POST HARVEST HANDLING KNOWLEDGE AND PRACTICES AMONG FOOD HANDLERS UNDER SCHOOL MEALS PROGRAMME AND INTAKE OF AFLATOXIN AND FUMONISIN IN SALIMA DISTRICT, MALAWI

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This thesis is my original work and has not been submitted for award of a degree in any other University.

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Dedication

This Thesis is dedicated to the Almighty God for the success of the research project. It is also dedicated to my beloved family for their prayer, support, encouragement and enduring the hardships during my study period.

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List of abbreviations and acronyms

CSB	Corn Soya Blend
SMP	School Meals Programme
WPF	World Food Program
FAO	Food and Agriculture Organization
HGSMP	Home-grown school meal programme
ECD	Early Childhood Development Centers
THR	Take Home Rations
DNHA	Department of Nutrition HIV and AIDs
IARC	International Agency for Research on Cancer
FISP	Farm Input Subsidy Programme
HPLC	High-Performance Liquid Chromatography
PICS	Purdue Improved Crop Storage

General abstract

The natural occurrence of molds in foodstuffs produces mycotoxins. Aflatoxins and fumonisins are the most common mycotoxins in foods. Exposure to mycotoxins contaminated foods pose serious threats to human health. The healthy problems associated with exposure to mycotoxins such as cancer, immunosuppression, nutrient deficiency, impaired growth, respiratory problems, diarrhea and abdominal pain among young children still remain a public health concern causing morbidity and mortality in Malawi. The study was carried out to assess post-harvest handling knowledge and practices among food handlers on toxigenic molds contamination in School Meals Programme and the extent of exposure of aflatoxins and fumonisins for school children consuming maize based school meals in selected Primary schools in Salima District, Central Malawi. The study involved 124 food handlers and 496 school children through administering structured questionnaires. These were sampled from 31 Primary Schools among those implementing Home-grown school meals programme. Thirty (30) maize-based porridge samples were randomly collected and tested for aflatoxins and fumonisins. Aflatoxins and fumonisins levels were determined using Reveal Q+ Kits test method. Data was collected and analyzed using descriptive statistics to summarise survey and laboratory results, while probabilistic modelling Mont Carlo simulation was used to determine the intake of the mycotoxins.

Results showed that 80% of food handlers had high knowledge of causes of toxigenic molds in maize foods, 47% had moderate knowledge of health effects of toxigenic molds, and 50% had moderate knowledge of control measures of toxigenic molds in maize foods. Eighty-five percent (85%) were not aware of mycotoxins in maize foods. The results also showed that 60% of food handlers practiced poor postharvest handling of maize based foods during transportation, storage and processing in schools. Furthermore, the results showed no significant differences ($P > 0.05$) in knowledge of toxigenic molds in maize-based foods and postharvest handling practices across demographic regions among food handlers.

The maize-based porridge consumed in schools had high levels of aflatoxins (2.13 – 33.37 µg/kg) and fumonisins (<0.3 - 1.0 mg/kg). The mean intake of aflatoxins (2 ng/Kg body weight per day) and fumonisins (6 ng/Kg body weight per day) were above the recommended acceptable levels of 0.017 ng/kg bwt/day for children and 2.0 µg/Kg bwt/day according to EFSA (2007) and JECFA (2008), respectively.

The study concluded that majority of food handlers had high knowledge of toxigenic molds in maize foods, however they practiced poor post-harvest handling of maize foods in School Meals Programme. The poor post-harvest handling practice of maize foods among food handlers might contribute to high levels of mycotoxins contamination in maize-based diet and high exposure of school children to aflatoxins and fumonisins from high consumption levels of maize based porridge in schools. There is need for appropriate measures to mitigate mycotoxins exposure to school children under School Meals Programme.

CHAPTER ONE: INTRODUCTION

1.1 Background

Nearly 368 million children in developed and developing countries are provided with free food through the School Meals Programme (SMP) which are implemented by many governments (FAO and WFP, 2018). Several benefits have been reported from the School Meals Programme which include increased leaners enrolments and improved nutrition (WFP, 2013). However, the programme is reported to be affected by foodborne illnesses which negatively impact on the health, education, growth and development of the school going children (Adolf and Aziz, 2012; Nhlapo *et al.,* 2014; Ababio *et al.,* 2016). School Meals Programme was introduced and adopted by many governments as one of social safety net programmes for combating poverty issues, motivate school enrolment and increase learner's performance (Zenebe *et al.,* 2018).

In Malawi, School Meals Programme includes provision of mid-morning porridge of Corn-Soya Blend (CSB), Take Home Rations (THRs) of maize or its cash equivalent, primarily to orphans in higher grades (Standard 5 to 8), and diverse locally sourced foods under Home-grown school programme (HGSP) (WFP, 2018b). Maize also known as Corn is one of the staple foods and ingredients for the school meals programme. Studies have however reported that maize and processed maize-based foods are prone to mycotoxins (Misihairabgwi *et al.,* 2017). The most common mycotoxins which have been reported in maize foods are aflatoxins and fumonisins which are respectively caused by species of *Aspergillus* and *Fusarium*. The most common types of aflatoxins and fumonisins in food crops include aflatoxins B1, aflatoxins B2, aflatoxins G1 and aflatoxins G2, and fumonisins B1 and fumonisins B2. Aflatoxins B1 and fumonisins B1 have been reported to be the most toxic and carcinogenic to human (IARC, 2012).

Several researchers have reported that aflatoxins and fumonisins levels in maize foods from Southern Africa including Malawi is high and exceed the maximum limits sets by regularly bodies (Mwalwayo and Thole, 2016; Probst *et al.,* 2014). The poor post-harvest handling of foodstuffs like maize, highly contributes to mycotoxins production (Eshiett *et al.,* 2013). In addition, inadequate knowledge on mycotoxins contamination in foodstuffs have been reported to increase health risk to human and animals (Negash, 2018).

Co-exposure to aflatoxins and fumonisins cause serious acute and chronic toxicity in humans (Alshannaq and Yu, 2017) which includes cancer, immunosuppression, impaired growth, respiratory problems, diarrhea, abdominal pain, and progression of HIV to AIDS (Gong *et al.*, 2016; Kowalska *et al.,* 2017; Kimanya, 2015). Children are the most at risk of dietary mycotoxins exposure compared to older people (Azziz-Baumgartne, 2005), due to their low developed immune system, increased food demand and uncontrolled diet (Gong et al., 2016). In Kenya, it was reported that 150 school aged going children died and about 500 children were hospitalized due to exposure to aflatoxins from consumption of aflatoxins contaminated foods (Angel, 2018).

Although studies have reported that exposure to aflatoxins and fumonisins is high in countries that largely consume maize foods (Misihairabgwi *et al.,* 2017 ; Kimanya *et al.,* 2008), there is limited information on dietary exposure to mycotoxin in Malawi. Therefore, the study was developed to assess the post-harvest handling knowledge and practices of food handlers on toxigenic molds contaminations in School Meals Programme and intake levels of aflatoxin and fumonisin among school children in Salima district of Malawi.

1.2 Statement of the problem

Mycotoxins (aflatoxins and fumonisins) are global food safety concern and children are the most at risk of mycotoxins exposure in developing countries (WHO, 2015). Food Born illnesses in schools is an international issue which negatively impact on health, education, growth and development of school going children (Adolf and Aziz, 2012; Nhlapo *et al.,* 2014; Ababio *et al.*, 2016).

The healthy problems associated with acute and chronic exposure to aflatoxin and fumonisins such as cancer, immunosuppression, nutrient deficiency, impaired growth (stunting), respiratory problems, diarrhea and abdominal pain among young children still remain a public health concern causing morbidity and mortality in developing countries including Malawi (Gong *et al.*, 2016; Liu and Wu, 2010; Oot *et al.,* 2016; DNHA, 2018). Children are more susceptible to mycotoxins effects than older people (Azziz-Baumgartne, 2005; CDC, 2004; Okoth and Ohingo, 2004) due to their low developed immune system, increased food demand and uncontrolled diet (Gong *et al.*, 2016). Maize, a major staple food in Malawi is prone to aflatoxin and fumonisins contamination (Mwalwayo and Thole, 2016). Despite increased usage of maize based meals in School Meals Programme, there is limited information on the extent of aflatoxins and fumonisins occurrence in diets and hence no knowledge of levels of intake in Salima District, Central Malawi.

1.3 Justification

Providing safe food to school going children is one of the major concern by many nations and stakeholders in developing countries including Malawi, as this improve health, education, growth and future well-being of children (DNHA, 2018; Oranusi *et al.*, 2007). This study will create awareness and influence decision makers to develop strategies and/or guidelines that will prevent school going children to mycotoxins exposure. This can potentially protect the health of school children and enable them to learn and significantly contribute to the economic growth and development of Malawi.

1.4 Objectives

1.4.1 Overall objective

To assess post-harvest handling knowledge and practices among food handlers on toxigenic molds contamination in School Meals Programme and the extent of exposure to aflatoxins and fumonisins for school children consuming maize based diets in Salima district, Central Malawi.

1.4.2 Specific objectives

I. To establish postharvest handling knowledge and practices among food handlers on toxigenic molds contaminations in maize-based diets under home-grown school meals programme in Salima district.

II. To determine levels of exposure to aflatoxins and fumonisins through consumption of maize-base based diet in schools under home-grown school meals programme in Salima district.

1.5 Hypothesis

I. Food handlers under home-grown school meals programme are not knowledgeable of toxigenic molds, and they practice poor postharvest handling practices of maize foods

II. Exposure of school children to aflatoxins and fumonisins under home-grown school meals programme are below international statutory standards.

CHAPTER TWO: LITERATURE REVIEW

2.0 Overview of School Meals Programme

School Meals Programme (SMP) was introduced as one of the social safety net programmes for promoting education and health of poor resource children in developing countries (Zenebe *et al.*, 2018). Many countries are implementing School Meals Programmes in order to deal with issues of poverty, increase school enrolments and improve leaners performance (Akanbi, 2013). Nearly 37 million school children in Brazil (Santana *et al.*,2009), and 2.7 million in Italy are fed under School Meals Programme (Marzono and Balzaretti, 2013). An estimated 1 million learners under basic education in Ghana are also given daily meals through School Feeding Programmes (Afoakwa, 2005). Despite these efforts by many countries, increased reports of foodborne infections affect the programmes (Ababio *et al.*, 2016).

2.1.1 School meals programme in Malawi

Approximately, 954,669 pupils in primary schools benefit from SMP of which 94,400 learners are covered under home Grown School Meal Programme (WFP, 2018b). In Malawi, School Meals Programme was introduced in 1999 in respond to concerns of rural people on poor health, poor nutrition and poverty which were barriers to access primary schools in rural areas despite universal free primary education (WFP, 2009; DNHA, 2007).

The School Meal Programme (SMP) constitutes daily Corn-Soya blend porridge which benefits all learners with emphasis on under five children in Early Childhood Development (ECD) Centers, the Take Home Rations (THRs) which primarily targets orphan girls and boys in upper grades as an incentive to keep them in schools and HGSP which provides meals to all learners at a particular schools (WFP, 2018b). Leaners are given a mid-morning Corn Soya Blend (CSB) porridge of about 100 g which was estimated to provide 22% of daily energy requirement for a primary school-going children (Burbano and Gelli, 2009).

In home-grown school meals programme (HGSMP), Schools and Farmer Based Organizations Sign contact agreement to procure and supply locally produced foods to schools. Many governments are encouraging locally sourcing of food in order to increase agricultural productivity and economic benefits of rural producers (FAO and WFP, 2018). In addition, home-grown school programmes is among the strategies for achieving Sustainable Development Goals (SDGs) to end poverty and hunger.

2.2 Maize production and consumption in Malawi

Over 80 percent of farmers in Malawi grow maize as stable food crop and it constitutes main diet for Malawian families (FAO, 2015; Mazunda and Droppelmann, 2012). Malawi has an average Maize production of 3.2 million tonnes per year (FAO, 2017). According to Mazunda and Droppelmann (2012), maize production is associated with food security in Malawi and it accounts for over 60 percent of the total food production. In Malawi, maize is commonly processed into flour which is prepared and eaten as a thin porridge or a thick porridge, nsima (ugali), which is served with other dishes such vegetables, legumes and very occasionally with fish and meat. Maize is also processed and blended with other cereals and legumes in making products such as local beverages (Thobwa). In Schools, maize is prepared as thin porridge, thick porridge and Corn Soya Blend porridge (WFP, 2018b).

The Government of Malawi is supporting increased maize production through Farm Input Subsidy programme (FISP) since 2005, which is relatively being affected by natural disasters such as Fall Armyworms attack and frequent droughts. Several development partners and Non-Governmental Organizations (NGOs) such as World Food Programme, Food and Agriculture Organization, Merry Meals, and Foundation for Irrigation and Sustainable Development (FISD) joined government effort in supporting SMP with inputs and agricultural facilities in order to increase maize food (WFP, 2018b) for school children consumption.

2.3 Occurrence and exposure to aflatoxins and fumonisins

Aflatoxins and Fumonisins are a group of mycotoxins that naturally occur and contaminate foodstuffs causing health implications to humans and animals (Vallabhbhai *et al.*, 2015).

2.3.1 Aflatoxins

These are natural toxic substances commonly produced by mold species; *Aspergillus flavus* and *Aspergillus parasiticus* (WHO, 2018a). Several types of aflatoxins have been documented which include; aflatoxins B1, aflatoxins B2, aflatoxins G1, aflatoxins G2, aflatoxins M1, aflatoxins M2 (Figure 2.1). *Aspergillus flavus* are most recognized molds causing aflatoxicosis in both human foods and animal feeds (IARC, 2012). It produces AFB_1 and AFB_2 which mostly contaminate commodities such as maize (corn). Another important producer of aflatoxin is *Aspergillus parasiticus* which produce aflatoxins B1, B2, G1 and G2 commonly occur in produce such as maize and nuts (Horn, 2003). AFB_1 is the most often present in contaminated food samples. Aflatoxins M1 and M2 which are hyroxylated metabolites of aflatoxins B1 and B2 respectively are also common in human breast milk and animal milk through intake of aflatoxins contaminated foodstuffs and feeds (WHO, 2018;Magoha *et al.*, 2014).

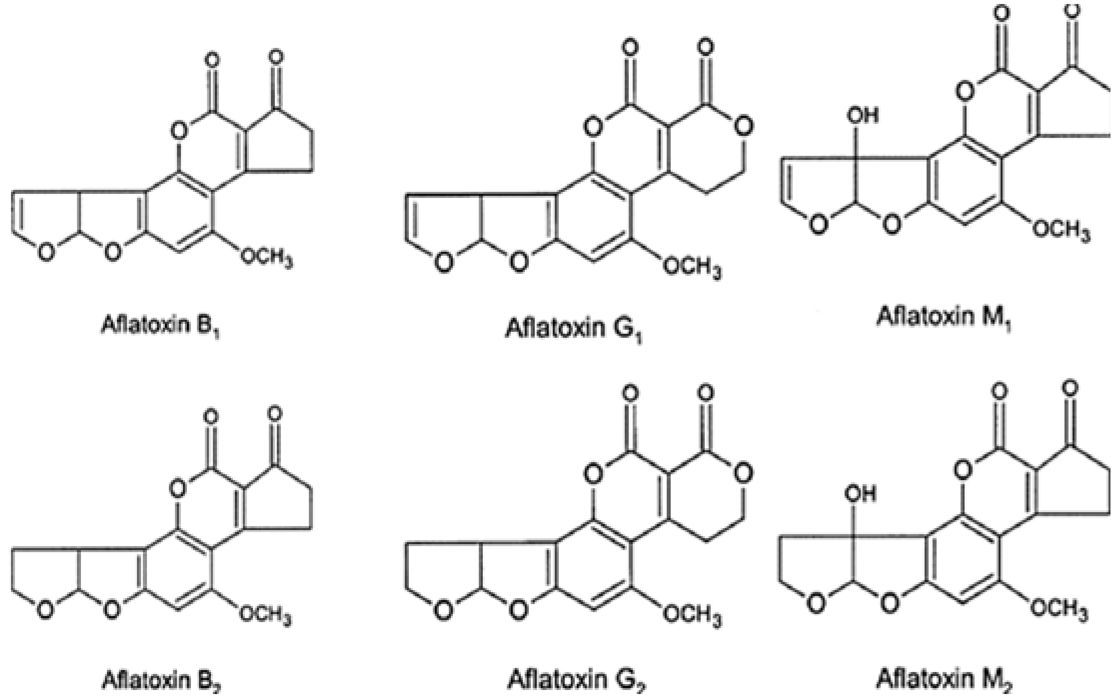

Figure 2.1: Chemical structures of aflatoxins (Jallow, 2015)

Aflavus grow very well in hot and dry conditions with temperature ranging from 28–30˚C that is also where fungus rapidly colonize and produce aflatoxins (Kiran *et al.*, 2014). Production of aflatoxins may occur at any stage in food chain which include in field, during harvesting and post-harvest operations like transportation, handling and storage (Vallabhbhai *et al.*, 2015). Aflatoxin are common and widespread in Africa countries because of the favorable climate and agricultural produce storage (Gnonlonfin *et al.,* 2013). Most parts of Sub-Sahara Africa experience tropical and sub-tropical climates, hot and dry humid conditions and frequent dry spells which favors aflatoxins and mycotoxins production (Mboya and Kolanisi, 2014; Darwish *et al.,* 2014). Foodstuffs such as maize are often contaminated with mycotoxins such as aflatoxins due to hot and humid conditions, inadequate knowledge of the risk and absence of regulatory enforcements (Gong *et al.,* 2016).

2.3.2 Prevalence of aflatoxins contamination worldwide

The prevalence of aflatoxin contamination is commonly high in stable food crops which includes maize, nuts and their derived products (Misihairabgwi *et al.*, 2017). Nearly 25% of food crops are destroyed across the world every year due to spoilage by aflatoxins (Choudhary and Kumari, 2010). This is mostly common to African countries due to lack of industrialization on farm and post-harvest practices that would reduce mycotoxins exposure. According to Choudhary, donation and supply of mycotoxin contaminated commodities and food products during food insecurity due to natural disasters and economic variability also exacerbate the prevalence. World Food Programme (WFP) the renowned major supporter of school meals programmes in Africa including Malawi, had reduced the quantities of maize purchased locally in Africa including Malawi since 2007 due to high aflatoxin contamination maize produced by smallholder farmers (IFPRI, 2013).

2.3.3 Prevalence of aflatoxin contamination in Malawi

The research that was carried on maize and their derived products confirmed the prevalence of aflatoxins contamination in Malawi (Matumba *et al.*, 2015; Mwalwayo and Thole, 2016). The aflatoxins concentration levels were reported ranging from 2 to 150 µg/Kg exceeding the regulatory limits levels of 10 µg/kg in Malawi (MBS, 2019 – unpublished). A study conducted in Mpingu EPA in Malawi had detected aflatoxin B1 in 45.3% of the maize samples of which 12.3% were above the regulatory limits (Matumba *et al.,* 2009). Aflatoxin levels were also found in 75% of the maize based products processed in Malawi than the imported baby cereal food products, and their quantifications surpassed the European Union maximum limit of 0.1 mg/kg for infant foods (Matumba *et al.,* 2004). Furthermore, aflatoxins were identified in traditional brewed maize based beers which ranged from 1898 to 1404 mg/kg which also exceeded the regulatory limit levels (Matumba *et al.,* 2014).

2.4 Aflatoxins and Food Safety Systems

The food safety systems such as monitoring and enforcement of regulations of aflatoxins in most sub-Sahara Africa region including Malawi are generally weak with poor collaboration and coordination, putting health of consumers at risks (FAO, 2015; Matumba *et al.,* 2015; Morse *et al.,* 2018). Food safety is a great issue causing serious outbreaks in most developing. Foodborne diseases (FBD) due to poor hygiene practices, handling and storage are reported worldwide in schools affecting the aim of providing quality foods (Dablool *et al.,* 2014).

