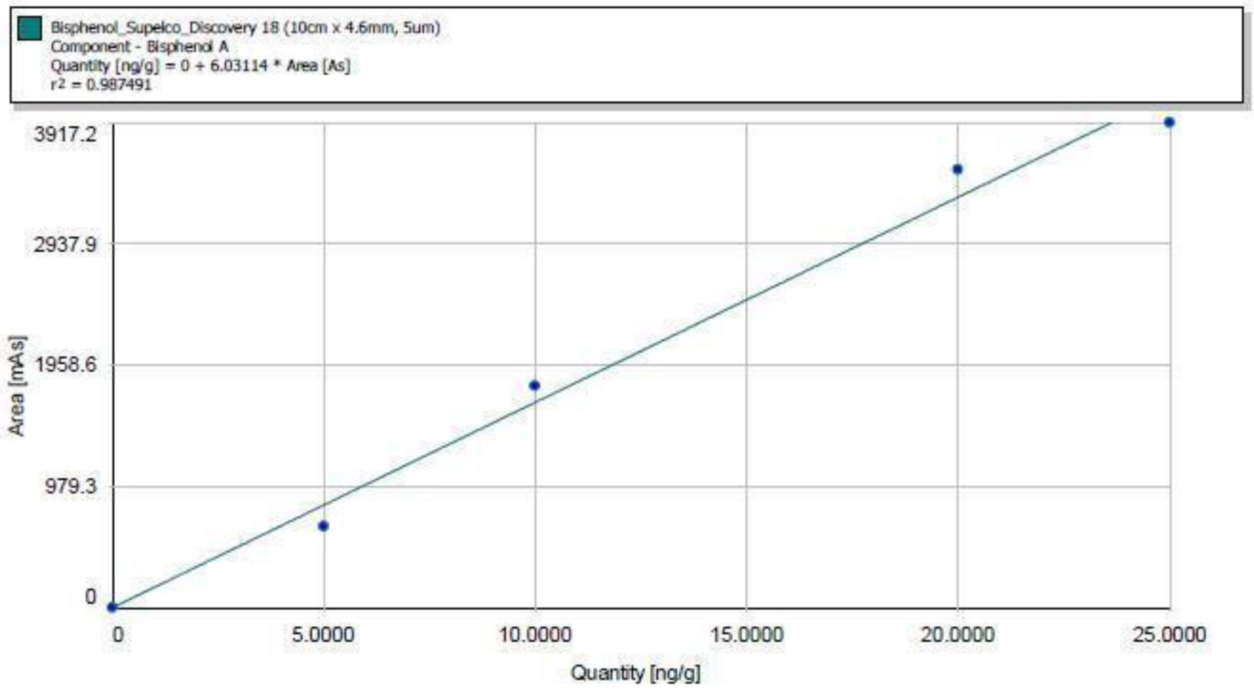


Figure A3: BPA Calibration curve

STANDARDS

Std. No	Active	Area [mAs]	Height [mA]	Quantity [ng/g]	Comment / Cgm File ID
01	Y	653.2	41.8	5.0000	
...\Bisphenol A-GAB_STD_5ppb_		653.2	41.8		BDA57B868290ED8Av1
02	Y	1787.7	110.4	10.0000	
...\Bisphenol A-GAB_STD_10ppb		1787.7	110.4		20B3FEEBE25810B6v1
04	Y	3535.6	200.2	20.0000	
...\Bisphenol A-GAB_STD_20ppb		3535.6	200.2		E84F2E19E45D2057v1
05	Y	3917.2	220.9	25.0000	
...\Bisphenol A-GAB_STD_25ppb		3917.2	220.9		A3BCEB18BF6245A4v1

