KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY KUMASI,
COLLEGE OF SCIENCE

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

FOOD HANDLING BEHAVIOUR OF FOOD HANDLERS AND ASSOCIATED RISK MODELLING

BY:

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COMMUNITY NUTRITION

A THESIS SUBMITTED TO THE DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY, COLLEGE OF SCIENCE IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOOD QUALITY MAMAGEMENT

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DECLARATION I hereby declare that submission of this thesis represents the true findings of my own research, performed under the supervision of Mrs. Gloria Ankar-Brewoo, Kwame Nkrumah University of Science and Technology. To the best of my knowledge, it contains neither material previously published by another person, nor material which has been accepted for award of any degree from the University except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this work first, to the Almighty God Who guided and granted me travelling mercies throughout my time of study.

I dedicate this also in memory of my late father, Mr. Berchmans John Ansoadii Bawa who helped me recognize the importance of always seeking more knowledge.

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ABSTRACT

Food safety is an issue of global concern therefore the activities of food handlers affect the level of safety of prepared foods, which require appropriate guidelines or measures to guide such activities. Various studies have been carried out over time, to guide such activities, and still the problem of safety persists. This study sought to use the fuzzy modeling approach to determine the level of risk food is exposed to due to various handling methods. This was done by determining microbial levels (Microbial Risk Index- output variable) in food samples from selected restaurants in relation to the food handling method such as personal hygiene (PH), facility sanitation (FS), cold holding of food (CHF), hot holding of food (HHF), prevention of cross contamination (PCC) and raw ingredient handling (RIH). Food handlers in the study were also interviewed for knowledge in food safety. Results showed that contamination was attributed to inadequate food safety knowledge and practices. Less than 50 % of food handlers practiced good (high) food temperature management, ≤ 30% exhibited good (high) practices in preventing cross contamination. Inappropriate food safety practices such as inappropriate dressing (82%) usage of jewelry (66%) inappropriate washing of hands (70%), lack of or inappropriate medical screening (82%) and not having requisite training (66%) were also implicated. Modeling of PCC and FS; PH and PCC; CHF and HHF; PCC and CHF; and HHF and RIH gave rapid and high risk with deteriorating conditions. Cold handling of food, CHF and RIH interaction on the other hand gave a gradual rise in risk of microbial contamination. It is thus suggested that, while further studies are required for authoritative conclusions, regulatory authorities should prioritize risk factors such as personal hygiene of food handlers, temperature control during food preparation among others. Also, monitoring of restaurants by regulatory authorities should focus more on those food handling methods that pose risk of higher contamination of food rather than treating all factors as same.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background

The safety of food has a strong correlation with its processing as well as the handler of the said food. Food handlers' ability to discern and manage food risk factors during preparation has a huge impact on food safety. The World Health Organization (WHO) supports these findings by drawing a link between food borne illness out break and food handlers' failure to observe satisfactory standards during food preparation, storage, cooking and retailing (World Health Organization, 1989). Food handlers therefore play a significant role in ensuring an increase or decrease in the incidence of food borne illness through their food handling methods. Food borne illness/disease is any disease that arises as a result of consuming foods that are contaminated by microorganisms or chemicals during processing (World Health Organization, 2016). Food preparation procedures vary according to the persons handling it and the kind of infrastructural lay-out. These varying procedures and the types of food prepared carry different levels of risk of contamination (Garden-Robinson, 2012). This means that for every food item prepared, the methods employed and the personal attributes of food handlers affects food safety.

Although food preparation seems to be a simple act of adding together ingredients to achieve a desired flavour, taste or colour, it requires much more knowledge and skill on specific processes involved in food preparation. The Ghana Public Health Act, 851, part seven, section 106 states that food for sale should be prepared or supervised by someone with the appropriate knowledge on food preparation to ensure its safety for consumption (Bernie-Bernie, 2014) . The law points to the fact that knowledge or skills in food preparation directly affect food handlers' behaviour when handling food.

Right from raw ingredient acquisition, food safety may be compromised through inadequate knowledge on food hygiene, poor personal hygiene practices, poor sanitary conditions etc. Food safety is being described by the WHO as all those actions involved in food processing aimed at achieving optimal safety of the food (World Health Organization, 2016b). These procedures may include raw material handling, personal hygiene practices, observing environmental hygiene etc.

Generally, three conditions that are directly linked to food borne disease include time- temperature abuse, cross –contamination of food and poor personal hygiene (The Angican church and food safety (NARU, 2005). Particularly important is the personal hygiene practices of food handlers because food hygiene draws heavily on that (Ifeadike *et al.,* 2014). This is because food handlers can carry and transfer harmful microorganisms that may be on their hair, fingernails, hands, clothing, etc. to food during preparation. In effect, the food handling behaviour of vendors influences the level of safety of the foods they offer for sale to the public. Consumers are at a greater risk of being infected with food borne illnesses when food vendors use improper food handling methods such as; the use of a single chopping board for multiple purposes, using unwashed hands to handle ready to eat food, attending to food while sick, among others (Kibret and Abera, 2012).

Amponsah and Anamoaba (2011) have it that, more people are at a greater risk of food borne illness due to high patronage of food sold by vendors (George Amponsah and Ekua Anamoaba, 2011). Their research findings further points out that poor personal hygiene and low educational levels were implicated for poor food handling practices in Ghana by most food vendors. Consequently, poor food handling practices more often than not translate to contamination of food and may lead to food borne illness outbreaks resulting in huge economic losses. Moreover public health is often affected greatly in cases of food borne illness outbreaks and even lives could be lost as a result.

1.2 Problem Statement and Justification

The incidence of food borne illnesses is a growing concern worldwide mostly because food is a very basic need and can easily be contaminated through several means. In the developing world, illnesses due to contaminated food are often not reported or not even associated to food which makes it difficult to ascertain accurate levels of infections as a result (Newman, 2005). Right from the farm, food passes through a number of processing steps before it gets to the final consumer, hence contamination may be introduced along this chain for a number of reasons, key among them being the poor food handling behaviour of food vendors. This is further clarified by the World Health Organization (World Health Organization, 1989) when they stated that errors in food handling and preparation is one of the leading causes of food borne illnesses. This calls for appropriate quality judgment of food handling methods by those handling the food.

The decisions made during food preparation by food handlers affects the safety of food offered to the consumer because judgments may either facilitate safe or unsafe food production. Consequently it is imperative to appreciate the background to judgments of quality made by food handlers. This thus require vigorous studies and data generation in the field of food handling behaviours of food vendors, sadly however, little data exist in this regard for Ghana.

When consumers make a choice to purchase ready to eat foods from vendors, they are exposed to whatever contamination that may be inherent in the food, and hence to food borne illnesses. While there is little data on food handling behaviours of food handlers to ensure sanity in the catering sector, food service facilities continue springing up in all parts of the country and are mostly operated by persons with little or no qualification in food safety (Newman, 2005).This poses a health risk to consumers because food handlers may have inadequate expertise (knowledge and practices) in food safety issues which may result in the contamination of food, and hence the incidence of food borne disease. There is therefore the need to assess adequately data collected on food handling behaviours and eliminate aspects of data that are presented with uncertainty in order to achieve results that are more probable through fuzzy modelling.

1.3 Main Objective

To contribute to baseline data that would help create a platform for policy makers to appreciate the need for food service establishments to be run under the supervision of food quality managers.

1.4 Specific Objectives

This study specifically aims at determining the association between food handling behaviour and risk of food contamination using fuzzy modelling. It was also designed to determine the proportion of food handlers exhibiting high, medium, and low knowledge and practices in food handling methods.

CHAPTER TWO

LITERATURE REVIEW

2.1 Background

Food is a basic need which every person requires for good health, growth and development. However, the processes or methods of preparation may compromise the primary purpose of food and it may pose a health risk to people who consume such food. Aderibigbe *et al.* (2015) identified a number of factors contributing to the poor practice of food hygiene among vendors which includes; lack of adequate and hygienic facilities, poor knowledge of food safety and inadequate personal hygiene practices (Aderibigbe *et al.*, 2015). In another study, it was established that some of the major factors that hinder safe food preparation included improper waste disposal methods, locating food facilities in unhygienic environments and inadequate water supply and poor drainage (Onyeneho and Hedberg, 2013). It stands to reason therefore that, not only does the food handler's poor personal hygiene practice a food risk factor, but the entire process methods employed right from raw ingredient acquisition, through storage and eventually to the consumer's plate all influence the level of safety of food. Consequently, contamination of food may be minimal if food handlers exhibit appropriate knowledge and practices of food hygiene in order to control these food risk factors. According to the World Health Organization's five keys to safer food manual, controlling those factors (such as temperature control, preventing cross contamination, personal hygiene, acquisition of safe raw ingredients among others) that pose a risk to food contamination is essential to achieving safe food (World Health Organization, 2006). Hence the knowledge of these factors and controlling them to safe limits is a vital requirement for food handlers to ensure food safety.

2.2 Food Safety and Hygiene Handling Practices

2.2.1 Safe Cooking Temperatures

Adequate cooking is one of the most important steps to ensure all dangerous food borne disease causing micro-organisms are destroyed (World Health Organization, 2006). Food handlers need to be well informed with regards to the appropriate temperatures to cook safely. When improper temperature levels for cooking is used some bacteria are able to survive and multiply (World Health Organization, 1989).

Depending on the kind of food, different temperatures levels are required to achieve adequate cooking. Temperature danger zones are a range of temperature levels that support very fast growth and multiplication of microorganism and are often between 5 ^{o}C and 60 ^{o}C (The Angican church and food safety (NARU, 2005). An inability of food handlers to keep food out of this temperature danger zone exposes food to microbial contamination. According to the USDA, it's an important requirement to ensure that foods are cooked to the appropriate minimum internal temperature and temperature measured using a food thermometer before removing from the source of heat (USDA, 2016). Also cooking food to safe temperatures should be accompanied with particular time limits as this would aid in achieving adequate cooking and safer food (Garden-Robinson, 2012).

In addition, leftovers also require proper handling since they can be a source of food contamination after being kept over a period of time. Reheating of foods should be done to the required safe temperatures if microbes are to be minimised or eliminated (World Health Organization, 2006).

According to the USDA allowing cooked foods to stand for some time completes the cooking

(USDA, 2016). Food handlers' knowledge about the importance of ensuring equal distribution of heat within cooked foods which can help increase the internal temperature and hence destroy microorganisms or inhibit their growth is essential for achieving safer food.

Meanwhile, prior to serving cooked food, venders need to ensure that foods are held at a temperature above 60 ºC (World Health Organization, 2006). Keeping foods at the required temperature is central to preventing food borne illness due to microbiological contamination. The USDA sets the following minimum internal temperature limits and rest time for proper cooking; for beef, pork, lamb (steaks, chops and roasts); 62.8 ºC and 3 min rest time, for ground meats; 71.1 ºC and 3 min rest time, for all poultry; 71.1 ºC, for eggs; 71.1 ºC, for fish and shell fish; 62.8 ºC, and left overs; 73.9 ºC respectively (USDA, 2016). Food handlers' knowledge and practice of appropriate temperature zones for various foods and the use of food thermometers would serve to maintain foods in safe temperature zones thereby preventing the possible contamination by microorganisms.

2.2.2 Safe Cooling and Cold Storage

Researchers have linked improper cooling of foods to being one of the leading causes of food borne disease (Garden-Robinson, 2012). When cooling, it's vital to be well informed on the particular temperature required for ensuring safety. The temperature danger zone indicated as 5 ºC - 60 ºC implies that cooling should be carried out below 5 ºC (World Health Organization, 2006).

Equipment meant for cold storage such as refrigerators and freezers need to be monitored and maintained constantly to ensure an optimum working condition to achieve a continuous cold chain.

Brandt described several factors that contribute to effective cooling of foods including the following: The size of food - smaller masses or portion of food facilitates faster cooling, food density - denser food is shown to cool faster compared to non-dense foods, Size of container - smaller and shallow containers aid faster cooling, material of food container- for instance stainless steel transfer heat from foods faster than plastic. Finally an important factor is to avoid putting food steaming hot in a cooler or freezer because it will cause the temperature within (cooler/freezer) to rise, placing all other foods within the temperature danger zone (Brandt, 2016).

However, it is important to note that food venders can only control temperature by constantly checking low or high temperatures with a thermometer. In addition, cold storage is essential to keep foods safe for longer periods and more importantly, the appropriate temperature limits should be known by food handlers in order to attain safe cold storage. According to the USDA (2016) specific temperature limits with corresponding periods (days or months) have been set for safe cold storage in refrigerators and freezers to ensure appropriate preservation of food items.