In most African countries, large supply of foods is from the informal sectors such as vendors and smallholder producers. The handling process and quality of these foods are challenging to food safety regulatory bodies such as Aflatoxins (Mensah *et al.*, 2012). The Aflatoxin regulation in Malawi is commonly applied to maize and groundnuts meant for export and supper markets supply (Mwalwayo and Thole, 2016).

Studies reports have shown that information on food safety and quality in relation to trade and heathy of consumers is limited (Mensah *et al.*, 2012). African countries are poorly labelled in providing scientific information on food quality standards, misinterpretation of International Standards (Codex) and lack of details on specific microbial contaminations in foods (Mensah *et al., 2012).* In addition, reports as regards to food safety and quality in relation to consumer health are inadequate and/or scanty by county

2.5 Implications of aflatoxin to human health

Aflatoxins pose serious threats to human being such as cancer, immunosuppression, impaired growth among other respiratory problems (Gong *et al.*, 2016; Kimanya, 2015; Jalili, 2015).

2.5.1 Aflatoxin associated with liver cancer

Approximately 4 billion people across the world consume aflatoxins contaminated diets which cause liver cancer (Liu *et al.,* 2012). Chronic exposure to aflatoxins have been associated with liver cancer. Nearly 25,000-155,00 liver cancer cases recorded every year in the world are associated with aflatoxin exposure (Liu and Wu, 2010), and approximately 26,000 liver cancer deaths are for Africans living in south of the Sahara (IFPRI, 2013). According to Liu and Wu (2010), individuals with Hepatitis-B are more to vulnerable to liver cancer when exposed to aflatoxins, than non-infected individuals. Cases of liver cancer due to aflatoxicosis have been recorded in countries like Uganda, Thailand, Mozambique and China (Casado *et al.,* 2001).

2.5.1 Aflatoxin associated with child impaired growth

Several studies show that aflatoxins are associated with impaired growth which include stunting (short-for-age) and wasting (low-weight-for-height). Studies carried out in Benin and Togo revealed that stunting and wasting children had higher detectable levels of aflatoxin abducts (30-40%) than those with normal nutrition status (Gong *et al.,* 2002). In Kenya, children wasting were associated with aflatoxin concentrations in household maize flours (Okoth and Ohingo, 2004). However, many researchers have indicated that child stunting includes other factors such as poverty, chronic diarrhea, infectious diseases and (JECFA, 2017b).

2.5.2 Impaired growth and school performance

Globally, about 155 and 51 million under-five years old children are respectively reported stunted and wasted (WHO, 2017), marking a concern to the public health. In Malawi, 37.1% of under-five years old are stunted (NSO, 2016). Stunted children have lower overall school achievement, delayed school enrollment, repeat grade levels, frequent absenteeism and high drop outs (Martorell and Grantham-McGregor, 2010). Stunted children are more at risk of morbidity, mortality, developmental delays and reduced lifelong productivity (Oot *et al.,* 2016).Furthermore, researchers had associated stunting with poor cognitive development, reduced academic performance and lower productivity which impacts to national development.

2.5.3 Aflatoxins associated with human immune suppression

A number of studies have associated immunosuppression with aflatoxins exposure. A research conducted in Ghana found that HIV positive persons exposed to aflatoxins had more concentration of aflatoxins abducts levels and decreased levels of CD4+ T- cells as well as B – Cells than the

HIV negative persons (Jiang *et al.,* 2005, 2008). In Gambia, a study showed that young children who had higher concentration levels of aflatoxin abducts had little levels of secretory Immunogloblin A, another important parameter of immune system (Turner *et al.,* 2003). Reductions in immunological parameters could lead to lowered immune system which allow opportunistic infections in the body (Gong *et al.,* 2016). Children are reported to have weak neurologic and immune systems which have greater risks to toxin effects (Magnussen and Parsi, 2013)

2.5.4 Aflatoxin associated with death

High intake levels of foods contaminated with aflatoxin causes death. In Kenya 317 death cases were reported in relation to Aflatoxin in which 125 deaths were recorded in 2004 (Lewis *et al.,* 2005), 15 deaths in 2005 and 16 death reported in 2006 (Anonymous, 2006) with high prevalence in drought prone districts. The case of aflatoxin in Kenya presumed that children younger than 14 years of age (51%) had greater aflatoxicosis risk than older people (Azziz-Baumgartne, 2005;CDC, 2004). Another deaths case due to aflatoxicosis were reported in 2016 in Tanzania (WHO, 2018a). According to WHO, adults are at least tolerant to acute mycotoxins exposure than children.

In addition, it has been suspected that there is also interaction of aflatoxin with infertility. A research in Nigeria showed that aflatoxins concentration were more in blood and semen of infertile men than fertile men (Uriah *et al.*, 2001).

2.5.5 Prevalence of aflatoxin exposure

The review on human exposure prevalence at global level indicated that about 4.5 billion people living in developing nations which include Malawi largely exposed to mycotoxins beyond regulatory acceptable levels. (Williams *et al.*,, 2004). However, there is no clear documentation on the prevalence of aflatoxin exposure specific to Malawian population (Mwalwayo and Thole, 2016). Studies found that almost 85-100% of African children had some levels of serum-aflatoxins albumin due to intake of aflatoxins contaminated foodstuffs (Polychronaki, et al., 2008).

2.5.6 Dietary exposure to aflatoxins

Studies have shown that large intake of maize foods in several African and Asian nations contribute to increase in aflatoxin exposure than developed nations with more diversified diets (Valdez, 2008). Dietary intake of aflatoxins in some African countries exceeds 100 ng/Kg bwt/day than in developed nations in which exposure rates are reported below 1 ng/Kg bwt/day (WHO, 2018). The intake of 1 mg/Kg of aflatoxins in foods and above has been reported to cause aflatoxicosis especially when taken for a period of 1 to 3 weeks (WHO, 2018a). In addition, exposure to aflatoxins B1 of range 20 to 120 µg/Kg bwt/day has been reported to cause acute toxicity and death. Furthermore, World Health Organization indicated that intake levels of aflatoxin M1 rarely exceeds 1 ng/Kg bwt/day in any country, though other researchers had reported higher levels ranging 6.5 to 8.8 ng/Kg bwt/day mostly to children. Mean exposure to Aflatoxins B1 in diets in developed countries range from 0.1 ng/Kg bwt/day, whereas in southern African nations up to 49 ng/Kg bwt/day (JECFA, 2017b). Several countries have acceptable limits of aflatoxins ranging 5 to 10 µg/Kg, while EU recommends 2 – 4 µg/Kg (Herzallah, 2009).

2.6 Fumonisins

Fumonisins are like aflatoxins, toxic substances commonly caused by mold species *Fusarium Verticilliodes* and *Fusarium Proliferatum*. *Fusarium Verticillioides* species is common in human foods and animal feeds (Michael and Wyatt, 1993). Fumonisin are grouped into series of A, B, C and P. Group B series is the most concern in human and animal toxicology. This include fumonisin B1, B2 and B3 (Segvic and Pepeljnjak, 2001). Fumonisins B1 is recognized as greatly toxic among other groups (Wild and Gong, 2010). The figure 2.2 show chemical structures of fumonisins.

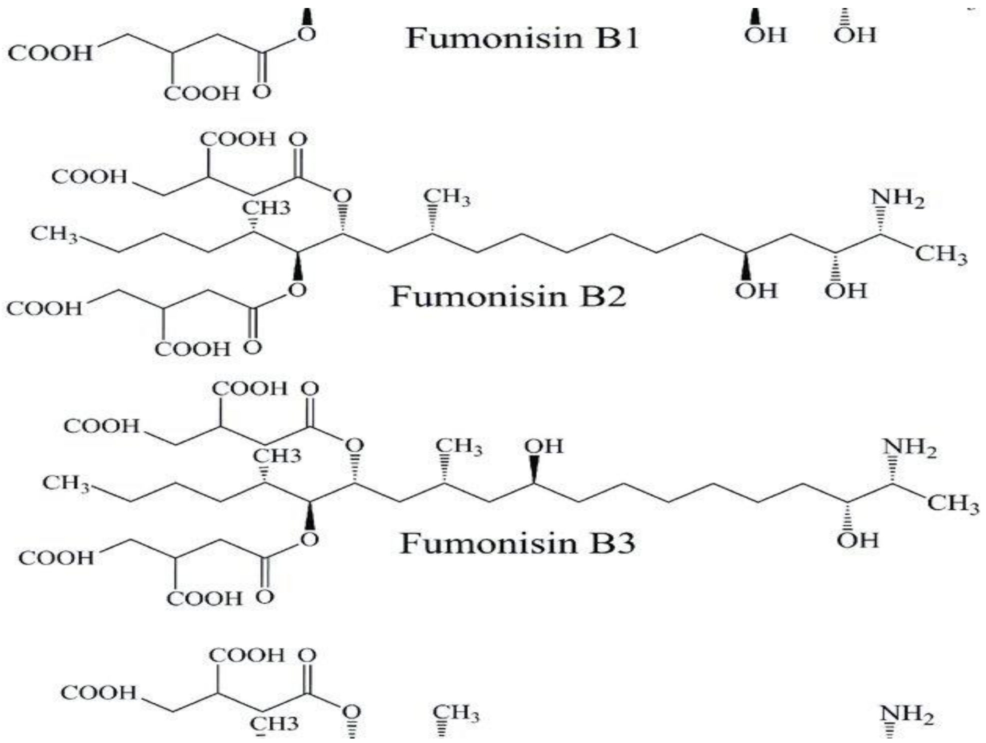

Figure 2.2: Chemical structure of fumonisins

The production and proliferation of fumonisins are like aflatoxins, which favours tropical and subtropical regions which are relatively warm and droughts prone areas. Other factors that influence fumonisin production includes high moisture content, poor harvesting practices and poor storage of crop produce (Boko *et al.,* 2007).

2.6.1 Prevalence of fumonisin worldwide

The occurrence of fumonisins is reported high in Sub-Saharan region where production and consumption of cereal based products is predominant (Warth *et al.*, 2012). Among the studies that were conducted on prevalence of fumonisin in cereal-based foods, maize-based foods had highest prevalence and levels of fumonisins (JECFA, 2017). The prevalence of maize contamination with fumonisins has been recorded in countries like America, China South Africa and Tanzania (Chilaka *et al.,* 2017) including Malawi (Mwalwayo and Thole, 2016). According to Mwalwayo and Thole, (2016) in Malawi, fumonisins levels in maize foods ranged from 1 -7 above acceptable levels set by European Union (4 mg/kg) in processed foodstuff and 1 mg/kg exceeding the maximum limit of European Union (4 mg/Kg (4 ppm) in processed foods and 1 mg/Kg for unprocessed human foods. However, the study done in Malawi was silent on prevalence of fumonisin on maize based diets for consumption by different population groups like school children including the extent of exposure to the Malawian population.

2.6.2 Dietary exposure to fumonisin worldwide

Dietary intake of fumonisin has been reported concurrently with prevalence levels. The high consuming maize regions have been reported highly exposed to fumonisin toxins intake. Among the countries reported with high fumonisin intake levels includes Tanzania, South Africa United States and China (Kimanya *et al.,* 2008). The study in South Africa showed that the population which consume maize on average of 400 to 500grams/person/ day, had higher fumonisins intake levels exceeding provisional maximum tolerable daily intake (PMTDI) of 2 µg/Kg bwt/day according to standards of Joint FAO/WHO 64 Expert Committee of Food and Additives for fumonisins B1, B2 and B3 or total (Shephard *et al.*, 2007).

Most study reports show that young children are largely exposed to Total fumonisins and B1 than adults (WHO, 2018). For instance, fumonisin exposure were reported very high among young children who were frequently fed maize based diets according to their respective body weights (Kimanya *et al.,* 2014). Maize consumption per capita in Malawi is estimated at 382 grams (Mazunda and Droppelmann, 2012), however data is limited on intake levels of fumonisins among young children in Malawi.

2.7 Effects of fumonisin to human health

2.7.1 Fumonisins associated with child impaired growth

Fumonisin like aflatoxin has been correlated with child growth impairment. A study that was conducted in Tanzania found that for infants that were largely exposed to fumonins were smaller and thinner than non-exposed infants (Chen *et al.,* 2018; Kimanya *et al.*, 2014). Fumonisins have been further suggested to affect fetal and postpartum by pregnant women in regions were maize is the stable food (Knutsen *et al.,* 2018 ; JECFA, 2017).

2.7.2 Fumonisin associated with esophageal cancer

High intake of fumonisin has been widely associated with esophageal cancer. Furthermore, fumonisins have been reported that causes apoptosis and oesophageal cancer in human being (Moreno *et al.*, 2009). A number of cases of esophageal cancer that were recorded, were connected to high dietary intake of fumonins in countries of Asia, South Africa, Italy, Iran and (Sun *et al.*, 2011 ;Paterson and Lima, 2010).

2.7.3 Fumonisin associated with utero and neural tube defects

The fumonisin toxin is suspected to cause utero and neural tube defects in people who largely consume fumonisin contaminated maize (Voss *et al.*, 2001). Epidemiological study that was conducted in Mexico had shown significant relationship between high levels of fumonisin intake by pregnant women and neural tubes deformities in babies (Missmer *et al.*, 2006). However, the researcher recommended for further studies on the link between fumonisin utero and neural tube defects.

2.8 Regulatory limits of aflatoxins and fumonisins in maize foods

Due to worldwide health complications of Aflatoxins and fumonisins, several regulations have been set to control and protect human and animal health. Malawi unlike other countries, it has a regulatory body which only look into aflatoxins (MAPAC, 2013), disregarding other important mycotoxins such as fumonisins. Table 2.1 highlights some of the international regulations for aflatoxins and fumonisins in maize and maize-based foods meant for human consumption.

Table 2.1: Aflatoxins and fumonisins regulatory limit levels in Maize

Mycotoxins	Food Commodity	EU	Codex	US FDA	Malawi	Source
Aflatoxins; B1, B2, G1, G2	General food maize grain	-	10-15 ppb	20 ppb	-	(Alshannaq and Yu, 2017**;** USA, 2016)
	Unprocessed maize	5-10 ppb	-	-	4ppb	(EU, 2016)
	Processed maize products	2-4ppb	-	-	-	(EU, 2016; FAO, 2004)
Fumonisins; B1, B2, B3	Maize and maize based foods	1000 ppb	2000-4000 ppb	2000–4000ppb	-	(Alshannaq and Yu, 2017;FDA, 2010; Codex, 2015; USA, 2016 ; EU, 2016)
	Maize breakfast cereals and snacks	800 ppb	-	-	**-**	**(**EU, 2016)
	Processed maize based infants and young children	200 ppb	-	-	**-**	**(**EU, 2016

2.9 Methods of reducing mycotoxins in food

There are several methods that have reported degrade levels of mycotoxins in foodstuffs. These methods are categorized into physical, chemical and biology methods.

2.9.1 Physical Methods

Several studies have reported that postharvest handling and processing such as drying (less 15%), sorting, washing, dehulling, milling, fermentation, soaking, boiling reduce mycotoxins production and increase storage shelf life of food crops (Fandohan *et al.,* 2005; Mutungi *et al.,* 2008; Lanyasunya *et al.,* 2005). Other methods that retards mycotoxins like aflatoxins and fumonisins includes proper storage of maize grains in bags, improved granaries, raised racks, and use of pesticides (Kaaya *et al.,* 2006).

Most mycotoxins such as aflatoxins require high temperature of about 237 °C to 306 °C to decompose. However all heat processing treatments such as boiling, steaming, roasting and baking were reported to reduce aflatoxins and fumonisin (Reddy and Rani, 2004). Researchers have also recommended decontamination of mycotoxins by irradiation (Vita *et al*, 2014). In Malawi, the traditional methods of processing maize flour such as removing bran, soaking, milling and sun drying had shown effective in reducing AFB1 level by 88.1% in the maize flour for preparing nsima and thick porridge (Matumba *et al.,* 2009). Despite several physical methods of reducing mycotoxins, further studies are required for low cost effective methods that can completely eliminate or degrade aflatoxins and mycotoxins in foods.

2.9.2 Biological Methods

Biological control methods have been described as potential techniques of reducing myctoxins contamination in food crops both on farm and post-harvest (Velazhahan *et al.,* 2010). Various organisms have been reported successful in control of mycotoxins, which include dairy strains of lactic acid bacteria (LAB), yeast strains of saccharomyces cerevisiac, and non-toxigenic *Aspergillus* fungi, have been reported successful in degradation of mycotoxins (Yin *et al.,*2008). Many researchers supported that Lactic Acid Bacteria effectively inhibit aflatoxin and other mycotoxins production (Fuchs *et al.*, 2008). All types of yeast have reported successful in aflatoxin reduction (Milani *et al.,* 2014). Proper use of non-toxigenic *Aspergillus flavus* and *parasiticus* significantly reduce pre harvest aflatoxins contamination in both maize and peanut fields by average reduction of 92%. Utilization of non-toxigenic strains of *Aspergillus flavus* which compete with toxigenic strains of *Aspergillus* in soil have been used on maize crops in Nigeria (Atehnkeng *et al.,* 2008), USA and Thailand (WHO, 2018;Weidenbomer, 2013). A significant reduction of fumonisin have been also observed in Bacillus thuringiensis (Bt) maize, through reducing insects damage and fungal infestation (WHO 2018).

2.9.3 Chemical methods

There are several chemicals which have been reported to detoxify mycotoxins and these includes acids, bases and oxidising agents. These chemical compounds include hydrochloric acid, citric acid, lactic acid, ammonium persulphate, calcium hydroxide , sodium bicarbonate and potassium carbonate, formaldehyde, hydrogen peroxide, sodium bisulfite, ozone gas, sodium hydroxide and sodium hypochlorite have been reported positively in reducing myctoxins in both human food and animal feeds (Amezqueta *et al.,* 2008; Whitaker *et al.,* 2005).

However, several studies have shown that most chemical methods are not feasible as they require extreme temperature and pressure. In addition, some chemicals produce toxic or poisonous residues toxic, and also affect nutrition sensory and physical characteristics of food products. For instance, acidic chemicals open the lactone-ring of the aflatoxins, but are reversible. Ammoniation treatment opens the lactone-ring but at very high temperature which result into decarboxylation of aflatoxins in the diet (Kumar, 2018). Ammoniation is also effective but has been mainly used in livestock feed in US.

Ozonization have been also considered as effective and safe method of degrading and detoxifying myctoxins such as aflatoxins in corn (Luo *et al.,* 2014), but has been highly recommended in peanut because of its potential to control and reduce aflatoxigenic fungi concentration in kernel.
Alkaline treatment such as calcium hydroxide has been reported to open the lactone ring in mycotoxins and is irreversible. The treatment of mycotoxins (aflatoxins and fumonisin) contaminated maize with alkaline has been reported successful in Mexico in making tortilla (traditional food) through Nixtamalization process (Guzm and Studies, 2016). Researchers still

recommended for further studies on simple chemical methods that can significantly detoxify mycotixins (100%) with low cost.

2.10 Post harvest handling practices and mycotoxins contaminations in foods

Food borne illnesses due to food contamination with pathogenic microorganisms and mycotoxins effects is a public health concern across the world (FAO, 2013). Reports show that food is contaminated through various factors such as traditional food processing methods, poor storage conditions, poor hygiene of food handlers and undercooking (Feglo and Sakyi, 2012). Ensuring high quality and food safety standard in schools is necessary because any slight incidences can largely affect several school children (Osaili *et al.*, 2013). Many researchers have found that poor food handling and storage of foodstuffs like maize contribute to increased mycotoxins production beyond acceptable limits (Eshiett *et al.*,2013)

Food safety regulatory boards like Food and Drug Boards, Codex Alimentarius FAO-WHO are very committed to enforcements of food standards regulations and capacity building on food safety issues, but there is little improvement according to reports on food borne diseases and contaminations of foods with pathogenic microbes and mycotoxins (DeWaal and Rober, 2013). Addressing food safety issues is also among the priority strategic actions in Malawi Multi-sector Nutrition Policy and Strategic plan including Agriculture Sector Food and Nutrition strategy (DNHA, 2018).