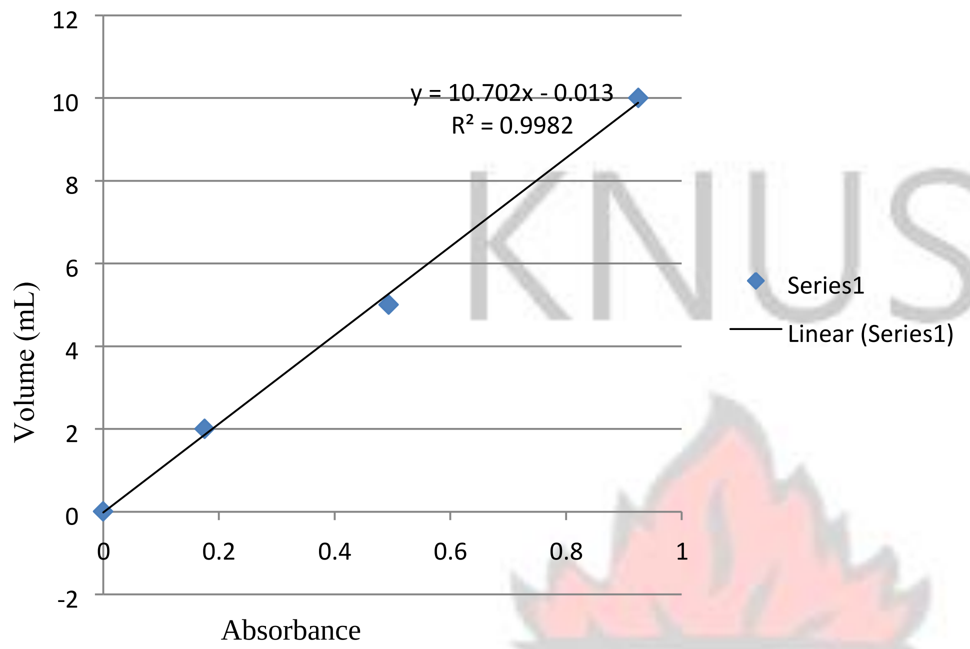


Figure A4: Calibration table for Bisphenol A standard

Fe STD -9/10/2014

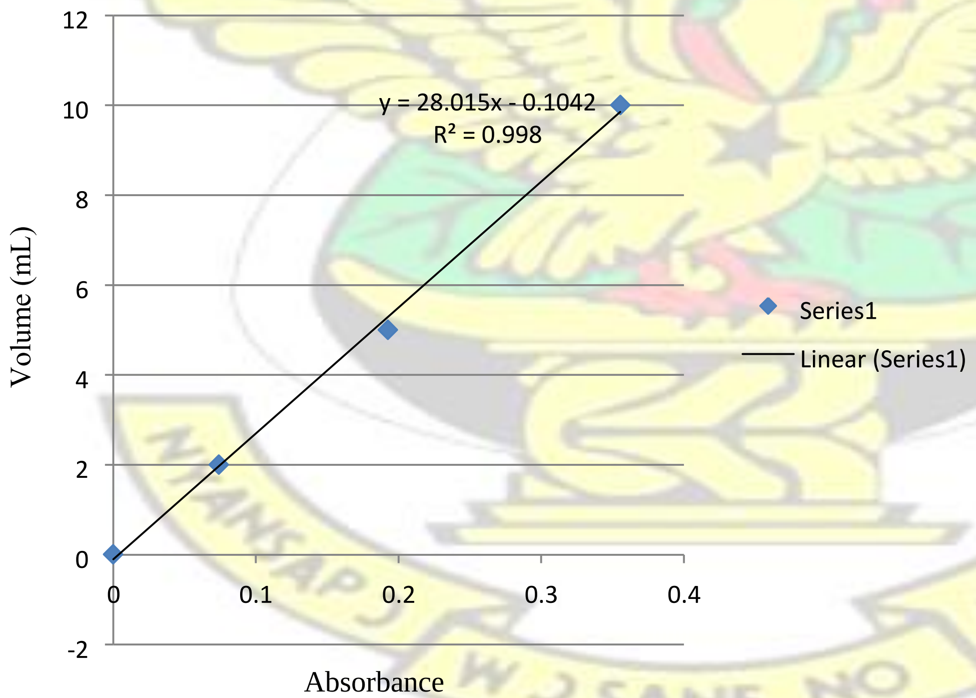
Absorbance Vol (mL)

0.0000 0.00 0.1

0.4934 5.00 0.9247

10.00

Figure A5: Calibration curve for Iron, Fe.