2.2.3 Preventing Cross-Contamination

Cross – contamination of food often times occur as a result of improper handling of raw and cooked foods. According to Osaili *et al*.(2013), most food handlers practiced cleaning of a single chopping board for several purposes after each use and a similar numbers practiced sanitizing of boards but a small group indicated that the same board should not be used for several tasks (Osaili *et al.*, 2013). In another study, 35 percent of food handlers used one chopping board which they rinsed after each use with warm water and 65 percent indicated that even though they used one chopping board, after each use it was properly cleaned and sanitized (Onyeneho and Hedberg, 2013). In addition, some studies found out that majority of food handlers were engaged in multi-tasking, used common chopping boards for various foods, used common sink for various activities, and used common utensils for various foods/activities (Jevšnik *et al.,* 2013; Soares *et al.,* 2012). The use of a single chopping board in particular may easily be a source of cross contamination when cleaning is improperly done and keeping several boards for different tasks would serve to minimise the risks of inadvertent cross contamination. As stipulated by the WHO, it's very important to separate raw and cooked foods because ready to eat foods that are contaminated increases the risk of food borne illness, because raw food and their juices like meat, pantry and seafood can contain very dangerous microorganisms that can contaminate other foods during processing and storage (World Health Organization, 2006).

Right from raw material acquisition, raw foods should be separate from ready to eat foods such as vegetables. Cross contamination of foods is one of the leading causes of food borne illnesses (USDA, 2016).It is recommended that, during shopping, food handlers need to separate raw meat, poultry and seafood from all other foods and keep their juices form dripping on other foods. Similarly stacking in refrigerators must be organized to keep dripping from meats from falling on other foods. In effect, possible contaminants that may be present in these juices would be prevented from reaching other foods when properly segregated (Agustina *et al.,* 2013; Nyenje *et al.,* 2012; USDA, 2016). Therefore, food handlers' ability to keep raw foods such as meats, eggs, fresh vegetables among others under safe conditions is vital to preventing food poisoning.

During purchasing of raw materials, refrigeration, cooking and serving food, meals can be exposed to contamination when hygienic methods of handling are disregarded (Agustina *et al.*, 2013; Nyenje *et al.*, 2012). Also stacking in refrigerators/ freezers should be arranged such that all seafood poultry and raw meat are stored below cooked or ready to eat foods to prevent cross – contamination (World Health Organization, 2006).

A study in Ghana showed that while some food handlers had knowledge on how to safely store vegetables and meat in a refrigerator to avoid cross contamination, a few were not certain about the right way to store vegetables and meat (Amponsah and Anamoaba, 2011). In a similar study by Osaili *et al.* (2013), 4% of food handlers stored raw meat and poultry together with ready to eat foods, but 70% understood how to properly segregate ready to eat foods from raw meat. This lack of knowledge poses a risk of contamination to ready to eat foods (Osaili *et al.*, 2013). Cross contamination may result in three (3) different ways; from contaminated water/food to food, from sick persons to food and from contaminated equipment/utensils to food.

Contamination from sick persons is common as most food vendors allowed sick workers to continue handling food with the reason that they could not pose a risk of transfer of pathogens to food (Onyeneho and Hedberg, 2013). It was observed that most food vendors still prepared food while suffering from diarrhoea, though some others indicated they stopped handling food (Amponsah and Anamoaba, 2011). Another study by showed that less than one-third of food handlers practiced hand washing before handling food (Ifeadike *et al.*, 2014). Hand washing is necessary even when not sick but handling food, however the risks increases greatly when hand washing is disregarded during ill health because disease pathogens may easily be transferred to food. For this reason, possible sources of contamination need adequate management by food vendors to prevent cross- contamination from occurring.

Finally, meals are required to reach consumers in a state that is safe, however, safety can be compromised at the stage of serving food when contaminated utensils are used (Parra *et al.,* 2014). Food handlers' tendency to use dishes that are not properly cleaned to serve consumers compromises the safety of meals and destroys all other safety measures that may have been employed during the preparation stage. When cross- contamination is prevented, then there also is a reduction in the risk of food borne disease outbreak (Agustina *et al.,* 2013; Nyenje *et al.,* 2012; USDA, 2016).

2.2.4 Personal Hygiene of Food Handlers

Persons handling food can directly or indirectly affect the level of safety of the food being prepared. It is very important to consider the role people play in keeping food safe from contamination because most often, people outline the hygiene rules they plan to use, follow them and also break them (Schmidt and Erickson, 2014). Workers who have direct contact with food pose a risk to the food as they can contaminate it during handling (Osaili *et al.,* 2013). Ifeadike *et al.*(2014) support this view and proposed that to achieve a desirable level of food hygiene, it is necessary to ensure minimal handling of food by vendors because these persons can easily be a source of contamination of food (Ifeadike *et al.,* 2014). Food handlers thus play an important role in reducing food-borne diseases when appropriate personal hygiene rules are adhered to. In other words, to a large extend, food handler determine the level of safety of whatever food is being prepared. In effect food service establishments that are run by workers with poor personal hygiene habits may be exposed to several biological, physical and chemical contaminants.

Takalkar and Kumavat (2011) views are not different from Ifeadike *et al*.(2014) they also affirmed the fact that a greater risk of contamination of food rests with the food handler since persons can be sources of microbial contamination (Takalkar and Kumavat, 2011). Their reasons being that, the hands, clothes, fingernails, hair, nose, mouth and several other parts of a person's body can be places of harbour for biological contaminants. Most importantly persons can become a source of very high microbial load in times of gastrointestinal disorders particularly if asymptomatic (Baş *et al.*, 2006). This poses a serious threat of microbiological contamination of food by workers if personal hygiene practices are poor and sick persons continue to handle food.

As shown the Ghanaian study (Amponsah and Anamoaba, 2011), although food handlers had fair knowledge and attitude toward food hygiene, it did not reflect in behaviour change with regards to handling food hygienically. Also, inadequate preparation methods which were mostly centred on personnel personal hygiene practices lead to a higher risk of food borne illnesses according to Ifeadike *et al.* (2014). In essence, having knowledge of personal hygiene rules alone is not adequate if not accompanied with practice or suitable behaviour change. Essentially, proper hand washing can aid in reducing the risk of transfer of contaminants to food and is therefore a vital hygiene practice for all food handlers. Akinboye *et al.* (2015) posits that food handlers have a vital role to play to ensure safe food as their practices affects the level of safety of food prepared. This role is central to achieving safe food because in the event that there is proper cooking and cooling, separation of raw and cooked foods and suitable waste management procedures, poor personal hygiene practices can still compromise the safety of food, it is therefore imperative for vendors to know and practice adequate personal hygiene.

These views are further supported by other studies which indicate that in addition to temperature management and cross contamination, personal and environmental hygiene count contribute greatly to contamination levels of processed food. And that most food handlers exhibit poor sanitary practice, wear inappropriate attire, jewellery, wash hands inappropriately, do not take appropriate medical screening, and do not having requisite training (Jevšnik *et al.*, 2013; Lelieveld *et al.*, 2014; Soares *et al.*, 2012).

2.2.5 Raw Material Handling

Acquisition of food items to be processed for consumption is the first step vendors take and this can greatly affect the outcome of the final product if the ingredients are contaminated. Most food handlers sourced their raw ingredients from markets exposed to several environmental contaminants and ingredients also are subjected to much handling by several buyers as they touch and squeeze for the most suitable texture (Onyeneho and Hedberg, 2013). This level of exposure increases the measures required to reduce possible contaminants that may be present and food handlers are tasked with observing strict hygiene rules to minimise risk of food contamination.

Raw materials can be a source of dangerous microorganisms and care in selection incorporated with preventive measures such as washing with treated portable water may reduce the risk of food contamination. It is necessary to ensure that raw ingredients are sourced from suppliers who have measures in place to assure safety for their products (The Angican church and food safety (NARU, 2005). This step would help prevent using unwholesome or damaged ingredients that may be contaminated and hence compromise food safety.

Essentially, food handlers are required to keep and use ingredients that still fall within their shelf life period and are held at their required temperature zones (Garden-Robinson, 2012). And as shown by Ifeadike *et al*. (2014) the safety of food largely rests on the handling practices of food vendors and the risks are higher because food that is ready for consumption may not indicate qualities of spoilage but may cause grave illness when consumed (Ifeadike *et al.*, 2014). Therefore, ensuring the use of wholesome ingredients by food handlers is fundamental to achieving safe food because some ingredients may not undergo heat treatment which can control microbial levels. Besides food handlers who may not exercise diligence in ingredient selection may expose consumers to both chemical and microbial contamination.

2.2.6 Sanitation in Food Service Establishments

Sanitation in food facilities covers every aspect or activity undertaken by food handlers, Schmidt and Erickson (2014) expressed that food sanitation is a protection from contamination. Hence every area, equipment, or food ingredient is required to be handled in a manner that would prevent food contamination. The overall sanitary conditions of food service facilities both inside and outside have direct effects on the safety of food prepared in the premises (Schmidt and Erickson, 2014). They pointed out that premises that have their surroundings covered in filth and dust, drainage problems, among others can easily cause contamination of food. Food service establishments that have poor sanitary conditions pose a higher threat of contamination of food which may result in food borne illnesses.

Giambrone (2009) explains this further that food service facilities should be designed such that they promote hygiene and sanitation by controlling worker and product flow to prevent cross-contamination of food (Giambrone, 2009). Also facility design should allow easy and adequate cleaning and discourage pest harbourage (Schmidt and Erickson, 2014). This is because appropriate structural design can enhance good sanitation as long as persons responsible for keeping premises clean follow sanitation programmes adequately. Furthermore; waste disposal methods can greatly compromise the safety of food. According to Schmidt is essential to keep and clearly identify all waste containers and ensure that they have lids to keep them well covered. Open waste containers can increase the risk of contamination because microorganisms can easily be transferred to food during food preparation. Aside, food establishments can facilitate food handlers' hand washing practices by providing hand washing facilities. Hand washing stations should be separate from sinks for food handling and should be equipped with soap, disposable towels and running water (Schmidt and Erickson, 2014).

2.3 Microbial Contamination of Food, Food Hygiene and Safety

Microbial contamination of food is very common and almost inevitable as microorganisms exist in the air, on surfaces, within and on the human body, on food items among others. They are however a threat to health and life when they occur in numbers that can cause food poisoning or produce disease causing toxins. Microbial contamination of food is therefore a public health concern, as the practices employed by food handlers may determine the level of microbial contamination of food handled and the resultant effect on consumers. *Staphylococcus aureus* and

Escherichia coli are both important bacteria because they mark inadequate food hygiene and safety practices in food processing. Their existences in food often result in food borne illnesses.

2.3.1 Staphylococcus Aureus

Staphylococcus aureus is a microbe that can be readily avoided by heat treatment. Nevertheless, it remains a major cause of food borne disease because it contaminates food products during preparation and processing (Le Loir *et al*., 2003). *Staphylococcus aureus* is found in the nostrils, and on the skin and hair of warm-blooded animals. Its presence in food is a marker of inadequate food hygiene and safety practices (Le Loir *et al.,* 2003). This is a type of microbe (bacteria) that is capable of contaminating food by producing toxins when staphylococcus populations exceed 100,000 per gram (U.S. Food and Drugs Authority, 2016). This implies that staphylococcus food poisoning occurs when there is an intoxication caused by consumption of foods with sufficient levels of one or more already formed entero-toxin (Argudín *et al*., 2010).

Further, *Staphylococcus aureus* is a bacteria leading in the cause of gastroenteritis caused by the consumption of food that has been contaminated due to enterotoxigenic staphylococci growth or production of toxins (Kumar *et al*., 2011). Moreover, staphylococcus enterotoxins pose a potential threat to food safety because of their stability at high temperatures- 100^{o}C for 1 h (Bhatia and Zahoor, 2007; Kumar *et al.,* 2011). This indicates that food handlers are required to have adequate knowledge and good practice of hot holding of food to avoid or minimize the level of *Staphylococcus aureus* contamination. Also, a wide range of food items can be contaminated by *Staphylococcus aureus*, however the most incriminated foods often include meat and meat products, poultry, salads etc. (Argudín *et al.,* 2010). Meanings raw or ready to eat foods are the most susceptible to *Staphylococcus aureus* contamination. On the whole, food handlers can be a major source of contamination as well as the surfaces on which they work. It is therefore essential that food handlers have adequate knowledge on microbial contamination of food and possible preventive measures to ensure minimal or no *Staphylococcus aureus* contamination of food.