2.11 Knowledge of mycotoxins contamination in foods

Little knowledge of mycotoxin contamination in foodstuffs contribute to increase health risks of human and animals (Negash, 2018). Studies show that majority of subsistence farmers, food handlers and processors lack knowledge of health effects of molds toxins (Eshiett *et al.*, 2013). However, the study in Malawi on knowledge, attitudes and practices (KAP) aflatoxins contamination in foods revealed that majority of Malawians (88%) were aware of negative effects of human exposure to aflatoxins, while 50% were not knowledgeable that mycotoxins are not destroyed by the normal cooking methods and 33% they reported that Malawian buy and consume moldy contaminated maize (Matumba *et al.*, 2015). Basing on the Matumba et al. (2015) findings, it is likely that school food handlers have inadequate knowledge of mycotoxins contamination in school meals. Furthermore, previous studies that were carried out in Malawi did not capture data on post-harvest handling knowledge and practices of food handlers on maize foods in school meals programme regarding mycotoxins contaminations.

Several researchers recommend educating and conducting awareness to general public on exposure of mycotoxins, in order to prevent and reduce aflatoxin and fuminisin contaminations in foods (Mboya and Kolanisi, 2014; Matumba *et al.*, 2016). Inclusion of pre-harvest and postharvest managements of food crops in primary and secondary school curricula can help growers and consumers to reduce mycotoxins exposure (Misihairabgwi *et al.*, 2017).

2.12 Common methods of detecting mycotoxins in foods

2.12.1 Immunochemical Method

The common immunochemical techniques used in determination of aflatoxins and fumonisins includes radioimmunoassay (RIA) and enzyme-linked immuosorbent assay (ELISA).

2.12.1.1 Radioimmunoassay (RIA)

Radioimmunoassay (RIA), has high degree of detecting mytocotixins and can be done concurrently with high level of sensitivity (Twyman, 2005), however the technique requires an antigen to be very pure and is also associated with health effects.

2.12.1.2 Immunoaffinity Column Assay (ICA)

An enzyme-linked immonosorbent (ELISA) is the most common technique used in detection of different types of mycotoxins in foodstuffs (Ondieki1 *et al.*, 2014). Enzyme-linked immunosorbent kits are affordable, simple and do not need intensive sample clean-up. It can detect aflatoxins and fumonisins in lowest concentrations. The Kit has no associated health effects. It has high sensitivity and can analyze many samples concurrently and accurately (Huybrechts, 2011).

2.12.2 Chromatographic Methods

Most popular chromatographic methods are Thin-layer chromatography (TLC) and High-performance liquid chromatography (HPLC).

2.12.2.1 Thin-layer chromatography

This is one of popular techniques for analyzing mycotoxins in different foodstuffs (Wacoo *et al.*, 2014), even at lowest concentration of 1–20ppb. However, TLC is reported to require high skilled personnel, pre sample preparation and is expensive equipment.

2.12.2.2 High performance liquid chromatography

This technique is widely used in separating and determining the organic compounds (Wacoo *et al.,* 2014). It is very sensitive and detects mycotoxins at lowest concentrations. HPLC is very fast in detecting myctoxoins and provides accurate results.

Based on evidence of occurrence of mycotoxins in foodstuffs and their complications to human health, there is need for assessment on post-harvest handling knowledge and practices on handling of maize foods among food handlers and safety of maize based diets consumed by school going children in School Meals Program in Malawi. Therefore, a study was carried out to assess post-harvest handling knowledge and practices among food-handlers on toxigenic molds contamination in School Meals Programme and the extent of exposure of aflatoxins and fumonisins for school children consuming maize based school meals in selected primary schools in Salima District, Central Malawi.

CHAPTER THREE: POSTHARVEST HANDLING KNOWLEDGE AND PRACTICES AMONG FOOD HANDLERS ON TOXIGENIC MOLDS CONTAMINATION IN MAIZE BASED DIETS IN SCHOOL MEALS PROGRAMME IN SALIMA DISTRICT, MALAWI

3.1 Abstract

The natural occurrence of toxigenic molds in foodstuffs pose serious health threats to humans such as cancer, immunosuppression, impaired growth and death. This study aimed at determining the postharvest handling knowledge and practices among food handlers on toxigenic molds contamination in maize-based diets in School Meals Programme in Salima District, Central Malawi. The study used a structured questionnaire which was administered to 124 individual food handlers who were purposively selected from 31 Primary Schools among those implementing home-grown school meals programme. Data was analysed using descriptive statistics. The results showed that 80% of food handlers had high knowledge of causes of toxigenic molds contamination in maize foods, 47% had moderate knowledge of health effects of toxigenic molds, while 50% had moderate knowledge of control measures of toxigenic molds in maize foods. Eighty-five percent (85%) were not aware of mycotoxins contamination in maize foods. Furthermore, the study revealed that 60% of food handlers practiced poor postharvest handling of maize foods during transporting, storage and processing in schools. The results also showed no significant differences in knowledge of toxigenic molds contamination in maize foods and postharvest handling practices across demographic regions among food handlers ($P > 0.05$). The study concluded that majority of food handlers had high knowledge of toxigenic molds in maize foods, however they practiced poor post-harvest handling which might influence molds contamination in maize-based diets for school children under School Meals Programme. There is need to educate all stakeholders involved in School Meals Programmes on mycotoxins and post-harvest handling of maize foods in order to prevent school children from the risk of mycotoxins exposure.

3.2 Introduction

School Meals Programme (SMP) has been introduced in many countries with aim of reducing hunger, while promoting healthy, education, growth and development of school going children. There are different types of the School Meals Programme which include provision of school meals during learning hours or distribution of home food rations to pupils (FAO and WFP 2018). According to World Food Programme (2018), approximately 368 million children in low-and middle-income countries are fed school meals under School Meals Programme which are supported by governments and development partners, of which 954,669 primary school children are from Malawi.

The School Meals Programme in Malawi include provision of porridge of Corn-Soya Blend (CSB), Take Home Rations (THRs) of maize for orphan children and home-grown school meals programme (HGSMP) which source a variety of foods locally and prepared for learners at school (WFP, 2018). Maize is one of the staple food and ingredient in home-grown school meals programme. Studies have however reported that maize and processed maize-based foods are prone to mycotoxins (Misihairabgwi *et al.,* 2017). The most common mycotoxins which have been reported in maize foods are aflatoxins and fumonisins which are respectively caused by species of *Aspergillus* and *Fusarium* (WHO, 2018 ; Horn, 2003). The most common types of aflatoxins and fumonisins in food crops include aflatoxins B1, aflatoxins B2, aflatoxins G1 and aflatoxins G2, and fumonisins B1 and fumonisins B2. Chronic co-exposure to aflatoxin and fumonisins have been associated with various health effects such liver cancer, esophageal cancer, immunosuppression, impaired child growth or stunted growth, mutagens and death in case of high toxin intake levels (Gong *et al.,* 2016; Kowalska *et al.,* 2017; Sun *et al.,* 2011). Aflatoxin B_1 and Fumonisin B_1 have been reported as the most carcinogenic in human being (IARC 2012).

Study reports show that lack of knowledge and poor postharvest handling practices of foodstuff contributes to aflatoxins and fumonisins production (Eshiett *et al.,* 2013). Inadequate knowledge of toxigenic molds contamination in foods further increases health risk to human and animals (Negash, 2018). Other researchers have reported that food is contaminated through various factors which include poor storage conditions, poor handling practices, poor hygiene of the food handlers, and inadequate processing and cooking of foodstuffs (Feglo and Sakyi, 2012). The presence of molds in foods has been associated with presence of mycotoxins (Campbell, 2016).

Children have been reported that are more at risk to effects of mycotoxins than older people (Azziz-Baumgartne, 2005; CDC, 2004; Okoth and Ohingo, 2004), due to their low developed immune system, increased food demand and uncontrolled diet (Gong *et al,* 2016). In Kenya, it has been previously reported that 150 school aged children died and about 500 were hospitalized due to exposure to aflatoxins (Angel, 2018). Mycotoxins illnesses outbreak have been also reported in USA where 155 school children at elementary school were ill when they consumed mycotoxins contaminated school meal (WHO, 2011). Promoting high quality and food safety standards in schools is necessary for good nutrition, health and continued education of school children (Osaili *et al.,* 2013: Oranusi *et al.,* 2007). Therefore, the study was developed to determine postharvest handling knowledge and practices of food handlers regarding toxigenic molds contamination in school meals under home-grown school meals programmes in Salima district, central region of Malawi.

3.3 Materials and methods

3.3.1 Description of study Area

The study was implemented between August and November, 2019 in Salima district, Central Malawi. Salima is one of the districts in Malawi implementing School Meals Programme through home-grown school meals programme. The programme covers three Extension Planning Areas (EPAs) namely: Katelera, Chipoka, and Tembwe. The Extension Planning Areas are demarcated based on agro-ecological zones.

Salima district has 2,196 km square area with population of about 478,346 of which 53% are under 18 years (NSO, 2018). It is located along the lake shores of Malawi in central region (Figure 3.1). The district has a sub-tropical climate which is relatively dry and strongly seasonal. The wet season is hot, and the dry season is warm, windy, and mostly clear.

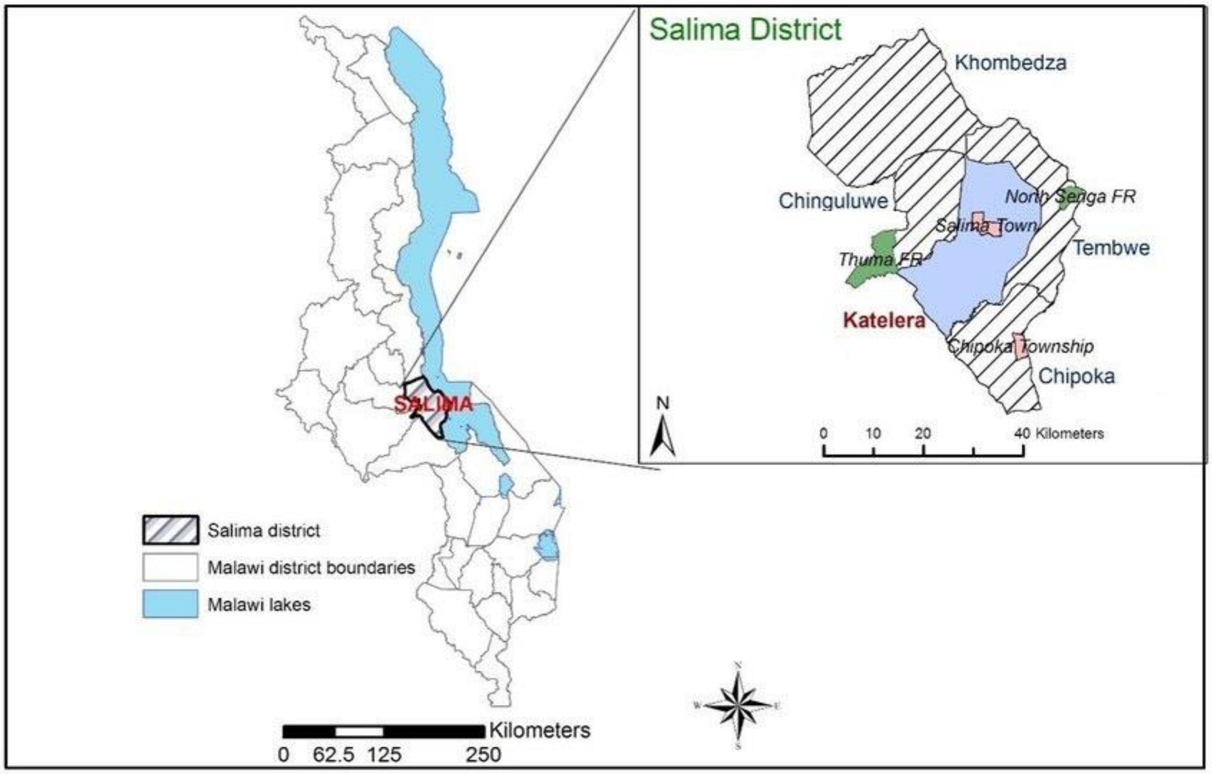

Figure 2.1: Location of Salima district in Malawi. Source: (Musa *et al.*, 2018)

3.3.2 Study design

This was cross-sectional study with qualitative and quantitative component. Data was collected using a structured questionnaire in primary schools implementing home-grown school meals in Salima District in central Malawi.

3.3.3 Sample size determination

A total of 31 schools and 124 food handlers was involved in the survey. The size of the sample was determined using formula by Yamane (1967; $n = N/1 + N(e)^2$, whereby n was the required sample size, N was the total number of schools implementing the Programme (44), and e level of precision. The level of precision of 0.10 was used to obtain appropriate sample representing the population of schools under the study.

This resulted into $n = \frac{44}{1+44\ (0.10)^2}$ =31 schools.

The number of the food handlers was calculated using Fisher's formula (1998) $N = Z^2pq/d^2$, whereby n was the required sample size, Z the normal standard variation at 95% Confident Interval (1.96), p being the expected proportion of the population of food handlers under home-grown school meals programmes (0.5), q the expected ratio of food handlers not under the programme of study (1-p), and d the level of precision. The level of precision of 0.09 was used to obtain appropriate sample representing the population of food handlers under the study.

This resulted into $n = \frac{1.96^2 \text{x } 0.05 \text{ x } 0.5}{0.09^2} = 124$ food handlers

Different levels of precisions were used to obtain the highest possible number of the food handlers as they were not many in a school.

3.3.4 Sampling procedure

The simple random sampling technique was used to select 31 Primary Schools among those implementing home-grown school meals programmes. One hundred twenty-four (124) food handlers were purposively selected from the sampled schools and interviewed using the structured questionnaires. These food handlers were school meals Cooks, Farmer Organization committee members/suppliers and school stores keepers.

3.3.5 Data collection

The data was collected through administering the structured questionnaire to individual food handlers. The questionnaire was designed to capture demographic characteristics of the respondents, knowledge and practices concerning causes of toxigenic molds during maize storage, associated health effects, knowledge of aflatoxins and fumonisins contaminations in maize foods, control measures of toxigenic molds, attendance to postharvest handling training, sources of school meals, handling practices during transportation, reception, storage and processing (Appendix 1).

Knowledge of the respondents was assessed using the "True", "False" and "Don't Know" statements while the practice was assessed through the "Yes" and "No" questions and observations. The overall knowledge assessment adopted Blooms cut-off points grade scores of $\leq$ 59% as low knowledge, 60 to 79% as moderate knowledge and 80 to 100 as high knowledge

(Nahida., 2007; Abdullahi *et al.,* 2016). These scores were allocated to the scale range of 1-23 points (representing a total number of 23 knowledge statements) which was categorized into three levels of 1-14, 15-19, and 20+, respectively.

3.3.6 Statistical data analysis

Data was subjected to Statistical Package for Social Scientist (version 20.0) for windows®. It was analyzed through descriptive statistics to obtain frequencies, percentages, mean and standard deviations. The One-way analysis of variance (ANOVA) was used to compare the mean scores among demographic characteristics of respondents. The independent t-test was used to compare significant differences between the mean scores of demographic characteristics of respondents and knowledge of toxigenic molds. The associations of knowledge, practices and demographic characteristics of the food handlers were analyzed through Pearson Correlations (Appendix 2). The statistical results were presented in tables and figures for easy interpretation.

3.4 Results

3.4.1 Demographic characteristics of the respondents

The results showed that 39% of respondents were male while 61% were female. Age of the respondents ranged 24 to 74 years old with mean age of 40 ± 10 years. Respondent's level of education ranged from primary (62%) to tertiary (9%), while 6% had not attended formal education (Table 3.1). The results showed that majority (61%) of respondents attended primary level. However, there was no correlation of age of the respondents and level of education (r = -0.127, P = 0.161). The significant association was observed between gender and level of education where men had significantly attended higher level of education than women (χ^2 = 11.694, P = 0.009). Furthermore, there was no significant association of gender and age of respondents (χ^2 = 41.001, p = 0.160).

Table 3.1: Demographic characteristics of the respondents

Characteristics	Frequency (n=124)	Percentage (%)
Gender		
Male	48	39
Female	76	61
Age		
20-29	18	15
30-39	43	35
40-49	44	36
50-59	14	10
60-69	2	2
70+	3	2
Education level		
Primary level	77	62
Secondary level	29	23
Tertiary level	11	9
None	7	6

3.4.2 Post-harvest handling knowledge of Food Handlers on toxigenic molds contamination in maize foods

3.4.2 1 Knowledge of the respondents on causes of toxigenic molds during storage

Majority of respondents (83%) had knowledge that placing maize on bare ground or in contact with floor and wall cause toxigenic molds, 82% indicated that wet or leakage store room can cause toxigenic molds, 75% had mentioned that toxigenic molds occur when stored wet or when maize grains are not fully dried. Seventy percent (70%) had knowledge that toxigenic molds occur due to insects and pest attack, while 60 % had mentioned that over-storage of maize grains and rodents cause molds contamination (Figure 3.2). Overall results showed that majority of the respondents (80%) had high knowledge about causes of the toxigenic molds in maize foods. Furthermore, there was no statistical differences in knowledge of the causes of toxigenic molds across respondents age and gender (P = 0.09). A significant different was observed within level of education (P = 0.000) where those who attended higher level of education had high knowledge of the causes of toxigenic molds that those with low education level.

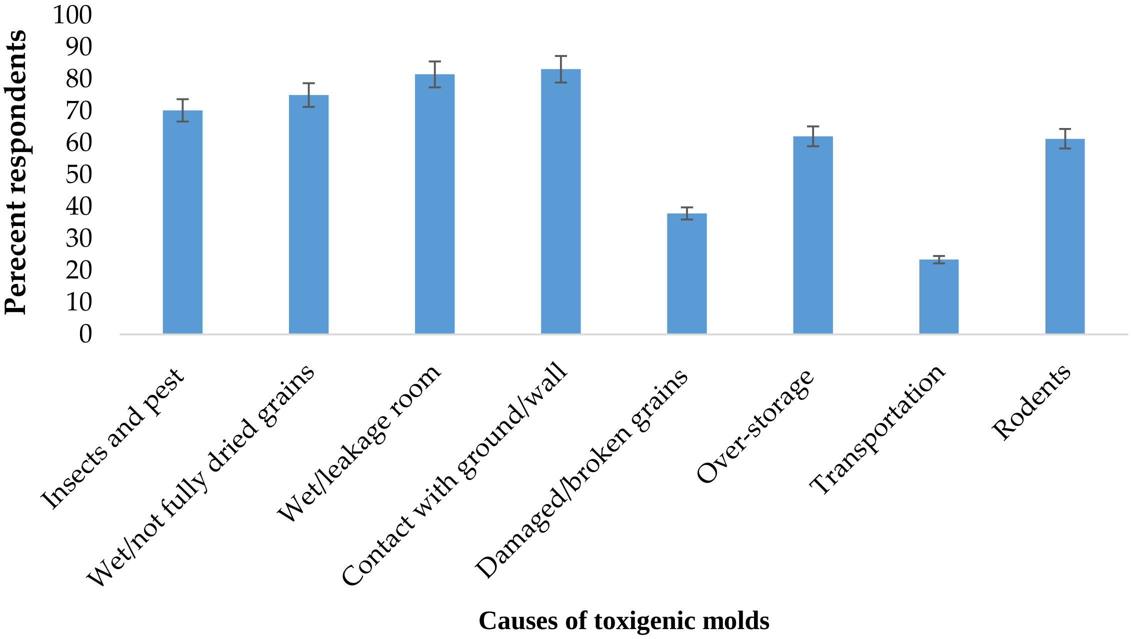

Figure 3.2: Knowledge of the causes of toxigenic molds during storage. Error bars represent standard errors of the means.