Pb STD- 9/10/2014

Absorbance Vol (mL)

0.000 0.00 0.0739 2.00

0.1924 5.00

0.3554 10.00

Figure A6: Calibration curve for Lead, Pb

APPENDIX V: Analysis of variance (ANOVA) tables

Table A9: Anova for Al concentrations in fried rice samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-1,667	No	ns
Oforikrom vs. Asawase	-4,333	No	ns
Subin vs. Asawase	-2,667	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	7,500	9,167	-1,667	6	6
Oforikrom vs. Asawase	7,500	11,83	-4,333	6	6
Subin vs. Asawase	9,167	11,83	-2,667	6	6

Table A10: Anova for Al concentrations in the salad samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-2,000	No	ns
Oforikrom vs. Asawase	-2,700	No	ns
Subin vs. Asawase	-0,7000	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	7,500	9,500	-2,000	6	6
Oforikrom vs. Asawase	7,500	10,20	-2,700	6	5
Subin vs. Asawase	9,500	10,20	-0,7000	6	5

Table A11: Anova for Al concentrations in the chicken samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-0,6667	No	ns
Oforikrom vs. Asawase	-0,3333	No	ns
Subin vs. Asawase	0,3333	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	9,167	9,833	-0,6667	6	6
Oforikrom vs. Asawase	9,167	9,500	-0,3333	6	6
Subin vs. Asawase	9,833	9,500	0,3333	6	6

Table A12: Anova for Al concentrations in shito samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-4,000	No	ns
Oforikrom vs. Asawase	-1,500	No	ns
Subin vs. Asawase	2,500	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	7,667	11,67	-4,000	6	6
Oforikrom vs. Asawase	7,667	9,167	-1,500	6	6
Subin vs. Asawase	11,67	9,167	2,500	6	6

Table A13: Anova for Al concentrations in ketchup samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-5,800	No	ns
Oforikrom vs. Asawase	-0,8333	No	ns
Subin vs. Asawase	4,967	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	7,000	12,80	-5,800	6	5
Oforikrom vs. Asawase	7,000	7,833	-0,8333	6	6
Subin vs. Asawase	12,80	7,833	4,967	5	6

Summary

ns ns

ns Mean rank diff,

Mean rank diff,	n1	n2
-1,100	6	5
-0,5000	6	6
0,6000	5	6

nples

Summary

ns ns

ns Mean rank diff,

Mean rank diff,	n1	n2
0,0	4	2
1,500	4	3
1,500	2	3

Table A14: Anova for Al concentrations in mayonnaise samples Dunn's multiple comparisons

test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-1,100	No	
Oforikrom vs. Asawase	-0,5000	No	
Subin vs. Asawase	0,6000	No	

Test details	Mean rank 1	Mean rank 2
Oforikrom vs. Subin	8,500	9,600
Oforikrom vs. Asawase	8,500	9,000
Subin vs. Asawase	9,600	9,000

Table A15: Anova for Al concentrations in macaroni sa Dunn's multiple comparisons

test	Mean rank diff,	Significant?
Oforikrom vs. Subin	0,0	No
Oforikrom vs. Asawase	1,500	No
Subin vs. Asawase	1,500	No

Test details	Mean rank 1	Mean rank 2
Oforikrom vs. Subin	5,500	5,500
Oforikrom vs. Asawase	5,500	4,000
Subin vs. Asawase	5,500	4,000

Table A16: Anova for Al concentrations in fufu samples Dunn's multiple comparisons

test	Mean rank diff,	Significant?	
Oforikrom vs. Subin	-4,000	No	ns
Oforikrom vs. Asawase	1,500	No	ns
Subin vs. Asawase	5,500	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	8,667	12,67	-4,000	6	6
Oforikrom vs. Asawase	8,667	7,167	1,500	6	6
Subin vs. Asawase	12,67	7,167	5,500	6	6

Table A17: Anova for Al concentrations in soup samples

Dunn's multiple comparisons

test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	2,667	No	ns
Oforikrom vs. Asawase	-0,6667	No	ns
Subin vs. Asawase	-3,333	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	10,17	7,500	2,667	6	6
Oforikrom vs. Asawase	10,17	10,83	-0,6667	6	6
Subin vs. Asawase	7,500	10,83	-3,333	6	6