2.3.2 Escherichia coli

This is a type of bacteria that can cause food contamination through fecal matter because it is mostly found in the digestive system of healthy humans and animals (Scheider *et al.*, 2003). In other words, food handlers become a good source of *Escherichia coli* contamination if their practice of personal hygiene is poor. The strains of *Escherichia coli* are many; the most recognized is *Escherichia coli* 0157:H7 which easily contaminates leafy greens. However, minimizing *Escherichia coli* contamination of food can be achieved through proper care in food handling such as; cleaning of equipment, separating raw from cooked foods, adequate heat treatment of food (Schneider et al.). In effect, the knowledge and practices food handlers exhibit are vital in preventing contamination.

Further, infections due to *Escherichia coli* contamination mostly manifest as abdominal cramps, diarrhea, fever and vomiting and in some cases can be life-threatening (World Health Organization, 2016). Therefore, food handlers' inability to handle food in the most hygienic way exposes consumers to *Escherichia coli* infections.

2.4 Fuzzy Modeling

In Ghana detailed information on microbial risk in the food system is very limited. Studies in this area do become very challenging. Fuzzy modelling was used in our analysis because of its ability to overcome aforementioned obstacles. Detailed assessment of a microbial risk in a food system requires a substantial amount of knowledge about the system's characteristics and microbial dynamics. In early-stage risk assessment when data and knowledge is limited, fuzzy methods are often appropriate for describing system parameters and relationships between variables (Davidson *et al.*, 2006). In addition, these fuzzy approaches could easily evolve to the traditional probabilistic methods as information is collected and the risk assessment process develops (Davidson *et al.*, 2006).

In instances of limited information (such as experts' judgements or sparse data sets) as in the case of Ghana, it is noted that initiating semi-quantitative analysis in identifying data gaps and areas requiring further research as being vital. Therefore, research employed qualitative risk assessment. Qualitative risk assessment is "based on data which, while forming an inadequate basis for numerical risk estimations, nonetheless, when conditioned by prior expert knowledge and identification of attendant uncertainties, permits risk ranking or separation into descriptive categories of risk". Qualitative risk assessment is needed in the case of Ghana to enable easy regulation and decision making by regulatory authorities.

In light of the above, fuzzy modelling was used to assess how different food handling methods affect the level of safety of food prepared. This was done by combining the food risk factors of interest such as; hot holding of food (HHF), cold holding of food (CHF), personal hygiene (PH), raw food handling (RIH), facility sanitation (FS) and prevention of cross contamination (PCC) using the fuzzy model rule-based system (If - then).

CHAPTER THREE

METHODOLOGY

3.1 Study Area

The research was carried out in Tamale Metropolis, the capital city of the Northern Region. According to the 2010 Population Census, the Metropolis is comprised of 60.1 percent literates and 39.9 percent illiterates who are engaged in various livelihoods but commonly involved in service provision (example is restaurant operators). Also the metropolis has a population of about 233,252 people and serves as a hub for various commercial activities including the hospitality industry which has developed to a great extent with hotels, guest houses and restaurants springing up with great speed (GSS, 2010). Northern region in general is occupied by people of varied religions and ethnic backgrounds, however the dominant religion and ethnic group is Islam and Dagombas respectively (GSS, 2010).

3.2 Data Collection

Data collection was done in three parts; first a survey was carried out on the food handling methods of vendors. It was conducted by administering questionnaires on food handling methods such as raw food handling, hot holding of food, and cold holding of food. Observation of food premises of restaurants was also carried out to assess general sanitary conditions of the food service facilities. Lastly, food samples were collected from each restaurant for microbial analysis (*Escherichia coli* and *Staphylococcus aureus*). Foods were purchased at each restaurant in the form as is served to all customers. It was preserved in an ice chest (with ice) to prevent microbial growth due to rise in temperature. Microbial analysis of sampled foods were made immediately.

3.2.1 Study Design and Sampling

A cross – sectional study design was used for the research and focused on fifty (50) food handlers who had direct contact with food in ten (10) selected restaurants. These included cooks, waiters/waitresses and persons in charge of food ingredient acquisition. The target population was mainly all food handlers in restaurants in the Tamale metropolis. Five food handlers were selected at each of the ten (10) restaurants included in the study. Hence only those food handlers who met the inclusion criterion of having direct contact with food were selected and interviewed. Purposive sampling was employed in selecting participants as the study targeted a specific group of people for the objectives of this study. Each food handler's consent was sought through a brief description on the rationale for the study and consequently, only those food handlers who accepted to participate in the study were interviewed during data collection.

3.2.2 Research Design

The data run employed fuzzy modeling because of the characteristics they presented which were considered imprecise. In an attempt to determine the level of risk posed by various food handling methods, considerations were given to all those factors that may contribute to inappropriate food handling behavior during food preparation. For instance, personal hygiene practices are affected by food handlers' dressing, hand washing practices, health status among others. All these determinants of personal hygiene therefore make data fuzzy. Similarly, facility sanitation is affected by factors such as appropriate cleaning methods, waste control management, among others, hence fuzzy. Likewise all food handling methods being studied were each affected by various determinants which made data fuzzy. Also; microbial contamination of food at various restaurants was influenced by the different methods of food handling and hence fuzzy.

3.2.3 Data collection and tools

An interview guide was used to collect information on food handlers and service establishments. Questionnaire was divided into six parts directed at answering specific questions for the following activities: Hot Holding of Food (HHF), Cold Holding of Food (CHF), and Facility Sanitation (FS), Personal Hygiene practices (PH), Prevention of Cross Contamination (PCC) and Raw Ingredients Handling (RIH). Interviewee's responses were measured using a line scale of between 1 and 5 for the purpose of fuzzy modelling. This range is defined by qualitative measures of low (3.5, 4, 5), medium (2, 3, 4) and high (1, 1, 2.5). Five questionnaires were administered at each restaurant to cater for the varied methods food handlers may be using and the subjective observations made by each interviewer. This was as illustrated in the interview guide shown.

3.2.4 **Interview Guide for Food Handlers**

A CHECKLIST TO DETERMINE FOOD HANDLERS KNOWLEDGE AND FOOD SAFETY PRACTICES IN RESTAURANTS

PERSONAL HYGIENE PRACTICES AND FOOD SAFETY KNOWLEDGE

SECTION ONE: PERSONNEL HYGIENE AND KNOWLEDGE IN FOOD HANDLING

Personnel properly uniformed with headgear and Appropriate headgear	………………………………………
Staff have the requisite academic qualification or Have received appropriate training	………………………………………
Personnel medically examined for communicable	
Diseases such as typhoid, hepatitis A among others	………………………………………
Staffs wash hands before serving food ………………………………………	
Vendors use the same hand to serve food and receive Money ………………………………………	
Personnel rub eyes, nose, and ears while handling food ………………………………………	

QUESTIONS/OBSERVATIONS HIGH MED LOW

SECTION TWO: FACILITY SANITATION

Facility appears clean with good drainage ………………………………………
Waste bins available in cooking area ………………………………………
Waste bins emptied as often as possible ………………………………………
Fitting lids for waste bins provided ………………………………………
Waste collected by waste management company ………………………………………
Hand washing stations available and adequately Equipped ………………………………………

SECTION THREE: COLD HOLDING OF FOOD

Refrigerators not rusty, overloaded and properly Maintained ………………………………………
Appropriate refrigerator temperatures maintained ………………………………………
Adequate stacking discipline in refrigerator ………………………………………
Temperature verified using a thermometer ………………………………………
Foods in cold storage in appropriate containers that are Covered ………………………………………

SECTION FOUR: HOT HOLDING OF FOOD

Food is served imn ………………………………
Food is held at app To serving (65 deg ………………………………
Temperature meas thermometer .

SECTION FIVE: PREVENTING CROSS CONTAMINATION

Staffs have specific assigned duties ………………………………………
Separate chopping boards used for raw and ready-to-eat Foods ………………………………………
Sinks for kitchen activities not used for other activities Such as washing utensils ………………………………………
System available for the control of the use of cooking Utensils to prevent cross contamination ………………………………………

SECTION SIX: RAW INGREDIENT AQUISITION

Purchases food ingredients from specific suppliers ………………………………………

Use only approved food additives	....
Expired or unwholesome food ingredients rejected	....
Raw materials received in cooking area	....
Ingredients stored using first-in-first-out (FIFO) Principle	....

3.3 Statistical Method

The following were tools used in data processing; the fuzzy inference system (FIS) editor, the membership function editor, the rule base editor, the rule viewer editor and the surface viewer. The following four step procedure shown in figure 1 was carried out in the fuzzy modeling of the various food risk factors

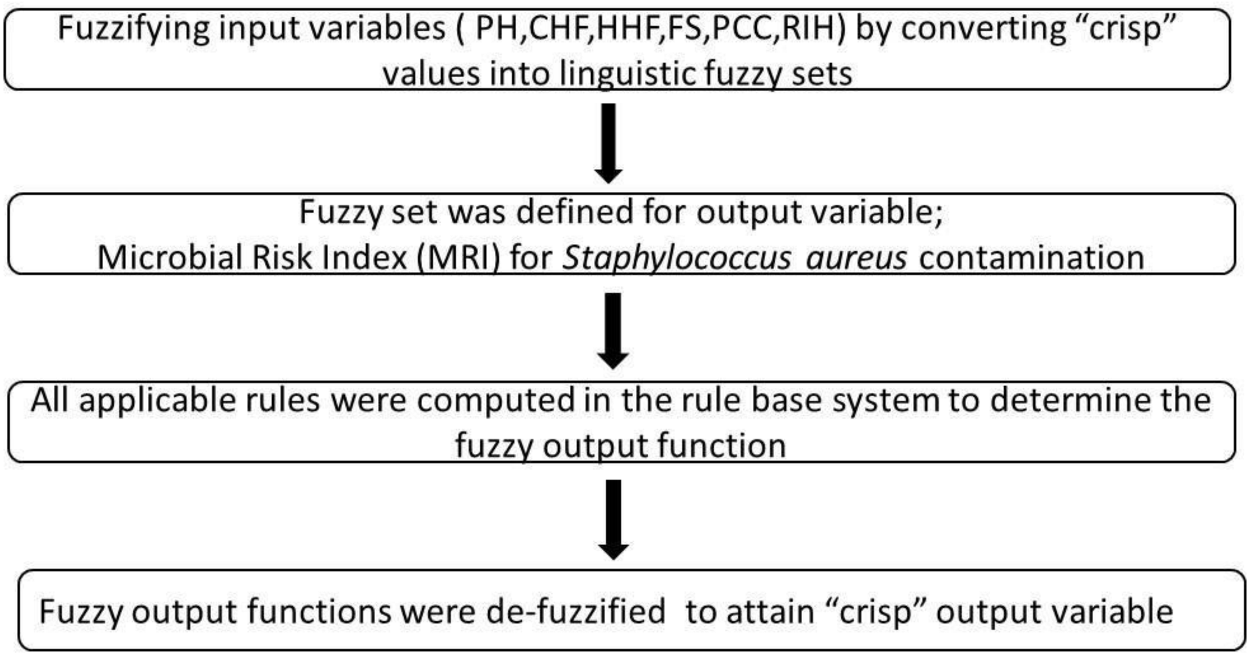


Figure 1. The Four Step Procedure Used In Fuzzy Modeling of Food Risk Factors Studied

Hence as shown in Figures 2, 3, 4, 5, 6, 7 and 8, the following diagrams illustrating member functions of input and output variables were generated by fuzzifying crisp values into linguistic fuzzy sets;