3.4.2.2 Knowledge of respondents on the side effects of consuming toxigenic molds

Seventy-eight percent (78 %) of the respondents had knowledge that toxigenic molds affect human health in general, while 70% had knowledge that toxigenic molds cause infections such nausea, vomiting and diarrhea. Thirty-two percent (32%) had knowledge that consuming moldy contaminated maize foods can impair child growth and/or cause malnutrition, 31% had mentioned that toxigenic molds can cause death, while 27% had reported cancer (Figure 3.3). Overall results showed that 47% of the respondents had moderate knowledge that toxigenic molds affect human health in general including some acute infections, while 30% had high knowledge of specific chronic health effects associated with toxigenic molds. In addition, no significant differences in knowledge of the side effects of toxigenic molds were observed across demographic regions of the respondents (P = 0.061).

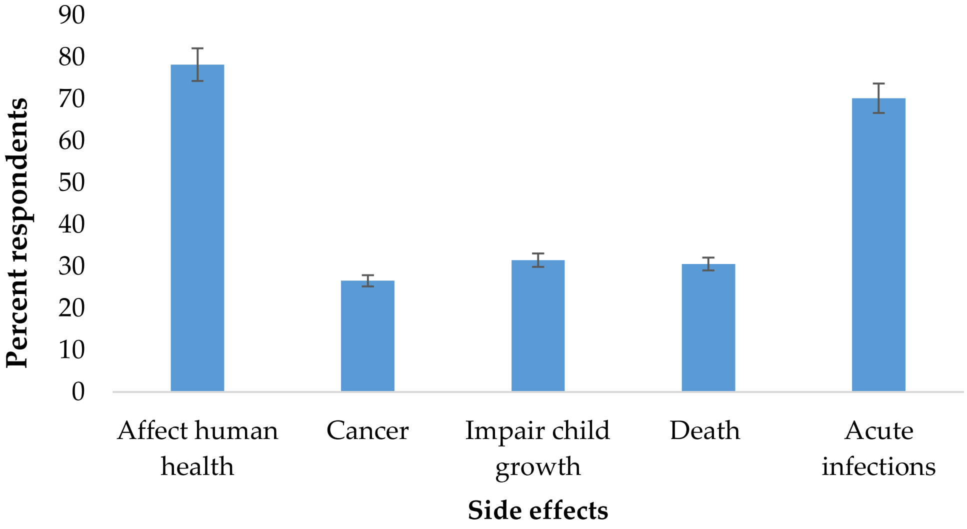

Figure 3.3: Knowledge of the side effects of consuming toxigenic molds. Error bars represents standard errors of the means.

3.4.2.3 Knowledge of the respondents about toxins found in molds

Seventy-nine percent (79%) of respondents had knowledge that molds contain toxic substances in general. When respondents were asked about mycotoxins “aflatoxins” and “fumonins”, only 15% and 4% were familiar or aware of the terms, “aflatoxins” and “fumonisins”, respectively. Overall, 85% of the respondents were not aware of mycotoxins in molds. There was significant difference in knowledge of mycotoxins within respondents’ level of education, where those that attended tertiary level had higher mean scores of knowledge of mycotoxins than the primary level (P = 0.013). Furthermore, results showed no significant difference in knowledge of mycotoxins across respondents age and gender (P =0.073).

3.4.2.4 Knowledge of the respondents about control measures of toxigenic molds

Eighty-six percent (86%) of the respondents had knowledge that sorting and grading of damaged or rotten maize grains control toxigenic molds, while 85% had reported that treatment of maize grains with pesticides and insecticides prevents molds contamination. Fifty-one percent (51%) had knowledge that toxigenic molds can be controlled by the traditional methods of processing maize flour which include dehulling, soaking and drying while 42% had indicated that toxins in molds can be degraded by cooking methods like roasting, boiling and deep frying (Table 3.2). Overall results showed that 50% of respondents had moderate knowledge of control measure of toxigenic molds in maize foods. There were no significant differences in knowledge about control measures of toxigenic molds among demographic regions of respondents (P = 0.090).

Table 3.2: Respondents knowledge on control measures

Factor	**Frequency (n=124)**	**Percentage (%)**
Sorting/grading damaged/rotten maize/foreign objects	107	86
Pesticides and insecticides application	105	85
Avoid storing maize with other non-food items	60	48
Feed livestock the contaminated maize grains	37	30
Process maize flour through traditional methods	64	52
Cook maize foods	52	42

3.4.2.5 Attendance of respondents to training on postharvest handling of maize foods

It was reported that 32% of respondents had attended training on postharvest handling of maize foods while 68% did not attend. When respondents were asked to specify topics covered during training sessions, they reported about control of maize weevils and Large Grain Borers (LGB), and stores managements for food commodities in schools. Despite that majority (68%) had not attended training on postharvest handling of maize foods, there was no significant different in knowledge or understanding of aflatoxins and fumonisins between respondents that attended training and those that did not attend training (p = 0.753).

Overall results showed no significant association of knowledge of toxigenic molds with gender of respondents (χ^2 = 20.328, P = 0.857). Furthermore, there was no correlation of knowledge of toxigenic molds with age of the respondents (r = 0.145, P = 105). The correlation though weak was observed between knowledge of toxigenic molds and education levels (r = -0.310, P = 0.000), where respondents who attended higher education level had significantly high knowledge of toxigenic molds than those who attended low education level (p = 0.024).

3.4.3 Food handlers practice in relation to toxigenic molds contamination in maize-based foods in schools

3.4.3.1 Source of maize foods in schools

Nighty-eight percent (98%) of the respondents had reported that maize foods were sourced from Farmer Based Organizations such as cooperatives and associations, 24% had indicated that maize foods in schools were supplied by government, while 17% had reported that vendors supplied maize foods to schools (Figure 3.4). When respondents were further asked about the selection criteria of the suppliers, 93% reported that suppliers were selected through competitive bidding or open tender to supply the commodity (Figure 3.5), for a period of one academic term (normally 3 months). The results clearly showed that maize foods were sourced from Farmer Based Organizations.

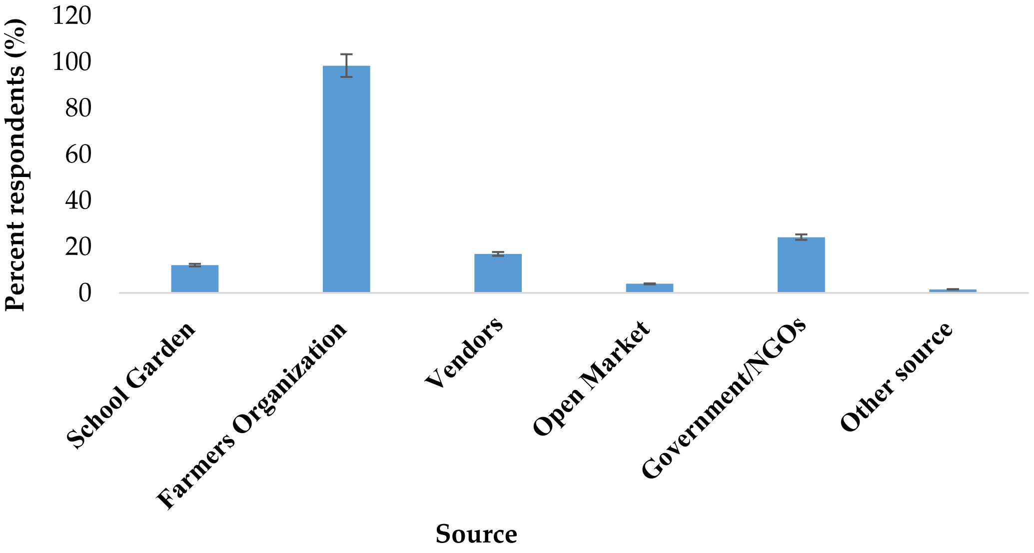

Figure 3.4: Source of Maize foods in schools. Error bars represents standard error of the means.

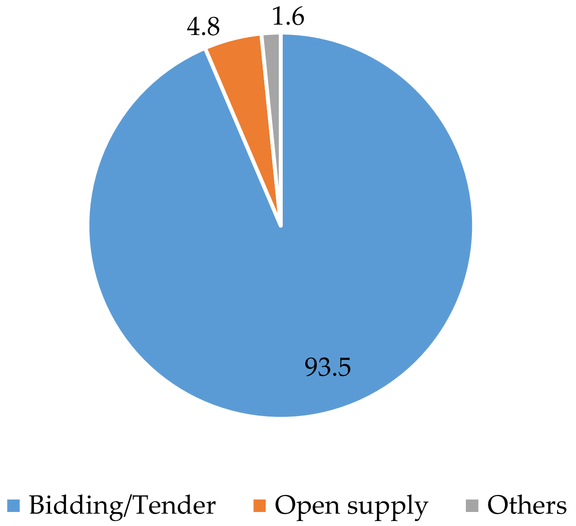

Figure 3.5: Selection criteria of maize suppliers in schools

3.4.3.2 Handling of maize foods during transporting to schools

Large proportion of the respondents (59 %) reported that maize foods were transported to schools uncovered on open Pickup trucks or Lorry, while 54% had indicated that maize foods was transported to school well covered on open Pickup trucks or Lorry. Fourteen percent (14%) had reported that maize foods was transported uncovered on Ox-Cart and 7% had reported that maize foods was transported uncovered on bicycles (Figure 3.6). Overall results showed that majority of respondents (82%) transported or delivered maize foods to schools uncovered or unprotected from the soil dust.

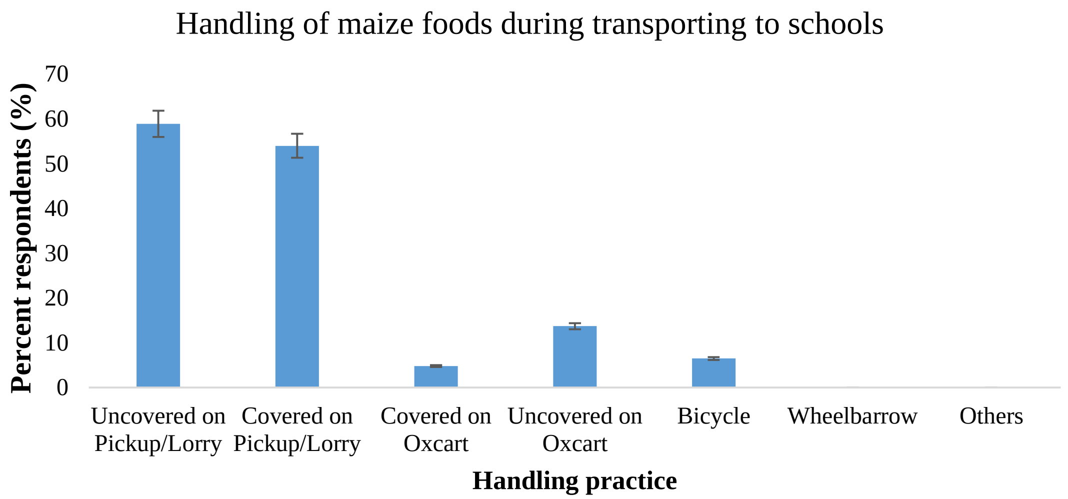

Figure 3.6: Handling of maize foods during transporting to schools. Error bars represents standard error of the means.

3.4.3.3 Handling of maize foods during reception in schools

Sixty-six percent (66%) of the respondents had reported that maize bags were offloaded direct on bare ground, 62% had indicated that maize bags were stored without winnowing or grading. A relatively small proportion (37%) of respondents had reported that maize bags were offloaded on mat/tents, 18% had reported that maize foods were winnowed before storage and 16% had indicated that maize were graded/sorted before storage (Table 3.3). These results showed that maize bags were exposed to soil as reported by majority of respondents that maize bags were offloaded direct on bare ground and stored without winnowing in order to remove some soils dust and other foreign matters. Furthermore, the results showed no significant differences in handling of maize foods during reception across demographic regions of respondents ($P > 0.05$).

Table 3.3: Handling of maize foods during reception in schools

Factor	Frequency (n=124)	Percentage (%)
Offload direct on bare ground	82	66
Offload on mat/tent	46	37
Grade or sort before storage	20	16
Winnow before storage	22	18
Store without winnowing/grading	77	62
Others	4	3

3.4.3.4 Storage of maize foods in schools

Eighty-two percent (82%) of respondents had reported that maize foods were stored in separate rooms away from other non-food items, 81% indicated that maize foods were stored on raised platforms/racks and 77 % had reported that stored maize on cool and dry place. Twenty- six percent (26.6%) had reported that maize foods were stored in classrooms in which learning sessions took place due to lack of storage structures in schools (Table 3. 4). However, when store -rooms were visited, it was observed that 60% of the storerooms had maize bags packed in contact with floor and wall, and some maize bags were stored in rooms together with other non-food items such as cooking utensils, school books, cleaning materials and construction tools which contradicted with verbal reports by respondents. Furthermore, some store-rooms were observed very dirty with soil dust, bird’s droppings and spider-nets. Overall results showed that 60% of schools had poor storage of maize foods which exposed maize grains to hazard foreign matters such as soil, bird’s droppings, chalk dust and other chemicals from the construction materials. There were no significant differences in storage practices of maize foods among respondents across demographic regions (P = 0.310).

Table 3.4: Storage of maize foods in schools

Factor	Frequency (n=124)	Percentage (%)
Cool and dry place	96	77
Clean place	98	79
Bags packed in contact with floor/wall	13	11
Bags packed on a raised rack	101	82
Well ventilated room	75	61
Foodstuff stored separate room from non-food items	102	82
Foodstuff stored in room with other non-food items	33	27
Foodstuff in a classroom with leaners	5	4
Pest and rodents control	0	0

3.4.3.5 Attributes used in determining good quality maize foods in schools

Ninety-three percent (93%) of the respondents had reported that they determined maize quality through observation (visual) of grains free from decay or rotting, 54% had reported that they observed colour change, while 35% had indicated that they observed undamaged grains. None of the respondents had reported of laboratory-based test (Figure 7). The results shown that large proportion of the respondents determined quality of maize by observing physical appearance of grains. There were no significant differences in the attributes used in determining good quality of maize foods across demographic regions of respondents (P = 0.406).

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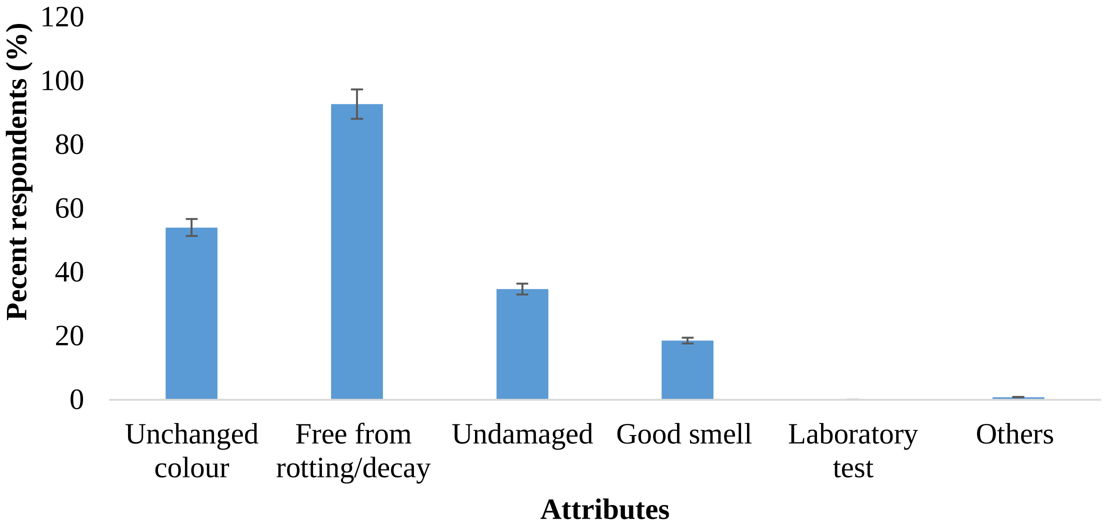

Figure 3.7: Attributes used in determining good quality maize in schools. Error bars represents standard errors of the means.

3.4.3.6 Processing of maize foods in schools

Eighty percent (80%) of respondents had reported that they winnowed maize grain before milling into flour, 57% had indicated that they sorted moldy or rotten maize grains before milling into flour, while 77% had reported that they milled maize grains without washing. Thirty percent (30%) of the respondents had indicated that do not remove moldy maize grains despite seeing them due to limited time of processing and preparation of the school meal (Table 3.5). These results raised doubt that majority of respondent's thoroughly sort, winnow and wash maize grains for school meals. However, the results showed no significant differences in practices during processing of maize foods in schools across demographic regions of the respondents (p = 0.258).

Table 3.5: Processing of maize foods in schools

Factor	N (%)	Percentage
Grading/ sorting	70	57
Winnow before milling	99	80
Wash maize grains before milling	26	21
Dehull maize grains and mill	21	17
Wash grain and mill	11	9
Mill maize grain without washing	95	77
Do not remove moldy grains when processing	37	30
Others	14	11

Overall results showed no significant association of postharvest handling practice of maize foods with gender of the respondents ($\chi^2 = 8.381$, P = 0.397). Furthermore, there was no correlation of postharvest handling practices of maize foods with age (r = 0.084, P = 0.334), and education level (r = 0.083, P = 0.360) of respondents.

3.5 Discussion

3.5.1 Demographic characteristics of the respondents

The demographic characteristics of the respondents revealed that the study had more women participants than men (Table 3.1). Generally and traditionally, most food processing activities are carried out by women than men in Malawi (WFP, 2018). The World Food Programme in Malawi also support empowering of women volunteer Cooks in the School Meals Programme. Similarly, several food and nutrition related programmes have shown more women participation than men. However, a study by Webb et al. (2015) reported no significant differences in handling of foods between men and women, of which all had unsatisfied scores of food safety. The results of the current study compare well with other studies that reported high proportion of women in most food handling studies than men (Akabanda *et al.*, 2017 ; Son *et al.*, 2015). However, the results of the present study contradicts with those of Pius (2013) who had reported more community men participation in school feeding programme than women. The age of the most respondents in the current study ranged 40-49 years old. People above 40 years are considered adults in Malawi, which would translate mature to handle and care children than younger aged ones. Other studies reported that older people handle food better than younger ones (Webb, 2015). Regarding education levels, men had significant higher level of education than women ($P<0.05$). High education level is associated with better food handling hygiene and food safety (Ababio *et al.*, 2016), of which in the current study majority (84%) of respondents had attended low education level, posing a threat to food safety for school children. This result is consistence with the previous study in Malawi which reported that men had higher level of education than women (Matumba *et al.,* 2015).

3.5.2 Knowledge of respondents on causes of toxigenic molds during storage

The study established that majority of food handlers had high knowledge of the causes of toxigenic molds. This could be attributed to the regular farmers trainings on postharvest handling of food crops which the Ministry of Agriculture promotes in order to reduce post-harvest losses in Malawi (Ministry of Agriculture, 2016). The study further revealed no significant differences in knowledge of causes of toxigenic molds across demographic regions of respondents. This study presumed respondents had equal access to information about toxigenic molds. However, the current results contradicts with Magembe et al. (2016), who reported that women respondents were more knowledgeable of molds contamination in foods than men, and that respondents with higher education level were more aware of molds in foods compared to the less educated ones. The results of the present study agree with several other researchers who reported that large rural population in developing countries have knowledge of the of toxigenic molds in maize foods (Udomkun *et al.,* 2018 ; Matumba *et al.*, 2015). Storage of not fully dried commodities, poor temperature control, moisture content, soil contacts and inadequate ventilations, allows insects attack and exacerbate fungal proliferations and mycotoxin production in foodstuffs (Matumba et al. 2015; Misihairabgwi et al. 2017).