Analysis of Variance (ANOVA) of Fe in the components of the two street vended meals

Table A18: Anova for Fe concentrations in rice samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-5,750	No	ns
Oforikrom vs. Asawase	-0,5000	No	ns
Subin vs. Asawase	5,250	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	7,417	13,17	-5,750	6	6
Oforikrom vs. Asawase	7,417	7,917	-0,5000	6	6
Subin vs. Asawase	13,17	7,917	5,250	6	6

Table A19: Anova for Fe concentrations in salad samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-1,750	No	ns
Oforikrom vs. Asawase	0,9667	No	ns
Subin vs. Asawase	2,717	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	8,667	10,42	-1,750	6	6
Oforikrom vs. Asawase	8,667	7,700	0,9667	6	5
Subin vs. Asawase	10,42	7,700	2,717	6	5

Table A20: Anova for Fe concentrations in chicken samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	0,1667	No	ns
Oforikrom vs. Asawase	1,333	No	ns
Subin vs. Asawase	1,167	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	10,00	9,833	0,1667	6	6
Oforikrom vs. Asawase	10,00	8,667	1,333	6	6
Subin vs. Asawase	9,833	8,667	1,167	6	6

Table A21: Anova for Fe concentrations in shito samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-1,500	No	ns
Oforikrom vs. Asawase	-2,500	No	ns

Subin vs. Asawase	-1,000	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	8,167	9,667	-1,500	6	6
Oforikrom vs. Asawase	8,167	10,67	-2,500	6	6
Subin vs. Asawase	9,667	10,67	-1,000	6	6

Table A22: Anova for Fe concentrations in ketchup samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-5,167	No	ns
Oforikrom vs. Asawase	-1,167	No	ns
Subin vs. Asawase	4,000	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	6,500	11,67	-5,167	6	3
Oforikrom vs. Asawase	6,500	7,667	-1,167	6	6
Subin vs. Asawase	11,67	7,667	4,000	3	6

Table A23: Anova for Fe concentrations in mayonnaise samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	4,333	No	ns
Oforikrom vs. Asawase	3,333	No	ns
Subin vs. Asawase	-1,000	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	10,83	6,500	4,333	6	4
Oforikrom vs. Asawase	10,83	7,500	3,333	6	6
Subin vs. Asawase	6,500	7,500	-1,000	4	6

Table A24: Anova for Fe concentrations in macaroni samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-3,875	No	ns
Oforikrom vs. Asawase	-2,292	No	ns
Subin vs. Asawase	1,583	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	3,375	7,250	-3,875	4	2

Oforikrom vs. Asawase	3,375	5,667	-2,292	4	3
Subin vs. Asawase	7,250	5,667	1,583	2	3

Table A25: Anova for Fe conc u fu samples

f Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-0,5000	No	ns
Oforikrom vs. Asawase	-3,000	No	ns
Subin vs. Asawase	-2,500	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	8,333	8,833	-0,5000	6	6
Oforikrom vs. Asawase	8,333	11,33	-3,000	6	6
Subin vs. Asawase	8,833	11,33	-2,500	6	6

Table A26: Anova for Fe concentration in soup samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	2,333	No	ns
Oforikrom vs. Asawase	7,667	Yes	*
Subin vs. Asawase	5,333	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	12,83	10,50	2,333	6	6
Oforikrom vs. Asawase	12,83	5,167	7,667	6	6
Subin vs. Asawase	10,50	5,167	5,333	6	6

Analysis of Variance (ANOVA) for Pb in the street vended foods

Table A27: Anova for Pb concentrations in fried rice samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-2,083	No	ns
Oforikrom vs. Asawase	-7,167	No	ns
Subin vs. Asawase	-5,083	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	6,417	8,500	-2,083	6	6
Oforikrom vs. Asawase	6,417	13,58	-7,167	6	6

Subin vs. Asawase	8,500	13,58	-5,083	6	6

Table A28: Anova for Pb concentrations in salad sam s

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-4,833	No	ns
Oforikrom vs. Asawase	-3,833	No	ns
Subin vs. Asawase	1,000	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	6,167	11,00	-4,833	6	6
Oforikrom vs. Asawase	6,167	10,00	-3,833	6	5
Subin vs. Asawase	11,00	10,00	1,000	6	5