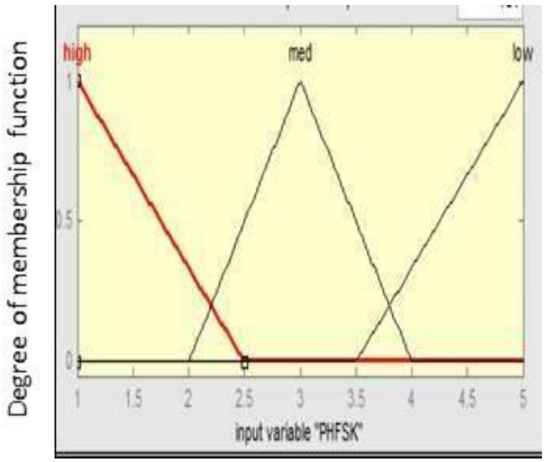


Figure 2. Membership function for Personal Hygiene practice

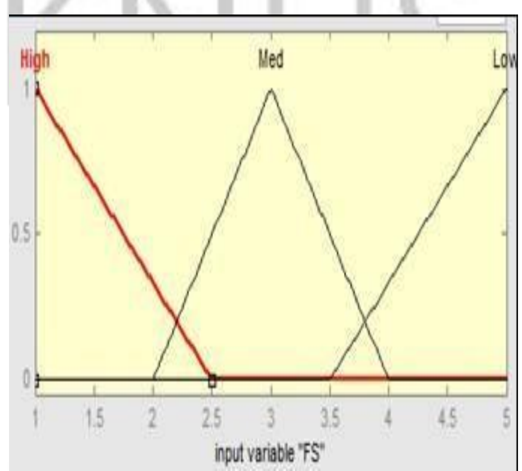


Figure 3. Membership function for Facility Sanitation

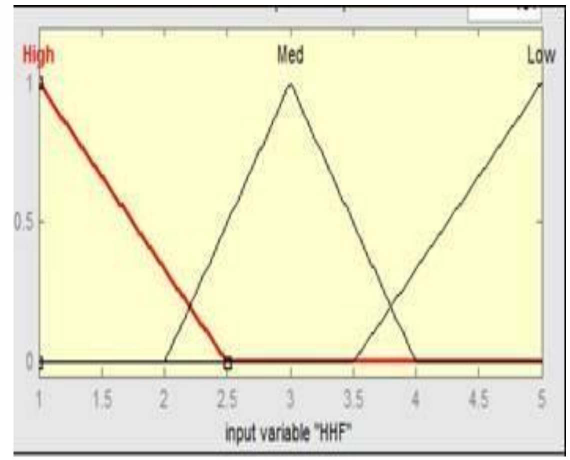


Figure 4. Membership function for Cold Holding of Food

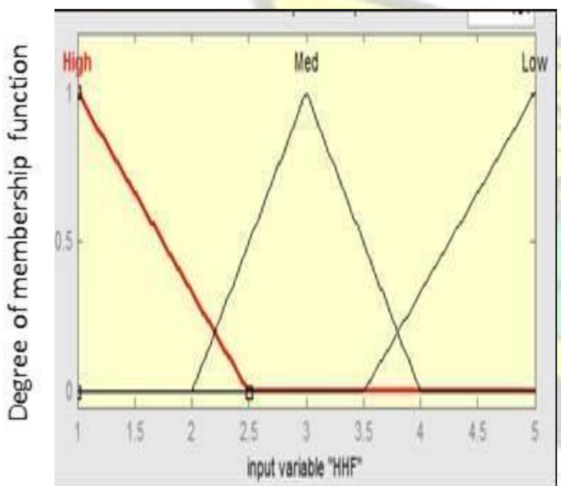


Figure 5. Membership function for Hot Holding of Food

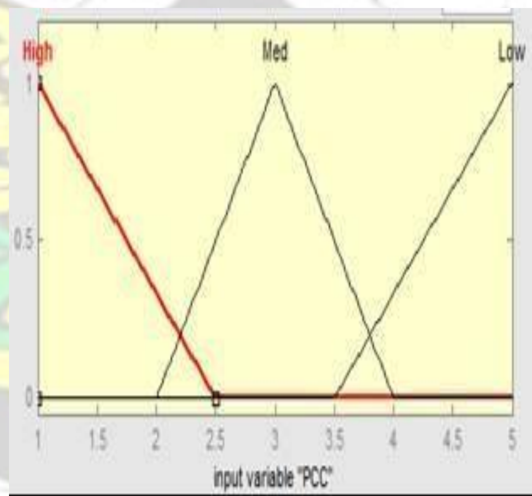


Figure 6. Membership function for Prevention of Cross Contamination

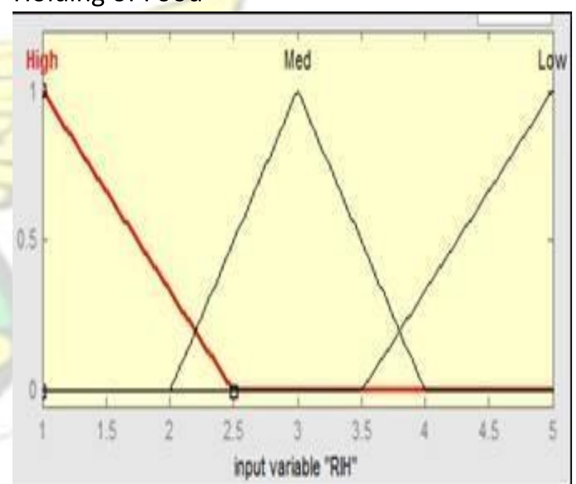


Figure 7. Membership Function for Raw Ingredient Handling

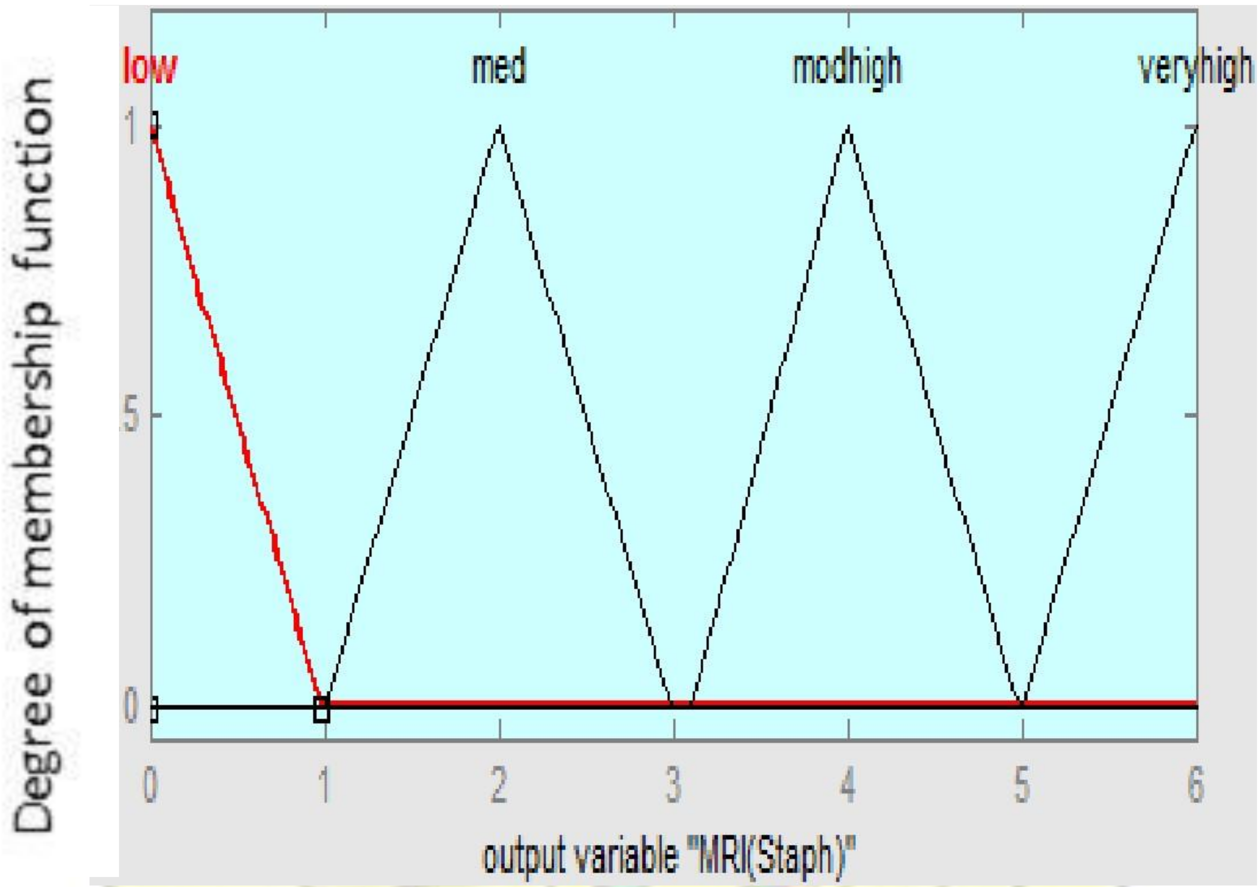


Figure 8. Membership function for Microbial Risk Index (MRI)

3.4 Data Analysis

Fuzzy modelling was used to find the association of risk of microbial contamination with the interaction of various risk factors. Fuzzy modelling was used because of its ability to determine precision in data that present degrees of truth or uncertainty. This modelling approach was used to assess how different food handling methods affect the level of safety of food prepared. This was done by combining the food risk factors of interest such as; Hot Holding of Food (HHF), Cold Holding of Food (CHF), Personal Hygiene (PH), Raw Food Handling (RFH), Facility Sanitation (FS) and Prevention of Cross Contamination (PCC) using the fuzzy model rule-based system (If - Then).

The data was processed using the Mamdani fuzzy type system to model in the FIS (Fuzzy inference System) editor and consequently, the rule base editor was used to set the input/output variables, following the "IF/THEN" rule. Hence all applicable rules were computed in the rule base system to determine the fuzzy output function. The "crisp" values for the output variable (MRI) were determined by de-fuzzifying fuzzy output functions. Also, the rule base viewer was run by sliding the six input variables (Personal Hygiene, Facility Sanitation, Cold Holding of Food, Hot Holding of Food, Prevention of Cross Contamination and Raw Ingredient Handling) which automatically affected values of output variable as illustrated in Table 4.

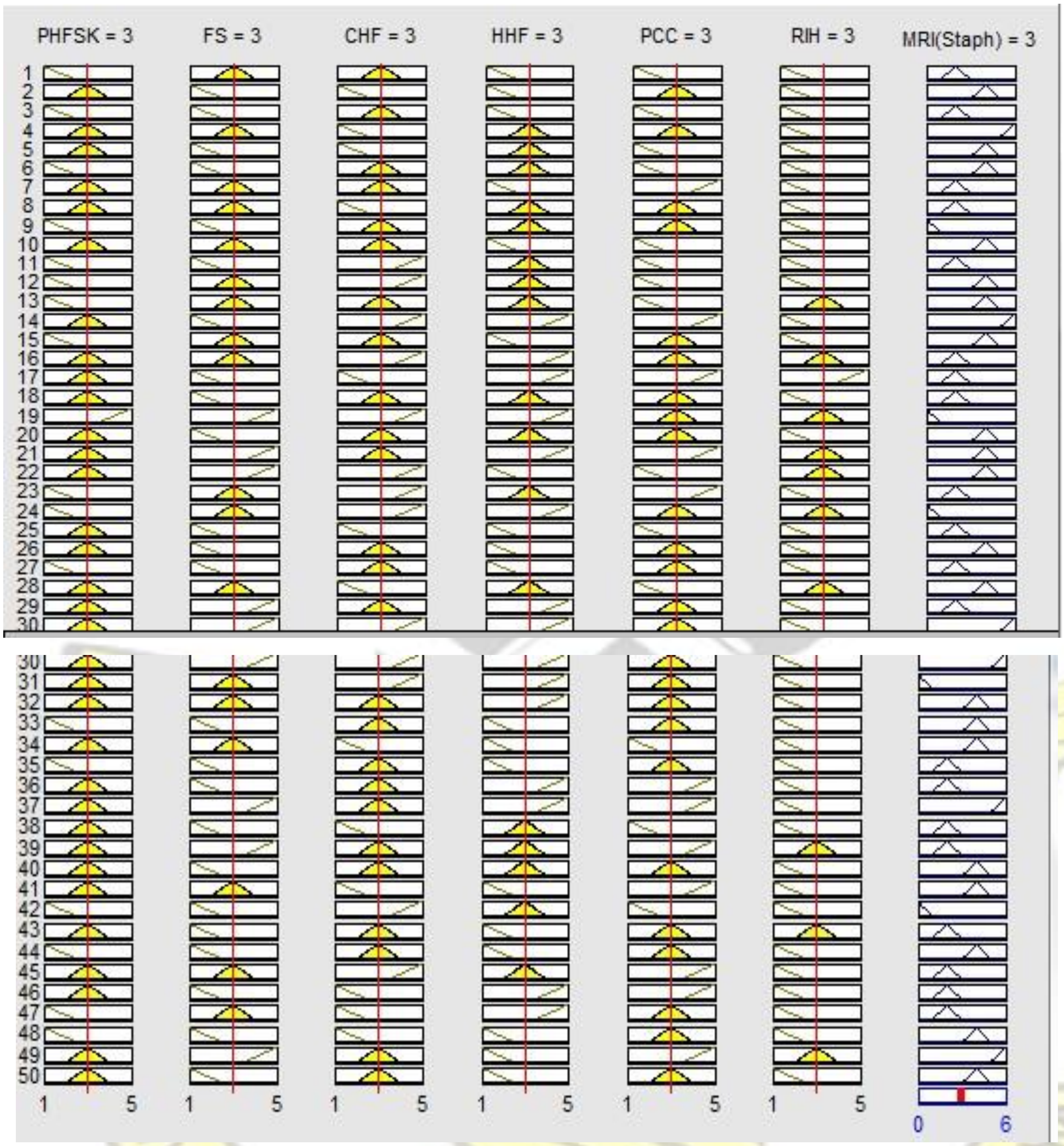


Figure 9. Illustration of "IF-THEN" rule base system for input and output variables