3.5.3 Knowledge of the respondents on the side effects of consuming toxigenic molds

The study revealed low knowledge among the food handlers on health effects associated with toxigenic molds (Figure 3.3). This could be due to inadequate information on health issues related to molds. In Malawi, there are inadequate formal trainings of food handlers on food safety (Morse *et al.*, 2018), and no serious case of mycotoxins outbreak have been recorded (Mwalwayo and Thole 2016). This might attributed to limit knowledge of food handler on the effects of mycotoxins exposure. These result contracts with previuos findings which indicated that men were more knowledgeable of health effect of molds than women counter part (Matumba *et al.,* 2015). The results of the present study are consistent with several other reseachers who reported that most rural community households in Southern Africa are less knowledgeable of health implications associated with consuming moldy contaminated maize foods (Matumba *et al.,* 2015; Mboya and Kolanisi 2014; Mukanga *et al.,* 2011). Consumption of mycotoxins contaminated foods pose serious acute and chronic effects to the consumers health (Reddy *et al.,* 2010), which include carcinogenic, mutagenic, teratogenic, hepatotoxic and immunosuppression (Mostrom 2016 ; Liu and Wu 2010 ; IARC 2015).

3.5.4 Knowledge of respondents about toxins found in molds

The study established that majority of food handlers had low knowledge of mycotoxins found in moldy contaminated maize foods. The low knowledge of food handlers on mycotoxins might be associated with low level of education of food handlers. These findings are comparable with those of Adekoya *et al.,* 2017, who had associated level of education with respondents knowledge of mycotoxins. Other authors have stressed that education is the powerful tool for sharing the information and knowledge (Udomkun *et al.,* 2018). Furthermore, the results of the present study agree with several other authors who reported that literate population had more knowledge of aflatoxin and other mycotoxins than those that did not attend formal education (Udomkun *et al.,* 2018 ; Magembe *et al.,* 2016 ; Matumba *et al.,* 2016). This shows that education has effects on knowledge of mycotoxins. The results of the current study are also in agreement with those of Suleiman *et al.,* 2017 that over 80% of the farmers, sellers, and buyers were not aware of the mycotoxins contaminations in foods. Equally, several studies reported that majority of rural population in developing countries lack knowledge of mycotoxins (Adekoya *et al.,* 2017; Matumba *et al.,* 2016; Udomkun *et al.,* 2018).

3.5.5 Knowledge of the respondents about control measures of toxigenic molds

As regards to control of mycotoxins, the study established that food handlers had moderate knowledge of the control measures of toxigenic molds. Lack of capacity building on mycotoxins might contribute to inadequate knowledge of mycotoxins control. It was evidenced in the present study that the postharvest handling trainings which was attended by food handlers did not include topics on mycotoxins. Other study reports have shown that capacity building trainings for rural communities concerning mycotoxins contamination is hardly conducted in sub-Saharan Africa countries (Mboya and Kolanisi, 2014 ; Mukanga *et al.,* 2011). The present study however revealed no significant association of knowledge of mycotoxins with attendance to training on postharvest handling of maize foods. The results of this study supports findings reported by Matumba *et al.,* 2015 , that large proportion of rural Malawians were not aware of effective control measures of mycotoxins in foodstuffs. There is limited information in developing countries on control strategies of mycotoxins contamination in food commodities ((Phokane *et al.,* 2019 ;Torabi *et al.,* 2016). Inadequate knowledge of food handlers on mycotoxins control may risk school children from consuming maize foods contaminated with toxins.

3.5.6 Source of maize foods in schools

The present study revealed that foodstuffs in schools were sourced from farmer-based organizations. The Home Grown School Meals Programme promote sourcing foodstuff locally in order to empower farmer's economy (WFP and FAO 2018). However, reports have shown that many subsistence farmers in Malawi live in poor houses that leak during rainy season and have poor aeration (MNSO, 2012), which can influence molds production in stored commodities (Matumba *et al.,* 2015), before supply to schools.

3.5.7 Handling of maize foods during transportation, reception and storage

The study revealed that food handlers practiced poor postharvest handling practice of maize foods which include transporting uncovered maize foods, placing bags in contact with bare ground or soil (Appendix 3) and keeping commodities in classrooms with children learning to the other side of the room. Poor handling of maize foods such as pacing maize on bare ground was reported as common practice in Malawi (Matumba *et al.,* 2016). The present study established no significant difference in handling of maize foods across respondents' age, gender and education level. These results contradicts with those of Midega *et al.,* 2016, who had associated postharvest handling practice with education levels, whereby farmers with higher level of education were reported practice proper post-harvest handling of food commodities than illiterate farmers. However, the current results support those of Mboya *et al.,* (2011) that most post-harvest handling practices are not adequate to protect maize from mycotoxins contamination. According to Demissie et al. 2008, majority of farmers store maize in same house with people due to lack of proper storage structures. Poor post-harvest handling of commodities have been reported to influence molds and mycotoxins production (Milani, 2013). Molds species such as *Aspergillus flavus*, *Aspergillus parasiticus* affect food crops at any stage in food chain including during transportation (Eshiett et al. 2013).

3.5.8 Determination of quality and processing of maize foods in schools

The study established that food handlers determine maize quality through physical observation of grains. Some food contaminates such as mycotoxins are toxic compounds in nature (WHO, 2018) which cannot be physically observed, laboratory test could be an ideal for determining the quality of foodstuffs. The results of the present study are in agreement with those of Suleiman *et al.*, 2017, that many consumers determine quality of commodities through observation of grains damage, insects and molds contamination. The presence of toxic molds in foodstuff has been associated with the presence of mycotoxins (Matumba *et al.,* 2016), which 30% of the respondents in the current study reported that do not remove because of limited time for processing. These findings clearly showed that maize foods in schools is not fully assessed for human consumption safety.

In general, the present study support previous studies that large population in developing countries have limited knowledge on mycotoxins issues such as health impacts and control measures (Changwa, 2017). Lack of proper strategies to inform the general public on effects of mycotoxins and postharvest handling practices of foodstuffs remains an issue to food safety (Torabi *et al.*, 2016). As evidenced in the present study, majority of food handlers in schools had high knowledge of toxigenic molds despite practicing poor post-harvest handling of maize foods. Food handlers had further demonstrated low knowledge of the associated health effects of mycotoxins. From the results of the present study, it is likely that the low knowledge and the poor post-harvest handling practice of maize foods among food handlers in schools might predispose school children to mycotoxins contaminated maize based diets.

3.6 Conclusion

It can be concluded that food handlers under School Meals Programme in Salima Distrct, Central Malawi have high knowledge of toxigenic molds contamination in maize-based foods. However, they have low knowledge of the chronic health effects associated with molds and control measures. Furthermore, it has been established that food handlers have low knowledge of mycotoxins contamination in maize-based foods. The poor postharvest handling practice of the school food handlers identified in this study may predispose school children to mycotoxins exposure.

3.7 Recommendations

It is recommended that the Ministry of Education in collaboration with Ministry of Agriculture train all stakeholders involved in the school meals programme on mycotoxins and post-harvest handling of maize foods in order to prevent school children from the risk of mycotoxins exposure.

CHAPTER FOUR: EXPOSURE TO AFLATOXINS AND FUMONISINS THROUGH CONSUMPTION OF MAIZE BASED DIETS IN SCHOOLS UNDER SCHOOL MEALS PROGRAMME IN SALIMA DISTRICT, CENTRAL MALAWI

4.1 Abstract

Exposure to aflatoxins and fumonisins contaminated food pose serious threats to human health. This study was carried out to evaluate the extent of exposure of aflatoxins and fumonisins to school going children by determining the levels of aflatoxins and fumonisins in maize based school meals in selected primary schools in Salima District, Central Malawi. Aflatoxins and fumonisins levels were determined using Reveal Q+ Kits test method. Data collected was analyzed using descriptive statistics and probabilistic modelling Mont Carlo simulation. Results showed that maize based porridge consumed in schools had detectable levels of aflatoxins and fumonisins ranging from 2.13 to 33.37 µg/kg and <0.3 to1.0 mg/kg, respectively. Results further showed that mean exposure of aflatoxins (2 ng/kg body weight per day) and fumonisins (6 µg/kg body weight per day) were above the maximum regulatory limits. The study concluded that school going children were exposed to aflatoxins and fumonisins beyond acceptable regulatory levels which may negatively affect their future well-being. The poor postharvest handling practices by food handlers might have significantly contributed to mycotoxins productions in foodstuffs for school children consumption. There is need for appropriate measures to mitigate mycotoxins exposure in schools.

4.2 Introduction

Approximately 368 million children worldwide receive free school meals every day (FAO and WFP, 2018). The School Meals Programme (SMP) were introduced in developing countries to address hunger and increase enrollment as well as learning ability for children. The program has been widely adopted by many countries as social protection interventions and productive safety net for children through providing foods (Drake *et al.*, 2016). Several benefits have been reported from the School Meals Programs which include increased leaners enrolments and improved nutrition (UN-WFP, 2013). However, the programme is reported to be affected by foodborne illnesses which negatively effect on health, education, growth and development of school going children. (Adolf and Aziz, 2012; Nhlapo *et al.,* 2014; Ababio *et al.,* 2016).

Implementation of School Meals Programme vary from country to country where some provide breakfast, others lunch only, while some provide both meals which are often prepared at school. In Malawi, the School Meals Programme includes provision of porridge of Corn-Soya Blend (CSB), Take Home Rations (THRs) of maize for orphan children, and home-grown school meals programme (HGSMP) which prepare a variety of foods sourced locally (WFP, 2018). Maize is one of the staple food and ingredient in home-grown school meals programme in Malawi.

Studies have however reported that maize and processed maize based foods are prone to mycotoxins (Misihairabgwi *et al.,* 2017). Mycotoxins are a global food safety concern causing foodborne illness (WHO, 2015). Children are the most at risk of dietary mycotoxins exposure compared to older people (Azziz-Baumgartne, 2005), due to their low developed immune system, increased food demand and uncontrolled diet (Gong *et al.,* 2016). The most common mycotoxins which have been reported in maize foods are aflatoxins and fumonisins which are respectively caused by species of *Aspergillus* and *Fusarium*. The most common types of aflatoxins in foodstuff include Aflatoxin B1, Aflatoxin B2, aflatoxin G1 and Aflatoxins G2, and, while fumonisins include fumonisins B1and fumonisins B2. Aflatoxins B1 and fumonisins B1 have been reported to be the most toxic and carcinogenic to human (IARC, 2012).

Mycotoxins occur at any stage along the food chain including harvesting, transporting, marketing, storage, processing and preparation (Marin *et al.,* 2016 ; Darwish *et al.,* 2014 ; Bryden, 2009).

Mycotoxins proliferation are exacerbated by poor postharvest handling practices like poor storage condition, insects and pest attack (Misihairabgwi *et al.*, 2017 ; Feglo and Sakyi, 2012). A number of studies have reported high aflatoxins and fumonisins levels in maize foods from Southern Africa including Malawi. Levels of mycotoxins have been reported exceeding the Maximum Limits sets by regulatory bodies (Mwalwayo and Thole, 2016 ; Probst *et al.*, 2014).

Exposure to aflatoxins and fumonisins contaminated foods cause serious acute and chronic toxicity in humans (Alshannaq and Yu, 2017). Several studies have confirmed interaction between dietary mycotoxin exposure with health effects such as cancer, immunosuppression, impaired growth, respiratory problems, diarrhea, abdominal pain, malaria and progression of HIV to AIDS (Kimanya, 2015 ; Warth *et al.*, 2012 ; Khlangwiset *et al.*, 2011). High exposure to mycotoxins for children has been widely associated with impaired growth, poor development, and increase in opportunistic infections (Shirima *et al.*, 2015 ; IARC, 2015). Although several studies have reported that aflatoxins and fumonisins are very high in countries that largely consume maize foods (Polychronaki, *et al.*, 2008; Kimanya *et al.*, 2008), there is limited information in Malawi on dietary exposure to mycotoxins especially for school going children under the School Meals Programme that are predominately maize based.

Therefore, the study was developed to determine the extent of exposure to aflatoxins and fumonisins for school going children by analyzing the intake levels of aflatoxins and fumonisins in maize based diets mostly porridges which are consumed by children in primary schools under home-grown school meals programme in Salima district, Central Malawi.

4.3 Materials and methods

4.3.1 Study design

This was cross-sectional study with analytical component. Data was collected through interviewing food handlers and school children using pre-tested structured questionnaires, and samples collection for laboratory analysis at Chitedze Agriculture Research Station in Lilongwe, Central Malawi.

4.3.2 Consumption pattern of maize based diets by children in schools

4.3.2.1 Sample size determination

A total of 496 school going children selected from 31 schools and 124 food handlers in Salima District, Central Malawi were involved in the study. The number of schools was determined using formula of Yamane (1967); n = N / 1+N $(e)^2$, whereby n was the sample size, N was the total number of schools implementing school meals programme through home grown initiatives (44), and e was the level of precision. The level of precision of 0.10 was used to obtain adequate sample representing the population of schools under the study.

This resulted into $n = \frac{44}{1+44\ (0.10)^2} = 31$ schools.

The number of school going children was estimated using formula of Fisher *et al.,* (1998); N = $Z^2pq/\ d^2$, whereby N was the required sample size, Z was the normal standard deviation (1.96), p the expected proportion of the total population of school children benefiting home-grown school meals programme (0.5), and q the expected ratio of the population of school children not under home-grown-school meals program (1-p), and d was the level of precision. The level of precision of 0.04 was used to obtain appropriate sample for children consuming maize based diets in schools.

This resulted into $N = \frac{1.96^2 \text{x } 0.5 \text{ x } (1-0.5)}{0.4^2}$ = 496 school children.

The sample size of food handlers was equally calculated using formula of Fisher *et al.,* (1998), in which the level of precision of 0.9 was applied in order to obtain appropriate sample representation for the food handlers.

This resulted into $N = \frac{1.96^2 \text{x } 0.5 \text{ x}1-0.5}{0.9^2}$ = 124 food handlers.

Different levels of precisions were used in order to obtain the highest possible number of school going children as they are the major consumers' maize based diet under the study. The level of precision was also adjusted to reach highest number of the food handlers as they are not many in School Meals Programme. Schools to be studied were also obtained by adjusting the level of precision in order to obtain an adequate sample size from the 44 schools under the School Meals Programme in the study area.

4.3.2.2 Sampling and data collection

A total of 31 primary schools and 496 school going children were selected using simple random sampling method. One hundred twenty-four (124) food handlers were purposively selected from the sampled schools and were interviewed using the structured questionnaires. These food handlers were school meals Cooks, Farmer Organization committee members/suppliers and school stores keepers.

The structured questionnaires were developed and administered to individual food handlers and school children. The questionnaire for school children was designed to capture data on social demographic characteristics of school children, body weights (bwt), meal consumption levels, meal consumption frequency and regular experienced health problems (Appendix 4). Meal consumption levels and body weights (bwt) were collected through direct measurement of individual served meal portions and body weight (bw) using digital weighing scales (seca gmbh and co. kg, designed in German- Made in China). The questionnaire for food handlers was designed to capture data on type of meals prepared for school children and ingredients used in meal preparation.

4.3.2.3 Statistical data analysis

Data obtained was subjected to Statistical Package for Social Scientists (version 20.0) for windows®. General descriptive statistics were used to obtain percentages, means and standard deviations. Pearson Chi-square was used to analyze the association between variables (demographic characteristics, consumption levels and health issues (Appendix 5). Independent t-test was also applied to compare mean differences with variables. The one-way analysis of variance (ANOVA) was used to obtain the least significant differences with variables.

4.3.3 Levels of aflatoxins and fumonisins in maize-based diets consumed by school children

4.3.3.1 Sample size determination

The sample size for aflatoxins and fumonisins tests was estimated using a formula of Fisher et al. (1998) as stated in section 4.3.2.1 The prevalence of 2 % of maize foods contaminated with toxins in Malawi was used according to Monyo *et al.,* (2012). The level of precision of 0.051 was applied in order to obtain appropriate sample of meals consumed in selected schools.

This resulted into $\mathrm{N} = \frac{1.96^2 \mathrm{x}\ 0.21\ \mathrm{x}1-0.21}{0.51^2}$ = 30 samples of maize based porridge.

The level of precision was adjusted to obtain reasonable sample size that can be easily handled and analysed in laboratory with the assumption that the sample obtained represented the foods consumed within a school term as the maize food is usually stocked at the start of the school term.

4.3.4.2 Sample collection

The maize based porridge were purposively sampled from 30 selected schools in triplicates. Thirty (30) samples were collected in triplicates from different cooking pots per school. Collected samples were packed in airtight plastic bottles of 400 mls (manufactured by Arky Plastics Industries in Malawi) and transported in cooler boxes to Aflatoxins Research and Training Laboratory at Chitedze Agricultural Research Station in Lilongwe, Central Malawi.

4.3.4.3 Determination of aflatoxins and fumonisins

Levels of aflatoxins and fumonins in maize-based porridge samples were analysed using Reveal ®Q^{+} immunoassay Kits (©Neogen Corporation, 2018). Approximately 20 grams of each sample was weighed on digital balance (Scout Pro balance Ohaus) and then mixed with 100 mls of 65% ethanol. The mixture was thoroughly blended for 60 seconds using a waring blender (Model 8120, made in USA). The mixture was filtered using the Whatman filter paper 185 mm (Cat no. 1001 185) into 250 ml Conical flask. A 100 µl of sample filtrate was then mixed with 500 ml of aflatoxin and homogenized in a sample dilution cup, while for fumonisins, a 100 µl of sample fitrate was mixed with 200 ml of fumonisins sample diluent and also homogenized in sample solution cup. Each sample extract of 100 µl was transferred into a clear sample cup. The test strips of Reveal ®Q^{+} Kits for aflatoxins and fumonisns were respectively placed into sample extract for 6 minutes to develop. The developed test strips were then removed from sample extract and immediately inserted into Reveal AccuScan® Gold reader system for analysis (Appendix 6). The test results were displayed and recorded. The Reveal ®Q^{+} Kits for aflatoxin and fumonisins had detection and quantification limits of 2-150 ppb and 0.3-6 ppm for total aflatoxins and fumonisins respectively.

4.3.4.4 Statistical data analysis

The data obtained was subjected to Genstat® 20th edition for windows. The One-way analysis of variance (ANOVA) was used to obtain means, standard deviations and compare significant differences of aflatoxins and fumonisins levels among the samples. Tukey Test at 95% confidence interval was applied to analyze the statistical significance among the samples. The obtained results from aflatoxins and fumonisins analysis were respectively converted from ppb to µg/kg, and ppm to mg/kg for easy interpretation.

4.3.5 Determination of aflatoxin and fumonisin intake levels from consumption of maize based porridge consumed by children in schools

4.3.5.1 Intake levels of aflatoxins and fumonisins in maize-based porridge in schools

Exposure to aflatoxins and fumonisins for children due to consumption of maize based porridge was assessed probabilistically using @Risk TopRank Palisade (UK) software for excel (Palisade, UK) V.8.0, where data for aflatoxins and fumonisins levels and consumption levels were fitted to obtain the best fit distributions. Distribution formulae and outputs are presented in Table 4.1. Data on consumption levels was combined with data for aflatoxins and fumonisins in maize-based porridge samples and levels of exposure calculated. The mean and 95th percentile (P95) intake levels were obtained for estimation of Margins of exposure (MoE) using Monte Carlo simulation which was performed to determine variability for exposure at 1,000,000 iterations. The Tolerable Daily Intake (TDI) of aflatoxins was estimated based on Margins of Exposure (MoE) of 10,000 as safety levels of public health (WHO, 2005 ; Benford *et al.,* 2010). The Margins of Exposure of 10,000 is equivalent to 0.017 ng/kg bwt/day of children according to EFSA (2007), which is also equal to 0.62 ng/child/day. Therefore, any exposure value of above 0.017 ng/kg bwt/day were regarded unsafe for school going children.