Table A29: Anova for Pb concentrations in chicken samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	1,167	No	ns
Oforikrom vs. Asawase	-6,167	No	ns
Subin vs. Asawase	-7,333	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	7,833	6,667	1,167	6	6
Oforikrom vs. Asawase	7,833	14,00	-6,167	6	6
Subin vs. Asawase	6,667	14,00	-7,333	6	6

Table A30: Anova for Pb concentrations in s nito samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	4,167	No	ns
Oforikrom vs. Asawase	1,833	No	ns
Subin vs. Asawase	-2,333	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	11,50	7,333	4,167	6	6
Oforikrom vs. Asawase	11,50	9,667	1,833	6	6
Subin vs. Asawase	7,333	9,667	-2,333	6	6

Table A31: Anova for Pb concentrations in ketchup samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	-3,417	No	ns
Oforikrom vs. Asawase	1,500	No	ns
Subin vs. Asawase	4,917	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	7,917	11,33	-3,417	6	3
Oforikrom vs. Asawase	7,917	6,417	1,500	6	6
Subin vs. Asawase	11,33	6,417	4,917	3	6

Table A32: Anova for Pb concentrations in mayonnaise samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	2,833	No	ns
Oforikrom vs. Asawase	1,667	No	ns
Subin vs. Asawase	-1,167	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	9,833	7,000	2,833	6	4
Oforikrom vs. Asawase	9,833	8,167	1,667	6	6
Subin vs. Asawase	7,000	8,167	-1,167	4	6

Table A33: Anova for Pb concentratio ns in macaroni samples

Dunn's multiple comparisons test	Mean ranl	Significant?	Summary
Oforikrom vs. Subin	-1,125	No	ns
Oforikrom vs. Asawase	-1,875	No	ns
Subin vs. Asawase	-0,7500	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	4,125	5,250	-1,125	4	2
Oforikrom vs. Asawase	4,125	6,000	-1,875	4	3
Subin vs. Asawase	5,250	6,000	-0,7500	2	3

Table A34: Anova for Pb concentrations in f ıfu samples

Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	3,083	No	ns

Oforikrom vs. Asawase	-5,583	No	ns
Subin vs. Asawase	-8,667	Yes	*

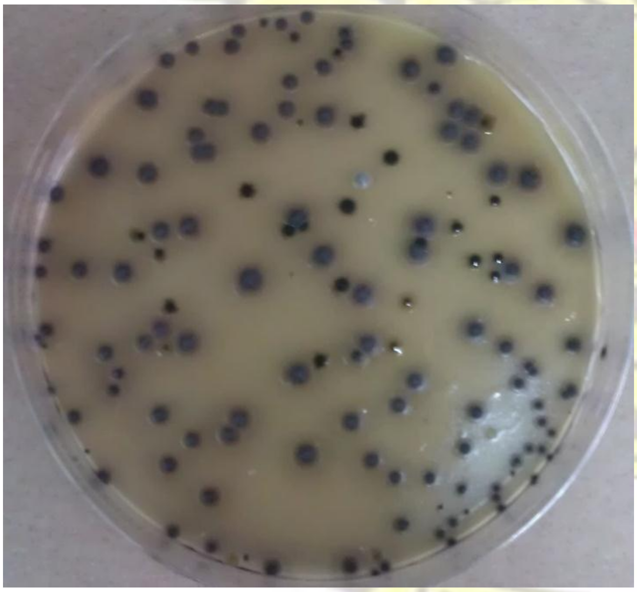
Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	8,667	5,583	3,083	6	6
Oforikrom vs. Asawase	8,667	14,25	-5,583	6	6
Subin vs. Asawase	5,583	14,25	-8,667	6	6