Table 1. Outline of “Crisp” Input and Output Variables for the various Food Risk Factors

Factors	Input variables						Output variable
Inspector/Facility	PH		CHF	HHF	PCC	RIH	MRI
1/1	1.8	2.9	3.1	2.0	1.4	2.1	1.5
1/2	3.0	1.5	1.2	1.6	3.6	1.9	4.0
1/3	1.1	1.4	2.5	1.3	1.1	1.6	2.5
1/4	2.8	3.1	1.5	2.5	2.2	1.4	5.3
1/5	2.5	1.3	1.7	2.6	2.0	1.5	3.5
1/6	1.2	1.8	3.5	3.1	1.4	1.8	3.0
1/7	2.6	2.9	3.1	1.2	4.3	2.5	2.2
1/8	2.8	2.5	1.4	2.6	2.8	1.3	2.7
1/9	2.1	1.9	3.1	2.5	3.0	1.7	0.6
1/10	______	2.4 2.2	2.8	1.5	1.1	1.3	3.7
2/1	3.3 1.6		4.8	2.9	1.7	1.2	2.6
2/2	1.3	3.1	3.5	2.7	1.3	2.3	3.0
2/3	1.1	2.5	3.0	3.5	1.2	4.0	4.2
2/4	3.1	1.5	4.8	3.5	4.1	1.2	5.6
2/5	1.8	2.3	3.6	1.4	2.4	1.6	4.7
2/6	3.7	2.5	3.8	4.0	3.2	2.9	2.3
2/7	3.2	1.1	1.7	4.9	3.6	4.5	1.7
2/8	2.5	1.1	2.8	3.1	3.4	2.2	2.5
2/9	3.6	4.1	5.0	4.3	2.7	3.8	5.5
2/10	______	1.9 3.9	3.3	3.5	3.5	1.8	3.8
3/1	4.0 2.6		3.2	4.4	5.0	3.5	3.1
3/2	2.5	3.7	4.3	1.2	1.5	3.1	4.6
3/3	2.3	3.1	4.5	2.7	4.6	1.3	1.9
3/4	2.4	3.0	3.6	3.5	2.9	2.7	5.8
3/5	3.0	2.1	1.6	1.4	1.1	2.4	2.8
3/6	3.5	1.7	3.9	2.2	2.5	2.4	3.7
3/7	1.3	2.2	3.3	1.8	2.8	1.2	2.3
3/8	4.0	2.6	1.4	3.2	1.5	1.4	4.3
3/9	3.6	4.1	3.3	3.9	2.5	1.7	1.5
3/10	3.0	3.7	4.8	3.5	2.8	2.5	5.2

PH: Personal Hygiene, CHF: Cold Holding of Food, HHF: Hot Holding of Food, PCC: Prevention of Cross Contamination, RIH: Raw Ingredients Handling

Table 1. (Cont'd)

Factors	Input variables						Output variable
Inspector/Facility	PH		CHF	HHF	PCC	RIH		MRI
4/1	2.7	3.4	3.9	3.5	3.1	1.4		0.8
4/2	2.5	2.9	4.0	4.1	2.4	2.2		3.4
4/3	1.8	1.2	3.5	1.4	2.5	1.6		4.4
4/4	3.3	3.1	1.1	2.4	2.1	1.2		3.1
4/5	1.9	1.9	2.8	1.4	2.5	1.1		2.2
4/6	2.6	1.3	3.0	3.7	4.1	1.4		2.5
4/7	3.7	4.5	3.1	4.4	3.8	2.4		5.7
4/8	2.5	2.4	2.1	2.6	1.9	1.8		2.8
4/9	2.3	3.5	2.8	3.1	3.6	2.5		3.0
		1.4	4.0	2.5	3.3	1.5		
		2.6	1.4	1.2	4.1	2.4	4/10	3.2
4.1								
5/1	2.9							4.2
5/2	1.2	1.7	3.5	2.4	1.3	1.1		0.6
5/3	3.2	2.0	2.5	1.9	3.2	2.8		3.0
5/4	1.4	1.8	2.9	1.4	3.5	2.0		3.6
5/5	2.8	3.1	3.9	2.4	3.5	1.3		2.9
5/6	2.6	1.6	1.1	3.5	3.7	1.8		2.5
5/7	1.4	2.8	1.6	4.3	3.0	1.2		3.0
5/8	1.2	1.2	1.7	2.4	3.8	2.2		3.4
5/9	3.8	4.2	3.5	2.3	4.0	2.7		5.6
5/10	3.0	2.1	3.3	2.1	3.4	1.7		3.7

PH: Personal Hygiene, CHF: Cold Holding of Food, HHF: Hot Holding of Food, PCC: Prevention of Cross Contamination, RIH: Raw Ingredients Handling

Output variable

Table 2. Outline of Fuzzy Sets for Input and Output Variables

Factors	Input variables						Output variable
Inspector/Facility	PH		CHF	HHF	PCC	RIH	MRI
1/1	H	M	M	H	H	H	M
1/2	M	H	H	H	M	H	MH
1/3	H	H	M	H	H	H	M
1/4	M	M	H	M	M	H	VH
1/5	M	H	H	M	H	H	MH
1/6	H	H	M	M	H	H	MH
1/7	M	M	M	H	L	H	M
1/8	M	M	H	M	M	H	M
1/9	H	H	M	M	M	H	L
1/10	M	M	M	H	H	H	MH
2/1	H	H	L	M	H	H	M
2/2	H	M	L	M	H	H	MH
2/3	H	M	M	M	H	M	MH
2/4	M	H	L	L	L	H	VH
2/5	H	M	M	H	M	H	MH
2/6	M	M	L	L	M	M	M
2/7	M	H	H	L	L	L	M

							Output variable
2/8	M	H	M	M	M	H	M
2/9	L	L	L	L	M	M	L
2/10	M	H	M	M	M	H	MH
3/1	M	L	M	L	L	M	MH
3/2	M	L	L	H	H	M	MH
3/3	H	M	L	M	L	H	M
3/4	H	M	L	L	M	M	L
3/5	M	H	H	H	H	H	M
3/6	M	H	M	H	M	H	MH
3/7	H	H	M	H	M	H	M
3/8	M	M	H	M	H	M	MH
3/9	M	L	M	L	M	H	M
3/10	M	L	L	L	M	H	VH

PH: Personal Hygiene, CHF: Cold Holding of Food, HHF: Hot Holding of Food, PCC: Prevention of Cross Contamination, RIH: Raw Ingredients Handling

Table 2. (Cont'd)

Factors	Input variables						
Inspector/Facility	PH		CHF	HHF	PCC	RIH	MRI
4/1	M	M	L	L	M	H	L
4/2	M	M	M	L	M	H	MH
4/3	H	H	M	H	M	H	MH
4/4	M	M	H	H	H	H	MH
4/5	H	H	M	H	M	H	M
4/6	M	H	M	L	L	H	M
4/7	M	L	M	L	L	H	VH
4/8	M	H	H	M	H	H	M
4/9	M	L	M	M	L	M	M
4/10	M	H	M	M	M	H	MH
5/1	M	M	H	H	L	H	MH

							Output variable
5/2	H	H	L	M	H	H	L
5/3	M	H	M	H	M	M	M
5/4	H	H	M	H	M	H	MH
5/5	M	M	L	M	L	H	M
5/6	M	H	H	L	L	H	M
5/7	H	M	H	L	M	H	M
5/8	H	H	H	H	M	H	MH
5/9	M	L	M	H	L	M	VH
5/10	M	H	M	H	M	H	MH

PH: Personal Hygiene, CHF: Cold Holding of Food, HHF: Hot Holding of Food, PCC: Prevention of Cross Contamination, RIH: Raw Ingredients Handling

3.5 Microbial Analysis

Laboratory analyses were carried out on food samples collected from facilities to determine the presence of *Escherichia coli (*an indicator of poor hygiene) and *Staphylococcus aureus* (an indicator of poor personal hygiene). Food samples were collected by sampling from the Food Handlers who agreed to participate in the study. Each food sample was carefully transferred from food packages into a plain air-tight plastic bag using disposable hand gloves. At the laboratory, ten (10 g) of each food sample (rice, salad, meat) was weighed and put in a stomacher filtered bag and topped up to 100 g with sterile Peptone Saline Diluent solution. The mixture was pulsified and one (1) mL of the pulsified food mix was taken from the filtered side of the stomacher and serial dilutions prepared up to the sixth dilution and inoculated on the appropriate agar for microbial analysis.

3.5.1 Determination of *Escherichia coli*

The pour plate method was used where one (1) mL of the serially diluted samples from 10^{-2} to 10^{-5} were taken from each of the tubes and placed in the centre of already labelled sterile petri dishes and between 10 to 15 mL of previously prepared and Hichrome media (*Escherichia coli* agar) was poured to the side of each petri dish, covered, swirled and allowed to cool. The dishes were then upturned and incubated at different temperatures of 37 ºC and 44 ºC for 48 h (Nordic Committee on Food Analysis (NMKL), 1996). Colonies appearing bluish-green on agar plates were counted using the colony counter and the numbers calculated using the Equation 1;

$$\mathbf{N = \Sigma c/v\ (n)\ d} \text{……………… } \textbf{Equation 1}$$

Where **N** is the number of colonies, **Σc** is the total number of counts, **v** is the volume taken in ml, **n** is the dilutions and **d** is the dilution factor.

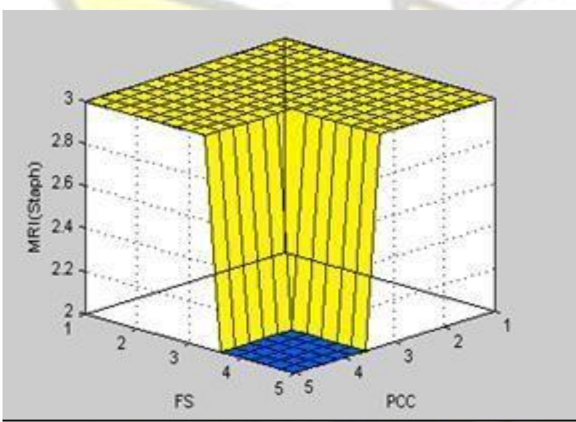
3.5.2 Determination of *Staphylococcus Aureus*

The pour plate method was used where one (1) mL of the serially diluted samples from 10^{-2} to 10^{-5} were taken from each of the tubes and placed in the centre of already labelled sterile petri dishes and between 10 to 15 mL of previously prepared and Manitol Salt agar (agar for *Staphylococcus aureus*) was poured to the side of each petri dish, covered, swirled and allowed to cool. The dishes were then upturned and incubated at different temperatures of 37 ºC and 44 ºC for 48 h Nordic Committee on Food Analysis (NMKL, 1996). Colonies appearing greyishwhite on agar plates were counted using the colony counter and the numbers calculated.

CHAPTER FOUR
RESULTS

4.1 Associated Risk Levels of Interactions of Food Handling Practices

The microbial risk index (MRI) key indicates risk levels with colours in descending order: red denotes *very high risk*, yellow denotes *high risk*, green denotes *minimum risk*, and blue denotes *low risk*. Risk of food contamination increases as knowledge and practices of PCC and FS deteriorate. Very low risk (blue) graduates into high risk (yellow) as knowledge and practices of PCC and FS deteriorate.



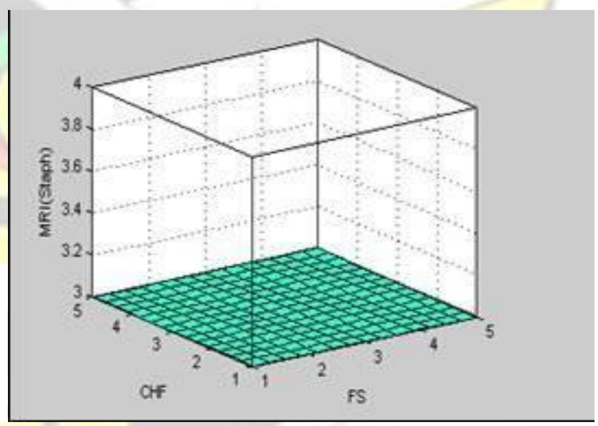
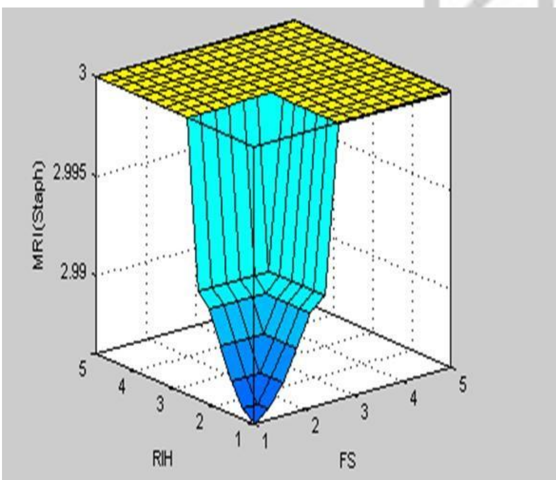


Figure 10: Contamination level with the effect of FS and PCC interactions

Figure 11: Contamination level with effect of CHF and FS interactions

Figure 10 illustrates the relationship between level of food safety, poor knowledge and practices of cross contamination prevention (PCC) and facility sanitation (FS).