Exposure to fumonisins was calculated based on provisional maximum total daily intake (PMTDI) of 2 µg/kg bwt/day (JECFA, 2008 ; WHO, 2012) which is equivalent to 0.073 µg/child/day. The estimated exposure rates to fumonisins above 0.002 µg/kg bwt/day and 0.073 µg/child/day were considered unsafe for school children's health.

4.3.5.2 Formulae used in quantitative risk assessment simulation model for Aflatoxin exposure in maize-based porridge

The consumption data was obtained based on daily consumption of maize based porridge which was estimated by diving the weekly intake of maize based porridge (kg/ person) by respondents' body weight (bwt) and dividing again by 7 days according to JECFA (2011) so as to obtain the amount consumed per Kg bwt/day. The distribution of aflatoxins and fumonisins in maize-based porridge was obtained by dividing levels of the mycotoxins per kilogram of maize based porridge, while intake levels were estimated through multiplying the respective amount of aflatoxins and fumonisins and consumption levels of maize based porridge to obtain the amount consumed per Kg bwt/day.

Table 4.1: Distribution functions used in quantitative risk assessment simulation for aflatoxins and fumonisins exposure in maize

Parameter	Distribution	Monte Carlo Function
	Aflatoxin	
Maize based porridge consumption (kg/Kg bwt/day)	Extent	RiskBetaGeneral(2.2546,13.245,0.0077801 ,0.08229,RiskName("Maize based porridge consumption (kg/Kg bwt/day)"))
Aflatoxins levels in maize based porridge (ng/kg)	Levels	RiskExpon(0.0094927,RiskShift(0.001813 6),RiskName("Aflatoxin distribution in maize based porridge (ng/kg)"))
Aflatoxins intake levels in maize based porridge (ng/kg bwt/day)	Intake	Aflatoxin distribution in porridge * Maize based porridge consumption
	Fumonisins	
Maize based porridge consumption (kg/Kg bwt/day)	Extent	RiskBetaGeneral(2.2546,13.245,0.0077801, 0.08229,RiskName("Maize based porridge consumption (kg/Kg bwt/day)"))
Fuminisins levels in maize based porridge (µg/Kg)	Levels	RiskExpon(0.29778,RiskShift(-0.0099259), RiskName("Fumonisin distribution in maize based porridge samples (µg/kg)"))
Fumonisins intake in maize based porridge (µg/kg bwt/day)	Intake	Fumonisin distribution in porridge * Maize based porridge consumption

Bwt – Body weight

4.4 Results

4.4.1 Consumption levels of maize based porridge by children in School Meals Programme

4.4.1.1 Demographic characteristics of the school children

The results showed that 43% of school children who participated in the study were male and 65% were female (Table 4.2). Age of school children ranged from 5 to 19 years and with average age of 11.7 ± 2.8 years. A large proportion (15.9 %) of children was from standard 6 and 7 grades, and a small proportion (8.1%) from standard one. There was significant association of gender and age of school children (χ^2 = 8.592, P = 0.032), where males were significantly older than females. A strong correlation was also observed between age and grade level (r = 0.631, P = 0.043), where older children were significantly in higher grade level, while younger children were in lower grade level. However, there was no significant association of gender and grade level of school children (χ^2 = 3.499, P = 0.835).

Table 4.2: Demographic characteristics of the school children

Characteristics	Frequency (n=496)	Percentage (%)
Gender		
Male	216	44
Female	280	56
Age		
5 to 7	41	8
8 to 10	193	39
11 to 13	118	24
14 to 16	116	23
17 to 19	28	6
Grade levels		
STD 1	40	8
STD 2	57	11
STD 3	58	12
STD 4	54	11
STD 5	68	14
STD 6	79	16
STD 7	79	16
STD 8	61	12

STD = Standard

4.4.1.2 Type of meals prepared in schools for children consumption

Ninety-six percent (96%) of food handlers reported that ingredient for preparing school meals was maize as main ingredients. Other respondents reported groundnuts (85%) and soybean (57%). A small proportion of respondents (3 %) included vegetables, rice and fruits. With respect to the meals prepared for school children, all respondents (100%) reported that maize porridge was the main meal prepared in schools (Table 4.3). Furthermore, respondents indicated that porridge could sometimes be prepared from the blend of maize-soybean-groundnuts flours also added mashed vegetables to porridge. The respondents also reported that ingredients were mixed in order to increase nutrient dense for the school meals. All respondents indicated that porridge was served once every day in morning before class sessions from Monday to Friday.

Table 4.3: Ingredients and meals prepared for children in 31 primary schools

Factor	Frequency (n=124)	Percentage (%)
Ingredients		
Maize	119	96
Groundnuts flour	105	85
Soy bean	71	57
Fruits	59	48
Vegetables	72	58
Animal source foods	0	0
Rice	61	49
Others	2	3
Type of meal prepared		
Nsima (Ugali)	5	4
Porridge	124	100
Others	2	2

4.4.1.3 Consumption levels of maize based porridge in schools

Consumption levels of maize based porridge in schools ranged from 450 to 800 grams per child per day and had a mean value of 609.7 ± 62.1 grams. Consumption levels of maize based porridge were significantly different among school children ($P < 0.05$). A large proportion (38%) of school children consumed porridge ranging from 552 to 602 grams per child per day, while the lowest proportion (2%) consumed more than 756 grams of porridge. The model distribution for consumption of maize based porridge for school children was defined by Beta general distribution and had ranged from 0.008 to 0.082 Kg/Kg bwt/day with a mean value of 0.019 Kg/Kg bwt/day (Figure 4.2). However, no correlation was observed between meal consumption levels and age of school children ($r = 0.033$, $P = 0.459$). Equally, there was no correlation of meal consumption levels and grade level of the school children ($r= -0.004$, $P = 0.937$). This was disappointing taking into account that the amount of food consumed is dependent on age of the child. There was also no significant association between meal consumption levels and gender of the school children ($\chi^2 = 85.624$, $P = 0.286$).

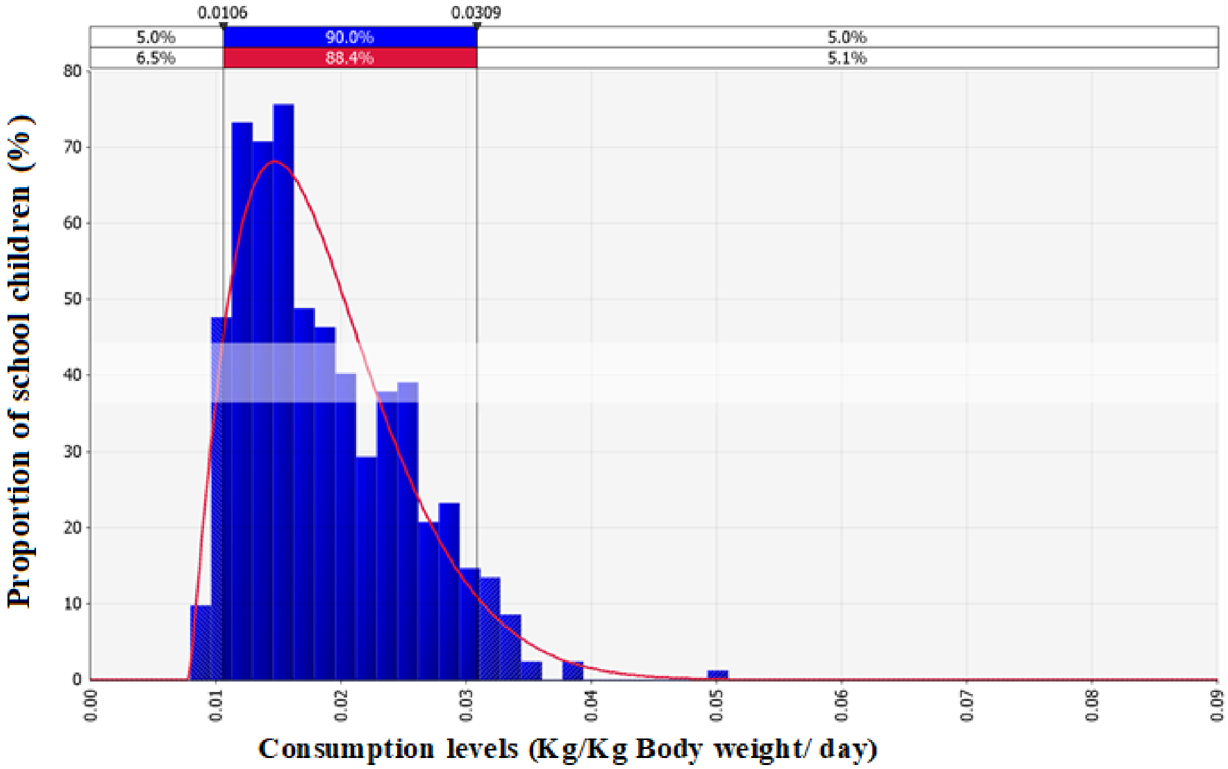

Figure 4.2: Model distribution for consumption (Kg/Kg bwt/day) of maize based porridge by school children in Salima district, Central Malawi.

4.4.1.4 Body weights of school children

The body weights of school children ranged from 12 to 66 kilograms with average weight of 34.6 ± 1.2 kilograms. Most school children (20.8%) weighed 24 to 29 kilograms, while the least (1%) weighed 12 to 17 kg (Figure 4.3). There were significant differences in body weights among the children in the schools (P = 0.017). Furthermore, it was observed that there were significant positive correlation between body weights and age of school children (r = 0.835, P = 0.000). A strong correlation was also observed between body weight and grade level of school children (r = 0.725, P = 0.000), whereby older school children had higher mean scores of body wieghts and higher mean scores of grade level than younger children. However, no significant association was observed between body weight and gender of school children (χ^2 = 2.859, P = 0.391). Furthermore, the results showed no correlation between body weight and meal consumption levels of school children (r = 0.076, P = 0.089).

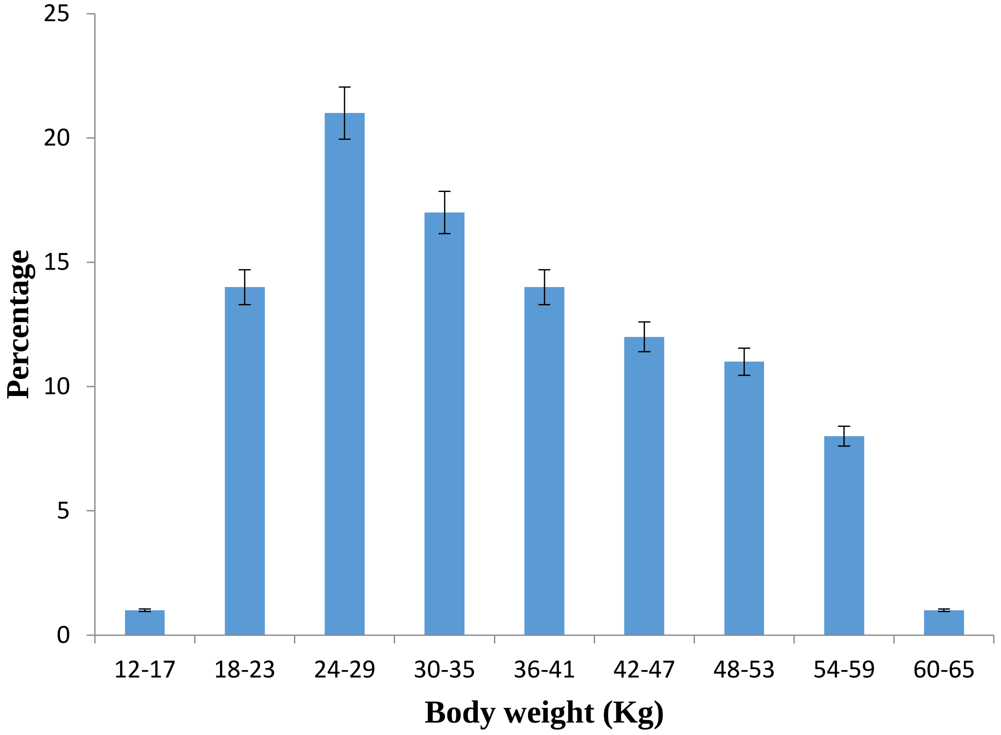

Figure 4.3: Body weights of children from 31 primary schools in Salima District, Central Malawi. Error Bars presents standard errors of the mean

4.4.1.5 Health problems experienced by school children

Nineteen (19%) of school children reported that they experienced frequent headaches, 16% reported that experienced occasional stomach discomforts, 14% reported occasional diarrhea diseases, 11 % reported frequent coughs while a small proportion (11%) suffered fevers and (5%) nausea and/or vomiting (2%). On the other hand, a large proportion (29 %) of school children reported that rarely experienced any health problems. There were no significant associations of health problems and gender of the school children (χ^2 = 12.507, P = 0.130). In addition, there was no association of health problems and age of the school children (χ^2 = 1.213, P = 0. 258). However, a significant association was observed between health problems and school grade level (χ^2 = 56.698, P = 0.029), where children of lower grade level had higher mean scores of health problems than children in higher grade level. No association was also observed between health problems and meal consumption levels (χ^2 = 49.250.001, P = 0.423) of school children. Similarly, no association was observed between health problems and body weight of school children (χ^2 = 66.934, P = 0.64).

4.4.2 Levels of aflatoxins and fumonisins in maize-based porridge consumed by children in schools.

All 30 analyzed samples of maize based porridge had detectable levels of aflatoxins and fumonisins with exponential distributions as shown in Figure 4.4 and 4.5. Levels of aflatoxins ranged from 2.13 to 33.37 µg/Kg with mean value of 11.62 µg/Kg. The results showed significant difference in levels of aflatoxins among samples obtained from schools ($P < 0.05$). Forty percent (40%) of the contaminated samples had levels of aflatoxins exceeding the regulatory levels of 10 µg/Kg set in Malawi according to the standard levels of aflatoxins in foods, mostly cereal or legume based, 17% of the samples had aflatoxins exceeding the recommended levels in United State of America of 20 µg/Kg, and 90% of the samples had levels of aflatoxins beyond limit levels set in European Union of 4 µg/kg for all processed maize based products. It was further observed that all 30 samples had aflatoxins above the acceptable levels for European Union (0.1 µg/Kg) for all cereal based products meant for young children consumption.

Fifty-six (56 %) of the contaminated samples levels had fumonisins ranging from non-detectable levels to 1.1 mg/Kg with mean value 0.30 mg/Kg. Levels of fumonisins were significantly different among the samples from schools ($P < 0.05$). Furthermore, 6% of the analyzed samples had aflatoxins concentration levels exceeding the recommended safety levels set by the European Union (0.1 mg/Kg) for all processed maize based products meant for young children consumption. Currently in Malawi there is no standards that specifies the recommended limits of fumonisins in foods.

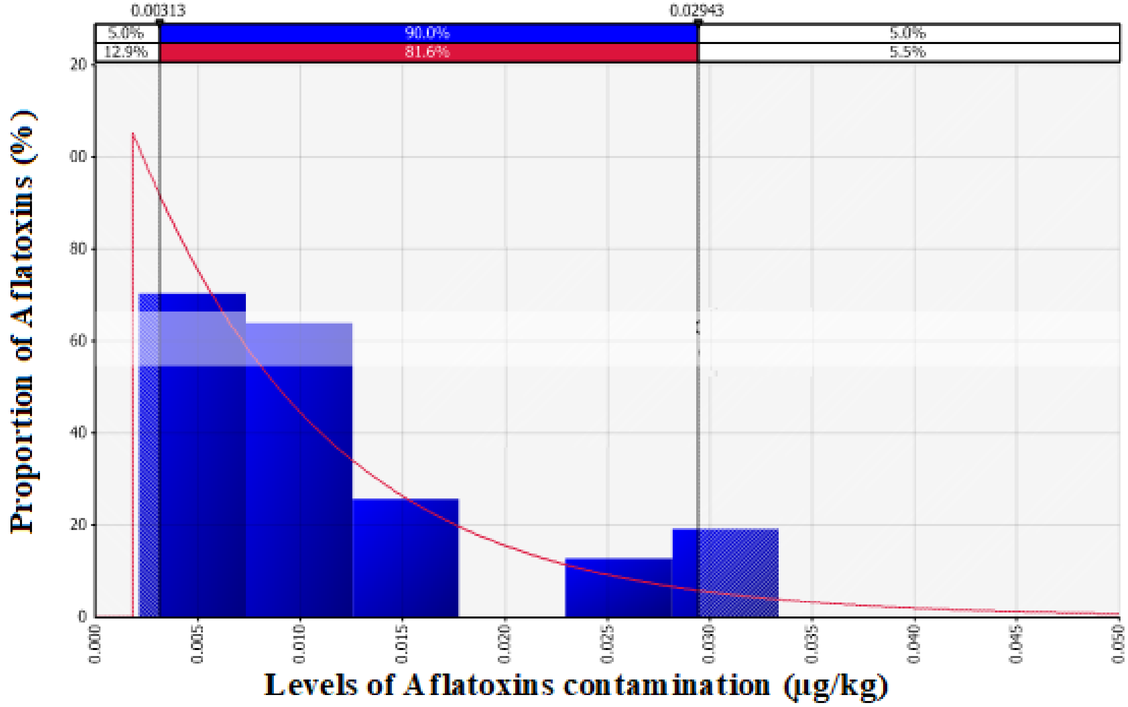

Figure 4.4: Distribution models for aflatoxin contamination (µg/kg) in maize-based porridge consumed by school children in Salima district, Malawi.

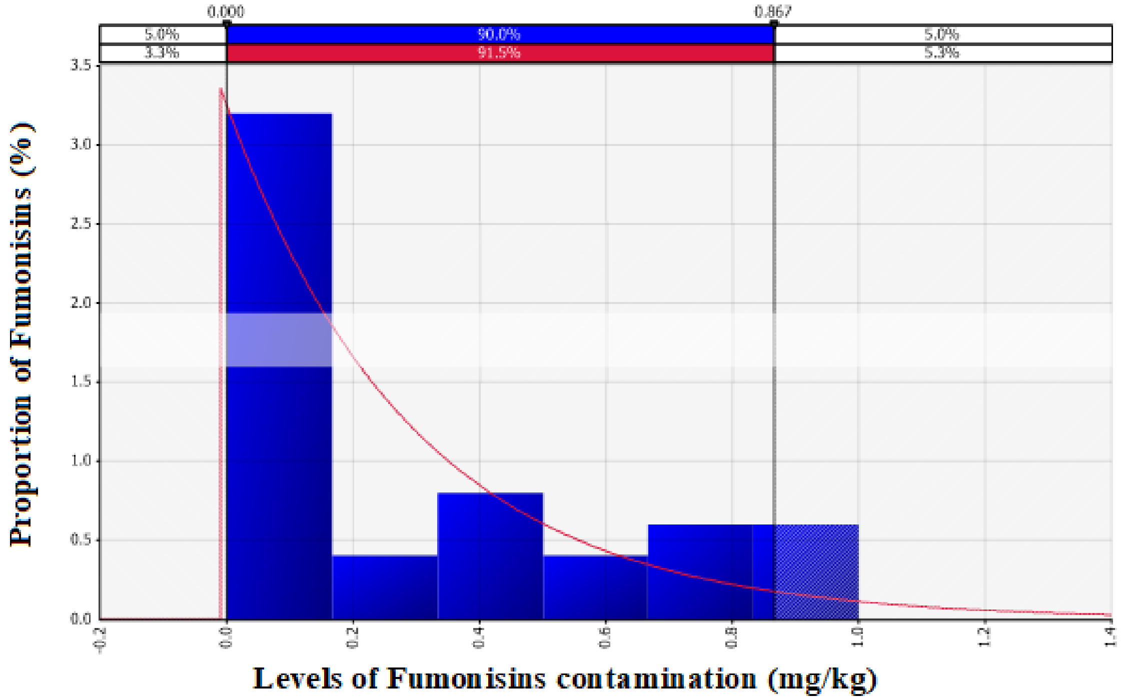

Figure 4.5: Distribution models for fumonisin contamination (mg/kg) in maize based porridge consumed by school children in Sanlima district, Malawi.