Table A35: Anova for Pb concentrations in soup samples

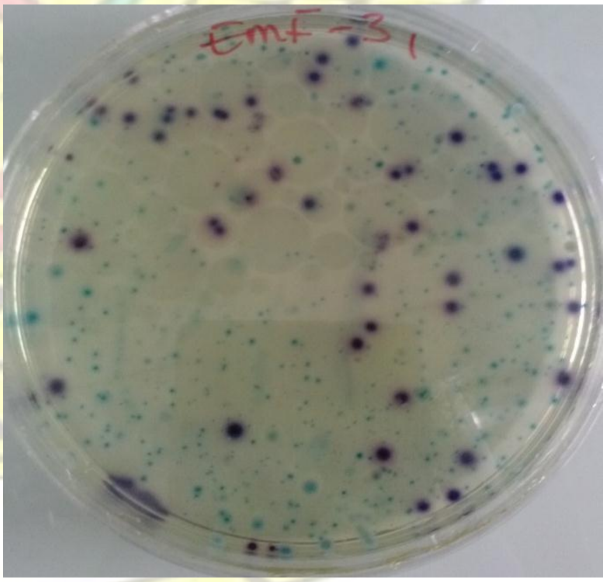
Dunn's multiple comparisons test	Mean rank diff,	Significant?	Summary
Oforikrom vs. Subin	4,833	No	ns
Oforikrom vs. Asawase	1,917	No	ns
Subin vs. Asawase	-2,917	No	ns

Test details	Mean rank 1	Mean rank 2	Mean rank diff,	n1	n2
Oforikrom vs. Subin	11,75	6,917	4,833	6	6
Oforikrom vs. Asawase	11,75	9,833	1,917	6	6
Subin vs. Asawase	6,917	9,833	-2,917	6	6

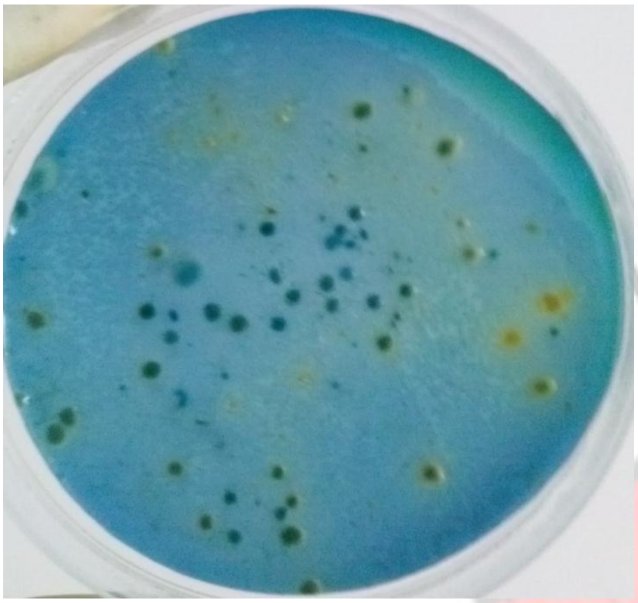
APPENDIX VI MICROBIOLOGICAL PLATES FOR THE PATHOGENS



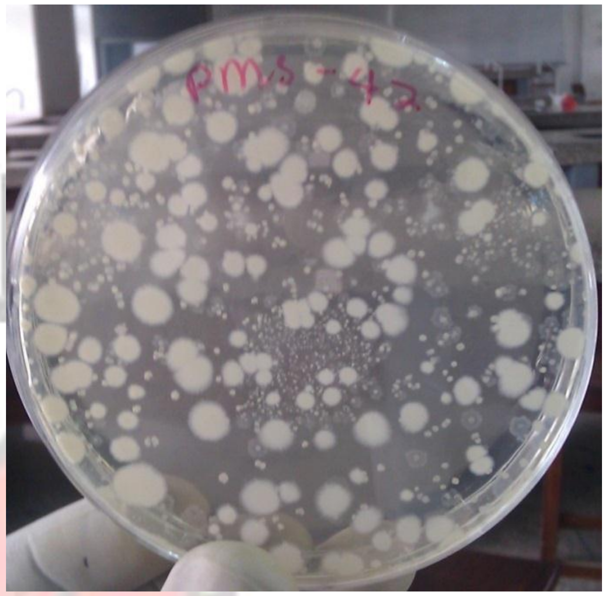
a. *S. aureus*



b. *E. coli*



c. *B. cereus*



d. Total Plate counts

Plate A1: Sample plates used in detection of various microorganisms in the food samples