Figure 11 illustrates minimum risk (green) for level of knowledge and practices in *cold holding of food* (CHF), and *facility sanitation* (FS) combination. Risk remains the same even when there was improvement in knowledge and practices of cold holding of food and facility sanitation.



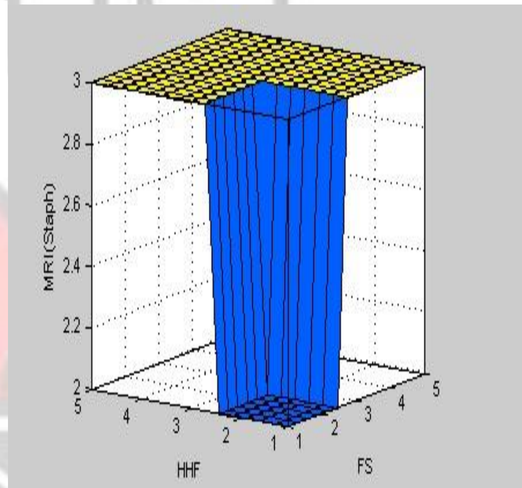
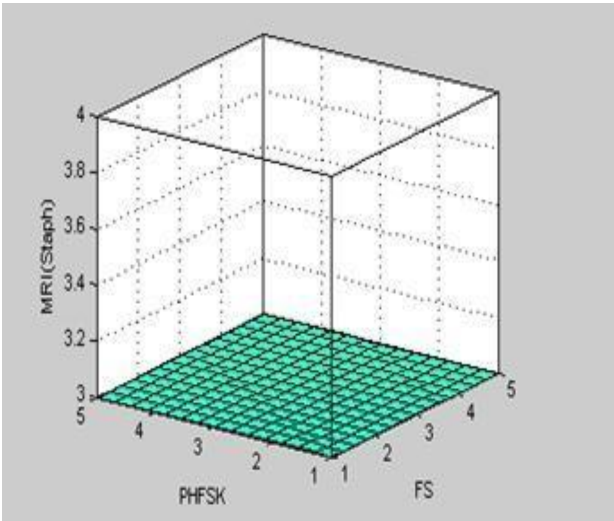


Figure 12: Contamination level with the effect of HHF and FS interactions

Figure 13: Contamination level with effect of RIH and FS interactions

Figure 12 however indicates a direct relationship between contamination levels and improved knowledge and practices in hot holding of food (HHF) and FS. Contamination risk increased from low (blue) to high risk (yellow) with corresponding MRI values of log 2cfu to log 3cfu.

Figure 13 showed same direct relationship, risk increased from low (blue) to minimum risk (green) and then to high risk (yellow) as knowledge and practices in FS and *raw ingredient handling* – RIH deteriorated. There was no significant effect of level of knowledge or practices on risk of microbial contamination of food in relation to RIH and FS as high or low knowledge and practices presented same risk level with MRI of log 3cfu



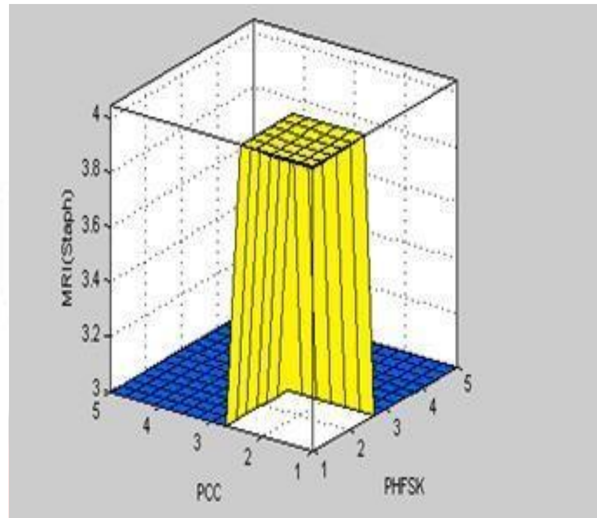


Figure 14: Contamination level with the effect of FS and PH interactions

Figure 15: Contamination level with effect of PCC and PH interactions

Figure 14 illustrates the presence of minimal risk regardless of improvement or deterioration in knowledge and practices (from 5-1 and from 1-5 respectively) of personal hygiene and facility sanitation.

Figure 15 illustrates the interaction of PH and PCC which gave low risk (blue) with MRI of log 3 cfu with improved PH and PCC (1 to 2.5), as PH and PCC deteriorated beyond 2.5 risk graduated to high risk (yellow) with MRI of log 4cfu. Risk thus accentuates with deteriorating PH and PCC. In figure 16 there was no difference in the level of risk of microbial contamination irrespective of improved or deteriorating PH and RIH. Risk level remained the same at log 3cfu regardless of improved or deteriorating level of knowledge or practices of personal hygiene and raw ingredient handling.

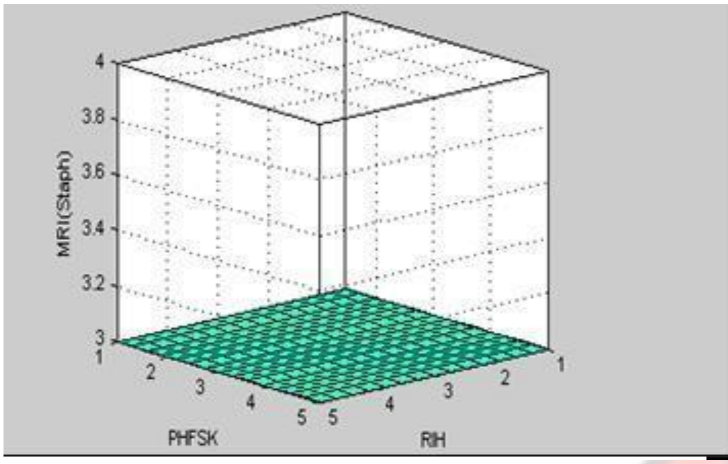


Figure 16: Contamination level with the effect of PH and RIH interactions

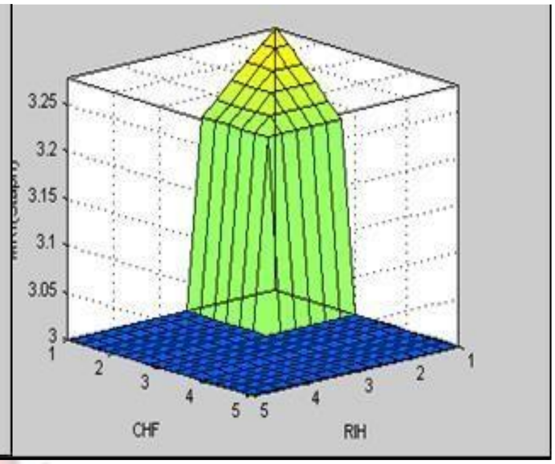


Figure 17: Contamination level with effect of CHF and RIH interactions

Figure 17. Risk of microbial contamination decreased from high risk (yellow) to minimum risk (green) and then to low risk (blue) as conditions of CHF and RIH improved. High, minimum, and low risk gave MRIs of log 3.3cfu, log 3.05cfu –log 3.25cfu, and log 3cfu respectively.

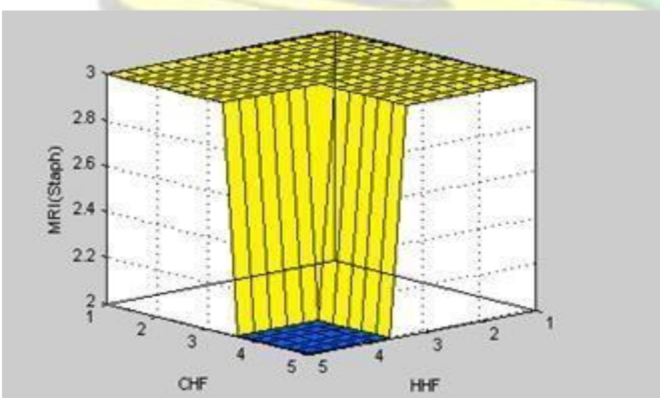


Figure 18: Contamination level with the effect of CHF and HHF interactions

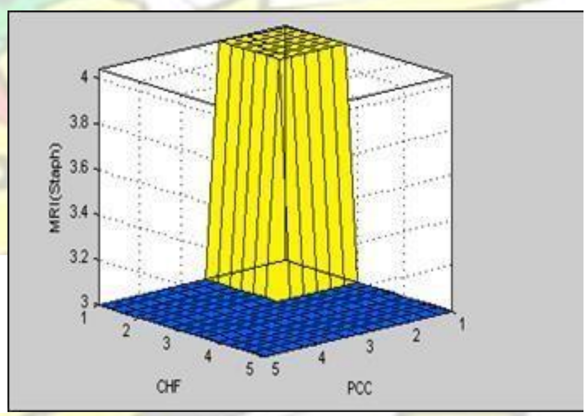
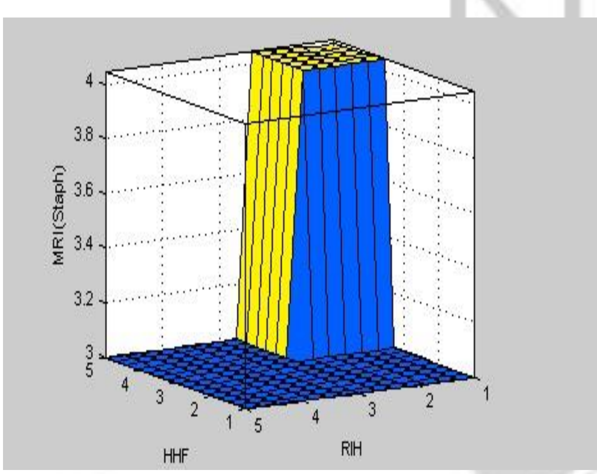


Figure 19: Contamination level with the effect of CHF and PCC interactions

Figure 18. Interaction of CHF and HHF gave low risk (blue) with MRI of log 2cfu with improved CHF and HHF (1 to 4), as CHF and HHF deteriorated beyond 4 risk escalated to high (yellow) with MRI of log 3cfu. Risk thus accentuates with deteriorating CHF and HHF.

Figure 19. PCC and CHF interaction indicates low risk (blue) with MRI of log 3cfu at improved PCC and CHF (1 -3) and high risk (yellow) with MRI of log 4cfu at deteriorating PCC and CHF (beyond 3).