The results based on Extension Planning Areas in salima District where the study took place showed that all areas had occurrence of aflatoxins and fumonisins (Table 4.4). The mean values of aflatoxin levels had ranged from 9.97 to 13.21 µg/Kg and was high (13.21 µg/kg) in maize-based porridge samples obtained in Chipoka Extension Planning Area, while the lowest level (9.97 µg/kg) was observed in samples from collected in Tembwe Extension Planning Area ($P > 0.05$). However, levels of aflatoxins were not significantly different between Extension Planning Areas. Mean levels of fumonisins had ranged from none detectable (<0.3) to 0.417 mg/kg. Levels of fumonisins was high (0.7 mg/kg) in maize-based porridge samples collected from Chipoka Extension Planning Area and the lowest level (0.12 mg/kg) was observed in samples obtained from Tembwe Extension Planning Area. Levels of fumonisins were significantly different between Extension Planning Areas ($P < 0.05$).

Table 4.4: Aflatoxins and fumonisins levels in maize-based porridge samples collected in 3 Extension Planning Areas in Salima District, Central Malawi

		Aflatoxins		**Fumonisins**	
EPAs	**Frequency (n)**	**Mean ± SD (µg/Kg)**	**Range (µg/Kg)**	**Mean ± SD (mg/Kg)**	**Range (mg/Kg)**
Tembwe	10	9.97 ± 4.9 ^{a}	3-17.6	0.3 ±0.338 ^{a}	<0.3-1.1
Katelera	10	11.61 ± 11.86 ^{a}	2-63.9	0.3 ± 0.384 ^{a}	<0.3-1.3
Chipoka	10	13.21 ± 14.35 ^{a}	3-74.7	0.4167 ± 0.471 ^{a}	<0.3-1.4

EPA – Extension Planning Areas (demarcated based on agro-ecological zone)

The superscript in the same column shows that mean scores were not significantly different through Tukey Test ($P < 0.05$)

4.4.3 Exposure of school children to aflatoxins and fumonisins from the consumption of maize based porridge in schools

Exposure of school children to aflatoxins as a result of consuming maize-based porridge in schools ranged from 0.034 ng/Kg bwt/day to infinity (+∞). The mean value and 95th percentile (P95) of exposure to aflatoxins through consumption of maize based porridge were respectively 0.2 and 0.6 ng/Kg bwt/day. The children with average weight of 36.4 kg had minimum aflatoxin exposure of

1.24 ng/Kg bwt/day, mean aflatoxins exposure of 7.28 ng/Kg bwt/day and 95th percentile of aflatoxins exposure of 1.24 ng/Kg bwt/day from the intake of maize based porridge. The recommended Margins of Exposure (MoE) for aflatoxins in children is 0.017 ng/kg bwt/day (EFSA, 2007). The results showed that the estimated minimum, means and 95th percentile values of exposure to aflatoxins were above the recommended regulatory limits of aflatoxins exposure for children. This observation demonstrated that school children were exposed to unacceptable levels of aflatoxins through the consumption of maize based porridge in schools which might eventually negatively affect their health (Table 4.5).

The exposure to fumonisins for school children through intake of maize based porridge in schools ranged from 2.0 to 3.0 µg/Kg bwt/day. The mean value and 95th percentile of exposure to fumonisins through consumption of maize based porridge were respectively 6.0 and 9.2 µg/Kg bwt/day. School children with average weight of 36.4 kg had minimum exposure to fumonisins of 73.0 µg/kg bwt/day, mean fumonisins exposure of 218 µg/Kg bwt/day, and 95th percentile of 334.9 µg/kg bwt/day through consumption of the maize based porridge. The recommended maximum regulatory levels of fumonisins exposure is 2.0 µg/Kg bwt/day (JECFA, 2008 ; WHO, 2012). From the results, the estimated values of minimum, means and 95th percentiles of fumonisins exposures were above the recommended regulatory limits of fumonisins exposure. Just like with aflatoxins exposure, these results demonstrated that school children were exposed above the acceptable limits of fumonisins exposure due to intake of maize based porridge in schools which might potentially harm the school children health (Table 4.5).

Table 4.5: Estimated margins of dietary exposure of children to aflatoxins and fumonisin due to consumption of maize based porridge in School Meals Program in Salima District in Malawi

	Aflatoxins Intake (ng/kg bwt/day)			**Fumonisins Intake (µg/kg bwt/day)**		
	Min	Mean	P95	Min	Mean	P95
Dietary Exposure	0.03	0.20	0.60	2.00	6.00	9.20
MOE (Min bwt =12 Kg child	0.41	2.40	7.20	24.00	72.00	110.40
MOE (Mean bwt =36.4 Kg child)	1.24	7.28	21.84	72.80	218.40	334.88
MOE (Mean bwt = 66 Kg child)	2.24	13.20	39.60	132.00	396.00	607.20

P95 = 95th percentile, MOE=Margin of Exposure, Min = Minimum, Max = Maximum, Bwt' = Body weight

4.5 Discussion

4.5.1 Demographic characteristic of the school children

The demographic characteristic showed that the study had more female school children as than their male counterparts and majority were below 13 years of age. The study revealed no significant association of gender and age of school children, whereby males were significantly older than females. Similar studies reported that young children are more susceptible to pathogenic microorganisms and environmental toxicants (CDC, 2004; Faustman *et al.,* 2000), compared to older people due to their low developed immune system, increased food demand and uncontrolled diet (Gong *et al.,* 2016). According to the results of the present study, children in lower grade might be more subjected to mycotoxins exposure than those in higher grade levels. Previous studies have shown that increased age and level of education has significant positive correlation with awareness of foodborne infections, food safety, and hygiene practice (Ababio 2016 ; George *et al.,* 2018).

4.5.2 Types of meals prepared in schools for children

This study has established that porridge was the main meal consumed by school children in schools prepared from the combination of maize-groundnut-soybean flour (Table 3). The combination of maize and legumes have been widely used to improve children nutrition in developing countries (Soro-Yao *et al.,* 2014; Mishra *et al.,* 2012). However, some studies have reported that most maize-legume based foods from Sub-Saharan Africa countries have mycotoxins (Njoroge *et al.,* 2016 ; Mupunga *et al.,* 2014). Previous studies have further confirmed high aflatoxins and fumonisins exposure to young children from consumption of maize-based foods (Kimanya *et al.,* 2014 ; Kang'ethe *et al.,* 2017).

4.5.3 Consumption levels of maize based porridge in schools

The average consumption of maize based diet mainly porridge (610 grams/day) by school children which has been revealed in the present was very high compared to the average consumption levels of maize based foods reported in other countries like 397 grams/day in South Africa, 356 grams/day in Tanzania (Burger *et al.,* 2014), 400 grams/day in Kenya (Sundsmo *et al.,* 2015), and also exceeded the average range of 150 to 500 grams/day estimated in East African countries (Gong *et al.,* 2015). Maize foods in Malawi constitutes 60 % of the total food production providing 74 % of caloric energy for most Malawians (Gonani, 2012; Mazunda and Droppelmann, 2012). However, some studies have reported that high consumption of maize based foods increases exposure to mycotoxins (Alberts *at al.,* 2019). A study in South Africa found that that the population which consumed maize based foods on average of 400 to 500 grams/person/per day, had detectable biomarkers of fumonisins exceeding the regulatory limits of 2µg/Kg bwt/day (Shephard *et al.,* 2007). The average consumption of maize based porridge reported in this present study might have exposed the school going children to mycotoxins beyond the safety levels.

4.4.4 Body weights of school children

The present study revealed no significant association of body weight, age and meal consumption levels of the school children. This might be due to the fact that most schools served porridge using similar serving spoons or cups regardless of age and body weight of a person. Studies estimate intake levels of mycotoxins based on levels of food consumption and body weights (Liu and Wu, 2010). The equal distribution of maize based porridge in schools might affect the health of younger children and those with too low weight from large intake of maize-based foods which have been widely reported prone to mycotoxins contamination. Children suffer most from mycotoxins exposure due to their low ability to detoxify toxins and increased food intake per kg body weight (WHO, 2018). The results of the present study agree with Kang'ethe *et al.,* 2017, who equally reported no significant difference in meal consumption levels of specific age group and exposure to mycotoxins. According to the same author, different age groups had similar aflatoxin exposure from consumption of different levels of maize based foods.

4.5.5 Health problems experienced by school children

The health problems reported in the current study might have been due to consumption of unsafe foods and poor hygienic practices observed in schools during the study visits. It was observed that most school children were consuming porridge from plates which were placed on bare-ground, while exposed to the soil dust from wind blows, footstep movements and overcrowd of school children at the serving points (kitchen) and dining areas. In addition, it was noted that all the sampled schools had no properly designated dining structures. It was further observed that some school Cooks were not wearing protective clothing such as aprons and head covers (chef hat) during meal preparations. Findings from previous researchers have reported that molds contaminates foods at any stage in value chain including during preparation (Eshiett *et al.,* 2013). The current results are similar with those reported by WHO (2011), that 155 school children in United State of America experienced abdominal cramps, vomiting, cough, fever, headache and nausea after consuming mycotoxins contaminated school lunch. Similar health problems were reported in Ghana and Indonesia after school children consumed school meals (Ababio *et al.,* 2016; Adolf and Azis, 2012).

The findings from the present study revealed significant association of health problems with grade level of school children ($p < 0.05$), whereby mean scores of health problems reported by children in lower grade level was higher than mean scores of leaners in higher grade level. According to Ababio (2016), high education level is positively associated with better knowledge of foodborne dieases, good hygiene and food safety practice. Furthermore, the present study established no significant association of regular health problems reported by school children with consumption levels of maize based porridge in schools. However, the results of the current study are contrary other studies which reported a significant association of health problems with consumption of maize based foods (Kimanya, 2015; Warth *et al.*, 2012 ; Khlangwiset *et al.,* 2011).

4.5.6 Aflatoxins and fumonisins levels in maize-based porridge consumed in schools

This study established co-occurrence and high aflatoxins and fumonisins levels in maize-based porridge consumed by school children under school meals programme. High aflatoxins and fumonisins levels in schools might presumably be attributed to poor postharvest handling practices of maize foods which were observed during samples collection in schools (Appendix 3). According to findings from unpublished work by authors of the present study, it was reported that maize foods and other foodstuffs constituting the school meals were transported to schools while uncovered on open pickup trucks/lorry, and bags of foodstuffs were offloaded directly on bare ground. It was further observed that some schools had stored maize bags in contact with floor and walls, while other storerooms had accumulated soil dust, birds' droppings and spider-nets. Some food handlers also reported that do not sort maize grains to remove rotten and moldy contaminated grains during processing due to the bulkiness of grains and limited time for meal preparations.

Previous studies have reported that foodstuffs are contaminated with mycotoxins due to many factors which includes poor post-harvest handling practices during transportation, storage, and processing (WHO, 2018). Eshiett *et al.,* (2013) reported that molds species contaminate food crops at any stage along the food chain including during handling and processing. The maize-based porridge samples that had high levels of aflatoxins and fumonisins might be attributed to the combination of the ingredients which included maize, groundnuts, and soybean. Most studies have reported that maize, groundnuts and their derived products from Southern Africa including Malawi are highly contaminated with aflatoxins and fumonisins (Misihairabgwi *et al.*, 2019 ; Mwalwayo and Thole, 2016 ; WHO, 2018). The results of the current study agree with other researchers who had reported of high aflatoxins and fumonisins levels in maize based foods intended for children consumption in countries like Ghana (Kumi *et al* 2015), Pakistan (Mushtaq *et al.,* 2012), Nigeria (Ojuri *et al.,* 2019), and Spain (Herrera *et al.,* 2019).

4.5.7 Exposure of children to aflatoxins and fumonisins due to consumption of maize based porridge in schools

This study established high aflatoxin exposure for school children from intake of maize based porridge in schools. Exposure of children to aflatoxins might be attributed to high consumption levels of aflatoxins contaminated maize based porridge in schools. The consumption of maize based porridge in schools might negatively affect the health of school going children. The current results agree with Kamala *et al.,* (2017) in Tanzania who reported high exposure of children to aflatoxins ranging 0.14 to 120 ng/kg bwt/day through regular intake of maize-based foods. Furthermore, exposure to aflatoxins were reported to be high in Tanzania for young children who frequently consumed complementary foods from corn-based ingredients (Magoha *et al.*, 2016). In Kenya, children exposure to aflatoxins have been reported ranging 0.011 to 0.49 ng/kg bwt/day through regular consumption of maize foods (Herrera *et al.*, 2019). The results of the present study further agree with Ojuri *et al.,* (2019) in Nigeria, who reported high aflatoxins exposure for young children from the intake of maize based products (*Tom bran*) which had median value of 641 ng/kg bwt/day.

The present study also established high fumonisins exposure for children from consumption of maize based porridge in schools. High fumonisins exposure might equally result from consumption of fumonisins contaminated maize-based porridge in schools. Children consuming large quantities of maize based porridge in schools might be at risk of mycotoxicosis. The results from the present study are comparable to Kamala *et al* (2017) who had reported high fumonisins exposure (0.005 to 0.88 µg/Kg bwt/day) for children in Tanzania who often consumed maize based foods. Ojuri *et al.,* (2019) reported high fumonisins exposure for children in Nigeria through consumption of processed complementary foods with median values of 18, 8.2 and 6 µg/kg bwt/day for family cereals, *Tom bra*n and *Og*i, respectively. Furthermore, the current results agree with World Health Organisation (2018) that total fumonisins exposure in diets range 0.013 - 0.82 µg/kg bwt/day.

Based on findings from the current study, high expsosure to aflatoxins and fumonisins for school going children through consumption of maize based porridge under school meals programme may affect their health, education and future well-being. Chronic exposure to aflatoxins and fumonisins has been significately associated with variuos heath effects like cancer, malnutrition, immunosuppression, impaired growth and promotes occurrence of other ailments including respiratory problems, stomach crumps, vomiting, diarrhea, malaria among problem (Ababio *et al.*, 2016 ; Kimanya, 2015 ; Warth *et al.,* 2012 ; Khlangwiset *et al.,* 2011; Wagacha and Muthomi 2008).

4.6 Conclusion

The study concludes that school children under school meals programme in Salima District, Central Malawi, are exposed to unacceptable levels of aflatoxins and fumonisins through the consumption of maize based porridge in schools. The high consumption of mycotoxin contaminated maize-based diets in schools contributes to high exposure of school children to aflatoxins and fumonisins. School children with lower body weights are likely to suffer more from mycotoxins effects compared to those with high body weights due to large consumption of mycotoxins contaminated maize based porridge. Moreover, poor hygienic practices in schools contributes to regular health problems of school children. Feeding school children mycotoxins contaminated maize based porridge may in long term affect their health, education and future well-being.

4.7. Recommendation

The study recommends regular monitoring of food commodities in schools to prevent school children from mycotoxins exposure. There is need for diversification of maize with other cereal based foods that are less prone to mycotoxins contamination. Substitution of maize-legume blend with roots and tubers can be recommended to reduce consumption levels of maize foods in schools. There is need to promote good hygienic practices in schools to prevent school children from regular health problems through providing capacity building on post-harvest handling, transportation and storage techniques

. Creating awareness and promoting proper post-harvest handling practices and processing of maize foods in schools can also minimize mycotoxins production.

CHAPTER FIVE: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

The study established that food handlers had high knowledge of toxigenic molds contamination in maize foods. On the other side, large proportion of food handlers had inadequate knowledge of the side health effects of consuming maize foods contaminated with toxigenic molds and also inadequate knowledge of control measures. Furthermore, majority of food handlers were not aware of mycotoxins contamination in maize foods. The knowledge of food handlers on toxigenic molds could be the outcome of regular farmers trainings on postharvest handling of food commodities which the Ministry of Agriculture promotes in order to reduce post-harvest losses in Malawi (Ministry of Agriculture, 2016). Inadequate awareness of food handlers on mycotoxins such as aflatoxins and fumonisins were significantly associated with education level of food handlers whereby those that that attended high education level (tertiary) had higher mean scores of knowledge of mycotoxins than those with low education level (primary). In the present study, it was further evidenced that food handlers where not trained on mycotoxins, which could also attribute to low knowledge of food handlers on health effects of toxigenic molds. The current study agree with previous studies that most food producers and consumers in developing countries have limited knowledge on mycotoxins related issues such as human health implications and mitigation measures (Changwa, 2017). Other authors have reported that lack of proper strategies to inform the general public on effects of mycotoxins and postharvest handling practices of foodstuffs persist to be an issue in food safety (Torabi *et al.*, 2016).

Despite food handlers having high knowledge of toxigenic molds, the present study established that large proportion of food handlers were practicing poor postharvest handling of maize foods during transportation, reception, storage and processing. Poor postharvest handling of maize foods has been reported as common practice in Malawi (Matumba *et al.*, 2016). The current study further established no significant differences in handling of maize foods across respondents' age, gender and education level. The results from the current study are comparable to previous studies which reported that most post-harvest handling practices among food suppliers and consumers are not adequate to protect foodstuffs from mycotoxins contaminations (Mboya *et al.*, 2011 ; Demissie *et al.*, 2008).

This study revealed that maize based porridge consumed by children in schools had aflatoxins and fumonisins. Levels of aflatoxins and fumonisins were above maximum limits recommended by regulatory bodies. High levels of aflatoxins and fumonisins in schools might be attributed to poor postharvest handling practices of maize foods during transportation, reception, storage and processing. Molds species such as *Aspergillus flavus*, *Aspergillus parasiticus* affect food crops at any stage in food chain including during transportation (Eshiett *et al.*, 2013). Several authors have reported that poor handling of food commodities like maize contribute to increased molds and mycotoxins productions (Eshiett *et al.*,2013 ; Milani, 2013). Reports have shown that food is contaminated with mycotoxins through various factors which include transportation, traditional methods of food processing, poor storage conditions and poor personal hygiene (Feglo and Sakyi, 2012 ; Vallabhbhai *et al.,* 2015). The results of the current study support other studies which had reported of high aflatoxins and fumonisins levels in maize based foods intended for feeding children in various countries like Ghana (Kumi *et al* 2015), Pakistan (Mushtaq *et al.,* 2012), Nigeria (Ojuri *et al.,* 2019), and Spain (Herrera *et al.,* 2019).

Furthermore, the present study established that school children were exposed to aflatoxins and fumonisins above acceptable levels from large consumption of maize based porridge in schools. High exposure of children to mycotoxins might be attributed to high consumption levels of maize based porridge in schools. Several studies have significantly associated high exposure to aflatoxins and fumonisins among children consuming high levels of maize foods (Valdez, 2008 ; Misihairabgwi *et al.,* 2017 ; Kimanya *et al.*, 2008). The results of the current study support several previous studies that reported high exposure of children to aflatoxins and fumonisins due to regular intake of maize based foods in many countries such as Tanzania (Kamala *et al.*, 2017 ; Magoha *et al.*, 2016), Kenya (Herrera *et al.*, 2019) and Nigeria (Ojuri *et al.*, 2019).

The present study revealed no significant association of regular health problems and consumption levels of maize based porridge, and body weights of the school children. However, the uniform serving portions of maize based porridge reported in the present study (chapter 3) might in long term affect the health of children with low body weight from large consumption of mycotoxins contaminated maize-based foods in schools, since intake levels of mycotoxins are estimated based on food consumption levels and body weight (Liu and Wu, 2010). Children have been reported to suffer most from mycotoxins exposure due to their low ability to detoxify toxins and increased food intake per kg body weight (WHO, 2018). A number of studies have significantly associated dietary exposure to mycotoxins with variuos acute and heath implications which include cancer, impaired growth, malnutrition, immune suppression and other ailments like respiratory problems, stomach crumps, vomiting, diarrhea, malaria among others (Ababio *et al.,* 2016 ; Kimanya, 2015 ; Warth *et al.,* 2012 ; Khlangwiset *et al.,* 2011; Wagacha and Muthomi 2008). The results of the present study contradicts with other studies which reported a significant association of health problems with consumption of maize-based foods (Kimanya, 2015; Warth *et al.,* 2012 ; Khlangwiset *et al.,* 2011). However, high intake of mycotoxins in maize-based porridge and poor hygiene observed in the current study might further exacerbate health problems of the school going children. From the results of the present study, inadequate knowledge on control of toxigenic molds among food handlers and poor post-harvest handling of maize foods greatly contributes mycotoxins contamination in maize-based diets consumed by children in schools. High exposure of children to mycotoxins will potentially affect their health, education and future-well-being from high intake levels of aflatoxins and fumonisins contaminated maize-based porridge in schools under school meals programme. Appropriate mitigation measures are required to prevent school going children from mycotoxins exposure

5.2 Conclusions

The study concluded that food handlers under School Meals Programme in Salima Distrct, Central Malawi have high knowledge of toxigenic molds contamination in maize-based foods. However, they have low knowledge of the chronic health effects associated with molds and control measures. The study also established that food handlers have low knowledge of mycotoxins contamination in maize-based foods. The poor postharvest handling practice of maize foods among food handlers identified in this study might contribute to mycotoxins contamination in school maize based diet. Furthermore, the study concluded that aflatoxins and fumonisins levels in maize based porridge were above regulatory maximum limits. School children were exposed to intolerable levels of aflatoxins and fumonisins due to consumption on maize-based porridge in schools. School children with lower body weights are likely to suffer more from mycotoxins effects compared to those with high body weights due to large consumption of mycotoxins contaminated maize based porridge. Moreover, poor hygienic practices in schools contributes to regular health problems of school children. Feeding school children mycotoxins contaminated maize based porridge may in the long term affect their health, education and future well-being.

5.3 Recommendations

The study recommends that all stakeholders involved in the school meals programme should be extensively trained on mycotoxins and their associated health effects to prevent school children from the risk of mycotoxins exposure. Creating awareness and promoting proper post-harvest handling practices and processing of maize foods in schools can further minimize mycotoxins production in school meals. There is need for regular monitoring of food commodities in schools to prevent from mycotoxins production and exposure of school children to mycotoxins. Diversification of maize with other cereal based foods that are less prone to mycotoxins contamination can be appropriate strategy to reduce intake levels of mycotoxins. Substitution of maize-legume blend with roots and tubers can be recommended to minimize consumption levels of maize foods in schools. Furthermore, the Ministry of Education, Science and Technology should promote good hygienic practices in schools to prevent school children from regular health problems.

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APPENDICES

Appendix 1: Food handlers' questionnaire

Questionnaire Number______________

Enumerator Name: ________________________Contacts____________________________

Background information

1. General information

District name:		
Date of interview		
Name of school		Zone:
Date checked		
Date of data entry		
GPS Coordinates		

2. Demographic characteristics of the respondent

2.1 Name of respondent		Phone No;
2.2 Respondent gender	Sex, M=1, F=2	
2.3 Level of education	1=Primary level 2=Secondary level 3=Tertiary level 4= none	
2.4 Age of respondent (years)		

3. Assessing post-harvest handling knowledge of food handlers

			
Show the respondent above samples/pictures of maize contaminated with molds.			
In reference to the samples shown above, ask the respondent the following statements;	**True**	**False**	**Don’t Know**
Causes			
1. This contamination is caused by insects and pest attack during storage			
2. This contamination occurs due to storage of wet or not fully dried maize grains			

3. This contamination is caused by placing maize grains on bare ground or in contact with floor/ wall			
4. Wet or leakage storage room causes this contamination			
5. Damaged/broken grains contribute to increase of this contamination			
6. This occurs due to over-storage of maize grains such as over the period of four months and above			
7. This contamination mostly occurs during handling and transportation of maize grains such as during loading, movement and offloading			
8. Rodents contribute to occurrence of this contamination			
Prevention;			
9. Sorting/grading of damaged, rotten maize grains and foreign objects before storage can prevent maize from this contamination.			
10. This contamination cannot occur to maize grain treated with pesticides and insecticides			
11. Maize grain and other non-food items (cooking utensils) can be kept in same storeroom without causing this contamination			
12. It is good to feed livestock this kind of contaminated maize grains than dispose away			
Health effects			
13. Consumption this contaminated grains may affect human health			
14. Consumption of this contaminated maize grains can cause cancer to human being			
15. Consumption of this contaminated maize grains can impair child growth (Malnutrition/Stunting			
16. Consumption of this contaminated maize grains cannot cause death to human being			
17. Consumption of this contaminated maize grain can cause infections such as nausea, vomiting and diarrhea			
18. This kind of contaminated grains contain toxic substances			
19. Aflatoxin is the poisonous substance found in this kind of contaminated grains			

20. Fumonisin is the poisonous substance found in this kind of contaminated grains			
Degradation/Reducing			
21. Processed maize flour undergone traditional methods of processing flour such as removing bran, soaking, drying and milling can reduce levels of toxins found in this contaminated maize grains			
22. The toxins found in this contaminated grains can be degraded or removed during any cooking methods such as boiling, deep frying and roasting. Therefore cooked food cannot contain toxic substances found in this contaminated maize grains			
23. This kind of contaminated grains can only be consumed during food crisis or disaster			

Practices of food handlers

1. Have you ever attended any training on post-harvest handling of maize grains	1=Yes, 2=No	
2. If yes, please specify the type of training or workshop		
3. What are the main meals prepared for leaners?	1= Porridge 2= Ugali 3= Others (Specify)	
4. What are the main foods/ingredients for preparing school meals	1=Maize, 2=Groundnuts, 3=Soybeans, 4=Fruits, 5=Vegetables, 6 =Animal source foods 7= Rice, 8=others (specify)____________________	
5. Where do you source foodstuff for the school meals?	1=School garden, 2= Farmer Organizations, 3=Vendors/Individuals 4=Open Market,	5=Government/NGO, 6=Others(Specify); _________________
6. How do you chose the suppliers	1=Bidding/Tender, 2= Open supply (Any), 3=Others (specify); __________________	
7. Do you know how suppliers handle or store foodstuffs before delivery to schools	1= Yes 2= No	
8. If yes, how do suppliers handle or store foodstuffs before delivery to school	1= Cool and dry place 2= Clean place 3= Bags packed in contact with floor or wall 4= Bags packed on raised platforms 5=Ventilated room	6= Store in separate room from other items 7= Store in room mixed with other items 8= Control pests and rodents 9= Others (specify)_______________

		10= Don’t know
9. How is foodstuff transported to the school?	1= Load on open vehicle/lorry 2=Load on covered vehicle/lorry 3=Load on covered ox-cart 4=Load on open ox-cart 5= Bicycle, 6=Wheelbarrow, 7= Others (specify)_____	
10. Do you check the quality of foodstuffs when receiving from suppliers?	1= Yes 2= No	
11. If yes, what attributes do you use to determine good quality foodstuff	1=unchanged colour 2=free from rotting/decay 3=undamaged/unbroken grains	4=good smell 5= Laboratory test 5= Others (specify)
12. If no, why not	1= Cannot reject because of contract agreement 2= Not necessary to check the condition 3= Trusted and reliable suppliers on delivery of good quality foodstuff 4= Foodstuff cannot be contaminated with toxigenic molds 5=Others (specify)	
13. How do you handle the foodstuff on reception from the suppliers?	1=Offload foodstuffs direct on bare ground 2=Offload foodstuffs on mat/tent 3= Grading/Sorting before storage 4=Winnowing before storage 5= Store without winnowing/grading 6=Others 10=(specify)________________________	
14. Where and how do you store your foodstuff (if possible, visit the storage place to see the condition)	1= Cool and dry place 2=Clean place 3=Bags packed in contact with floor or wall 4=Bags packed on raised platform 5=Ventilated room 6=Store in separate room from other items	7=Store in room mixed with other items 8=Store in classroom with learners 8=Control pests and rodents 9=Others (specify)_______________
15. How long is the foodstuffs stored or last from day of purchase?	1= less than 4 months 2= 4 to 8 months	3= 9 to 12 months 4= Over 12 months
16. How do you process or prepare the school meals? Highlight the steps from the storage place	1=Grading/ sorting 2=Winnowing 3=Washing 4=Dehulling and milling	5=Washing and mill whole grain 7=Mill whole grains without washing 8=Others (specify________________

17. Have you ever seen this kind of contaminated grains during processing and preparation (**refer to samples of contaminated grains**)	1= Yes 2= No	
18. What do you do with such foods or grains	1= Sorting/remove 2= Cook with other grains	3= Feed animals 4= Others______________
19. How often do you see this kind of contaminated grains during processing and preparation	1= Every day/Always 2= Once a week/Sometimes	3= Once a month/Rarely 4= Once only
20. Is there a different on processing/preparation of school meals and home meals	1= Yes 2= No	
21. If yes, please mention the differences	1= No grading/ sorting at school 2=No winnowing at school 3=No washing at school	4=No dehulling at school 5=Others (specify)________________ _____________
22. Why are there differences in processing of school meals and home meals	1=Laborious work to sort large quantity at school 2=Time consuming 3= Few moldy seeds cannot have side effects 4=Others __________________________	
23. What quantity of food is served per learner in grams		

Any other information you may wish to share regarding this contamination in foodstuffs ____

Check if all questions have been asked before you release the respondent

Thank you

Appendix 2: Inferential Statistics (Chapter 3)

Association between gender and level of education among food handlers under School Meals Programme in Salima District, Malawi.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.694[a]	3	.009
Likelihood Ratio	13.956	3	.003
Linear-by-Linear Association	.057	1	.812
N of Valid Cases	124		

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is 2.71.

Correlation of age and level of education among food handlers under School Meals Programme in Salima District, Malawi

Correlations

		Level of education for the respondents	Age of respondents
Level of education for the respondents	Pearson Correlation	1	-.127
	Sig. (2-tailed)		.161
	N	124	124
Age of respondents	Pearson Correlation	-.127	1
	Sig. (2-tailed)	.161	
	N	124	124

Association between age and gender in School Meals Programme under Salima District, Malawi.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	41.001[a]	33	.160
Likelihood Ratio	50.630	33	.026
Linear-by-Linear Association	.769	1	.380
N of Valid Cases	124		

a. 67 cells (98.5%) have expected count less than 5. The minimum expected count is .39.

Correlation of education level and knowledge of toxigenic molds in maize foods among food handlers under School Meals Programme in Salima District Malawi

Correlations

		Knowledge of toxigenic molds	Level of education for the respondents
Knowledge of toxigenic molds	Pearson Correlation	1	-.310**
	Sig. (2-tailed)		.000
	N	124	124
Level of education for the respondent	Pearson Correlation	-.310**	1
	Sig. (2-tailed)	.000	
	N	124	124

**. Correlation is significant at the 0.01 level (2-tailed).

Association between gender and knowledge of toxigenic molds in maize foods among food handlers under School Meals Programme in Salima district, Malawi

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	20.328[a]	13	.087
Likelihood Ratio	22.687	13	.046
Linear-by-Linear Association	.034	1	.854
N of Valid Cases	124		

a. 16 cells (57.1%) have expected count less than 5. The minimum expected count is .39.

Correlation of age and knowledge of toxigenic molds among food handlers under School Meals Programme in Salima District, Malawi

Correlations

		Age group of the respondent	Knowledge of toxigenic molds
Age group of the respondent	Pearson Correlation	1	.146
	Sig. (2-tailed)		.105
	N	124	124
KAP scores	Pearson Correlation	.146	1
	Sig. (2-tailed)	.105	
	N	124	124

Association between gender and post-harvest handling practices of maize foods among food handlers under School Meals Programme in Salima District, Malawi

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.381[a]	8	.397
Likelihood Ratio	9.740	8	.284
Linear-by-Linear Association	1.533	1	.216
N of Valid Cases	124		

a. 9 cells (50.0%) have expected count less than 5. The minimum expected count is .77.

Correlation of age and post-harvest handling practices among food handlers under School Meals Programme in Salima District, Malawi

Correlations

		Post-harvest handling practices	Age of respondent
Post-harvest handling practices	Pearson Correlation	1	.084
	Sig. (2-tailed)		.355
	N	124	124
Age of respondent	Pearson Correlation	.084	1
	Sig. (2-tailed)	.355	
	N	124	124

Correlation of education level and post-harvest handling practices among food handlers under School Meals Programme in Salima District, Malawi

Correlations

		Post-harvest handling practices	Level of education for the respondent
Post-harvest handling practices	Pearson Correlation	1	.083
	Sig. (2-tailed)		.360
	N	124	124
Level of education for the respondents	Pearson Correlation	.083	1
	Sig. (2-tailed)	.360	
	N	124	124

Appendix 3: Photos showing poor post-harvest handling practices of maize foods in schools under School Meals Programme

Maize foods in contact with soil or ground during reception

Maize foods in contact with floor or wall during storage

Maize foods stored in room mixed with other non-food items

School children eating porridge while sitting on bare ground

School children eating porridge while plates are in contact with soil

Appendix 4: School children questionnaire

Consumption pattern

Enumerator's Name____

Background information

1.0 General information

Date of interview			
Name of school	Zone:_______________	District:_____________	Division:____________
Date checked			
Date of data entry			

2.0 Respondent and general information

2.1 Name of respondent		**Responsibility:**
2.2 Respondent gender	Sex M=1 { } F=2 { }	
2.3 School grade	1=Standard 1 5=Standard 5 2=Standard 2 6=Standard 6 3=Standard 3 7=Standard 7 4=Standard 4 8=Standard 8	
2.4 Age (years)		
2.5 Estimated body weight (Kg)		
2.6 Estimated height (Metres)		

3.0 Consumer study

3.1 What meal are you often served at school	1= Plain Maize Porridge, 2= Maize-legume Porridge 3= Maize nsima (Ugali) served with meat/Fish/eggs, 4= Maize nsima (Ugali) served with Legumes	5=Maize nsima (Ugali) served with Vegetables 6= Plain rice 7= Rice-legume porridge 8= Others (specify)
3.2 How often do you consume school meal per week?	1= Every day served once 2= Every day served twice 3= Others____________________	

3.3What quantity of meal do you consume or served? (Estimate/measure quantity in grams)	

4.0 Health problems

4.1 Do you have any health problem which you feel or experience regularly at school or home?	1. Stomach pain 2. Vomiting 3. Headache 4. Nausea 5. Fever 6. Diarrhea 7. Coughing 8. None 9. Others (Specify)

Any other information you may wish to share as regards to school meals?

____

Name of person checking questionnaire________________________________

Check if all questions have been asked before you release the respondent

Thank you

Appendix 5: Inferential statistics (chapter 4)

The association between gender and age of school children under the School Meals Programme in Salima District in Malawi

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.592[a]	4	.032
Likelihood Ratio	8.612	4	.072
Linear-by-Linear Association	.215	1	.643
N of Valid Cases	496		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 12.19.

The association between gender and grade level of school children under the School Meals Programme in Salima District in Malawi

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.499[a]	7	.835
Likelihood Ratio	3.513	7	.834
Linear-by-Linear Association	.018	1	.892
N of Valid Cases	496		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 17.42.

The correlation of age and grade level of school children under the School Meals Programme in Salima District in Malawi

Correlations

		Age category	School Grade
Age category	Pearson Correlation	1	.631**
	Sig. (2-tailed)		.043
	N	496	496
School grade	Pearson Correlation	-.021	1
	Sig. (2-tailed)	.643	
	N	496	496

**. Correlation is significant at the 0.01 level (2-tailed).

The association between meal consumption levels and gender of school children under the School Meals Programme in Salima District in Malawi

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	85.624[a]	79	.286
Likelihood Ratio	106.603	79	.021
Linear-by-Linear Association	.418	1	.518
N of Valid Cases	496		

a. 131 cells (81.9%) have expected count less than 5. The minimum expected count is .44.

The correlation of age and meal consumption levels of school children under the School Meals Programme in Salima District in Malawi

Correlations

		Meal quantity category	**Age in years**
Meal quantity category	Pearson Correlation	1	.033
	Sig. (2-tailed)		.459
	N	496	496
Age in years	Pearson Correlation	.033	1
	Sig. (2-tailed)	.459	
	N	496	496

The correlation of school grade level and meal consumption levels of school children under the School Meals Programme in Salima District in Malawi

Correlations

		Meal quantity category	School Grade
Meal quantity category	Pearson Correlation	1	-.004
	Sig. (2-tailed)		.937
	N	496	496
School Grade	Pearson Correlation	-.004	1
	Sig. (2-tailed)	.937	
	N	496	496

The correlation of age and body weight of school children under the School Meals Programme in Salima District in Malawi

Correlations

		Age in years	Estimated body weight
Age in years	Pearson Correlation	1	.835**
	Sig. (2-tailed)		.000
	N	496	496
Estimated body weight	Pearson Correlation	.835**	1
	Sig. (2-tailed)	.000	
	N	496	496

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation of body weight and school grade of school children under the School Meals Programme in Salima District in Malawi

Correlations

		Estimated body weight	School Grade
Estimated body weight	Pearson Correlation	1	.725**
	Sig. (2-tailed)		.000
	N	496	496
School Grade	Pearson Correlation	.725**	1
	Sig. (2-tailed)	.000	
	N	496	496

**. Correlation is significant at the 0.01 level (2-tailed).

The association between gender and body weight of school children under the School Meals Programme in Salima District in Malawi

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.859E2[a]	280	.391
Likelihood Ratio	386.781	280	.000
Linear-by-Linear Association	.336	1	.562
N of Valid Cases	496		

a. 562 cells (100.0%) have expected count less than 5. The minimum expected count is .44.

The association between gender and health problems experienced by school children under the School Meals Programme in Salima District in Malawi

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.507[a]	8	.130
Likelihood Ratio	12.514	8	.130
Linear-by-Linear Association	1.121	1	.290
N of Valid Cases	496		

a. 3 cells (16.7%) have expected count less than 5. The minimum expected count is 2.18.

The association between age and health problems experienced by school children under the School Meals Programme in Salima District in Malawi

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.213E2[a]	112	.258
Likelihood Ratio	122.236	112	.239
Linear-by-Linear Association	.097	1	.756
N of Valid Cases	496		

a. 98 cells (72.6%) have expected count less than 5. The minimum expected count is .02.

The association between school grade level and health problemshool experienced by children under the School Meals Programme in Salima District in Malawi

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	56.698[a]	56	.029
Likelihood Ratio	59.981	56	.333
Linear-by-Linear Association	.120	1	.730
N of Valid Cases	496		

a. 33 cells (45.8%) have expected count less than 5. The minimum expected count is .40.

The correlation of health and meal consumption levels of school children under the School Meals Programme in Salima District in Malawi

Chi-Square Tests

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	49.250[a]	48	.423
Likelihood Ratio	55.857	48	.204
Linear-by-Linear Association	.001	1	.969
N of Valid Cases	496		

a. 41 cells (65.1%) have expected count less than 5. The minimum expected count is .11.

The association between health problems and body weights of the school children under the School Meals Programme in Salima District Malawi

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	66.934[a]	72	.647
Likelihood Ratio	75.533	72	.365
Linear-by-Linear Association	.173	1	.678
N of Valid Cases	496		

a. 55 cells (61.1%) have expected count less than 5. The minimum expected count is .01.

Analysis of variance for aflatoxins in maize based porridge samples

Variate: Aflatoxins

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Agriculture Zone	2	154.9	77.4	0.62	0.540
Residual	86	10721.4	124.7		
Total	88	10876.3			

Analysis of variance for fumonisins in maize based porridge samples

Variate: Fumonisins

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Agriculture_Zone	2	0.8800	0.4400	2.72	0.071
Residual	86	13.8996	0.1616		
Total	88	14.7796			

Appendix 6: Determination of aflatoxins and fumonisins levels in 30 maize based porridge samples using Reveal Q+ Kits test