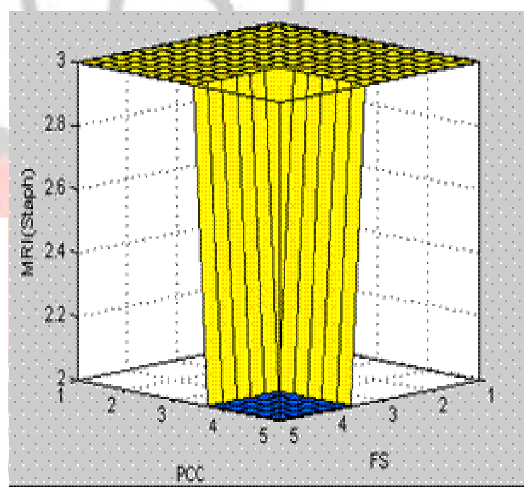


Figure 20: Contamination level with the effect o HHF and RIH interactions

Figure 21: Contamination level with effect of PCC and FS interactions

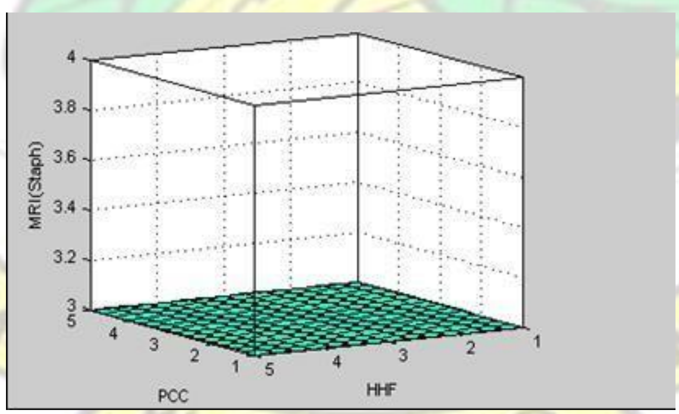


Figure 22: Contamination level with effect of PCC and HHF interaction

Figure 20 indicates a sharp rise in risk of contamination (log 4 cfu) as knowledge and practices deteriorated from 1 to 5 for HHF but improved for RIH. And inversely, as practices improved from 5 to 1 for HHF and deteriorated from 1 to 5 for RIH, risk was low as shown by blue colour. Figure 21. Similarly, PCC and FS showed same interaction as in fig J: low risk (blue) with MRI of log 2cfu at improved PCC and FS (1 -4) and high risk (yellow) with MRI of log 3cfu at deteriorating PCC and FS (beyond 4). Figure 22: Interaction of HHF and PCC during food handling did not affect risk, as there was same minimum risk level with MRI of log 3cfu irrespective of improved and unimproved knowledge and practices of HHF and PCC.

Interaction of PCC and RIH, CHF and PH, HHF and PH, and FS and PH by food handlers did not affect risk, as there was same minimum risk level with MRI of log 3cfu irrespective of improved and unimproved parameters as shown below in Figures 23, 24, 25 and 26.

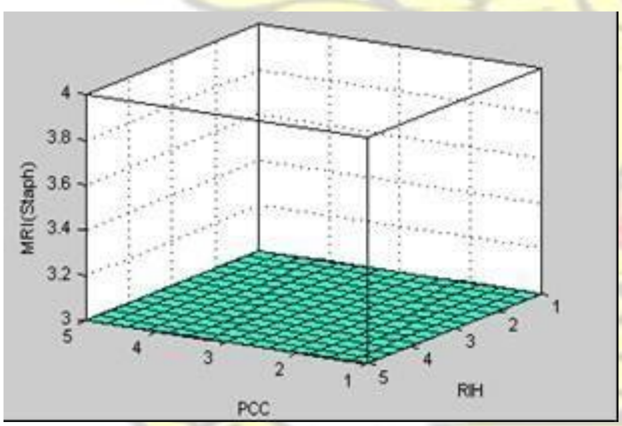


Figure 23: Contamination with the effect of PCC and RIH interactions

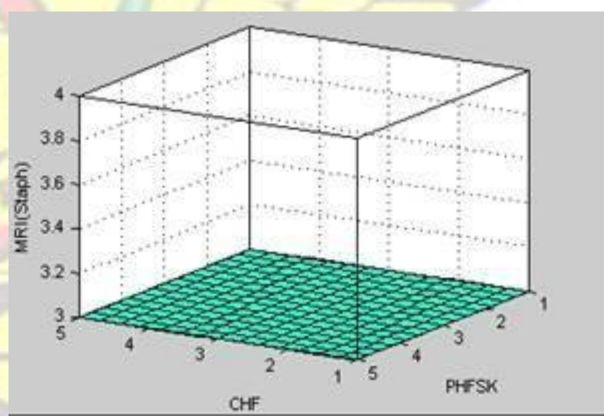


Figure 24: Contamination with the effect of CHF and PH interactions

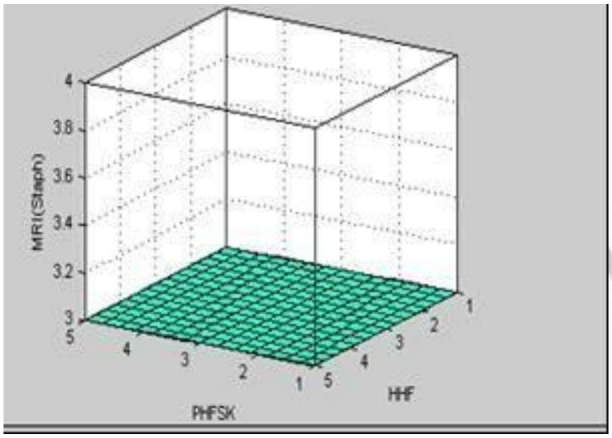


Figure 25: Contamination level with effect of PH and HHF

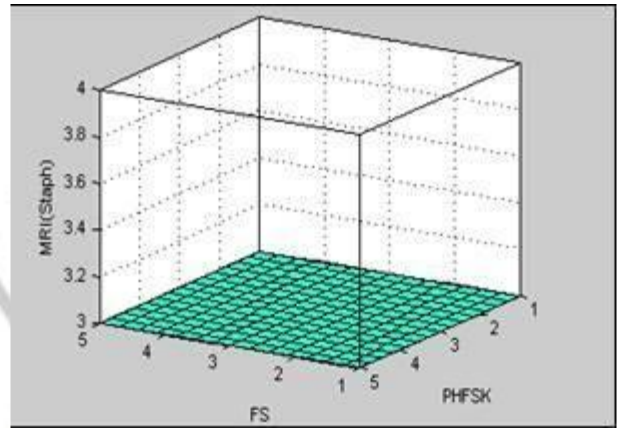


Figure 26: Contamination level with effect of PH and FS interactions

4.2 Microbial Contamination Levels of Sampled Foods

Table 3**: Results Indicating The Level of Microbial Contamination of Sampled Food**

Sample	*E. coli (cfu/g)*	*Staphylococcus Aureus (cfu/g)*	*Staphylococcus Aureus (log cfu/ml)*
	10^{-2}	10^{-2}	10^{-2}
Restaurant 1	0	1	3.0
Restaurant 2	0	88	4.9
Restaurant 3	0	158	5.2
Restaurant 4	0	35	4.6
Restaurant 5	1	1	3.0
Restaurant 6	0	1	3.0
Restaurant 7	5	46	4.7

Restaurant 8	0	1	3.0
Restaurant 9	0	0	0.0
Restaurant 10	0	11	1.0

cfu: colony forming unit

In Table 3, *Escherichia coli* was only detected in 10^{-2} dilution (dilution factor 2) for samples Restaurant 5 and Restaurant 7 (1 and 5 cfu/g respectively). *Staphylococcus aureus* was detected in all samples for 10^{-2} dilution except for Restaurant 9. Contamination was only detected in Restaurants 2, 3, 4, 7, 8 and R10 dilutions. Also, contamination was only in Restaurants 2, 3 and 4 in 10^{-4} dilution. 10^{-2} dilution was sensitive to detecting contamination; log cfu/mL of *Staphylococcus aureus* for 10^{-2} was therefore used as indicated.

4.3 Food Safety Practices and Training (Knowledge)

Table 4. Proportion of Food Handlers Exhibiting Various Levels of Personal Hygiene Practices

Practice Observed	High	Medium	Low
Requisite attire	9 (18%)	18 (36%)	23 (46%)
Requisite education/training	17 (34%)	18 (36%)	15 (30%)
Jewellery	32 (44%)	14 (28%)	14 (28%)
Medical screening	9 (18%)	19 (38%)	22 (44%)
Hand washing	25 (30%)	17 (34%)	8 (16%)
Same hand service and receipt of money	31 (62%)	10 (20%)	9 (18%)
Inappropriate body contacts	16 (32%)	23 (46%)	11 (22%)

High: Good level of personal hygiene practices, Medium: Fair level of personal hygiene practices, Low: Poor level of personal hygiene practices

Table 5**: Proportion of Food Handlers Exhibiting Various Levels of Facility Sanitation Practices**

Practice Observed	High	Medium	Low
Facility cleanliness and drainage	26 (52%)	9 (18%)	15 (30%)
Waste collection and disposal	14 (38%)	10 (20%)	21 (42%)
Frequency of waste disposal	22 (44%)	13 (26%)	15 (30%)
Nature of waste containers	16 (32%)	8 (16%)	26 (52%)
Utilization of waste management companies	27 (54%)	10 (20%)	13 (26%)
Availability of hand washing facilities	12 (24%)	9 (18%)	29 (58%)
Maintenance of waste containers and surroundings	19 (38%)	12 (24%)	19 (38%)
Protection of food from flies and dust during cooking	23 (24%)	12 (24%)	15 (30%)

High: Good level of facility sanitation practices, Medium: Fair level of facility sanitation practices, Low: Poor level of facility sanitation practices

Table 4 shows proportion of respondents exhibiting good (high), fair (medium) and poor (low) knowledge and practices on personal hygiene and food safety. Table 5 illustrates proportion of respondents exhibiting good (high), fair (medium) and poor (low) knowledge and practices on *facility sanitation.*

Table 6**: Proportion of Food Handlers Adhering to Various Forms of Cold Holding of Food**

Practice Observed	High	Medium	Low
Stocking and nature of Refrigerators	21 (42%)	12 (24%)	17 (34%)
Refrigerator temperature maintenance	15 (30%)	13 (26%)	22 (44%)
Adequate stacking discipline in refrigerator	11 (22%)	16 (32%)	23 (46%)
Temperature verified using a thermometer	3 (6%)	4 (8%)	43 (86%)
Use of appropriate storage containers	18 (36%)	16 (32%)	16 (32%)

High: Good level of adherence to cold temperature holding, Medium: Fair level of adherence to cold temperature holding, Low: Poor level of adherence to cold temperature holding

Table 6 Shows proportion of respondents exhibiting good (high), fair (medium) and poor (low) practices in Cold Holding of Food.

Table 7**: Proportion of Food Handlers Adhering to Various Forms of Hot Holding of Food**

Practice Observed	High	Medium	Low
Food served immediately after cooking	23 (46%)	14 (28%)	13 (26%)
Food held at 65^{+} degrees Celsius prior to serving	19 (38%)	12 (24%)	19 (38%)
Temperature measurements taken with thermometer	5 (10%)	4 (8%)	41 (32%)

High: Good level of adherence to hot temperature holding, Medium: Fair level of adherence to hot temperature holding, Low: Poor level of adherence to hot temperature holding

Table 8**: Proportion of Food Handlers Adhering to Prevention Cross Contamination**

Practice Observed	High	Medium	Low
Staff have specific assigned duties	14 (28%)	20 (40%)	16 (32%)
Separate chopping boards for various tasks	15 (30%)	19 (38%)	16 (32%)
Separate sinks for various activities	9 (18%)	9 (18%)	32 (64%)
System available cross usage of Utensils	10 (20%)	9 (18%)	31 (62%)

High: Good level of adherence to preventing cross contamination, Medium: Fair level of adherence to preventing cross contamination, Low: Poor level of adherence to preventing cross contamination

Table 9**: Proportion of Food Handlers Exhibiting Various Forms of Raw Ingredient Handling**

Practice Observed	High	Medium	Low
Have specific ingredients suppliers	36 (60%)	10 (20%)	10 (20%)
Use only approved food additives	23 (46%)	13 (26%)	14 (28%)
Rejects unwholesome food ingredients	36 (72%)	8 (16%)	6 (12%)
Raw materials received in cooking area	18 (36%)	13 (26%)	19 (38%)
Use first-in first-out (FIFO) principle for ingredients	40 (80%)	6 (12%)	4 (8%)

High: Good level of adherence to practicing raw ingredients handling, Medium: Fair level of adherence to practicing raw ingredients handling, Low: Poor level of adherence to practicing raw ingredients handling

Table 7 illustrates the proportion of respondents exhibiting good (high), fair (medium) and poor (low) practices for various parameters in hot holding of food. Table 8 illustrates the proportion of respondents exhibiting good (high), fair (medium) and poor (low) practices for the various parameters in prevention of cross contamination. Table 9 illustrates the proportion of respondents exhibiting good (high), fair (medium) and poor (low) practices for various parameters in raw ingredients handling.

CHAPTER FIVE
DISCUSSION

Although the research focused on assessing the levels of two bacteria of interest; *Escherichia coli* and *Staphylococcus aureus*, the resultant zero (0) level of *Escherichia coli* after microbial analysis indicated a no risk in the food sampled. However, this was not the case for *Staphylococcus aureus* as levels went up as high as 240 coliform forming units (cfu). Studies have shown that even if heat treatment is able to eliminate the bacteria, there are often the risks of *Staphylococcus* Enterotoxins (SE) which may cause *Staphylococcus* Food Poisoning (SFP) at levels as low as 20-100ng (Radstrom *et al.*, 2011).

5.1 Food Contamination, Food Safety and Hygiene Practices among Food Handlers

Food-borne diseases are of major concern worldwide. They mostly result from food contamination. *Staphylococcus aureus* is a microbe that can be readily avoided by heat treatment. Nevertheless, it remains a major cause of food borne disease because it contaminates food products during preparation and processing (Le Loir *et al.,* 2003). *S. aureus* is found in the nostrils, and on the skin and hair of warm-blooded animals. Its presence in food is a marker of inadequate food hygiene and safety practices (Le Loir *et al.,* 2003).

By inference, there was evidence of inadequate food hygiene and safety practices among respondents as all food samples were contaminated by *Staphylococcus aureus.* This could be due to fewer numbers of respondents (<50%) practicing good (high) food temperature management (*hot holding of food)* because*:* Food served immediately after cooking, food held at 65 ^{o}C Celsius prior to serving, and temperature measurements taken with thermometer stood at 46%, 38%, and 10% respectively for good (high) practices.

Similarly, fewer number of respondents (<50%) practiced good (high) food temperature management (cold *holding of food)* through these activities*:* stocking and nature of refrigerators, refrigerator temperature maintenance, adequate stacking discipline in refrigerator, temperature verification using a thermometer and the use of appropriate storage containers in facilities under study were 42%, 30%, 22%, 6%, and 36% respectively. The poor temperature management could have led to the levels of *Staphylococcus aureus* present in food samples since *Staphylococcus aureus* is able to grow in a wide range of temperatures (7 °C to 48.5 °C) with an optimum of 30 to 37°C) (Schmitt et al., 1990).

Aside temperature, the microbes' presence could be due to cross contamination as very few respondents (≤ 30%) exhibited good (high) practices in preventing cross contamination. This is very much evident in the fact that 68% of respondents were engaged in inappropriate body contacts (such as nose, skin and hair). In addition, majority of staff (72%) were engage in multitasking, 60% used common chopping boards for various foods, and 82% used a common sink for various activities, and 80% used common utensils for preparation of various foods. All these practices serve as a catalyst for cross contamination. Research findings are being confirmed in other literatures (Jevšnik *et al.*, 2013; Soares *et al.*, 2012) which identified these same parameters as contributing to cross contamination.

In addition to temperature management and cross contamination, personal and environmental (facility environment) hygiene count in a great deal in affecting contamination levels of processed food. Large number of respondents exhibited poor personal hygiene practices as we had proportion of respondents using inappropriate dressing (attire), jewellery, washing of hands inappropriately, not taking appropriate medical screening, and not having requisite training to be 82%, 66%, 70%, 82%, and 66% respectively. These inappropriate practices could contribute partly to the contamination levels. Our findings is in consonance with various literature that victimized these same parameters for contributing to food contamination (Jevšnik *et al.*, 2013; Lelieveld *et al.*, 2014; Soares *et al.*, 2012).

Similarly, environment or food facility environment contributes largely to the safety of the food being processed (Lelieveld *et al.*, 2014). Our studies indicate that the proportion of respondents with Good facility cleanliness and drainage, waste collection and disposal, waste disposal frequency, waste containers, utilization of waste management companies, hand washing facilities, maintenance of waste containers and surroundings, protection of food from flies and dust during cooking ranged between 24% and 52%. This portrays that majority of respondents, with the exception *facility cleanliness and drainage*, had inadequate practices for all parameters under facility sanitation. These inadequacies in practices contribute to the observed contamination levels as being supported by other studies (Agustina *et al.,* 2013; Nyenje *et al.,* 2012).

5.2 Association between Food Handling Behaviour and Risk of Food Contamination

In our study, all the parameters have been implicated one way or the other for food contamination as well as in literature. Information on risk assessment is however limited, this section of discussion looks at qualitative risk assessment among food handlers in Tamale Metropolis to enable easy regulation and decision making by regulatory authorities. We specifically looked at the association between food handling behaviour and risk of food contamination by modelling the interactions of the various food handling behaviours and risk of contamination.

In modelling poor knowledge and practices of cross contamination prevention (PCC) and facility sanitation (FS). It was observed that as PCC and FS improves, risk decreases: low risk (blue) with MRI of log 2cfu at improved PCC and FS (Figure 10) and high risk (yellow) with MRI of log 3cfu at deteriorating PCC and FS (beyond log 4cfu) **.**This confirms the fact that cross contamination as well as facility sanitation play major roles in What is outstanding is that risk does not move gradually, from low risk, it escalates to high risk as practices deteriorate the safety of processed food (Agustina *et al.,* 2013; Nyenje *et al.,* 2012). Similar observation was found in the interaction of PH and PCC as low risk (blue) with MRI of log 3cfu is obtained with improved PH and PCC (1 to 2.5), as PH and PCC deteriorated beyond 2.5 risk graduated to high risk (yellow) with MRI of log 4cfu. Risk thus accentuates with deteriorating PH and PCC (Figure 15).

In addition, temperature is largely victimized for food contamination (Garden-Robinson, 2012; USDA, 2016), it was observed in our study that temperature management was a key determinant of associated risk as illustrated in Figures 18, 20, 22, and 25. Figure 18 indicates a direct relationship between contamination levels and improved knowledge and practices in *hot holding of food* (HHF) and FS. Contamination risk increased from low (blue) to high risk (yellow) with corresponding MRI values of log 2cfu to log 3cfu. Interaction of CHF and HHF gave low risk (blue) with MRI of log 2cfu with improved CHF and HHF (1 to 4), as CHF and HHF deteriorated beyond 4 risk escalated to high risk (yellow) with MRI of log 3cfu. Risk thus accentuates with deteriorating CHF and HHF (Figure 18). PCC and CHF interaction indicates low risk (blue) with MRI of log 3cfu at improved PCC and CHF (1 -3) and high risk (yellow) with MRI of 4cfu at deteriorating PCC and CHF (beyond log 3cfu) Figure 19. HHF and RIH showed similar interaction as in figure 19: low risk (blue) with MRI of log 3cfu at improved

HHF and RIH (1 -4) and high risk (yellow) with MRI of log 4cfu at deteriorating HHF and RIH (beyond log 4cfu in Figure 25).

Contrary to the observation in the PCC and FS interaction, it was also observed that some interactions gave minimal risk irrespective of sanitary practices status: Interaction of PCC and RIH, CHF and PH, HHF and PH, and FS and PH by food handlers did not affect risk, as there was same minimum risk level with MRI of log 3cfu irrespective of improved or unimproved parameters in Figures 15, 19, 23, 25 and 26. Similarly interaction of HHF and PCC by food handlers did not affect risk, as there was same minimum risk level with MRI of log 3cfu irrespective of improved and unimproved HHF and PCC (Figure 22). Same observations were detected in PH and RIH interaction (Figure 16), and Personal hygiene (PH) and FS interaction (Figure 14). This suggests that although all interactions pose some level of risk, combinations of certain interactions pose a greater risk than others.

Aside the above, an interesting observation was found which is contrary to risk being either constant or escalates from low to high subject to improvement or deteriorations in interactions. This observation is gradual. Risk graduated gradually: risk of microbial contamination increased from low risk (blue) to minimum risk (green) and then to high risk (yellow) as conditions of CHF and RIH deteriorate. Low, minimum, and high risk gave MRIs of log 3cfu, log 3.05-log 3.25cfu, and log 3.3cfu respectively (Figure 17). Implication of RIH and CHF as posing food contamination in this study is in consonance with some other research (Ifeadike *et al.*, 2014).

Attention therefore needs to be paid to RIH and CHF in monitoring food handlers' activities. Additionally, it was observed that temperature management was a key determinant of associated risk (as shown in Figures 18, 20, 22, and 25); Contrary to gradual rise in risk for CHF and RIH interaction, risk accentuates with deteriorating CHF and HHF; HHF and FS; PCC and CHF; and HHF and RIH. Microbial load is however higher (log 4cfu) in the latter two than the former two (log 3cfu).

In General, for the purposes of monitoring and decision making, certain interactions were found to give high risk which escalates with deteriorating factors, however at the same risk, some interactions had higher microbial loads than others. It would therefore be prudent to classify these two as *severe risk* (one with higher microbial loads) and *very high risk* for the other.

Finally, *high risk* should be labelled as risk that rises gradually (CHF and RIH interaction).

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 Conclusion

Inadequate food hygiene and safety practices among our respondents were observed and all food samples were contaminated by *Staphylococcus aureus*. Contamination is attributed to fewer respondents (<50%) practicing good temperature management (*hot and cold holding of food).* Cross contamination was also victimized as we had very few respondents ($\leq$ 30%) exhibiting good practices in preventing cross contamination. In addition, personal and environmental (facility) hygiene also contributed to the high levels of contamination.

Fuzzy modelling on the other hand showed that all interactions pose some level of risk; combinations of certain interactions however pose a greater risk than others. PCC and FS, PH and PCC interactions do not pose a gradual risk but an escalating risk. This implies that cross contamination of food regardless of initial heat treatment or other food handling methods is a major cause of food contamination and hence an important food risk factor.

Aside, when there is poor prevention of cross contamination in combination with certain food handling methods, the risk of contamination is higher as shown in the interaction of PH and PCC which resulted in a given higher microbial load of log 4cfu than PCC and FS (log 3cfu).

In addition, temperature management proved to be vital in controlling food contamination because results from the study indicated either low risk of contamination or a gradual rise in risk in cases where there was interaction of HHF/CHF and other food risk factors.

It can however, be concluded that *Staphylococcus aureus* contamination of food samples resulted mostly from cross-contamination due to poor personal hygiene of food handlers or inappropriate sanitary conditions of food service establishments.

6.1 Recommendations

Based on findings it’s recommended that:

- Regulatory bodies in the field of food should role out regular and mandatory food hygiene and safety education programs within the Tamale metropolis on quarterly basis with emphasis on prevention of cross contamination and personal hygiene practices
- Monitoring activities should be categorized and flagged:
  - Facilities with one or more deteriorating combinations of PH and PCC; PCC and CHF; and HHF and RIH should be flagged red (severe risk).
  - One or more deteriorating combinations of HHF and FS; HHF and CHF; and PCC and FS should be flagged yellow (very high risk).
  - Deteriorating combinations of CHF and RIH should be flagged green (high risk).
  - Any other combination should be flagged blue (medium risk).
- Priority for monitoring and follow ups should be based on the severity of risk.
- Lastly, further research should be conducted on a larger scale in the other nine cities of Ghana to confirm the applicability of this research conclusion or otherwise.

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APPENDICES

A CHECKLIST TO DETERMINE FOOD HANDLERS KNOWLEDGE AND FOOD SAFETY PRACTICES IN RESTAURANTS

PERSONAL HYGIENE PRACTICES AND FOOD SAFETY KNOWLEDGE

SECTION ONE: PERSONNEL HYGIENE AND KNOWLEDGE IN FOOD HANDLING

QUESTIONS/OBSERVATIONS	HIGH MED LOW
Personnel properly uniformed with headgear and Appropriate headgear	....
Staff have the requisite academic qualification or Have received appropriate training	....
Personnel medically examined for communicable	
Diseases such as typhoid, hepatitis A among others	....
Staffs wash hands before serving food	....
Vendors use the same hand to serve food and receive Money	....

Personnel rub eyes, nose, and ears while handling food ....

SECTION TWO: FACILITY SANITATION

Facility appears clean with good drainage ....
Waste bins available in cooking area ....
Waste bins emptied as often as possible ....
Fitting lids for waste bins provided ....
Waste collected by waste management company ....
Hand washing stations available and adequately Equipped ....
Proper maintenance of waste bin surroundings ....
Food adequately protected from flies and dust during Cooking ....

SECTION THREE: COLD HOLDING OF FOOD

Refrigerators not rusty, overloaded and properly Maintained ....
Appropriate refrigerator temperatures maintained ....
Adequate stacking discipline in refrigerator ....

Temperature verified using a thermometer	....
Foods in cold storage in appropriate containers that are Covered	....

SECTION FOUR: HOT HOLDING OF FOOD

Food is served immediately after cooking	....
Food is held at appropriate temperatures prior To serving (65 degrees Celsius or more)	....
Temperature measurements done with a thermometer	....

SECTION FIVE: PREVENTING CROSS CONTAMINATION

Staffs have specific assigned duties	....
Separate chopping boards used for raw and ready-to-eat Foods	....
Sinks for kitchen activities not used for other activities Such as washing utensils	....
System available for the control of the use of cooking Utensils to prevent cross contamination	....

SECTION SIX: RAW INGREDIENT AQUISITION

Purchases food ingredients from specific suppliers	....
Use only approved food additives	....
Expired or unwholesome food ingredients rejected	....
Raw materials received in cooking area	....
Ingredients stored using first-in-first-out (FIFO) Principle	....